High School

MATH & SCIENCE LESSON 2

Hilleman & Vaccines

LEARNING GOALS

This series of lessons will allow students to use mathematics to improve scientific and mathematical literacy, and combine the two to help students understand where humans are in the context of a pandemic, especially during the development of an entirely new vaccine. Students will understand the development and use of a variety of vaccines.

WHERE DOES THIS FIT INTO YOUR CURRICULUM?

MATH

Using simulations as models and then applying computational thinking to understand processes

Using probability and statistics to understand population dynamics

SCIENCE

Understanding the spread of diseases in populations

Understanding the development and use of a variety of vaccines and the process of achieving herd immunity to stabilize the human population during a pandemic

Understanding how genetic mutations occur and their effect on organisms and the stability of a system

MATHEMATICAL PRACTICES

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Construct viable arguments and critique the reasoning of others.
- Model with mathematics.
- Use appropriate tools strategically.
- Attend to precision.
- Look for and make use of structure.
- Look for and express regularity in repeated reasoning.

MATHEMATICAL STANDARDS

- Statistics and Probability: Interpreting Categorical and Quantitative Data (S.ID1,2,3, 5, 6a,6b, 6c).
- Conditional Probability and the Rules of Probability (S.CP 1,2,3,4,5,6,7,8).
- Making Inferences and Justifying Conclusions (S.IC, 1,2,3,4,5,6).
- Using Probability to Make Decisions: (S.MD 6,7).

NEXT GENERATION SCIENCE STANDARDS ALIGNMENT

***HS-LS2-1*: Interdependent Relationships in Ecosystems**

Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

***HS-LS3-2* Inheritance and Variation of Traits**

Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

***HS-LS3-3* Inheritance and Variation of Traits**

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

MONTANA SCIENCE STANDARDS

Crosscutting Concepts: Cause and effect; proportion and quantity, and systems and system models.

Science and Engineering Practices: Developing and using models; analyzing and interpreting data; using mathematics and computational thinking, constructing explanations as it applies to science.

LS2. A: Use mathematical or computational representations to support arguments about environmental factors that affect carrying capacity, biodiversity, and populations in ecosystems.

LS3.B: Make and defend a claim based on evidence from multiple sources that inheritable genetic variation may result from:

- New genetic combinations through meiosis
- Viable errors occurring during replication
- Mutations caused by environmental factors

LS3. B: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Lesson 2

Graphing Scientific Data

Hilleman & Vaccines

LESSON INSTRUCTIONS - GRAPH RUBRIC

Lesson 2: Graphing Scientific Data

INSTRUCTIONS

Finish watching HILLEMAN then use the guide to facilitate class discussion.

Use the background information to connect the film to infectious diseases, vaccine development in Montana and the COVID-19 pandemic. Begin by asking if anyone can name any diseases for which children are routinely vaccinated? (responses might include measles, polio and whooping cough). Explain that each of these were once communicable diseases that were common in Montana then were eradicated but are now back on the rise. Refer to the talking points on page 149.

ENGAGEMENT

Students will complete a graphing activity (pages 157-166)

PREPARATION

- Review background information (154-156).
- Review data on student pages (164-166).
- Make copies of the student pages, one per student
- Review the links below for potential questions that may come up about the COVID-19 pandemic.

LINKS

The Children's Hospital of Philadelphia. The Coronavirus Pandemic-Answering Your Questions. Vaccinemakers.org. https://vaccinemakers.org/news-events/coronavirus-pandemic-answering-your-questions. Updated March 19, 2021. Accessed March 2021.

The Children's Hospital of Philadelphia. Archived Coronavirus Pandemic Questions. vaccinmakers.org. https://vaccinemakers.org/news-events/archived-coronavirus-pandemic-questions. Updated March 15, 2021. Accessed March 2021.

ASSESSMENT

Students will share their finished graphs with the class during the next class period. They must include a verbal introduction of themselves and their graph subjects.

LESSON INSTRUCTIONS - PRESENTATION RUBRIC
Lesson 2: Graphing Scientific Data

TALKING POINTS

Smallpox
Smallpox is a highly contagious, disfiguring and often deadly disease that killed millions of people over thousands of years. After the creation of the vaccine, the disease remained prevalent throughout the world for almost two more centuries.

Brought by sick individuals who traveled across the Atlantic Ocean to the Americas, the disease killed over 90 percent of Native Americans. Outbreaks occurred along the Missouri River, killing 17,000 Indigenous peoples, including half of the Arikara tribe, in what would be called the 1837 Great Plains Smallpox Epidemic. Others occurred in Butte, Missoula, Anaconda and Great Falls throughout the late 1880s-90s, prompting the creation of the Montana State Board of Health in 1901. The board was authorized to "make sanitary investigations and inquiries respecting the causes of disease, and especially epidemics, the causes of mortality and the influence of locality, employment habits, and other circumstances and conditions, upon the health of the people."

