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Lesson Title:	An introduction to Electron Microscopy
Lesson Duration:	2 x 60 minute lessons

Learning Outcomes (Australian Curriculum):

Year 7	Year 8	Year 9	Year 10
• Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120) • Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124) • Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125)	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE135) Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS139) Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS140)	People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE160) Formulate questions or hypotheses that can be investigated scientifically (ACSIS164) Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)	People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE194) Formulate questions or hypotheses that can be investigated scientifically (ACSIS198) Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)
Additional outcomes (optional)	*Additional outcomes (optional)* • Chemical change involves substances reacting to form new substances (ACSSU225)	*Additional outcomes (optional)* • Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (ACSSU176) • Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed (ACSSU178)	*Additional outcomes (optional)* • The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence (ACSSU185) • Different types of chemical reactions are used to produce a range of products and can occur at different rates (ACSSU187)

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Introduction

The following series of lesson plans have been developed as a national resource for teaching concepts related to the underlying theory of microscopy, and applying these concepts to great challenges in the biological, engineering and mineralogical sectors. These plans also seek to illustrate the development of microscopy technology from the 2D space into 3D expressions of data and VR representations. The lesson plans are developed containing components suitable to students in years 7-10 (stages 4-5 in the NSW curriculum). Each plan draws on a range of online resources and both individual and group learning strategies to achieve a broad-based learning experience. The lesson plans are based around a set of accompanying images and 3D datasets. These images and datasets were presented and recorded in association with an outreach program during IMC19 (19th International Microscopy Congress), held in Sydney from September 10-13th, 2018. The following plans contain a prework component which prepares students for imaging samples and datasets. These will be accompanied by on-the-day activity sheets which were provided to students visiting the outreach program. Finally, postwork lesson plans will explore each of the samples in greater depth, and the underlying challenges that are associated with each sample and its environmental context.

Summary of Tasks / Actions:

Lesson 1: What is Microscopy?

1. See, Think, Wonder
    a. Give students an A4 piece of paper and divide into 3 sections (I see, I think, I wonder)
    b. Show students up to 5 different microscopy images and for each image, ask them to write down what they see/think/wonder in each column. Give students approx 2-3 mins for each image. (What do you see? - http://myscopeoutreach.org/whatDoYouSee.html)
    c. Discuss the images as a class, using the key terms - see, think, wonder

2. Class discussion
    a. With students: What is microscopy?
    b. Brainstorm: what do we know about microscopes? what are they used for? what TYPES of microscopes exist?
    c. Video - what is an electron microscope
        i. Yrs 7 to 8: https://www.youtube.com/watch?v=aQStOWzj93A
        ii. Yrs 9 to 10: scroll down to embedded video under “What is electron microscope?” heading https://www.sciencelearn.org.nz/resources/502-types-of-electron-microscope

3. Learning to use an Optical Microscope
    a. Complete the sheet ‘How does an optical microscope work?’
    (Note: Some students may already be familiar with the optical microscope and may wish to proceed straight to Part 4)

4. Learning to use an SEM
    a. Use the animated simulator provided at http://myscopeoutreach.org/virtualSEM.html to explore how an SEM works.
    b. Begin at the ‘Basics > The Scanning Electron Microscope’ section, then work through each/some of the activities, choosing one sample each time.
    c. Working in partners, students can use the virtual SEM simulator for a chosen sample.
    d. Answer questions on the sheet ‘How does an SEM work?’

5. Learning about the Atom Probe and Micro CT
    a. In groups, brainstorm reasons why 2D datasets might lack crucial information about a sample
    b. For younger groups, an introduction to atoms and X-rays may be necessary
    c. Using the following links:
        i. https://www.youtube.com/watch?v=NcG9H3v3xW4
        ii. https://www.sciencelearn.org.nz/videos/1133-4-micro-ct-how-it-works

    And working in groups, brainstorm the key differences between these 3D imaging techniques, and explain what is unique about the information they give compared to optical and electron microscopes.

