

Monkey Health Explorer Lesson Plan

(Version 2.2 – Flash Card Version)

Lesson Abstract:

Lesson Plan Title: Learn about monkey blood and health with the Monkey Health Explorer project! (Version 2)	Essential Question: What are the different components of blood? How do we identify cells in a blood smear? What are the roles of white blood cells in health? How does blood tell us about health?
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Abstract to Lesson Plan: (Max. 1 paragraph) <i>Summary description of the main activity(ies) of your lesson plan and the main learning goal for each activity. Include aspects of the lesson that are unique and innovative.</i> In this lesson, students will learn about the composition of blood and how it relates to health through the unique perspective of an active research project studying rhesus macaque monkeys on an island off the coast of Puerto Rico. In the first activity, students explore the composition of blood through a proportional candy model of a blood smear, learning about the three main cell types (white blood cells, red blood cells, and platelets) in blood. The second activity focuses on white blood cells and the role they play in the immune system. Students will learn how to identify white blood cells by participating in the Monkey Health Explorer project on the public participation platform, Zooniverse.org. They will practice their newly-learned skills with images of blood cells from a particular monkey. Students will then evaluate the results of their white blood analysis and tie them back to what they learned about the immune system to determine if the monkey might be sick. The final activity will take what the students have learned about blood analyses and expand it to assess blood cell data from a group of monkeys. They will analyze blood cell and demographic data from a set of monkeys to look for differences in blood cell values across different variables, such as in females versus males. Students will learn how this type of analysis is used in the larger research collaboration investigating how genes and health influence social behavior in rhesus macaque monkeys, and how this translates back to humans. Students will learn how Machine Learning (ML), a type of Artificial Intelligence (AI), is used in this project. Quick Summary of Activities: 1) Explore the composition of blood through a proportional candy model of a blood smear. 2) Learn how to identify white blood cells in monkey blood smear images and evaluate the results to determine if the monkey might be sick. 3) Analyze blood cell and demographic data from a set of monkeys to look for differences in blood cell values across different variables.	

Lesson Plan Information:

Class Subject and Grade Level: Biology/STEM 6-8 Biology/STEM 9-12	Learning Objectives (L.O.): By the end of the lesson, students will be able to: ● Recall and describe the different components of blood. ● Illustrate what a blood smear looks like. ● Recognize the different blood cell types. ● Distinguish the types of white blood cells on a blood smear. ● Evaluate the relative amounts of each type of white blood cell. ● Formulate a hypothesis on the health status of an individual based on blood cell data.
Class Duration/Logistics: Time is variable depending on optional activities.	
Class Setting: These activities can be done indoors or online. Though not necessary to the class, if students want to contribute to the Monkey Health Explorer Project, they will need access to a computer and internet.	
Class Size: Depending on class size and teacher preference, activities may be done individually, in pairs, or in groups of 3-6.	Lists of Standards (Common Core, NC Essential Science, Next Gen, etc.): LS.7.1 Understand the processes, structures and functions of living organisms that enable them to survive, reproduce and carry out the basic functions of life. LS.7.1.2 Use models to explain how the relevant structures within cells (including cell membrane, cell wall, nucleus, mitochondria, chloroplasts, and vacuoles) function to support the life of plant, animal, and bacterial cells. LS.8.1 Understand the hazards caused by agents of disease that affect living organisms LS.Bio.1 Analyze how the relationship between structure and function supports life processes within organisms. MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.
Materials Needed for Teacher: <u>Main Activities</u> ● Computer and projector/display ● MHE_Classroom_Slides_V2 ● MHE_Classification_Worksheet_V2-Key ● MHE_DataFile_key Key <u>Optional Activities</u> ● MHE_BloodCellCrossword_Key ● Internet access to go to Monkey Health Explorer project at Zooniverse.org	
Materials Needed for Students: (1 per student unless otherwise noted) <u>Main Activities</u> ● Sealable snack-sized bag with candy (pre-made or made during activity) ○ 1 tsp (3-5) different color jelly beans/Skittles ○ 1 tsp Nerds candy pieces ○ 2 Tbsp Red Hots candy ● MHE_FieldGuide (1 per student or per group) ● MHE_Classification_Worksheet_V2 ● Computer for advanced activity ○ MHE_DataFile_Student ○ MHE_Summary_Student <u>Optional Activities</u> ● Colored pencils, pens, or markers ● MHE_BloodSmearModelWorksheet ● MHE_BloodCellCrossword_Student	

Lesson Activity:

ENGAGE: LEARNING OBJECTIVES PREVIEWED - Capture students' attention, activate prior knowledge, and stimulate student thinking so that they are prepared for today's lesson and have sufficient context around which to construct new knowledge.