One of the first actions taken by the Montana State Board of Health was to require children to be vaccinated before attending school. As a result of this campaign, fewer children became infected with the disease. There was some opposition to this campaign on the grounds of cost or perceived violation of personal liberty. To the former, vaccinations were free to the public and it was proven cheaper than funding the care of infected persons. In the latter, these individuals would often change their minds when they or those close to them caught the disease.

Similar vaccination campaigns were enacted throughout the United States. In 1980, the World Health Assembly declared smallpox eradicated, making it one of the biggest achievements in international public health.

Influenza
More than 5,000 Montanans, or 1 percent of the population, died of influenza during the 1918-19 pandemic. This was a time when medical science and public health were ill-equipped to deal with the Pandemic, as a vaccine for influenza had not been developed, which was the case for other diseases at the time, such as measles, diphtheria, typhoid and scarlet fever.

Rubella
In Montana, women are asked to get a blood test for Rubella before a marriage certificate is issued to the couple. In 2007, this law was modified to offer a waiver option, and further legislation was introduced against it in 2019 because widespread use of the MMR vaccine has nearly eradicated this disease.

VACCINES & INFECTIOUS DISEASE

Infectious diseases have been around for thousands of years and have plagued humanity across the globe. As early as 1000 CE, people in China, India, Africa and Turkey used variolation to immunize people against smallpox. This method involved inoculating people with material taken from an infected patient in the hope that a mild infection would result and cause immunity. The practice spread to Europe where it caught the attention of Edward Jenner, who used cowpox pustules to inoculate patients successfully against smallpox in 1796, laying the foundation for the modern concept of vaccines.

In the late 1800s, Louis Pasteur proposed the Germ Theory of Disease and created the first live attenuated bacterial vaccine in 1879 against chicken cholera, followed by rabies in 1884, which he used in humans in 1885. Vaccine research and development saw exponential expansion in the mid-20th century through the efforts of Dr. Maurice Hilleman, Dr. Jonas Salk (polio), Dr. Charles Mérieux (vaccine mass production), and others.

Vaccine Safety

Today, vaccines are credited with saving millions of lives. Their regulation, development and use are organized around mandates, research and testing, informed consent and disparities in access.

Vaccine mandates, particularly in schools, seek to protect the greatest number of people. Research and testing ensure that vaccines must pass rigorous safety and efficacy standards. The inclusion of diverse experts of scientific and social disciplines invites ethical discussions that prioritize safety and communication. Informed consent is part of the transparency process. Access issues remain a challenge as access can depend on socioeconomic and ethnic status. There is a need for continued efforts to ensure equal opportunity for people to benefit from vaccination.

Throughout his life, Dr. Hilleman was obsessed about vaccine safety. He rigorously tested all of his vaccines and led by example. In developing his hepatitis B vaccine in the late 1970s, Dr. Hilleman used human blood and developed a chemical process to kill any possible contamination. Convinced of its safety, Dr. Hilleman first tested the vaccine on himself, then conducted a successful trial among Merck employees and executives. In the case of the mumps vaccine, he vaccinated his second daughter, Kirsten, with the vaccine he had named for his first child, Jeryl Lynn.

When a vaccine works, the disease does not manifest. People often forget the devastating effects of past pandemics when millions died. When asked about the growing levels of vaccine skepticism in the documentary HILLEMAN: A Perilous Quest to Save the World's Children, Dr. Hilleman lamented, "I think the only way we're actually going to get people to understand the importance of these vaccines is to watch children suffer again."

STUDENT PAGE
Lesson 2: Graphing Scientific Data

Vaccines undergo a rigorous safety process, including review of every study, phase and trial by an independent safety board of experts and the Federal Drug Administration, before a vaccine is authorized for use in the United States public. People concerned about the safety of vaccines are invited to visit cdc.gov/vaccine safety/index.html for more information.

Vaccine Development in Montana

Founded in response to the outbreak of spotted fever in the Bitterroot Valley in 1900, Rocky Mountain Labs is now a National Institute of Health biomedical research facility located in Hamilton, Montana. For the first two decades of its existence, scientists traveled to the valley to investigate the cause, treatment and prevention of spotted fever. Initially, they lived in tents and worked out of cabins and farmhouses. In fact, Dr. Ralph Parker even performed research on ticks in an old woodshed before renting an abandoned schoolhouse in 1921. Dubbed the Schoolhouse Lab, this building would become the site of the creation of the first effective vaccine against spotted fever.