Lesson 2: The Stories behind the samples

1. Teacher to introduce excursion to the IMC19 Outreach Learning Space (post-conference, refer to the dedicated IMC19 Outreach Learning Space webpage for all resources).

    a. Looking at images of a variety of natural structures under a variety of microscopes, including an SEM
    b. Describing the images viewed and the reasons behind why each material is scanned and possible future directions of research

2. Split students into their 4 student groups, one for each storyline. On the day of your visit, or otherwise in class using the online resource, each group to collect their matching worksheets and work through the descriptive/drawing activities identified. Some groups may request to complete the extension activities - this can be done at the teacher's discretion in a subsequent lesson.

    Group 1 - Tooth Enamel

    Group 2 - Corals in Competition

    Group 3 - Rusticles and Corrosion

    Group 4 - Eucalyptus Leaves

3. At the end of the lesson, each group can briefly share what they learnt and observed whilst working on their worksheets and make a prediction about why Australian microscopists would be looking at objects like the ones they have just viewed under electron microscopes now and in the future.

Materials / Equipment:

- Access to projector, speakers and device to play Youtube clips
- Hard copies of storyline Worksheets
- A4 paper
- Textas or markers, ruler and pencil/rubber
- NB: some teachers may need to access practical equipment if they chose to conduct extension activities with their students

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Other Resources:

"See Think Wonder" Chart
https://esledu.files.wordpress.com/2015/08/seethinkwonderchart.pdf

Youtube video "50 images taken with a scanning electron microscope"
https://www.youtube.com/watch?v=-QNe-mt1tzE

Coloured SEM images
http://myscopeoutreach.org/sideActivities/ColoringActivity.pdf

Everyday things in SEM
http://myscopeoutreach.org/sideActivities/EverydayThings_SEM_Information_Sheet.pdf

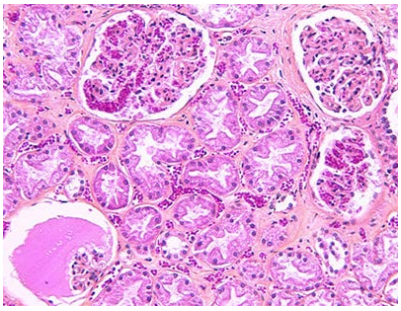
Optional extra:

Download "Zeiss Labscope" app from itunes
https://itunes.apple.com/au/app/labscope/id688689220?mt=8

Download "Leica AirLab" App
- Itunes
- Android

The Optical Microscope

How does an Optical Microscope Work?



This worksheet will guide you through understanding how an Optical Microscope functions by explaining how all the different parts work together.

1. A diagram of an optical microscope is contained in the link below.

   Using https://www.dkfindout.com/us/science/microscopes/how-does-microscope-work/ label the features of an optical microscope on the below diagram.

2. There are some safety rules around using optical microscopes.

   Suggest two important safety rules that apply when using an optical microscope.

   _____

   _____

   _____

3. There is some key terminology associated with any microscopy work. Complete the table below:

Terminology	Definition
field of view	
magnification	
resolution	

specimen	
working distance	

4. Complete the following statements summarising relationships between the terms in the previous question.

   As the magnification increases, the resolution of the image _____.

   As the magnification increases, the field of view diameter _____.

   As the magnification doubles, the field of view diameter _____.

   As the magnification increases, the working distance _____.

   As the magnification increases, the specimen _____.

5. The magnification of an optical microscope is calculated in the following way:

   ocular lens magnification x objective lens magnification

   Whilst the Field of View of a microscope can be measured in millimetres, measurements are often made in micrometres (um).

   1 millimetre = 1000 micrometres

   Use this information (and some reasoning) to complete the table below.

	Ocular Lens Magnification	**Objective Lens Magnification**	**Total Magnification**	**Field of View (millimetres)**	**Field of View (micrometres)**
Low Power	10 x	4 x		4.4	
Medium Power	10 x	10 x			1800
High Power	10 x	40 x			

6. When you make an observation through an optical microscope you may record your data in the form of a biological drawing.