Slide 1

Start by asking the class about health and about blood.

- Who has ever had blood drawn at the doctor's office?
- What does blood do for us?

Gather everyone's responses and then elaborate on the topic of the composition of blood.

Explain that blood plays many important roles in keeping us alive and healthy, such as oxygen transport, protection, and regulation!

Slide 2

Follow up with showing an image of a cartoon blood smear.

Explain that if we zoom in very closely, we can see that blood is composed of different parts: **plasma** (mostly water), **platelets**, white blood cells (WBCs) also called **leukocytes** and red blood cells (RBCs) also called **erythrocytes**.

Components of Blood:

Plasma makes up 54% of blood. It is mostly composed of water and salt and contains blood proteins; it is the substance that suspends the other components of blood (RBCs, WBCs, and platelets).

Red Blood Cells (RBCs) make up 42% of blood and contain hemoglobin, which is responsible for carrying oxygen to your body.

Platelets make up about 3% of blood and are the smallest cells in blood. They form clots to stop the flow of blood when you have a cut or other injury.

White Blood Cells (WBCs) make up about 1% of blood and are our immune system cells that help fight off infections and diseases.

When we go to the doctor's office, sometimes we get our blood drawn for blood tests. Blood tests provide valuable insight to what's going on inside our bodies. I.e. Are we fighting off an infection or parasite? Are we having an allergic reaction?

The percentages of each component of blood we discuss here, is based on humans.

Slide 3

How are blood smears made?

A sample of blood is collected.

A drop of blood is placed on a microscope slide and then smeared across the slide using another slide or other tool.

The slide is processed so the cells are fixed in place on the slide and a stain is applied, which binds to certain components of the cells to make them visible under a microscope, as shown here.

What prior knowledge must be brought up to get them ready to explore the new concepts of today's objective?

What questions can I ask to elicit that prior knowledge?

To what previous content and/or real-life experience can I connect today's objective to capture students' attention and build anticipation for the lesson?

What misconceptions might students have and what questions can I ask to have them reveal those misconceptions?

Monkey Blood This is actually an image of blood from a rhesus macaque monkey. All the blood images we are working with today come from an ongoing collaborative research project investigating how genes and health influence social behavior in rhesus macaque monkeys. We will explore more about these monkeys and the research project as we learn about blood. First, we will be making our own blood smear model to visualize the proportions of each component, and make our own blood count analysis. Next, we will learn about the different blood cell types, how to identify them in blood smears, and what they can tell us about the health of an individual. At the end, we'll be able to help scientists analyze blood smears and contribute to research with the Monkey Health Explorer project.	
EXPLORE: LEARNING OBJECTIVES DISCOVERED - Students make observations, record data, design and execute experiments, create graphs, interpret results, organize their findings, and develop hypotheses or conclusions so that they can construct knowledge independently and practice their scientific habits of mind.	
Explain more about rhesus macaque monkeys and the research project. Slides 4-5 Rhesus macaques (<i>Macaca mulatta</i>) are monkeys native to many countries across Asia, especially India and Southern China. The monkeys on Cayo Santiago were brought to the island in 1938 from different regions across India, and the population has been studied for decades. The Caribbean Primate Research Center maintains the island. These social animals are the largest mammal on the island and free to roam the island and form social groups. They are provided supplemental food (Purina monkey chow) and water, but otherwise mostly left alone. Researchers observe the social behaviors between individuals, such as who is more or less dominant and who grooms who. Once a year, a group of monkeys are captured briefly to be evaluated and measured. A sample of blood is taken at this time, similar to when we go to the doctor for a checkup. The blood smear images used in today's class come from these monkeys. Learn more about rhesus macaques at https://primate.wisc.edu/primate-info-net/pin-factsheets/pin-factsheet-rhesus-macaque/ What can we learn by studying monkey blood? This allows the researchers to evaluate the health of the animals at the time their blood was collected as well as study their DNA. Researchers are looking to find connections between their health, genetics, and social behavior. Studying monkey health can give us valuable insights into similar processes in humans. <i>Guess how much of our DNA we share with Rhesus macaques?</i> 52%, 76%, 93%, 98% (Answer: 93%)	<i>What must students be doing and thinking to discover the key points through their doing instead of my telling?</i> <i>How can I set up an experience to allow my students to do and think these things?</i> <i>What questions must I ask to guide their thinking to arrive at the key points?</i> <i>How are students pushed to develop the explanations or solutions I am looking for?</i> <i>How and where are students recording information/data?</i> <i>How will I ensure that all students are not just participating in the activity, but engaging in the thinking required to arrive at the key points?</i>