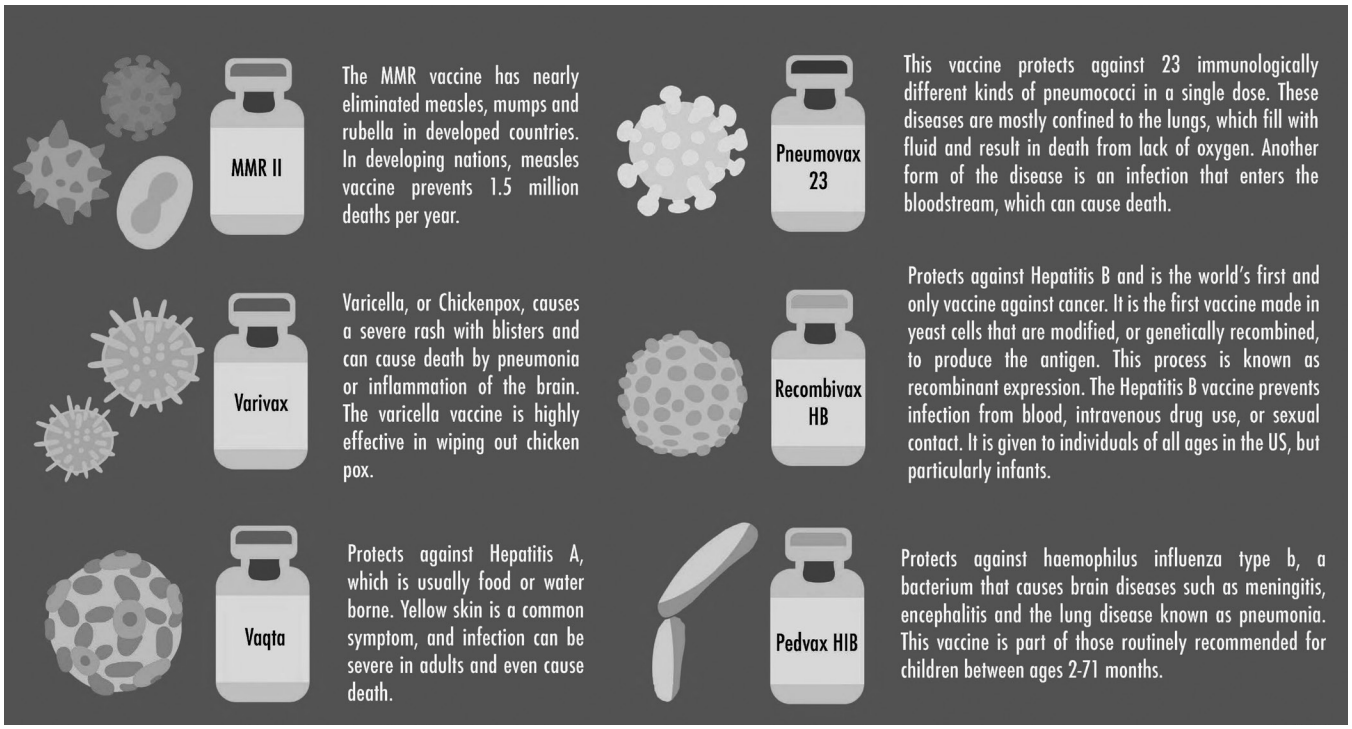
In 1927, the Montana state legislature appropriated $60,000 for the construction of an entomological laboratory, and Hamilton was chosen as the site. This inspired protests, as residents were worried that ticks might escape and widespread infection would occur. Construction was completed in 1928, and the Public Health Service rented space within the building for continued research on vaccine production. In February 1932, the federal government purchased the facility for $68,757 from the state of Montana. Rocky Mountain Labs became part of the National Institute of Health in 1937, manufactured the United States' supply of yellow fever vaccines during World War II, and helped develop the Ebola vaccine in 2014 for use in West Africa.

Today, the facility is one of nine federal facilities in the country with a biosafety Level 4 capacity, the highest such rating, and scientists there are responsible for Investigating a wide variety of infectious diseases.

Front exterior view of the Canyon Creek Schoolhouse Laboratory in Hamilton, Mont. Image Courtesy Rocky Mountain Labs Historical Collection, Montana Memory Project

VACCINE SPOTLIGHTS

During his lifetime, Dr. Hilleman developed over 40 vaccines, including eight of the 14 vaccines commonly recommended for children. The pediatric vaccines prevent more than four million deaths per year worldwide. Other vaccines prevent respiratory illness, hepatitis A and B, and even cancer. Thanks to these vaccines, the principal diseases of children are no longer significant in the USA and in much of the developed world. Some of these vaccines and their associated diseases are described in the infographic below.



Graphic by Jenn Hall,
Words by Sabre Moore
"Shots Felt 'Round The World" Exhibition
by Carter County Museum and Museum of the Rockies (2021).

LESSON INSTRUCTIONS
Lesson 2: Graphing Scientific Data

INSTRUCTIONS
Lead a discussion of what kinds of graphs students know and can do. Have students complete the worksheet using either Google Sheets or another graph maker to practice. Proficiency depends on grade level.