   Visit the following link: https://www.biologyforlife.com/lab-drawings.html

   Name three important things you need to do when making a biological drawing so that others can rely on your observational data, and explain why they are important:

   _____

   _____

The Scanning Electron Microscope

How does an SEM Work?

This worksheet will guide you through understanding how a Scanning Electron Microscope (SEM) functions by explaining how all the different parts work together.

1. Electrons are important to this type of microscope. State what an electron is and Identify where you would most likely expect to find them.

   _____
   _____
   _____

2. In the space below, draw a labelled diagram of an atom showing the positive central particles and negative electrons.

3. When are electrons able to be pushed and move freely?

   _____
   _____

4. In a SEM, the wire inside with moving electrons is bent into the shape of a 'V'. Suggest why is this done and what happens when you change the shape of the wire.

   _____
   _____
   _____

5. Identify what an Anode plate is and state what it does.

   _____
   _____
   _____

6. Describe what happens to the beam of electrons when electricity runs through a magnetic lens.

   _____
   _____

7. Identify where the process of scanning comes into the process of a SEM. Suggest why is this done.

_____
_____
_____

8. State what a detector device does to electrons. Describe the result of this change.

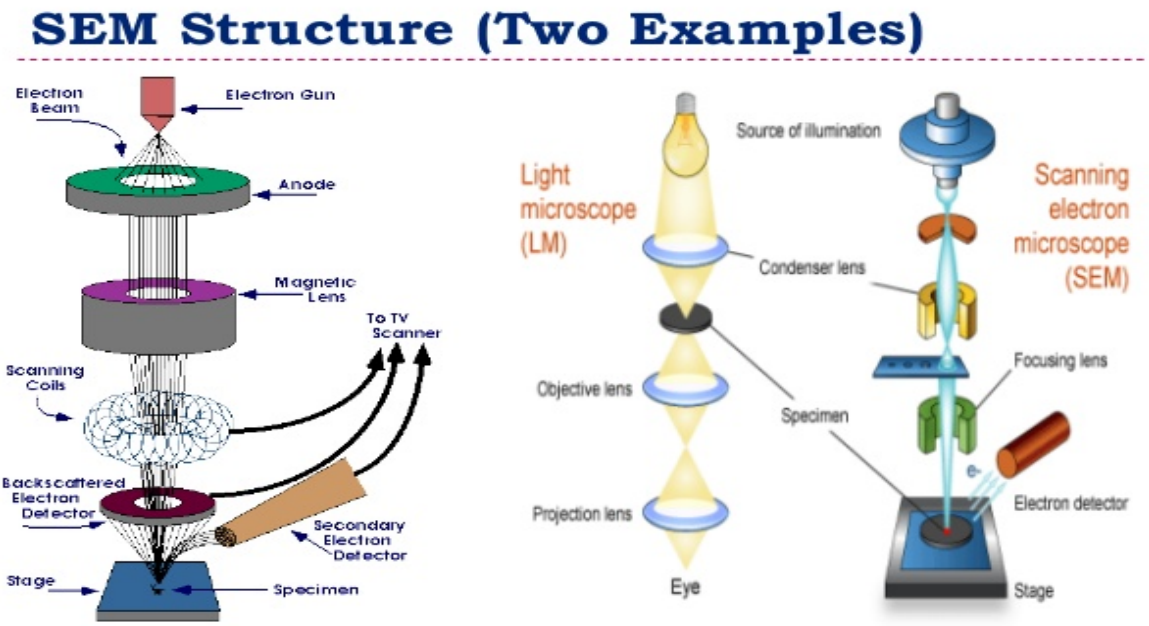
_____
_____
_____

9. Describe in a few steps, how we obtain an image of the sample. Explain how we get black, gray, and white dots from the sample, which ultimately form a micrograph image.