The monkey blood smears we are discussing today are part of a public participation project called Monkey Health Explorer on an online platform called Zooniverse. This is part of a larger collaborative project involving multiple researchers working on different projects with these monkeys.

Slide 6

The Zooniverse website has many research projects spanning a wide range of disciplines that anyone with an internet connection can participate in. You can also get to the Monkey Health Explorer project and others through SciStarter.org, a website that helps people find projects to get involved in both online and in person in their area.

Slide 7

For the Monkey Health Explorer project, blood samples taken from rhesus macaque monkeys are spread onto microscope slides to make blood smears, which are then scanned by a special microscope.

The scanned images are broken into thousands of smaller images for uploading onto the Zooniverse project page, where volunteers from all over the World help identify the blood cells.

There are 2 types of workflows and each start off with a tutorial to show you how the project works.

Slide 8

The original workflows (on the left) show large images where you click on each white blood cell, then choose the type of cell it is from a list.

The newer, “single cell” workflows (on the right) show cropped images where you just select from a list the type of white blood cell found in the center of the image.

Slide 9

Now let’s explore the components of blood with a candy blood smear model.

Provide each student with a sealed plastic snack bag with measured candies [2 Tbsp Red Hots, 1 tsp Nerds, 1 tsp (3-5) Jelly Beans or Skittles]. Bags can be prepared ahead of time or scooped during class for an extended activity.

Explore the example blood smear image to identify the components of blood: plasma, platelets, RBCs, and the 5 different WBCs.

Note that we will go more in depth on WBC’s in the next activity.

Have the students check that their bag is **sealed**, then have them mix up the contents by shaking the bag. Have them pretend to collect a smear by placing the bag on the desk in front of them and gently swiping the side of their hand across the baggie to spread out the items inside.

- What do they see?
3 different types of candy

Ask the class what they think each item represents in their candy blood smear. - Which candy is larger/smaller? <i>Skittles/jelly beans are largest, like white blood cells. Nerds are smallest, like platelets.</i> - Which candy is more/less abundant? <i>Red hots are the most abundant, like red blood cells. Skittles/jelly beans are the least abundant, like white blood cells.</i> Assign the air/empty space in the bag as plasma, the Nerds as platelets, the Red Hots as red blood cells (RBCs), and the jelly beans/Skittles as white blood cells (WBCs). Expanded activity: Provide each student with a Blood Smear Model Worksheet. Page 1 Have students draw and label what they see in their candy blood smear. Assign each white blood cell type to a different color of jelly beans/Skittles. (Ex. Skittles: red = lymphocytes, orange = monocytes, green = neutrophils, yellow = eosinophils, purple= basophils) Page 2 Have students read the text, then analyze their ‘blood smear’ by counting each type of cell they see and calculating the relative amounts of RBCs, WBCs, and platelets in the “blood”. Page 3 Have students answer the questions based on their data from page 2.	
EXPLAIN: LEARNING OBJECTIVES FORMALIZED - Solicit student ideas of what they’ve just done, introduce laws/models/theories/vocabulary, guide students towards generalizations that explain the results of their explorations, and confirm ideas so that students are clear on what is correct, why it’s correct, and what they need to take away.	
Provide each student with a WBC field guide. Slide 10 Why identify and count blood cells? Explain what a complete blood count (CBC) is. In a traditional complete blood count, a technician examines a blood smear under a microscope and counts how many red blood cells, white blood cells, and platelets they find. They also record which type of white blood cells they see as they count them. They continue to count blood cells until they have counted 100 white blood cells. Now, blood is typically evaluated on a machine which can read additional components such as hematocrit and hemoglobin. The ratio of WBCs to RBCs is calculated as well as the percentage of each type of WBC, and the Neutrophil to Lymphocyte Ratio (NLR). These values in the blood sample are compared to the “normal” ranges expected for a healthy individual to determine if any particular cell types are out of the normal range. - Why do you think it is important to study blood counts? A CBC can show valuable insight about our overall health and detect a wide range of infections and diseases	<i>How will I set students up to create accurate explanations and justify them with evidence?</i> <i>How will students share and engage in the findings of their classmates (whole class or smaller groups)?</i> <i>How will students receive information on formal definitions, labels, rules and procedures – and record in a way that makes sense?</i> <i>How will students compare their explanations to formal definitions and rules so</i>