You may want to pass out the table for vaccination coverage percent by grade and antigen, published by the Montana Department of Public Health in May 2019, to the students for context on the vaccinations required by school districts from K-12. Review this data and the document it comes from prior to using in class (https://dphhs.mt.gov/Portals/85/publichealth/documents/Immunization/2018-2019SchoolImmunizationReport.pdf). The data for grades 9-12 is included in the student worksheet on page 166.

OBJECTIVES
Students will learn

1. The differences between circle, line and bar graphs
2. The definitions of independent and dependent variables

ASSESSMENT
Students will share their finished graphs with the class during the next class period. They must include a verbal introduction of themselves and their graph subjects.

Circle, Line and Bar Graph Practice

Instructions:
Use the data below to make a graph in Google Sheets. The graph must include a title, labels in each section of the graph, and a color key. (Communicable Disease in Montana's Annual Report 2018. Montana Department of Public Health)

Category	Percentage of Reported Communicable Diseases
Enteric Diseases	9.8
General Communicable Diseases	0.5
Hepatitis	17.2
Sexually Transmitted Diseases	67.6
Vaccine Preventable Diseases	3.8
Zoonotic Disease	1.0

1. Create your own data and make a pie chart of the data. Make sure your data table is well-labeled.

Instructions:
Create a graph of the data below. Make sure you include a title, label both axes, and a color key with the series labeled. (Vaccination coverage percent by grade and antigen among public and private school students, Montana 2018-19 academic year. Montana Department of Public Health). *(Note: students may want to start their y-axis at 90 if creating a line graph.)*

Grade Level	2+ Dose MMR (%)	3+ Doses IPV (%)	4+ Doses DTaP (%)	1+ Dose Tdap (%)
9	97	96.9	96.7	95.8
10	96.8	96.2	96	96.2
11	97.3	96.8	96.5	96.4
12	97.9	97.3	97.1	97.2

2. What is the independent variable? *Grade level*
3. What is the dependent variable? *Percentage of vaccination coverage*
4. What could you use as a control? *Students at the same age who are not vaccinated*
5. What would you have for constants (at least 3)? *Answers might include: Same amount of time after injection, same number of boys and girls, all percentages are calculated on the same date.*

6. Create your own data and make a line graph

Instructions:

Make a bar graph of the following data. Make sure you include a title, labels for both axes, labels for the categories, and a color key. (COVID-19 Vaccination Data from Montana Department of Public Health, April 9, 2021.)

Montana County	Number of Eligible Population Fully Immunized	Total Eligible Population
Blaine	1654	4910
Carter	201	1003
Dawson	1795	6944
Gallatin	18017	94211
Garfield	218	1001
Hill	3686	12328
Liberty	462	1917
Musselshell	649	3895
Phillips	831	3113
Teton	1000	4810
Valley	1411	5917
Wheatland	340	1722

7. What are the dependent variables? *Eligible number of people and the number of fully vaccinated people.*

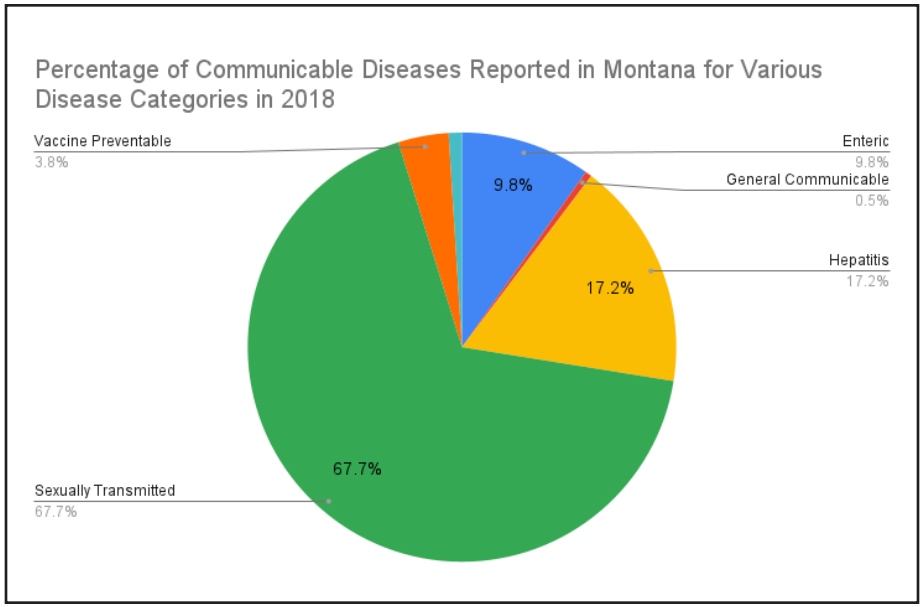
8. What is the independent variable? *The Montana County.*

