

Butterfly Wings and Microscopes

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 Subject: Biology
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 Standards: NYS Living Environment
 Standard 1 – Analysis, Inquiry and Design
 Standard 2 – Information Systems
 Standard 4 – The Living Environment
 Standard 6 – Interconnectedness: Common Themes
 English Language Arts
 Standard 1 – Language for Information and Understanding
 Standard 3 – Language for Critical Analysis and Evaluation
Schedule: Activity #1 3 days Activity #2 3 days

Objectives:

Appreciate the connection between science knowledge and technology advancements.

Determine the structure of butterfly wings using multiple technologies and different magnifications. Compare and contrast wing structures of two species showing mimicry

Create a hypothesis, draw a conclusion and give suggestions for additional research

Communicate and discuss findings.

Students will:

- Make a hypothesis about the structure of the wing scales in different parts of the wing
- Make a hypothesis about similarities in wing scales between two butterfly mimics
- Examine butterfly wings at various magnifications and record their observations
- Explain how the different types of microscopes helped them learn about wing structure and relate this to the history of science discovery
- Draw a conclusion based on their hypothesis
- Give suggestions for further research
- Discuss their experience with the class.

Vocabulary:

light microscope	resolution
scanning electron microscope	magnification
mimicry	scale bar

Materials:

For Each Pair/group: Butterfly wing	(monarch and viceroy needed for activity 2)
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At the Stations- per group

Station 1:
 Colored pencils
 2 Hand lens
 Tweezers
 Ruler

Station 2:
 Compound Microscope
 Microscope slides
 Measurement slide
 Tweezers
 Colored pencils

Station 3:
 Compound Microscope
 Gooseneck lamp
 Measurement slide
 Tweezers
 Colored pencils
 Microscope slide

Station 4:
 Stereo Microscope
 Measurement slide
 Tweezers
 Petri dish
 Ruler

Station 5:
 Scanning Electron Microscope
 Prepared mounts of wings and/or electron micrographs of wing scales

Science Content for the Teacher:

Resolution - the ability to distinguish space between two objects and to see them as distinct images.

Magnification – the ratio of the size of an image compared to its actual size.

If a microscope cannot resolve two points, then magnifying the image will not help. For example, if you take a picture out of focus with your camera, enlarging it will only make it a big fuzzy picture.

Scale Bar – line drawn on an image to demonstrate actual size of the magnified image. Due to the increased use of digital media, it is no longer enough to state the magnification. The final product is not to the same scale because the programs in which it is used will change the ultimate size. The scale bar allows quantitative analysis of images and comparisons, just as it does on maps with different scales.

Light Microscope – uses visible light to illuminate the object and optical lenses to focus and enlarge the image.

Scanning Electron Microscope – a beam of electrons is used to create an image of the surface of an object. The electron beam is controlled by electromagnets as it sweeps across a small area of the sample in a series of rows. The electrons that are emitted from the sample are then collected and read by a detector which sends information to a viewing monitor. The image is saved digitally or by photograph.

Background information:

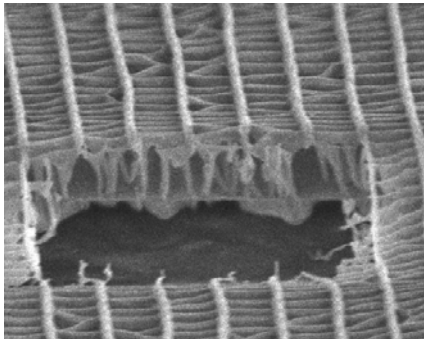
Knowledge about the natural world began when man made observations about his environment. The first known systematic studies of nature were done in the fifth century BC from the writings of Hippocrates and Aristotle. Their knowledge was limited to what was visible with the naked eye. Lenses have been found dating back to the ancient Assyrians and by the fifteenth century became commonly used for correcting vision. However, the development of the microscope did not happen until the seventeenth century. This new technology led to a number of new ideas about the natural world, and especially contributed to the development of the cell theory. As lenses improved, more details could be seen by scientists. Unfortunately, the wavelength of light became a limiting factor. Even the best microscopes could not resolve any two objects closer than half the wavelength of the light used (~ 0.2 microns). With the discovery of the electron in the nineteenth century, electron microscopes were developed. Electrons travel with a much smaller wavelength and the resolution increases (~ 0.0002 microns). Structures of the cell never before seen became visible. As technology improved, our ability to gain a deeper understanding of the natural world also improved. At each stage of learning, scientists not only answered questions, but generated new ones.



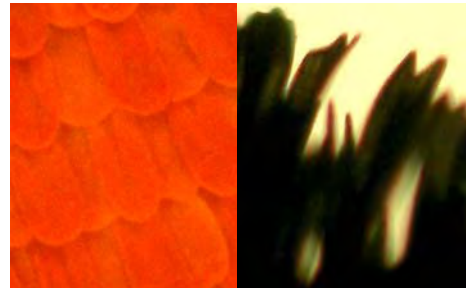
The amount of additional detail that can be seen at each magnification makes butterfly wings an excellent choice for this investigation. To the naked eye, a wing looks like a solid structure. Scales can be seen under the low power of a microscope. At higher powers, stripes or ridges in the scales are visible. Even higher magnification reveals the fretwork between the ribbing and the layers that make up the ribbing. By looking at different areas of the wing, different scale shapes and sizes can be found. The scales at the edges of the wings are fringed. Scales that cover the veins are narrower and appear more curved. The base layer of scales is wider than the covering scales. In some areas the tips of the scales are rounded, in others there are two or



three scallops at the end of each scale. Sensory organs (sencilla) can be seen on the wings either as bumps in the veins or hair like protrusions. The fretwork pattern of the scale structure helps with heat regulation and contributes to the color in a butterfly wing.



FIB-SEM micrograph of butterfly scale showing fret work



Butterfly scales – center of wing and edge of wing

The non iridescent scales are pigmented and each one is usually only one color. The pattern of color seen on the wing is made up of sections of color that blend together, like pixels of a digital camera image. Iridescent colors in butterflies come from light interference patterns as diffraction occurs at the scale fretwork. Each species of butterfly seems to have different fretwork patterns and differences in scale shapes.

Preteaching Concepts:

- Scientific Method
- Use of a scale to determine size
- Metric measurement including microns and nanometers
- Use of a light microscope including how to measure when using the microscope
- Mimicry as an adaptation
- Binomial Nomenclature

Preparation:

Butterfly wings - One side of a butterfly (both fore and hind wing) per group is preferred. Wings can be purchased through supply houses or you can collect them yourself with or without the students. The wings need to be detached. If purchased from a supply house nothing else needs to be done. If collected, place the wings between two pieces of paper on top of a piece of foam board. Place pins through the paper into the foam board close to but not into the wing. This keeps the wings from curling as they dry. Dry for a couple of days to a week depending on the size. Keep the dried wings in a glassine envelope or between two sheets of thin paper inside a plastic reclose-able bag. Use tweezers to handle the wings, since touching them with fingers will remove scales. Mark the group number on each bag. A list of butterflies that display mimicry can be found on the internet if the monarch and viceroy are not obtainable.

Schedule time at SEM lab to take class or get micrographs

- Copy :**
1. “Investigation – Butterfly Wings, Microscopes and History” for each student.
 2. Station Sheets (laminate them if possible). Make 5 copies of “Butterfly Terminology” – one for each station.



Arrange students in groups. Students can be assigned roles such as materials handler, recorder, reader, task manager, technology engineer, etc. Students should rotate roles at the different stations except the role of materials handler.

Set up stations

Place station sheets, schematic diagrams and butterfly terminology sheets at stations. Materials given are **for each pair or group** of students at the station. Your class size and materials availability will determine how many groups and their size. Ideally, students should work in pairs with two pairs of students at each station.

Station 1: one Petri dish, one tweezers, ruler, colored pencils, and two hand lenses.

Station 2: Compound microscope, microscope slide, tweezers, colored pencils, measuring slide

Station 3: microscope slide, tweezers, colored pencils, measuring slide, compound microscope set up with light source at the side. Place a piece of black paper over the stage aperture to prevent the students from using the microscope light source. Goose neck lamps can be used to illuminate the wings from the side. This will set up a shadowed effect for the students to view the scale arrangement and other areas in relief. Try various angles of light to get the best view. Alternately, LED flashlights can be mounted in clamps on ring stands.

Station 4: Binocular microscope, Petri dish, tweezers, colored pencils, ruler

Station 5: If you have access to an SEM, have prepared mounts ready for when the students arrive at the machine. Sections of the wings need to be cut to fit on the mounting stage buttons and attached using conductive double sided tape. The samples need to be coated with a conductive material (sputtered) so that the buildup of electrons can be discharged through a ground. Samples that are not grounded will not be easy to focus or image. The operator of the SEM will be more than happy to help you have a properly prepared sample.