Slide 11

Today we're going to help evaluate the blood of this monkey who doesn't seem to be feeling good. [Show them the image of a "sick" monkey.]

These are wild animals, so they don't have names like pets do, so let's give it a name just for today. Before we can figure out what might be wrong with our monkey friend, we need to learn more about the different types of white blood cells and how to identify them.

Slide 12

Now we are going to focus more on white blood cells and how they play a role in health.

Have students look at the example images in the WBC field guide as you discuss each WBC type. Note that the cell stains can differ slightly between samples, with some looking more pink and others more purple. Generally, red blood cells all look similar, no matter what color the stain gives them.

Slide 13

Here we show close ups of 5 white blood cells as examples for describing their distinguishing characteristics.

First, you will notice that the majority of cells found in the images will be red blood cells like those pointed out here.

There are also platelets, which are seen as very small darkly-stained shapes.

The cells we are focusing on in this project are the white blood cells indicated here: Neutrophils, Eosinophils, Monocytes, Lymphocytes, and Basophils

Slide 14

We will look at Neutrophils and Eosinophils together because they have similarities that can cause them to be mistaken for one another.

Both are 2 to 3 times as large as red blood cells

The nuclei of both have multiple lobes that show up as connected dark shapes. Eosinophils typically have 2 to 3 shapes as shown in the example image on the right, while neutrophils tend to have more as shown in the example on the left.

A very distinguishing characteristic is the relative darkness of the cytoplasm.

Neutrophil cytoplasm is lighter with small pinkish granules, while eosinophil cytoplasm is darker, red-purple granules that give it a shaded look.

One way to help identify the relative light or darkness of the cytoplasm is to compare it to an adjacent donut-shaped red blood cell.

The neutrophil cytoplasm will look more similar to the inside of the donut, while the eosinophil cytoplasm will tend to be as dark as the outer, solid part of the donut.

One more factor to consider is how common the cells are. In humans, Neutrophils make up 40 to 60 % of white blood cells, while eosinophils are only 1 to 4 %.

that they make sense of their own experience?

What misunderstandings do I anticipate students still having and how can I correct them?

*How will I know when students understand?
What questions must they be able to answer?*

Neutrophils attack bacterial invaders that enter the body; also called first responder cells.

Eosinophils attack parasites that enter the body (example: worms) and are part of allergic response and asthma.

Slide 15

Let's test what we've learned so far. Which is an Eosinophil? (B)

Key: (A) Neutrophil, (B) Eosinophil, (C) Neutrophil, (D) Red Blood Cell

Slide 16

Now let's compare Monocytes to Lymphocytes because their similarities can cause them to be confused for one another as well.

A major distinguishing characteristic between these two cells is their size.

Monocytes are the largest of the white blood cells and can be more than 3 times as large as red blood cells.

Lymphocytes are much smaller with the nucleus being about the size of a red blood cell.

Both appear to have a single, large nucleus, but the shape of it is typically different.

The monocyte nucleus has two lobes that are often pushed together to look like a single irregular shape, like a ball of clay that has been pushed in multiple places.

The lymphocyte nucleus is typically more rounded and smooth.

They both have a lighter cytoplasm that can be more blue-purple and have no granules. You typically see much more of the cytoplasm in the monocyte than in the lymphocyte and monocytes sometimes have vacuoles.

Monocytes are much less common and make up only 2 to 8 % of white blood cells in humans, Lymphocytes are more common and make up 20 to 40 %.

Monocytes are considered circulating phagocytes. When debris, microbes, or parasites invade the tissues, monocytes attempt to engulf and devour the invaders through openings called vacuoles.

Lymphocytes are responsible for carrying out specific immune responses and primarily attack cells (for example, attacking cancerous and virus-infected cells). There are two types of lymphocytes, T & B cells. We can't distinguish between T and B cells in this activity.