_____
_____
_____
_____

10. Briefly describe some regular uses of SEMs in industry, medical or government sectors.

_____
_____
_____



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Corals in Competition - International year of the reef

The Coral Phenomenon

How are corals even possible? It's thanks to many tiny species living together in a symbiotic relationship. But life is crowded on the reef and only the most robust survive. Learn how the structure of stony and soft polyp corals helps them take advantage of the reef environment, and how bleaching of the reef leads to new competition and challenges.

https://en.wikipedia.org/wiki/Coral_reef

Visit the following websites and conduct some research of your own to respond to the following questions:
https://www.nationalgeographic.com/animals/invertebrates/group/corals/
https://www.coral-reef-info.com/

1. Corals are considered animals, but do not necessarily look like other animals. Describe some unique characteristics or features of the organism called corals.

2. Corals are colonial organisms. Describe what is meant when they are described in this way.

3. Describe the features of a coral polyp. Draw a diagram showing the major parts of a typical polyp.

4. Describe the typical diet of corals and the method by which they feed

5. On the map of Australia, highlight the regions in which corals are most likely to be found.

6. Describe how a reef can develop over time

7. Explain how coralline algae and stony corals play their role in building the reef

Investigate the following websites and conduct some research of your own to respond to the following questions:

http://oceanadventures.co.za/why-do-corals-compete-for-space-on-the-reef/
https://www.thesprucepets.com/coral-competition-2924468

1. Describe abiotic and biotic factors that can affect the growth of corals.

2. Suggest how corals protect themselves from a) predators and b) abiotic factors in their environment.

Download and watch the videos available from the following links:

Movie 1
Movie 2
Movie 3
Movie 4
Movie 5

After watching each video:

a) Describe and Explain what you think has occurred in each case
    i. between the interacting corals/other animals, or
    ii. between individual coral polyps.
b) Outline some of the differences between the ways the coral Platygyra responds to different interactions
c) Suggest why this might be the case

Download and view 'Supplementary Figure 6' from the following link:

Supplementary Figure 6

After reading the description in the caption, compare what you have read with your answers above, and outline the differences between feeding, competition, and polyp-to-polyp interaction.

Sharing time - summarise your learning back to the class - this could be in response to how corals interact to the environment and one another, or about corals in general. Feeling creative? Present it as a Ted talk or as a concept map of your learning.

Further Resources:

“Nature’s perfect match is breaking down and the reef is in peril”
http://www.abc.net.au/news/2018-08-20/great-barrier-reef-natures-perfect-match-is-breaking-down/10113132

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Eucalyptus Leaves - Oil Producing Machines

Eucalyptus Leaves

Eucalyptus trees are everywhere in Australia - if you looked outside your window, or looked at trees as you walked down the street, you would almost certainly see a Eucalyptus tree. They even have their own National Day in Australia - March 23rd. In fact, Eucalyptus are a common tree across the globe.

Eucalyptus leaves are prolific producers of a flammable oil, known as Eucalyptus oil. But why do these trees produce such a large amount of this oil?

https://en.wikipedia.org/wiki/File:Eucalyptus_tereticornis_flowers,_capsules,_buds_and_foliage.jpeg

AN INTRODUCTION TO THE EUCALYPTUS

Watch the video “Eucalyptus” (https://www.youtube.com/watch?v=mMiIiCMSzkY)

Answer the following questions:

1. Why are Eucalyptus plants described as being “fire adapted”?

2. Why do young Eucalyptus trees grow so tall so quickly?

EUCALYPTUS LEAVES

3. Describe the normal shape and features of Eucalyptus leaves.

4. Use the article at the below link to answer the following questions:
   http://www.bbc.co.uk/bitesize/standard/biology/world_of_plants/making_food/revision/3/

   a. Suggest reasons why the mesophyll layer (containing chloroplasts), are more densely packed than the spongy layer below
   b. Suggest some functions of the leaf vein
   c. Identify the function of the Stomata

5. Why do young Eucalyptus trees have such different leaves compared with more mature Eucalyptus plants?

6. Compare the Eucalyptus leaves with the leaves of other species (non-native) plants. Describe features that may differ between the two types of leaves.