If you do not have access to an SEM, there are numerous micrographs of butterfly wing scales on the internet. Just be sure to include your source when downloading and printing them.

Additional preparation for Activity #2 –

Copy: Investigation: Butterflies, Microscopes and Mimicry

Obtain samples of viceroy and monarch butterfly wings. If you used monarch wings in the first activity, you only need viceroy wings.



Activity #1: Butterfly Wings, Microscopes and History **Classroom Procedure:**

Day 1: In classroom: Double period

15 minutes: Have students list as many tools used by scientists as they can. Discuss why so many tools are needed and what the tools help them learn. Ask what the first scientists used as tools. What do you think they were they able to discover about the world? What was the most important tool developed for biologists? What does the microscope do for a scientist?

Explain that this lab will show them the difference in the type of information obtained using different forms of observation – from the unaided eye to the electron microscope. Their tasks will give them an understanding of how advances in technology have helped increase our science knowledge.

Hand out lab “Butterfly Wings, Microscopes and History”.

Have students complete the first section (Prediction and Hypothesis) before they begin their stations.

Inform them of their groups and which station will be their starting point. Also assign one member of the group to be the materials handler who will be responsible for the butterfly wings at all times.

Students begin stations. Teacher circulates to assist in technical matters.

The electron microscope operator will assist the students at that station if you are at the SEM facility.

Students have approximately 18 minutes at each station to complete their tasks.

Day 2: Single period

Students go to lab stations and complete the tasks.

Day 3: Double Period –

Share findings and have class discussion.

Activity #2: Butterfly Wings, Microscopes and Mimicry

Follow the same schedule as Activity #1, but begin with a classroom discussion about mimicry.

Hand out information on the viceroy mimicry of the monarch butterfly.

The questions they will be trying to answer in this lab are: How much of a mimic is the viceroy? Do the butterflies share similarities in scale structure as well as pigment and pattern?



Assessment:

Assessment will be based on the students answers on their worksheets and their participation in the class discussions and group work.

The following rubric can be used to assess students during each part of the activity. The term “expectations” here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below. Students should be given a copy of this rubric along with their lab paper.

1= exceeds expectations

2= meets expectations consistently

3= meets expectations occasionally

4= not meeting expectations

	Engage	Explore	Explain	Expand/Synthesis
1	Shows leadership in the discussion and offers creative ideas reflecting a good understanding of science principles	Completes work accurately noting details that will help with explanations. Works well with and assists other students in tasks.	Provides in depth explanations; Uses science vocabulary appropriately and shows understanding in a concise and clear manner	Able to apply knowledge to new situations and suggest additional applications of knowledge
2	Participates in class discussion and shows understanding of topic.	Completes work accurately and works well with other students.	Provides clear explanations and uses science vocabulary; shows understanding	Applies knowledge to new situations but does not suggest additional applications
3	Contributes to discussion, but shows little understanding	Makes some mistakes or omissions but works well with group	Provides a limited answer to most questions; uses little science vocabulary	Does not fully or clearly make connections to new situation
4	Does not participate or demonstrate understanding of topic	Does little or no work and does not help partner or group complete tasks	No explanation of findings are given; incomplete worksheet	No connections are made; cannot apply findings to new situations

Extension Activities:

Students create a timeline of the history of microscopes and optics

Students prepare a PowerPoint presentation of their lab results.

Examine different butterflies to develop a library of images.

Publish the class images on a web site.

Look at butterflies that have iridescent and non iridescent areas and see if the scales have the same structure.

Compare the dorsal and ventral sides of the wings.

Examine the sensory organs on the wings

Examine other parts of the butterfly – such as the antennae, body, legs.



Supplemental Information:

A History of Optics:

<http://www.ece.umd.edu/~taylor/optics.htm>

History of the Microscope:

<http://paperproject.org/microscopehistory/index.html>

<http://www.microscope.com/compound-microscope-history-t-4.html>

<http://www.anatomy-resources.com/micro/sm101.htm>

<http://www.edwardwillett.com/Columns/microscopes.htm>

Scanning Electron Microscopy:

<http://www.mos.org/sln/sem/seminfo.html>

Mimicry:

<http://home.cogeco.ca/~lunker/mimicry.htm>

Viceroy/Monarch mimicry and evolution:

http://www.iscid.org/encyclopedia/Monarch_Viceroy_Puzzle

Swallowtail mimics:

http://www.fcps.edu/islandcreekes/ecology/eastern_tiger_swallowtail.htm

Safety: There are no specific safety precautions, but students are working with electrical devices (microscopes and lamps) and glass slides. All general lab safety guidelines should be followed.

Acknowledgments:

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District Director of Science – Al Romano

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Butterfly Wings, Microscopes and History

Background:

Humans have always been interested in understanding the world around them, but their understanding has been limited by the tools available for their investigation. Early information was limited to what could be learned through the senses. The development of the lens added some new information about small things. But it wasn't until the 1500s that the first microscope was invented. The cell theory developed along with a new understanding of how organs and tissues functioned. Suddenly, a whole new world of small things was revealed.

Microscope technology advanced and with it scientists learned more details about the things around them. Better lenses, different angles of illumination, different colors of light and an understanding of the physics of optics contributed to a variety of microscopes. By the beginning of the 1900s, the limits to magnification and resolution using light had been reached.

Luckily, in 1931 the first transmission electron microscope (TEM) was invented that passed electrons through a sample instead of visible light. Since electrons travel with a shorter wavelength than light, a greater degree of resolution was obtained. In 1942 the first scanning electron microscope (SEM) was used. An SEM sends a beam of electrons across a small section of a sample in a series of rows. Electrons emitted from the surface are detected and the signal is sent to a monitor. Biologist could now see the smallest structures of a cell. Another new world of small things was revealed.

Each new advance in technology brought a greater wealth of information. It also brought more questions. When one closed door opened, another closed door was revealed.

Objectives:

- use a variety of magnification tools
- use the scientific method as a discovery learning tool
- examine, record and compare images of the wings of a butterfly.
- Use rulers and scales to measure

Cautions to Students:

Only handle the butterfly wings with the tweezers.

You will be using electrical equipment – all electrical safety rules must be followed.

Tweezers are sharp and can cause injury if not handled properly.

If a glass slide should break inform the teacher and follow broken glass safety rules.

Remember: 1cm = 10mm

1mm = 1000 μ

1 μ = 1000nm

Butterfly Classification:

Kingdom: Animalia (Animals)

Phylum: Arthropoda (Arthropods)

Class: Insecta (Insects)

Order: Lepidoptera (Butterflies and Moths)
 (Lepidoptera means "scale wing")

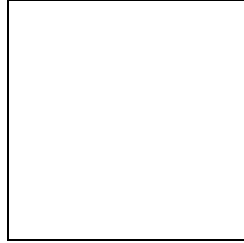


Procedure: Part A: Prediction and Hypothesis

The wings of butterflies and moths are covered with scales (see classification).

When you look at a butterfly, do you see these scales? _____

Draw what you think a butterfly scale would look like if you could see it:



Predict: Are all the scales on the wings the same? _____

Explain your answer: _____

Write a hypothesis about the wing scales of a butterfly that you will be able to answer in this lab activity: _____

Procedure: Part B: Stations

In this part of the lab you will rotate between five stations. Each station has different tools for you to examine the wings. You will also find information to help you answer the questions. When you finish, return your wings to the envelope provided. Move to the next station at the direction of your teacher, making sure all of materials are left for the following group.

Be as complete and accurate as you can. Explain your answers clearly.

You will have 18 minutes at each station to complete the tasks.

READ the precaution on handling the butterfly wings.



Station #1

Materials: ruler, colored pencils, Petri dish, hand lenses, tweezers

What is the earliest time listed at this station? _____

What magnifying instrument is available for you to use? _____

- With tweezers, gently remove the wings and place them in the Petri dish, dorsal (brighter) side up. Do NOT use the hand lenses yet.
- Examine the wings and make your observations below:

Size: measure with the ruler in cm and convert to mm and microns.

	Length			Width		
	cm	mm	μ	cm	mm	μ
Forewing						
Hindwing						

Can you see any scales only using your eyes? _____

- Use the hand lens at the station and examine the wings.

Can you see any scales using the lens? _____

Describe any differences you see when using the hand lens:

Color pattern on wings: Draw and label the dorsal wing color pattern with and without using the hand lens.



Station #2

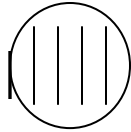
Materials: microscope slide, tweezers, colored pencils, measuring slide

What is the earliest time listed at this station? _____

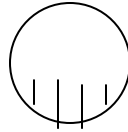
What magnifying instrument is available at this station? _____

- To use measuring slide: Place the measurement slide on the stage and focus it so that the markings go completely across the center of the field of view. Place one mark at the extreme left of your field of view.