Slide 17

Let's test what we've learned now. Which is a lymphocyte? (C)

Key: (A) 2 Eosinophils, (B) Neutrophil, (C) Lymphocyte (with a Neutrophil to the right of it), (D) Monocyte

Slide 18 Like most of the white blood cells, Basophils are 2 to 3 times as large as red blood cells. The cell has an s or c-shaped nucleus almost hidden by the many darkly-stained granules that look like small pebbles in the cytoplasm. They are very rare with fewer than 1 found for every 100 white blood cells identified. Basophils store the chemicals heparin and histamine and are used to promote inflammation (example: allergies) Slide 19 Let's test what we've learned about identifying WBCs. What are these marked cells? Key: (A) Neutrophil, (B) Lymphocyte, (C) Eosinophil, (D) Neutrophil Expanded activity: Provide each student with a Blood Cell Crossword.	
ELABORATE: LEARNING OBJECTIVES USED - Students practice applying ideas to new domains in an increasingly independent way and practice problems for skill objectives so that they reinforce their knowledge, check their understanding while the teacher is present, and can extend ideas beyond just the problem or application in the example.	
Provide each student with a Classification worksheet. Slide 20 Now's your chance to collect and analyze blood cell images from our sick monkey to assess what might be wrong. Slide 21 We'll be using our classification worksheet to evaluate our monkey's blood. The front page is like the original workflows in the Monkey Health Explorer project looking at larger images, while the back page is like the single cell workflows using cropped images. Slide 22 As a class, classify the white blood cells in image 1 The WBCs on this image are blown up on the screen to make it easier for students to see for this practice. Key from top to bottom: Neutrophil, Neutrophil, Neutrophil, Lymphocyte, None (cluster of platelets) Slide 23 As a class, classify the white blood cells in image 2 and enter the classification data in the worksheet. The WBCs on this image are blown up on the screen to make it easier for students to see for this practice. Key from top to bottom: Monocyte, Neutrophil, Lymphocyte	<i>How will students use their new definitions, rules, and skills to investigate or solve problems in a new, yet similar situation?</i> <i>How will I scaffold my support and include whole class, group, and individual checks for understanding?</i> <i>How will students demonstrate their knowledge of the new information and ability to apply it in new ways?</i> <i>How will I ensure that students are able to apply their knowledge in an increasingly independent (and eventually independent) way?</i>

Slide 24

Have students count each white blood cell type on the front page and record it at the bottom of the page.

Key: Neutrophil 4, Lymphocyte 2, Monocyte 1, Eosinophil 0, Basophil 0

Have students copy their front page counts to the table at the bottom of the back page.

Slide 25

Have the students study their field guides and classify the WBC's on the back of the worksheet.

Slides 26-30

Review images as a class with the correct answers.

Row 1 **Key** from left to right: Neutrophil, Lymphocyte, Lymphocyte, Neutrophil, Neutrophil, Eosinophil, Neutrophil, Eosinophil, Eosinophil

Row 2 **Key** from left to right: Basophil, Eosinophil, Neutrophil, Eosinophil, Lymphocyte, Neutrophil, Neutrophil, Eosinophil

Row 3 **Key** from left to right: Neutrophil, Neutrophil, Neutrophil, Lymphocyte, Neutrophil, Eosinophil, Neutrophil, Neutrophil, Lymphocyte

Row 4 **Key** from left to right: Neutrophil, Lymphocyte, Neutrophil, Neutrophil, Neutrophil, Neutrophil, Monocyte, Lymphocyte, Lymphocyte

Row 5 **Key** from left to right: Lymphocyte, Neutrophil, Eosinophil, Neutrophil, Neutrophil, Neutrophil, Lymphocyte, Neutrophil

Slide 31

Have students count each white blood cell type on the back page and record it at the bottom of the page.

Key: Neutrophil 23, Lymphocyte 10, Monocyte 1, Eosinophil 8, Basophil 1

Have students calculate the total counts for each white blood cell type.

Key: Neutrophil 27, Lymphocyte 12, Monocyte 2, Eosinophil 8, Basophil 1

Slide 32

Look at the White Blood Cell Counts along with the typical ranges (for humans).

Can we compare the numbers to the “Normal” ranges?