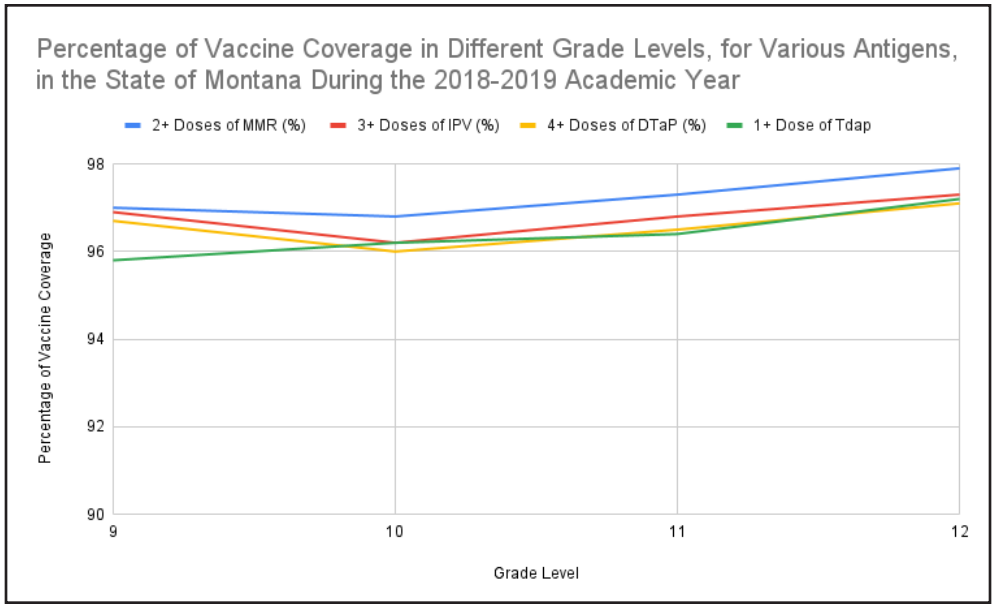
9. Create your own data and make a bar graph.

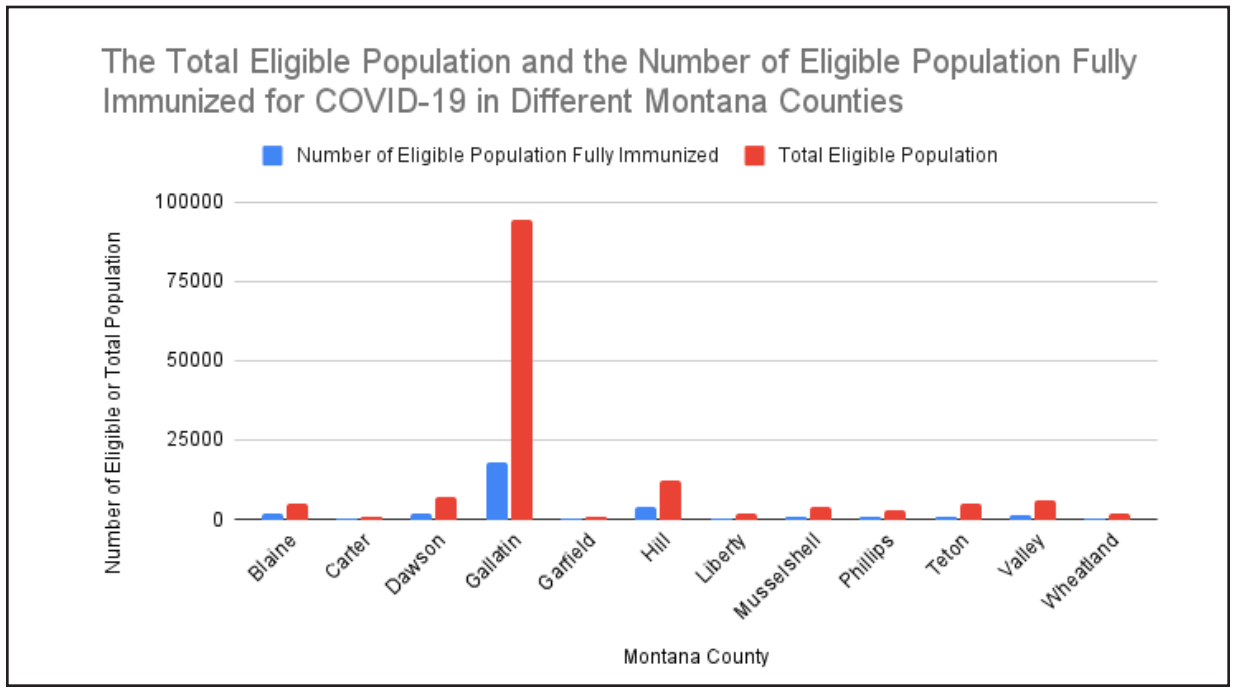
Bibliography

Montana Department of Public Health and Human Services. 2018-2019 School Immunization Assessment Results. dphhs.mt.gov. https://dphhs.mt.gov/Portals/85/publichealth/documents/Immunization/2018-2019SchoolImmunizationReport.pdf. Published May 2019. Accessed March 2021.