This:



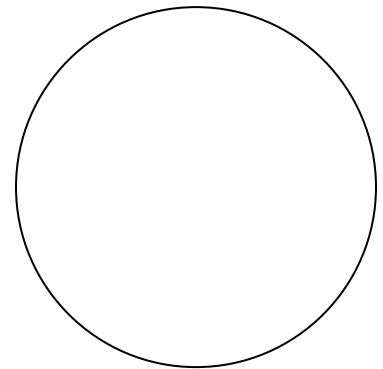
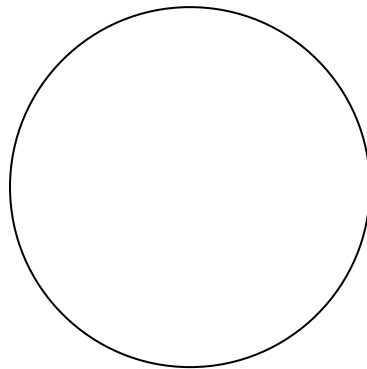
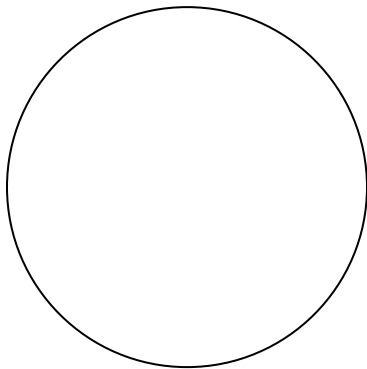
Not this:



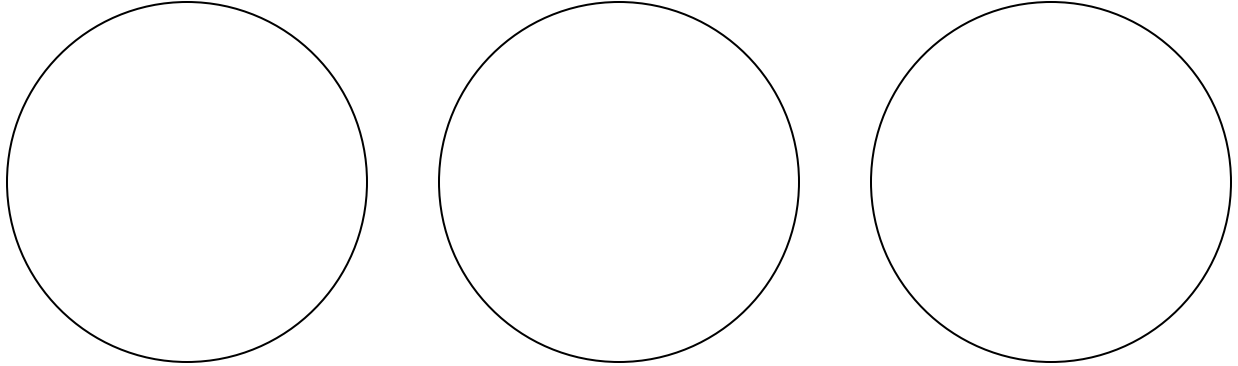
- Record the diameter of the field of view in millimeters and microns and the total magnification for both low and high power in the chart

		Low Power	High Power
Total magnification			
Diameter of Field of View	mm		
	microns		

- Carefully place the wings on the microscope slide.
- Look at the wings under low magnification.
- Draw and label a few scales from three different areas of the wing. Record the area you are viewing. Keep the size to the same scale as your field of view:



- Look at the wings under high magnification.
- Draw and label a few scales from three different areas of the wing. Record the area you are viewing. Keep the size to the same scale as your field of view:



- Estimate the width and length of two different scales.
 Scale #1 Width: _____ Length _____
 Scale #2 Width: _____ Length _____

In the space below, compare details between low and high power for each area.

Area of wing	Observations



Station #3

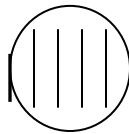
Materials: glass slide, tweezers, colored pencils, measuring slide

What is the earliest time listed at this station? _____

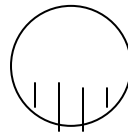
What magnifying instrument is available at this station? _____

- To use measuring slide: Place the measurement slide on the stage and focus it so that the markings go completely across the center of the field of view. Place one mark at the extreme left of your field of view.

This:



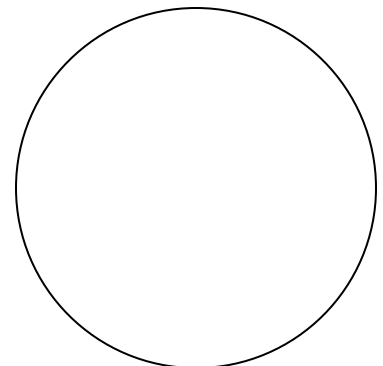
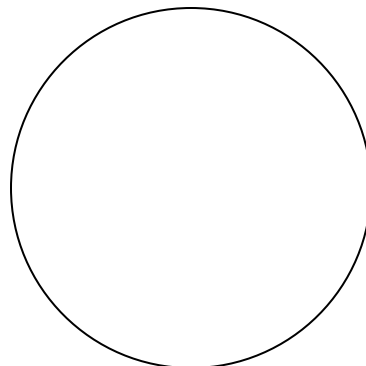
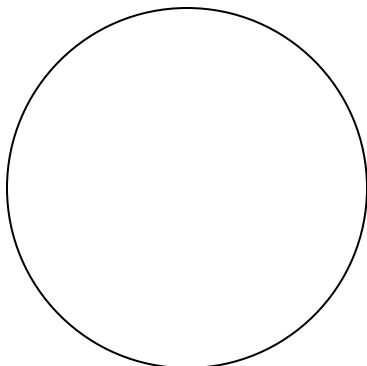
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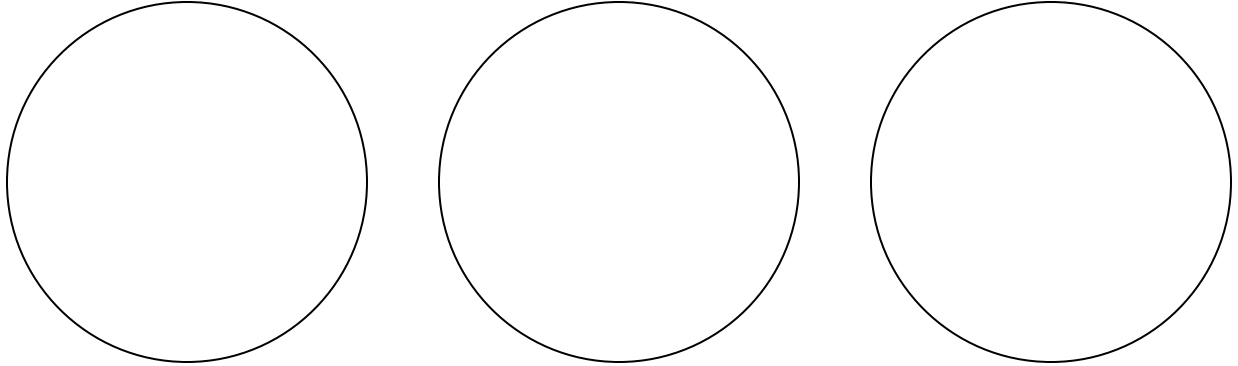
- Record the diameter of the field of view in millimeters and microns and the total magnification for both low and high power in the chart

		Low Power	High Power
Total magnification			
Diameter of Field of View	mm		
	microns		

- Carefully place the wings on the microscope slide
- Look at the wings under low magnification.
- Draw and label a few scales from three different areas of the wing. Record the area you are viewing. Keep the size to the same scale as your field of view:



- Look at the wings under high magnification.
- Draw and label a few scales from three different areas of the wing. Record the area you are viewing. Keep the size to the same scale as your field of view:



- Estimate the width and length of two different scales.
Scale #1 Width: _____ Length _____
Scale #2 Width: _____ Length _____

Describe the difference in illumination between this microscope and a regular compound microscope. _____

How does this difference change the image? _____

What advantage does this technology have over the regular light microscope?



Station #4

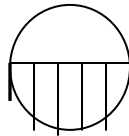
Materials: Petri dish, tweezers, colored pencils, ruler

What is the earliest time listed at this station? _____

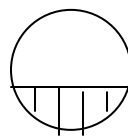
What magnifying instrument is available at this station? _____

- To measuring field of view: Place the ruler on the stage and focus it so that the top edge of the ruler goes completely across the center of the field of view. Place one mark at the extreme left of your field of view.