7. State three ways “adult” Eucalyptus leaves are adapted to suit harsh Australian conditions.

EUCALYPTUS AND FIRE

Read through the news article found at the following link. Use the information in the article to answer the questions that follow.

https://www.livescience.com/40583-australia-wildfires-eucalyptus-trees-bushfires.html

1. What common plant is known to fuel Australian Wildfires?

2. What weather conditions can also contribute to Australian Wildfires?

3. Why is Eucalyptus oil such a significant contributor to Australian Wildfires?

4. Based on the following link:
https://www.anbg.gov.au/cpbr/cd-keys/Euclid/sample/html/leaves.htm
Suggest some possible trade-offs if some of the space in the leaf cell is taken up by oil glands. Why do you think the oil glands are still retained in eucalyptus leaves?

5. Other than oil, outline 3 ways Eucalyptus trees contribute to fires.

6. Explain why Blue Gums are sometimes referred to as “Gasoline trees”.

7. How do Eucalyptus trees take advantage of the destruction caused by a bushfire? Give specific examples in your answer.

8. Why do you think Eucalyptus trees are still so popular in Australian gardens, if they pose such a huge risk?

9. Consider the quote in the article from David Bowman, a forest ecologist with the University of Tasmania, Australia
“Looking at the eucalyptus forest outside my window in Tasmania, I see a gigantic fire hazard”

   What do you think Mr Bowman means by this statement? Justify your answer.

   Do you agree that Eucalyptus forests are a danger to humans and society? Justify your answer.

THE EUCALYPTUS - Scavenger Hunt

Use the following website to find information to answer the questions in the table below. (http://www.abc.net.au/news/science/2018-01-26/eucalyptus-trees-an-iconic-australian/9330782)

	Question	**Answer**
1.	What does the term “Eucalypt” actually mean?	
2.	What is the age of the oldest known Eucalyptus fossils?	
3.	What is the scientific name for the twisted Sydney Red Gum?	
4.	List two other places in the world where we can find Eucalyptus.	
5.	How many species of Eucalypt are there?	
6.	Why do some Eucalypts have rough bark around the base of the tree?	
7.	How do Indigenous peoples use the bark of Eucalyptus?	
8.	What part of the Eucalypt tree produces the oil?	
10.	How does Eucalyptus oil help prevent pest attack?	
11.	What rare and expensive element has also been found in Eucalypt leaves?	
12.	Why do gum nuts have hard, thick walls?	
13.	Eucalyptus oil fuels fire so they burn hot and fast. Why is this an advantage to Eucalyptus trees?	

EXTENSION - Burning Leaves

If time allows, work with your teacher to conduct the small experiment found at the link below.
https://s3.amazonaws.com/ed.edim.co/5595/leaves_disasters_07.pdf?response-content-disposition=filename%3D%22leaves_disasters_07.pdf%22%3B%20filename%2A%3DUTF-8%27%27leaves_disasters_07.pdf&AWSAccessKeyId=AKIAJXGLFWCDC7HTECXQ&Expires=1533801139&Signature=0Ibuv9ymNhXKUBAZIddyEeWzKzw%3D

ADDITIONAL VIDEO - *Eucalyptus Regnans* (Mountain Ash) Fires

If time allows, students may also like to watch the following video on the fire ecology of *Eucalyptus Regnans (Mountain Ash)*
https://www.youtube.com/watch?v=jLgrxYbj5OU

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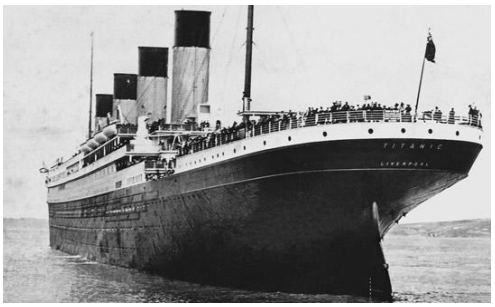
Rusticles - The End of the Titanic?