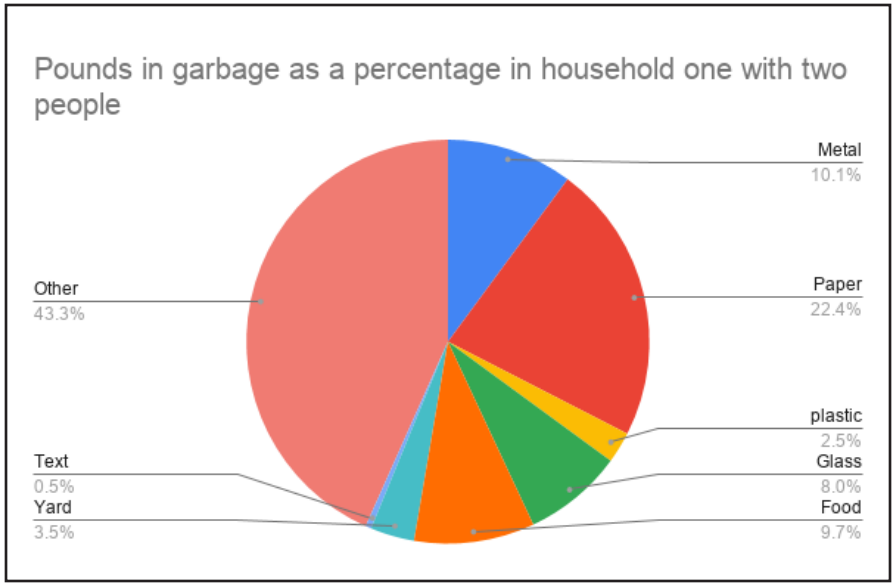
Communicable Disease Epidemiology Section, Public Health and Safety Division, & Montana Department of Public Health and Human Services. Communicable Disease in Montana Annual Report 2018. dphhs.mt.gov. https://dphhs.mt.gov/Portals/85/publichealth/documents/CDEpi/StatisticsandReports/CDEpiAnnualSummaryReports/2018CDEpiannualreport_final.pdf. Accessed March 2021.