This:



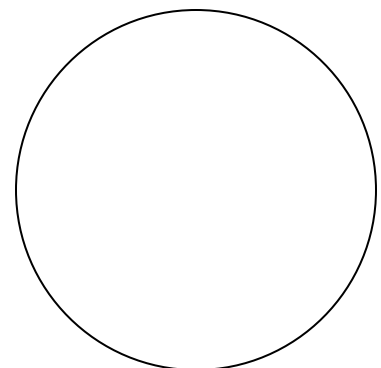
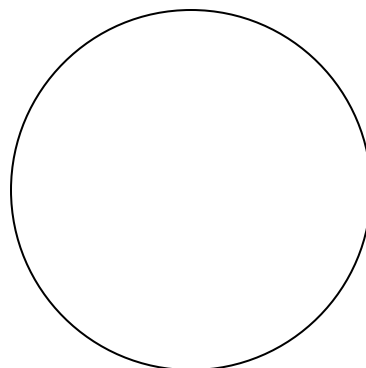
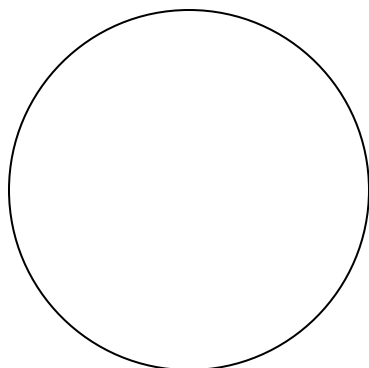
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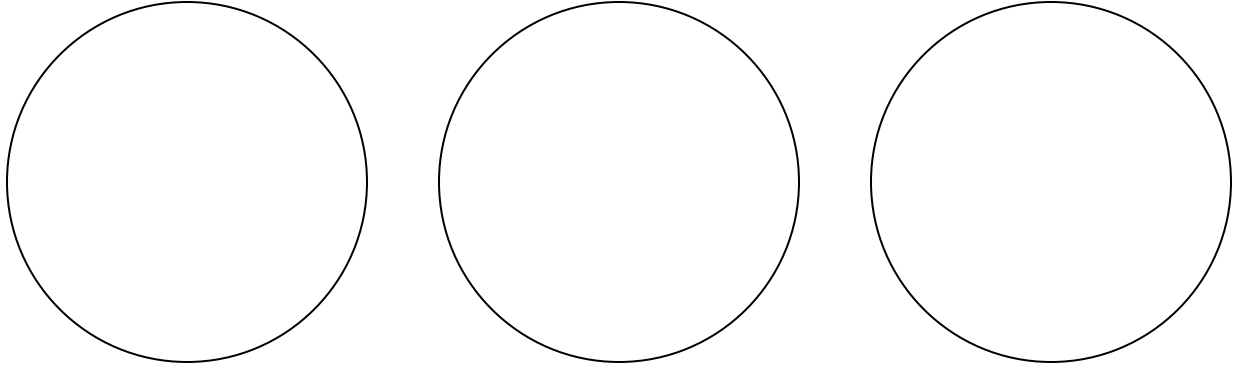
- Record the diameter of the field of view in millimeters and microns and the total magnification for both low and high power in the chart

		Low Power	High Power
Total magnification			
Diameter of Field of View	mm		
	microns		

- Carefully place the wings in the Petri dish.
- Look at the wings under low magnification.
- Draw and label a few scales from three different areas of the wing. Record the area you are viewing. Keep the size to the same scale as your field of view:



- Look at the wings under high magnification.
- Draw and label a few scales from three different areas of the wing. Record the area you are viewing. Keep the size to the same scale as your field of view:



- Estimate the width and length of two different scales.
Scale #1 Width: _____ Length _____
Scale #2 Width: _____ Length _____

Describe the difference between this microscope and a regular compound microscope. _____

What is the advantage of a stereo microscope?



Station #5

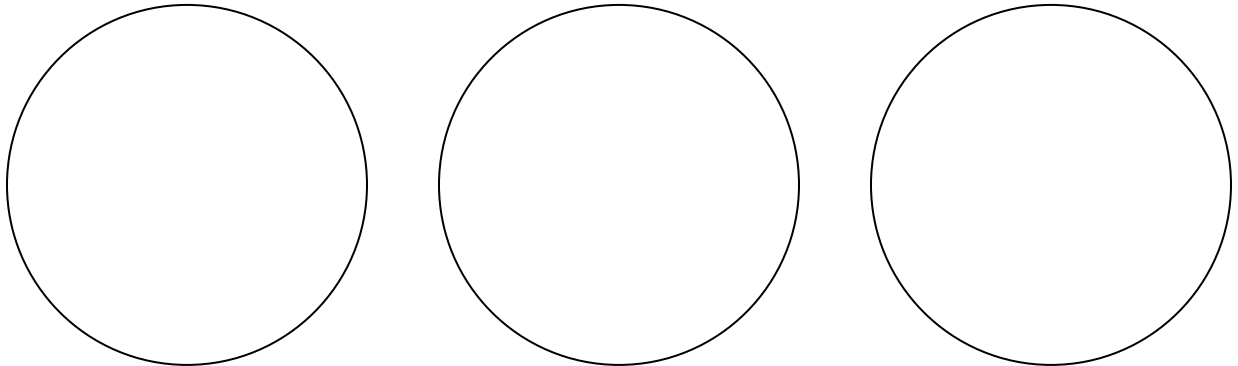
Materials: mounting button, tweezers, colored pencils, ruler, micrographs

What is the earliest time listed at this station? _____

What magnifying instrument is available at this station? _____

What new details are visible in the micrographs?

- Draw and label an area from three different magnifications of the wing. Record the area you are viewing.



- Use the scale bar on the micrographs to help you measure the length and width of three different scales.

Scale #1 Width: _____ Length _____

Scale #2 Width: _____ Length _____

Scale #3 Width: _____ Length _____

- Explain the difference in illumination between the light electron microscopes.

What advantage does this give the electron microscope over the light microscope?



Conclusion Questions:

1. State a conclusion for your hypothesis and support it with details from this lab.

2. Which microscope did you find the most useful to answer your hypothesis?

Explain your answer. _____

3. Suggest a reason for the different sizes and shapes of scales. _____

4. Of all of the different types of tools used, are any **not** being used today?

5. Why would a scientist use more than one of these tools during research?

6. How is scientific knowledge dependant upon technology? _____

7. What is the difference between magnification and resolution? _____



8. Which microscope had the best resolution? _____

Why? _____

9. Why did they not know about microorganisms and germs until the 1500's?

10. Suggest two questions for further study using microscopes and butterfly wings.



Butterfly Wings, Microscopes and Mimicry

Background:

Mimicry is an adaptation for survival. It can take many forms. Orchid mantids resemble the flower and wait to ambush its next meal. Its larvae resemble ants and are left alone. Walking sticks hide safely among the tree twigs they resemble. Scarlet king snakes are avoided because they look like the poisonous coral snake.

There are also butterfly mimics, most notably the viceroy butterfly. Their coloration is similar to the monarch butterfly. Monarchs have long been known to be distasteful to birds. Their caterpillars feed on milk weed plants and an unpleasant tasting chemical stays in their bodies even through metamorphosis. Naturalists originally thought that the viceroy was left alone because it resembled the monarch. But they have been shown to also be distasteful to birds. It is now considered a Mullerian mimicry, where two species evolved similar warning colorations and both contain unpleasant consequences for predators. Both species benefit because the predators learn to leave them both alone after only tasting one.

How far does their mimicry go? Do the butterflies resemble each other in more than their pigment pattern? Do they share similar structure in their scales?

Objectives:

- use a variety of magnification tools
- use the scientific method as a discovery learning tool
- examine, record and compare images of the wings of two different butterfly species
- Use rulers and scales to measure

Cautions to Students:

Only handle the butterfly wings with the tweezers.

You will be using electrical equipment – all electrical safety rules must be followed. Tweezers are sharp and can cause injury if not handled properly.

If a glass slide should break inform the teacher and follow broken glass safety rules.

Remember: 1cm = 10mm

1mm = 1000 μ

1 μ = 1000nm

Butterfly Classification: Monarch

Kingdom: Animalia
 Phylum: Arthropoda
 Class: Insecta
 Order: Lepidoptera
 Family: Danaidae
 Genus: Danaus
 Species: *Danaus plexippus*

Viceroy

Animalia
 Arthropoda
 Insecta
 Lepidoptera
 Nymphalidae
 Limenitis
Limenitis archippus



Procedure: Part A: Prediction and Hypothesis

The question to be answered:

Do the viceroy and monarch butterflies, as mimics, share similar structure in their scales as well as their color?

What is your prediction? Give a reason for your answer.