No, we need to compare percentages to the “Normal” percentages.

Have students calculate the percentages of each WBC type.

e.g. % Neutrophils = (# Neutrophils/Total WBCs)*100

Key Neutrophil 54%, Lymphocyte 24%, Monocyte 4%, Eosinophil 16%, Basophil 2%

*Math trick - there are 50 total WBCs counted in this example, so a quick percentage calculation would be to multiply the number of cells by 2 [(X/50)*100 = 2X where X = # of a particular type of white blood cell)].*

Compare the percentages of each white blood cell type with the standard ranges provided on the worksheet. Which looks the most different from “normal?”

The % Eosinophils are the most different from the “normal” range.

Ask students to hypothesize what might be wrong with the monkey based on what they've learned of the job of each type of white blood cell. Have them look at the info about each type of WBC on the back of the worksheet.

Viral infection, bacterial infection, parasitic infection?

Eosinophil 1-4% - Fight parasites & cancer cells, Part of allergic response,& asthma (high levels might indicate a response to a parasite, allergens, or asthma)

Most likely a parasitic infection

Optional Advanced Activity:

Provide students with Student Data file containing only Animal Data or Student Summary file containing Blank Summary Sheet.

Teacher data file contains these plus completed summary sheet and T-test examples.

Slide 33

For this next activity, we're going to examine real blood count data from a set of animals from the Monkey Health Explorer Project and use statistics to test hypotheses.

When investigating monkey health, it is important to research the environmental factors and social dynamics at play.

For example, female rhesus macaques are born into one (their natal) group and rarely move to other groups. In contrast, males at puberty will emigrate from their natal group to another group.

What might be health differences between females and males?

- *might be less stress staying in a familiar place versus leaving to join another group*

What might be the consequences of moving to a new group?

- *exposure to new pathogens from new monkeys and environment*

Additionally, we can add that many human societies show social gradients in health with socioeconomic status being one of the fundamental causes of health inequalities. In rhesus macaques, social rank and hierarchy in females can affect stress levels, and in turn, their immune system.

Sex, social group, and age are all variables that may affect monkey health and are included in the data you will be examining.

Take a look at the data given. How can the data be used to discern monkey health? What sorts of statistical tests would you apply? Which variables would you focus on?

Have students first calculate the WBC percentages for each animal. Then have them continue to create a descriptive analysis (means and standard deviations will be most pertinent), of the WBC percentages. *Completed summary page included in the teacher data file with formulas to use.*

Slide 34 Have the students conduct a t-test to compare females with males for each WBC type, and write a short conclusion based on the findings. <i>Completed t-tests are shown in the teacher data file with formulas to use.</i> Slide 35 For more practice, have the students calculate t-tests for each pairing of the 3 sampling years to determine if any WBC types show a statistically significant difference. <i>Completed t-tests comparing sampling years are shown in the teacher data file.</i> Share that the island was hit by Hurricane Maria in 2017. What impact might this event have on the animals? Have students write a short conclusion based on the findings. Slide 36 For more practice, have them calculate another t-test based on other variables to determine if any are statistically significant. <i>Completed t-tests comparing sampling year and social groups are shown in the teacher data file with formulas to use.</i> Discuss findings in groups or as a class.	
EVALUATE: LEARNING OBJECTIVES ASSESSED - Assess students' current mastery of knowledge, skills, and concepts, and determine students' self-assessed level of comfort and confidence with the objective so that the teacher knows where to remediate or reinforce ideas the next day, and the extent to which each individual has mastered the lesson.	
Have the class answer the short answer questions on the last page of their worksheet packet. If there's time, discuss the students' responses. Slide 37 Students have the opportunity to take what they've learned and apply it to research by helping identify blood cells in the Monkey Health Explorer project at monkeyhealthexplorer.org. Optional Additional Topic: AI/Machine Learning for Image Analysis. Slide 38 The Monkey Health Explorer (MHE) project is using machine learning algorithms to streamline workflows by prescreening the blood smear quality in images. This provides a simpler process for volunteers to identify the white blood cells and makes summarizing the classifications easier. Machine Learning is one type of Artificial Intelligence. This figure is a combination from two sources, which shows the relationship between different types of AI with a quick description of each. - Artificial Intelligence (AI) is broadly defined as intelligent machines. - Machine Learning (ML) is when machines perform pattern recognition tasks by first learning patterns from defined training data. - Deep Learning (DL) is when machines create neural networks based on learning general patterns in unstructured data, such as images, text, and audio.	<i>How will students show mastery of the objective?</i> <i>If students will be self-evaluating their efforts and abilities, what are the guidelines they will follow?</i>

- Large Language Models (LLMs) are developed through deep learning to understand natural language (i.e. text) and can be used to summarize and interpret text.
- Generative AI is a type of AI that creates new content, such as text, images, & music by learning patterns from large amounts of data, then responding to a user's prompt.