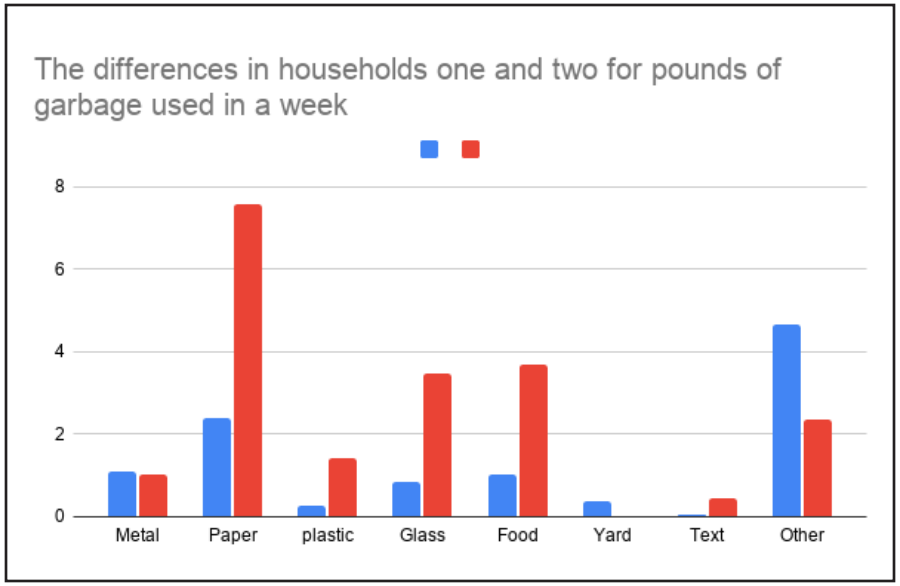


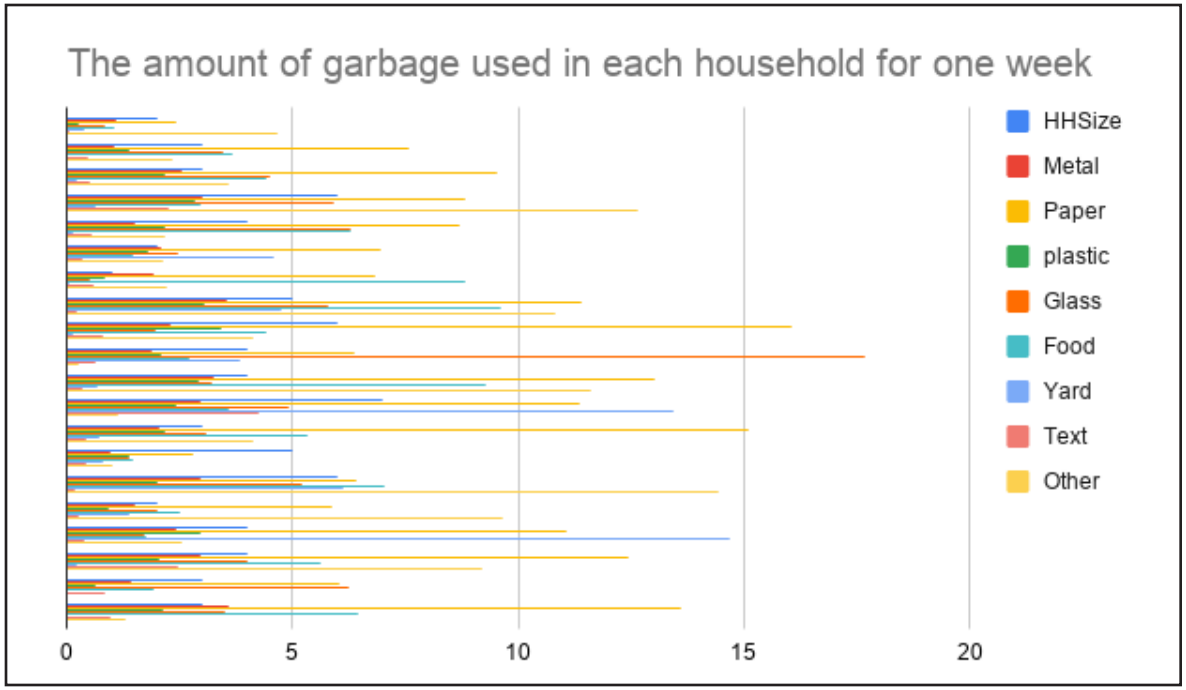




SAMPLE GRAPHS FOR WORKSHEET DATA







SAMPLE GRAPHS FOR STUDENT CREATED DATA

Note: This student is a freshman and used the same data for all three types of graphs.

LESSON INSTRUCTIONS - GRAPH RUBRIC

Lesson 2: Graphing Scientific Data

	Minimal (1 pt.)	Basic (2 pts.)	Proficient (3 pts.)	Advanced (4 pts.)
Graph Type	This is a graph.	This graph adequately displays the data. Some information is missing.	This graph appropriately displays the data. All information is present.	This graph appropriately displays the data, all information is presented, and trends are clear.
Title	No Title	Title present at the top of the graph.	Title is present at the top of the graph and relates to the data presented.	Title is present at the top of the graph, relates to the data presented, and the information presented on both axes.
Appropriate number spread on axes	The scale makes it difficult to identify data points and the visual representation of the data is poor.	One or more pieces of data did not fit within the scales or the graph was visually misleading.	The scales include all data, but cannot easily be used to make predictions.	Scales include all data, do not create a misleading visual, and allow enough room for interpolation.
Axes Labeled and Units of Measure on Axes	Axes have labels that do not match the data OR one or more axes labels are missing.	Axes are labeled but units of measurement are missing or many significant words were not capitalized.	Part of an axis label is not capitalized or a unit of measurement is missing.	The first letter of significant words are capitalized, proper units/ abbreviations are used, and the meaning is clear.
Correct Plotting of Data	The exact location of data points has to be estimated and the range of possibilities is too broad.	Data points seem to be plotted correctly, but the scale is not precise enough for the teacher to really tell.	One data point is not plotted correctly.	All data are plotted correctly in accordance with your scale, the data points are accurate, and data points do not have to be estimated.
Neatness	Color was not used and little attempt was made to enhance the visual representation of data.	Two colors or fonts are difficult to read.	The graph is attractive and colorful, but a color or a font is difficult to read.	Well-designed, neat,and attractive. This graph is in color, and the colors chosen enhance the presentation. The font does not distract from the readability.

Graphing Guidelines

1. Graphs should have a **title** that is clear and concise about the content so that the graph can stand alone. The title should include the information on both axes and describe the visual you are trying to portray. The reader should not have to study the axes closely to figure out what you were trying to represent.

2. In APA formatting, the **title** is to be italicized, in title case, and left aligned (The Writing Lab, The OWL at Purdue, & Purdue University, 1995-2020). This is up to your teacher.