The Titanic

Titanic is perhaps the most iconic ship in history, its tragic story known the world over. ... Its maiden voyage ended in tragedy when it struck an iceberg and sank, killing more than 1,500 passengers and crew.



http://www.bbc.co.uk/history/titanic

Watch the video “Titanic Decay | Top Stories | CBC” (https://www.youtube.com/watch?v=dDd2pedW4XI)

Answer the following questions:

1. Where is the Titanic currently located?

2. Suggest reasons why looking at the deterioration of the Titanic is important?

3. Scientists chose to have a ‘hands-off’ study of the shipwreck. Why did they not touch the ship?

4. Describe what is now covering the shipwreck?

5. Explain how this covering assists scientists throughout their studies?

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What is Corrosion?

Watch the video “Corrosion of Metals | The Chemistry Journey | The Fuse School” (https://www.youtube.com/watch?v=T4pSuflO9fk) Be sure to pause the video when instructed and answer the questions that provided.

Answer the following questions:

1. Was your initial hypothesis - Which would be in the best condition - correct?

2. Define Corrosion.

3. Identify the 3 substances that cause corrosion?

4. What is a compound?

5. What compound was formed through the process of corrosion?

6. Explain why the iron nail was the most corroded.

7. Outline how you could ‘protect’ a shipwreck from corroding?

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Read the article *"New Species of Rust-Eating Bacteria Destroying the Titanic"* By Live Science Staff (December 6, 2010) Sourced from: **https://www.livescience.com/9079-species-rust-eating-bacteria-destroying-titanic.html**

1. Outline the main purpose of the article.

2. Explain how over the past 25 years the titanic has been 'rapidly deteriorating".

3. Describe a 'rusticle' and identify how they were discovered. Outline how bacteria are related to the rusticles.

4. Compare the picture in the Live Science article and other pictures of rusticles with the below picture of rusting railway tracks. Identify ways in which the rust formation differs, and suggest reasons why.

Credit: Dr Ingrid McCarroll, ACMM, The University of Sydney

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Why is rust a problem in the maritime industry?

The Australian National Maritime Museum

The Australian National Maritime Museum is Australia's national centre for maritime collections, exhibitions, research and archaeology. The museum has one of the largest floating historical vessel collections in the world, featuring the renowned replica of Captain Cook's HMB Endeavour, the former Navy destroyer HMAS Vampire, the former Navy patrol boat HMAS Advance and former Navy submarine HMAS Onslow which are all docked at the wharf in Sydney's Darling Harbour.

http://www.anmm.gov.au/

You have just been employed at the Maritime Museum. You have been given a role as a conservationist involving the maintenance of vessels located in Darling Harbour, to ensure that their historical value can be preserved.

1. What type of water is found in Sydney's Darling Harbour? Saltwater or Freshwater

2. Reflecting upon this, describe any issues that you may encounter within your new role.

3. Outline how you would go about overcoming these issues to preserve the vessels.

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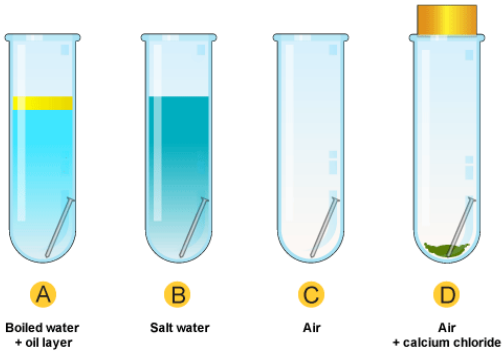
Practical Investigation - Rust Prevention

Aim: to investigate the conditions under which rusting occurs.

Hypothesis:
What effect do you think distilled water, tap water, salt water, oil, added magnesium or no solution will have on the corrosion of iron nails?

Method: Using the information provided, outline the method required for this investigation below.



Results
Outline your results.