Slide 39

A quick video from Khan Academy and code.org that give a brief introduction to machine learning.

This is part of a Khan Academy course "AI for Education".

Slide 40

The Goldilocks Test evaluates whether the cells in a particular blood smear are spread too thin, too thick, or just right. (referencing the children's story of Goldilocks)

The MHE project's first machine learning model was trained to identify the spread quality of each blood smear image by providing it images that were identified as Dense, Sparse, and Good.

When evaluating a blood smear slide, cell technicians focus on the best, most evenly spread section of the slide to be sure it is a good representation of the sample.

The MHE project only uses images from regions of the slide that are well spread.

The trained ML model can sort the images based on the spread quality, so only the Good images are used in the next step.

Slide 41

The MHE project's second machine learning model was trained to detect white blood cells among the other cells in the image by learning from images with WBC locations provided.

The trained model for this step produced a cropped section of the original image with the detected WBC in the center of the image.

These cropped images are used in the "Single Cell" workflows of the Monkey Health Explorer project.

Changing workflows from larger to smaller images makes the task easier for volunteers because they only need to identify the cell in the center of the image.

Slide 42

The MHE project's machine learning model was trained to evaluate the cell in the center of the cropped images to classify the type of WBC present.

The model had a high success rate for identifying the most common WBC type, Neutrophils, a moderate success with the 2nd most common WBC type, Lymphocytes, and a low success rate for classifying the less common WBCs. One potential reason for this failure is that there were not enough examples of the less common WBC types in the training data for the model to learn them well enough. More training images are needed in part because the quality of our slides has been inconsistent due to being prepared in the field with a quick stain rather than in a clinical setting. <i>Links to additional AI & ML resources can be found on the project education page.</i>	
NOTES/CONSIDERATIONS	

Differentiation Strategies:

Modifications for Online/Hybrid Classroom: <i>(Are there ways to run this activity online?)</i> This material can be easily shifted to online learning by sending materials to students ahead of time.	Differentiation Strategies: <i>(Are there ways to make the activity more or less challenging?)</i> After explaining the roles of WBCs, you can have students guess what sort of health issue a monkey patient may have if they have higher ratios of a certain WBC. For example, a high concentration of eosinophils may signify a parasitic infection. If you would like to involve your students in analyzing real blood smears, you can track their activity in the project on SciStarter.org by adding https://scistarter.org/monkey-health-explorer to a List on your SciStarter account. Share your List with your students, so they can each follow the link to create a SciStarter and Zooniverse account (using the same email address for both accounts) to start participating. This step is imperative if you'd like to keep track of students' classifications. Once the two accounts are linked with the same email, students can simply log in through either website to start identifying and counting blood cells! The SciStarter page will take them to the Zooniverse project page or they can go directly to https://www.zooniverse.org/projects/mbarrierz/monkey-health-explorer
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Extra Materials:

List Extra Materials for Activity <i>(List any images, powerpoint slides, worksheets, appendices, or extra reading that should be included with this activity)</i> Please check our “Education” tab in the “About” section on the Zooniverse project page (https://www.zooniverse.org/projects/mbarrierz/monkey-health-explorer/about/education) to locate additional PDFs and other files for this lesson plan, listed below.	
- MHE_Classroom_Slides.pptx / GoogleSlides / pdf - MHE_Info-Sheet.pdf - MHE_Classification_Worksheet.pdf - MHE_Classification_Worksheet_Key.pdf - MHE_FieldGuide.pdf - MHE_BloodSmearModelWorksheet.pdf - MHE_BloodCellCrossword_Student.pdf - MHE_BloodCellCrossword_Key.pdf	- MHE_DataFile_Student.xlsx / .csv - MHE_Summary_Student.xlsx / .csv - MHE_AllDataFiles_Key.xlsx / Google Sheets Additional files are available in the Google drive