Write a hypothesis that can be answered in this investigation.

Procedure: Part B: Stations

In this part of the lab you will rotate between five stations. Each station has different tools for you to examine the wings. You will also find information to help you answer the questions. When you finish, return your wings to the envelope provided. Move to the next station at the direction of your teacher, making sure all of materials are left for the following group.

Be as complete and accurate as you can. Explain your answers clearly.

You will have 18 minutes at each station to complete the tasks.

READ the precaution on handling the butterfly wings



Station #1

Materials: ruler, colored pencils, 2 Petri dishes, hand lenses, tweezers

- With tweezers, gently remove the wings and place them in the Petri dishes, dorsal (brighter) side up. Label the dishes. Examine the wings and make your observations below:

Size: measure with the metric ruler in cm and convert to mm and microns.

Monarch	Length			Width		
	cm	mm	μ	cm	mm	μ
Forewing						
Hindwing						

Viceroy	Length			Width		
	cm	mm	μ	cm	mm	μ
Forewing						
Hindwing						

Color pattern on wings: Draw and label the dorsal wing color pattern of each of the butterflies.



What similarities and differences do you see? _____

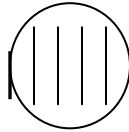


Station #2

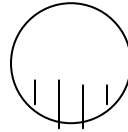
Materials: glass slide, tweezers, colored pencils, measuring slide

- To use measuring slide: Place the measurement slide on the stage and focus it so that the markings go completely across the center of the field of view. Place one mark at the extreme left of your field of view.

This:



Not this:



- Record the diameter of the field of view in millimeters and microns and the total magnification for both low and high power in the chart

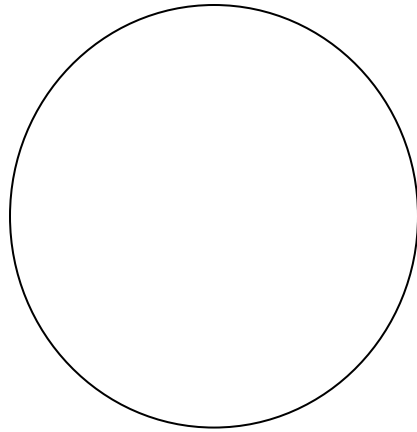
		Low Power	High Power
Total magnification			
Diameter of Field of View	mm		
	microns		

- Carefully place the monarch wings on the microscope slide.
- Look at the wings under low magnification.
- Draw and label a few scales from three different areas of the wing in the circle labeled “Monarch Low Power” on the following page. Include where on the wing the scales are located. Keep the size to the same scale as your field of view.

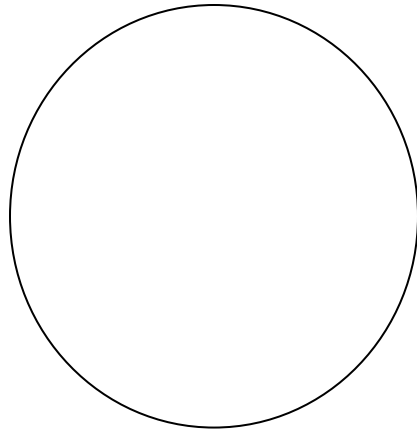
- Look at the wings under high magnification.
- Draw and label a few scales from three different areas of the wing in the circle marked “Monarch High Power” on the following page. Include where on the wing the scales are located. Keep the size to the same scale as your field of view.

- Repeat the procedure with the viceroy wings, but draw the scales in the set of circles labeled for the viceroy.

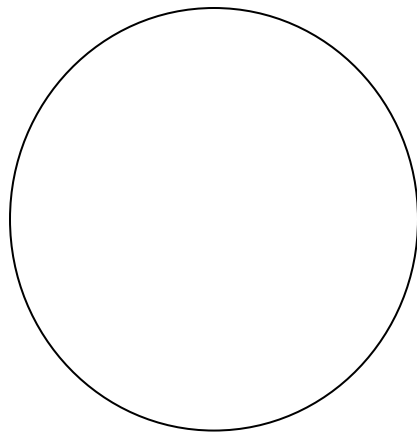




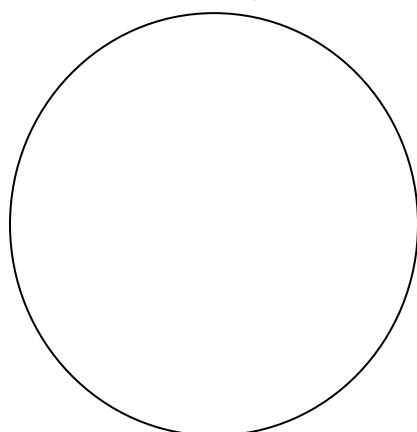
Monarch Low Power



Monarch High Power



Viceroy Low Power



Viceroy High Power

- Estimate the width and length of two different scales for each butterfly.

Monarch

Scale #1 Width: _____ Length _____

Scale #2 Width: _____ Length _____

Viceroy

Scale #1 Width: _____ Length _____

Scale #2 Width: _____ Length _____

What similarities and differences do you see? _____

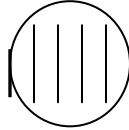


Station #3

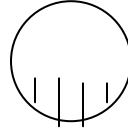
Materials: glass slide, tweezers, colored pencils, measuring slide

- To use measuring slide: Place the measurement slide on the stage and focus it so that the markings go completely across the center of the field of view. Place one mark at the extreme left of your field of view.

This:



Not this:



- Record the diameter of the field of view in millimeters and microns and the total magnification for both low and high power in the chart

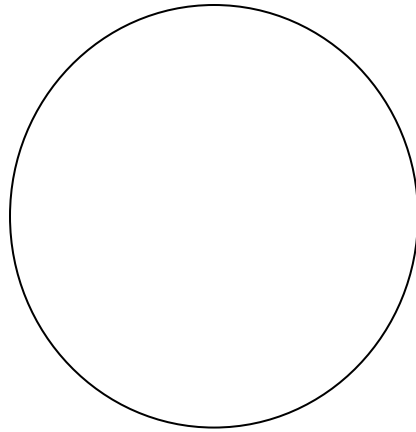
		Low Power	High Power
Total magnification			
Diameter of Field of View	mm		
	microns		

- Carefully place the monarch wings on the microscope slide.
- Look at the wings under low magnification.
- Draw and label a few scales from three different areas of the wing in the circle labeled “Monarch Low Power” on the following page. Include where on the wing the scales are located. Keep the size to the same scale as your field of view.

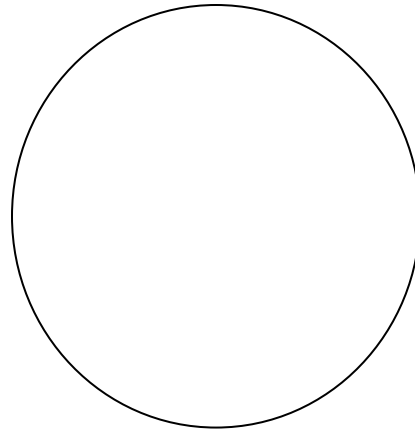
- Look at the wings under high magnification.
- Draw and label a few scales from three different areas of the wing in the circle marked “Monarch High Power” on the following page. Include where on the wing the scales are located. Keep the size to the same scale as your field of view.

- Repeat the procedure with the viceroys wings, but draw the scales in the set of circles labeled for the viceroy.

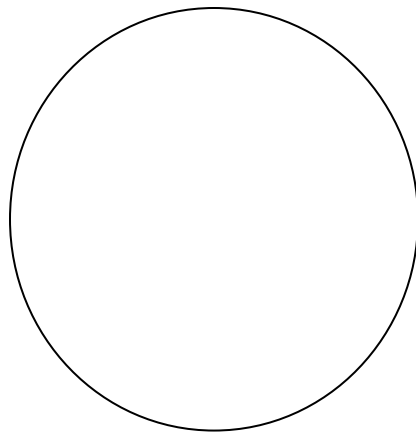




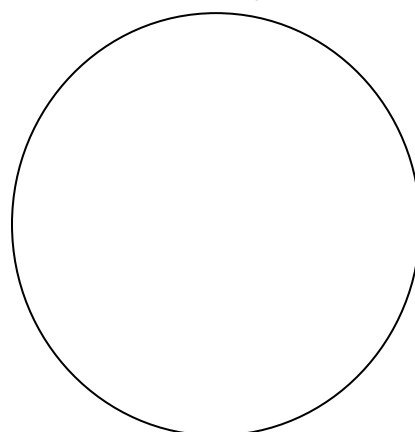
Monarch Low Power



Monarch High Power



Viceroy Low Power



Viceroy High Power

- Estimate the width and length of two different scales for each butterfly.