Conclusion:

Discussion:

1. State both the worded equation and the chemical equation for rusting.

2. Use your results to explain why iron structures such as car bodies rust faster in coastal areas than inland areas?

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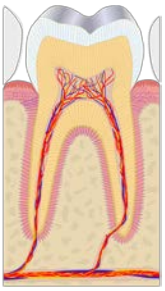
Tooth Enamel - Clean Your Teeth

Tooth Enamel



Your body puts a lot of work into generating 32 hard, rigid teeth to tear and crush your next meal.
Yet both organic and metallic contaminants can slowly undermine their tough enamel barrier. Take an atomic resolution look at this amazing, unique, composite structure, its strength, and its weaknesses.

TOOTH STRUCTURE

Watch the video – Structure of Teeth in Humans https://youtu.be/FV1rrbTYIM4?t=20

1. Draw a picture of a tooth below and label the following sections:

   enamel, crown, root, dentin, gums, pulp, root canal, cementum, peridontal membrane

2. Write a sentence explaining the function of each part of the tooth.

   _____

   _____

   _____

3. Teeth are considered to be the hardest part of the body. Explain why.

_____

_____

_____

4. Explain the function of teeth within the digestive process.

_____

_____

_____

_____

_____

_____

5. Identify the different types of teeth found in humans and explain their functions?

_____

_____

_____

_____

_____

_____

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CELL STRUCTURE

Information on the cells in teeth can be found at the following links:
https://pt.slideshare.net/DrAbusallamah/histology-of-dentin/14?smtNoRedir=1

https://www.gettyimages.com.au/photos/nerve-cell?sort=mostpopular&mediatype=photography&phrase=nerve%20cell

https://www.histology.leeds.ac.uk/blood/blood_rbc.php

6. Complete the table below by drawing a diagram of each type of cell that would be found in a tooth (odontoblasts, nerve cells, red blood cells). Explain how these cell structures help teeth do their job in the body.

Cell in a tooth	Diagram of cell	How do these cell structures help teeth do their job?
Odontoblast		
Nerve cell		
Red blood cell		

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CHEMICAL STRUCTURE OF A TOOTH (Suitable for Stage 5 learners)

Watch the videos and read the articles below to answer the following questions.

Video and article:
Bone and tooth minerals https://www.sciencelearn.org.nz/resources/1796-bone-and-tooth-minerals

Article:
https://www.fluidinova.com/hydroxyapatite-properties-uses-and-applications

Images:

- Tooth http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-14392007000200004
- Enamel Rods http://thed3group.org/trickier-tooth-brick-pictures.html

See endnotes for further resources on atomic bonding

1. State the chemical formula of the main mineral used to make enamel in teeth.

   _____

2. Identify which elements from the periodic table are used to make tooth enamel.

   _____

   _____

3. Identify the cations (positive ions) and anions (negative ions) within the mineral used to make up enamel.

   _____

   _____

4. Is the chemical used to make enamel in teeth the same as the mineral found within rocks? Suggest how enamel and the mineral are similar or different.

   _____

   _____

   _____

   _____

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5. Describe how the chemical compounds found in tooth enamel bond.

_____

_____

_____

_____

3D IMAGING OF TOOTH ENAMEL

Read the following article and video to answer the following questions
https://www.forbes.com/sites/carmendrahl/2016/09/07/nanoscale-view-of-enamel-might-help-us-treat-tooth-decay/#4b14ae083ce1

1. Outline what the Atom Probe Tomography technique contributed to scientist's understanding of tooth enamel

2. Describe how samples are prepared for Atom Probe Tomography on tooth samples.

Further Resources:

Videos

- What are ions? https://youtu.be/900dXBWgx3Y?t=39
- Ionic Bonds https://www.youtube.com/watch?v=zpaHPXVR8WU
- Covalent Bonds https://youtu.be/LkAykOv1foc?t=52
- Metallic Bonds https://youtu.be/S08qdOTd0w0?t=35