Monarch

Scale #1 Width: _____ Length _____

Scale #2 Width: _____ Length _____

Viceroy

Scale #1 Width: _____ Length _____

Scale #2 Width: _____ Length _____

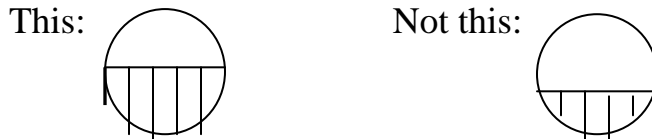
Compare the arrangement of scales between the monarch and the viceroy. Can you tell them apart from one another?



Station #4

Materials: Petri dish, tweezers, colored pencils, ruler

- To measuring field of view: Place the ruler on the stage and focus it so that the top edge of the ruler goes completely across the center of the field of view. Place one mark at the extreme left of your field of view.



- Record the diameter of the field of view in millimeters and microns and the total magnification for both low and high power in the chart

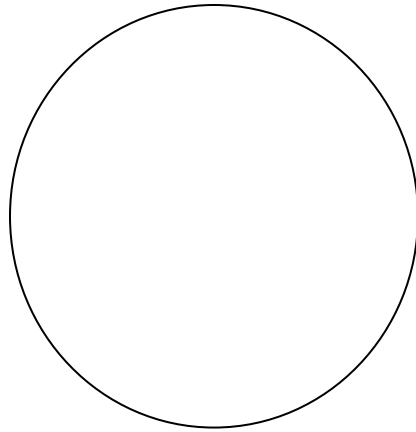
		Low Power	High Power
Total magnification			
Diameter of Field of View	mm		
	microns		

- Carefully place the monarch wings in the Petri dish.
- Look at the wings under low magnification.
- Draw and label a few scales from three different areas of the wing in the circle labeled “Monarch Low Power” on the following page. Include where on the wing the scales are located. Keep the size to the same scale as your field of view.

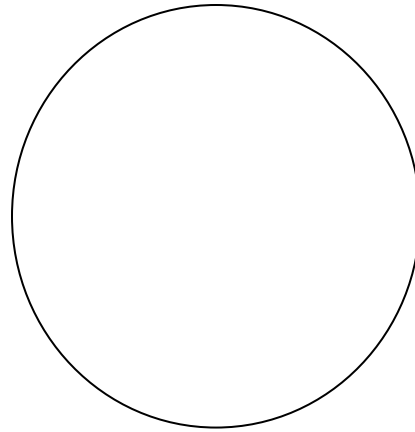
- Look at the wings under high magnification.
- Draw and label a few scales from three different areas of the wing in the circle marked “Monarch High Power” on the following page. Include where on the wing the scales are located. Keep the size to the same scale as your field of view.

- Repeat the procedure with the viceroys wings, but draw the scales in the set of circles labeled for the viceroy.

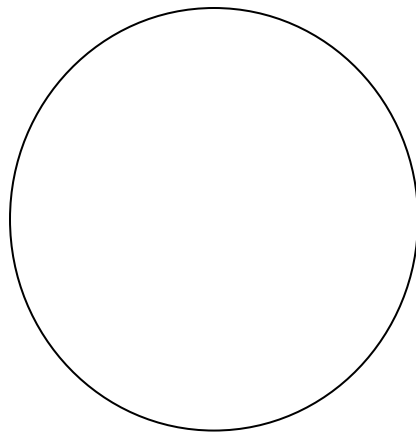




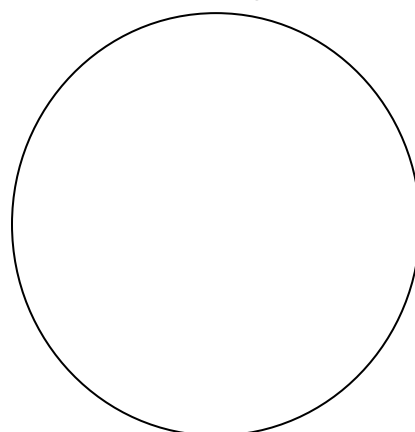
Monarch Low Power



Monarch High Power



Viceroy Low Power



Viceroy High Power

- Estimate the width and length of two different scales for each butterfly.

Monarch

Scale #1 Width: _____ Length _____

Scale #2 Width: _____ Length _____

Viceroy

Scale #1 Width: _____ Length _____

Scale #2 Width: _____ Length _____

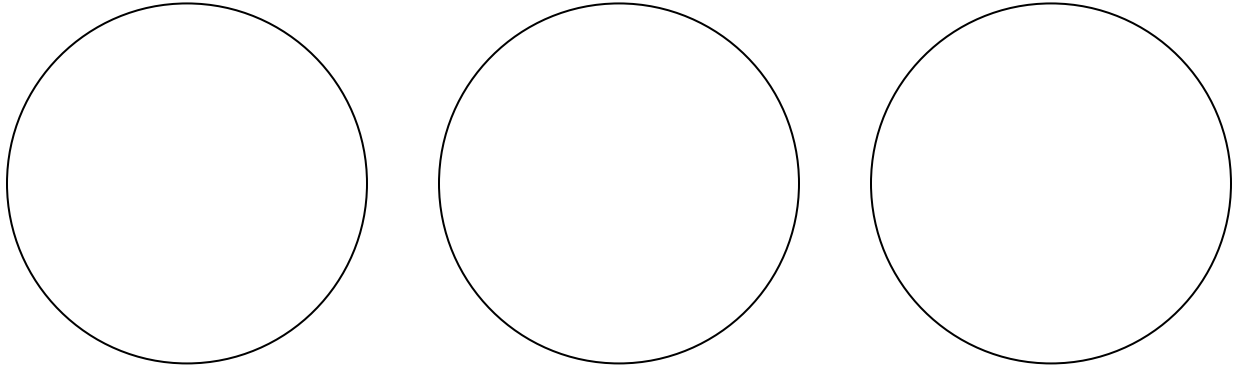
What additional differences or similarities can you see with this microscope?



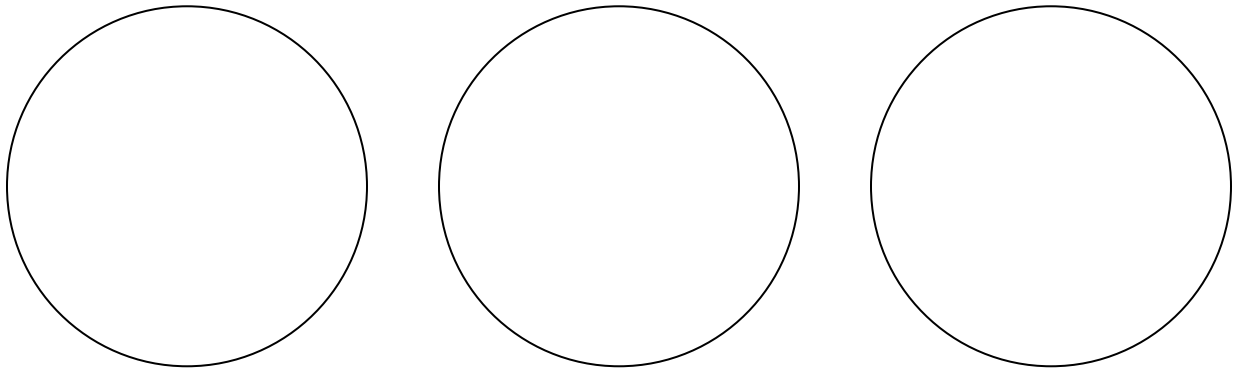
Station #5

Materials: mounting button, tweezers, colored pencils, ruler, micrographs

- Draw and label an area from three different magnifications of the wing for the monarch. Record the area you are viewing.



- Draw and label an area from three different magnifications of the wing for the Viceroy. Record the area you are viewing.



- Use the scale bar on the micrographs to help you measure the length and width of three different scales for each butterfly.

Monarch

Scale #1 Width: _____ Length _____
Scale #2 Width: _____ Length _____
Scale #3 Width: _____ Length _____

Viceroy

Scale #1 Width: _____ Length _____
Scale #2 Width: _____ Length _____
Scale #3 Width: _____ Length _____

Compare the framework pattern of the monarch butterfly scale to that of the viceroy butterfly scale.

What other similarities or differences are seen in the micrographs?



Conclusion Questions:

1. Write a conclusion based on your hypothesis. Be sure to back it up using details from this lab.

2. Based on your observations, do you think scale structure would be a useful tool to identify or classify butterflies? Explain your answer.

3. Do you think that the two butterflies are more closely related than their species name suggests? Explain.



Station #1

Observations with Eyes and Simple Lenses

Materials at this station:

Ruler, Petri dish, tweezers, colored pencils, hand lenses

Time period:

Ancient Assyrian, Greek and Roman times (2000 – 400 BC)

To

Present

Technology available – simple lenses date back to the Assyrians (700 BC)

Better quality lenses were made by the early 11th century

Magnification limits: various

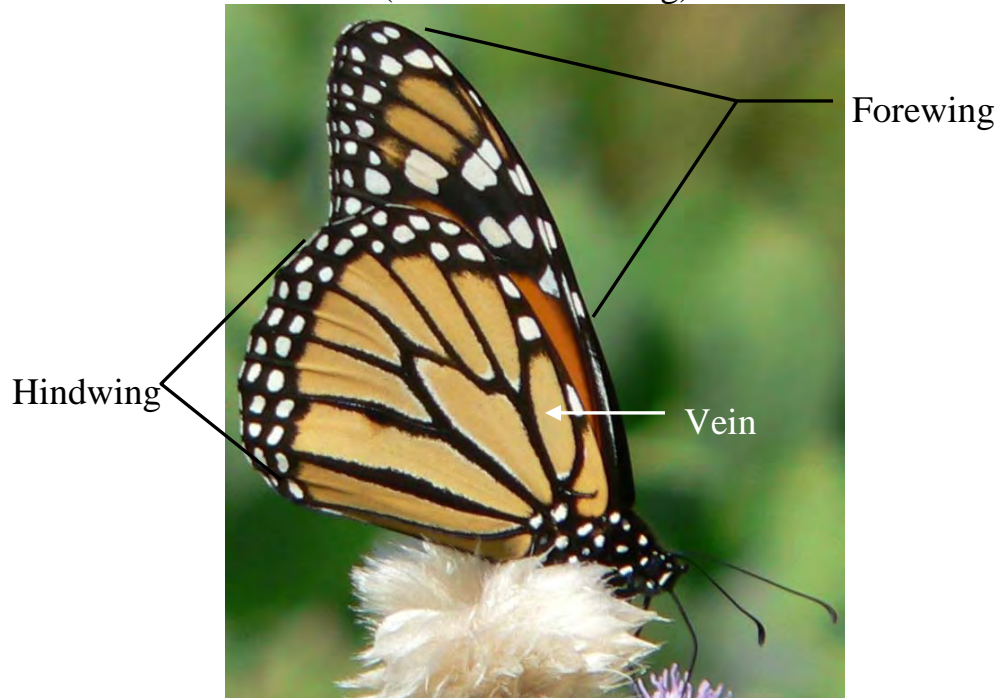
Resolution limits: 0.5 – 0.03 mm

Tasks:

1. Record observations using your unassisted eyes.
2. Record observations using a hand lens.
3. Measure objects

Butterfly Wing Terminology

Ventral (Underside of Wing) View



Dorsal (Top of wing) View



Station #2

Observations with Compound Microscope

Materials at this station:

Glass slide, Tweezers, Colored pencils, Measuring slide

Time period:
1590 AD – present

New Technology available – Compound Microscope
Light passes through thin sections
Able to magnify up to 2500x
Resolution limit $\sim 0.2\mu$ (=200nm)

Tasks:

1. Measure field of view – low power and high power
2. Record your observations under low power
3. Record your observations under high power
4. Measure objects

Station #4

Observations with a Stereo Microscope

Materials at this station:

Petri dish, Tweezers, Colored pencils, Ruler

Time Period:
1894 to present

New Technology Available – Stereo microscope
Light is reflected or transmitted
Able to view thick objects
3-D image obtained
Same resolution as Compound Microscopes
Usually only up to 500x magnification

Tasks:

1. Measure field of view – low power and high power
2. Record your observations under low power
3. Record your observations under high power
4. Measure objects

Station #3

Observations with an Oblique Light Source

Materials at this station:

Glass slide Tweezers, Colored pencils, Measuring slide

Time Period:
1830 – Present

New Technology Available – Dark Field Microscope
Illumination light at an angle
Creates contrast in unstained samples
3-D effect

This a simulation – true dark field microscopes have a ring of illumination light

Tasks:

1. Measure field of view – low power and high power
2. Record your observations under low power
3. Record your observations under high power
4. Measure objects

Station #5

Observations with a Scanning Electron Microscope

Materials at this station:

Mounting button, Tweezers, Colored pencils, Ruler, Micrographs

Time Period:
1942 – Present

New Technology Available – Scanning Electron Microscope
Illumination is with electrons passing over a small surface area

Smaller wavelength improves resolution to ~ 0.2nm

Magnification – AMRAY 1000 (at NFA) 100,000x

Can be as high as 1,000,000x

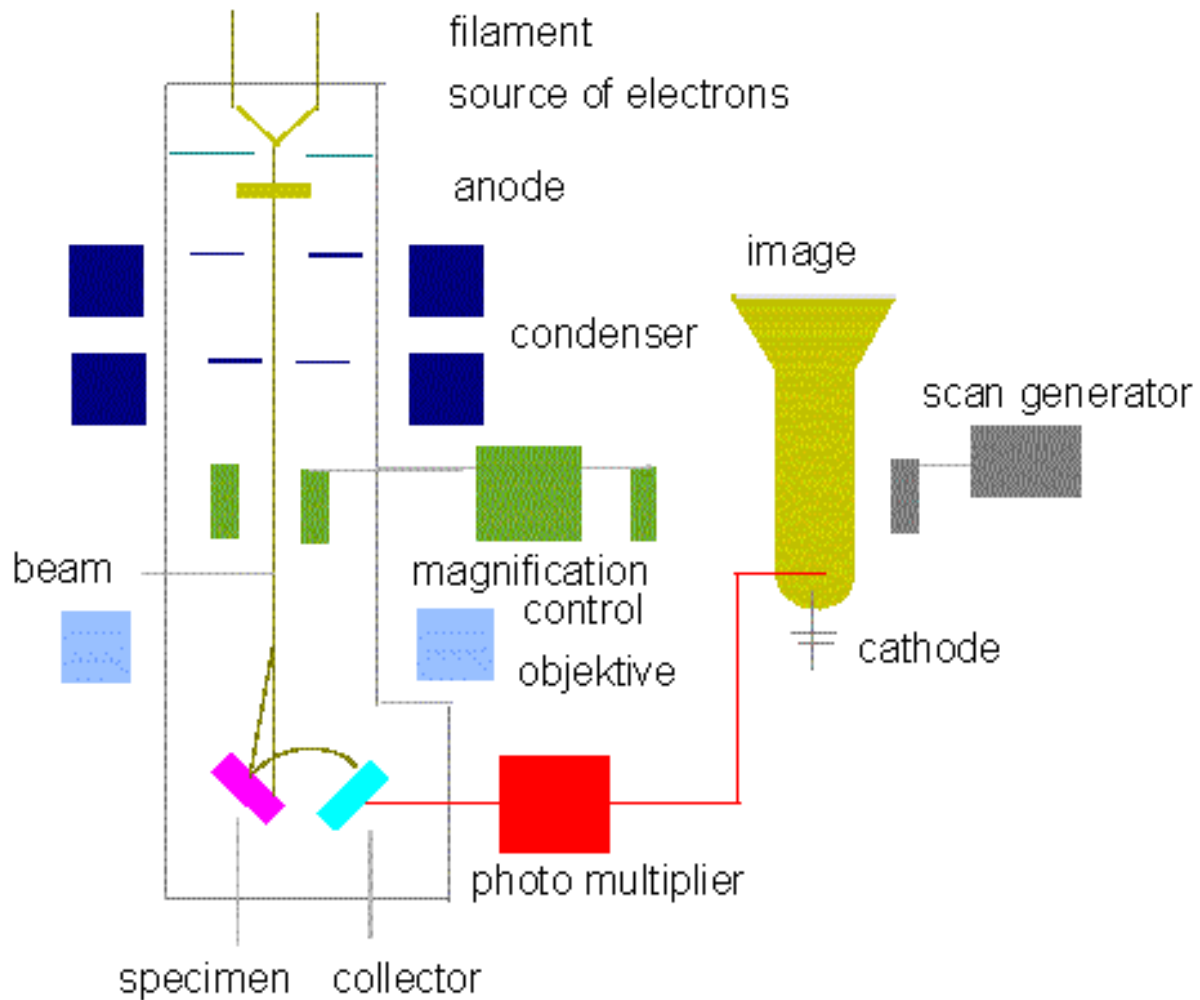
“3-D” image of surface of object

Samples need to be covered with conductive material (usually gold)

Tasks:

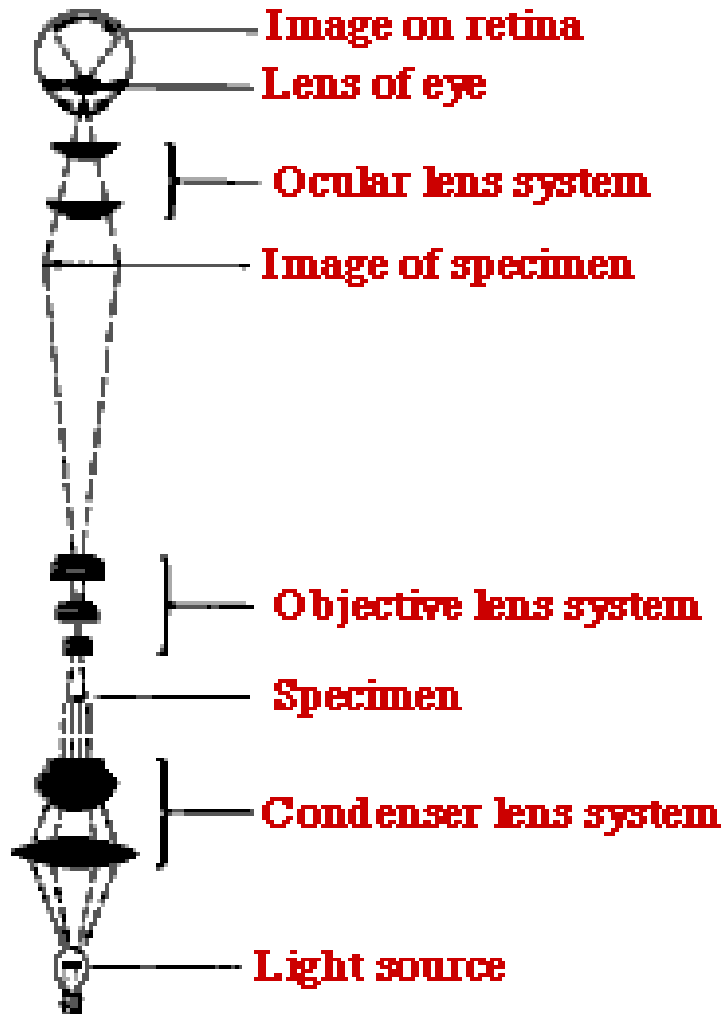
1. Record observations of micrographs
2. Measure objects and calculate their true size

Schematic of a Scanning Electron Microscope:



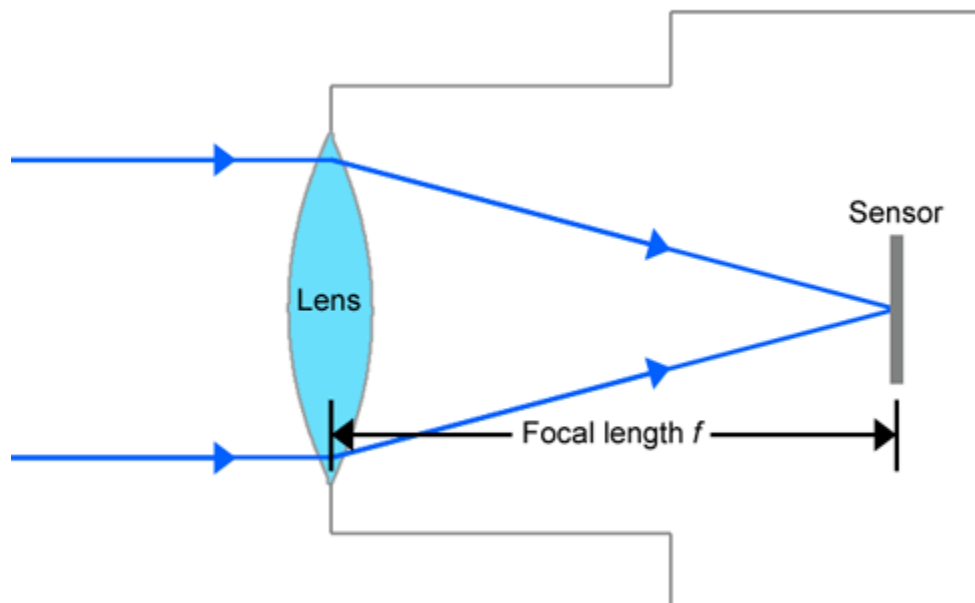
<http://www.biologie.uni-hamburg.de/b-online/e03/03e.htm>

Schematic of Light Microscope



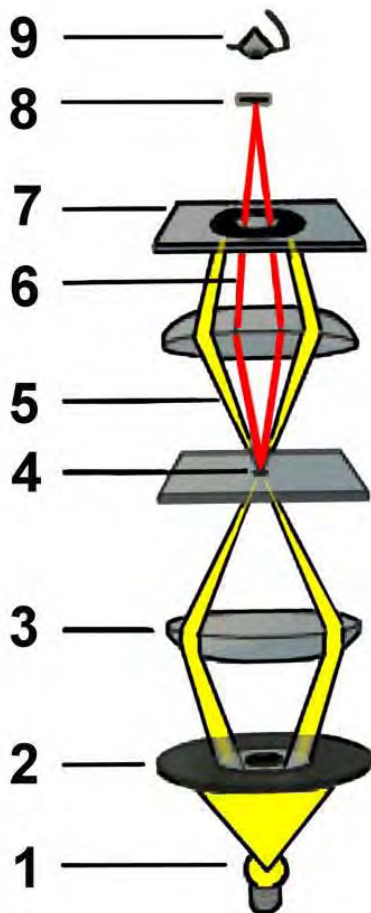
<http://www.microbiologybytes.com/introduction/graphics/i2.gif>

Schematic of Path of Light through a Magnifying Lens



http://www.trustedreviews.com/images/article/inline/3973-FocalLength_diag.gif

Schematic of Dark Field Microscope



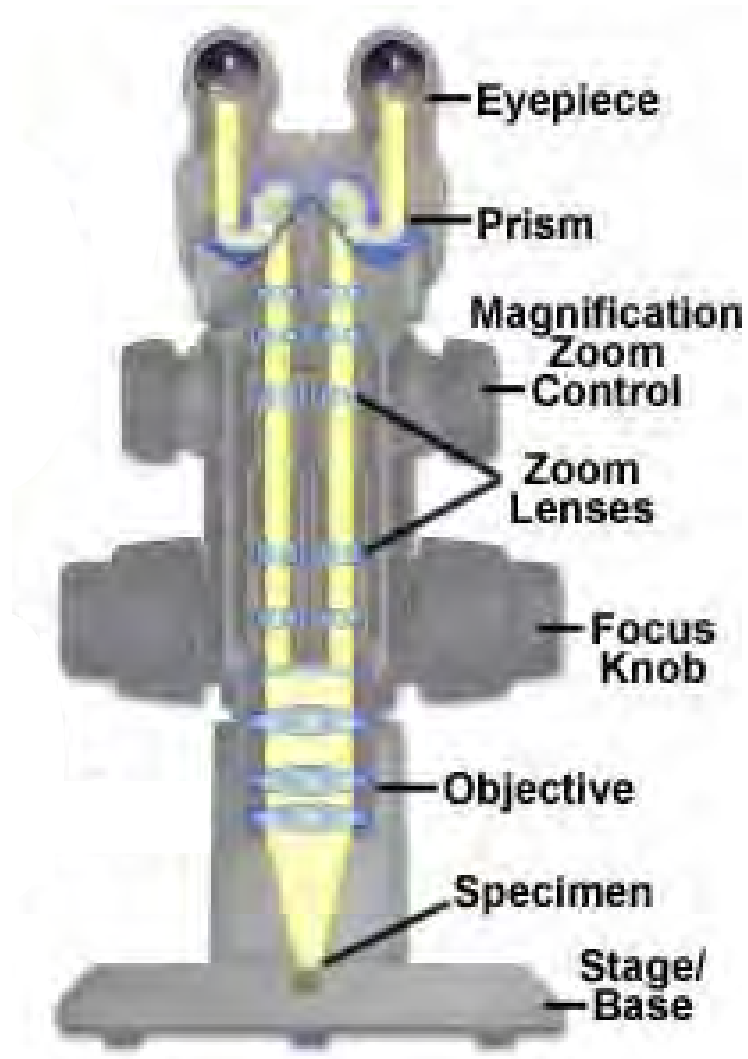
- 1 = light source*
- 2 = light ring or light mask*
- 3 = condenser*
- 4 = specimen*
- 5 = illuminating light*
- 6 = light bent by the specimen*
- 7 = annular beam stop within the objective*
- 8 = eyepiece with intermediate image*
- 9 = eye*

a: luminance dark field in concentric illumination



http://www.luminance-contrast.com/Modification_of_lenses/fig.5_a_and_b.jpg

Path of Light through a Stereo Microscope



<http://www.microscopyu.com/articles/stereomicroscopy/stereointro.html>