3. **Axes** should have significant words capitalized and include units of measurement with proper abbreviations. For example, you might use days, or months, or milliliters. One axis might read, "Branch Length (cm) or Volume (mL)". The abbreviations will appear in parentheses. You could also write out, "Branch Length in Centimeters". The first way is more brief and still includes the units of measurement.

4. The s**cale** you choose should include all data points and allow for interpolation or making predictions.

5. **Fonts and colors** should be very easy to read and not distract the reader from the visual representation of data.

6. A **legend** should be used, and well-labeled, anytime it makes the graph clearer.

Bibliography

The Writing Lab, The OWL at Purdue, & Purdue University. *Tables and figures.* Retrieved from https://owl.purdue.edu/owl/research_and_citation/apa_style/apa_formatting_and_style_guide/apa_tables_and_figures.html.

Circle, Line and Bar Graph Practice

Instructions:
1. Use the data below to make a graph in Google Sheets. The graph must include a title, labels in each section of the graph, and a color key. (Communicable Disease in Montana Annual Report 2018. Montana Department of Public Health)

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Enteric Diseases	9.8
General Communicable Diseases	0.5
Hepatitis	17.2
Sexually Transmitted Diseases	67.6
Vaccine Preventable Diseases	3.8
Zoonotic Disease	1.0

Instructions:
2. Create a graph of the data below. Make sure you include a title, label both axes, and a color key with the series labeled. (Vaccination coverage percent by grade and antigen among public and private school students, Montana 2018-19 academic year. Montana Department of Public Health)

Grade Level	2+ Dose MMR (%)	3+ Doses IPV (%)	4+ Doses DTaP (%)	1+ Dose Tdap (%)
9	97	96.9	96.7	95.8
10	96.8	96.2	96	96.2
11	97.3	96.8	96.5	96.4
12	97.9	97.3	97.1	97.2

3. What is the independent variable?

4. What is the dependent variable?

5. What could you use as a control?

6. What would you have for constants (at least 3)?

Instructions:

7. Make a bar graph of the following data. Make sure you include a title, labels for both axes, labels for the categories, and a color key. (COVID-19 Vaccination Data from Montana Department of Public Health, April 9, 2021.)

Montana County	Number of Eligible Population Fully Immunized	Total Eligible Population
Blaine	1654	4910
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Liberty	462	1917
Musselshell	649	3895
Phillips	831	3113
Teton	1000	4810
Valley	1411	5917
Wheatland	340	1722

8. What is the dependent variable?

9. What is the independent variable?

Bibliography

Montana Department of Public Health and Human Services. 2018-2019 School Immunization Assessment Results. dphhs.mt.gov. https://dphhs.mt.gov/Portals/85/publichealth/documents/Immunization/2018-2019SchoolImmunizationReport.pdf. Published May 2019. Accessed March 2021.

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Table 2. Vaccination coverage percent by grade and antigen among public and private school students, Montana, 2018–2019 academic year.

Grade	No. students	Conditional Exemptions (%)	Medical Exemptions (%)	Religious Exemptions (%)	1 Dose Hib (%) *	1 or 2 doses Varicella (%)‡	2+ doses MMR (%)	3+ doses IPV (%)	4+ doses DTaP (%)	1+ dose Tdap (%)
Pre-K under 59 months	4,039*	62 (1.9)	9 (0.2)	138 (4.2)	3736 (92.5)	4,754 (92.9)	4,785 (93.3)	4,924 (93.7)	4,866 (93.0)	
Pre-K 59 months+	5,380									
K	12,480	238 (.5)	27 (0.4)	529 (3.4)		11,588 (95.4)	11,683 (96.1)	11,698 (96.0)	11,607 (95.6)	
1	12,088	60 (0.5)	27 (0.2)	482 (4.0)		11,481 (95.0)	11,515 (95.3)	11,531 (95.4)	11,459 (94.8)	
2	12,007	31 (0.3)	35 (0.3)	409 (3.4)		11,506 (95.8)	11,534 (96.1)	11,526 (96.0)	11,455 (95.4)	
3	11,878	37 (0.3)	35 (0.3)	429 (3.6)		11,353 (95.6)	11,391 (95.9)	11,378 (96.0)	11,305 (95.2)	
4	12,257	45 (0.4)	39 (0.3)	426 (3.5)		11,752 (95.9)	11,823 (96.5)	11,792 (96.2)	11,716 (95.6)	
5	12,714	55 (0.4)	47 (0.4)	423 (3.3)		12,143 (95.5)	12,242 (96.3)	12,213 (96.1)	12,129 (95.4)	
6	12,386	43 (0.3)	51 (0.4)	355 (2.9)		11,936 (96.4)	12,008 (96.9)	11,996 (96.9)	11,982 (96.7)	
7	12,470	77 (0.6)	54 (0.4)	450 (3.6)		12,008 (96.3)	12,081 (96.9)	12,070 (96.8)	12,067 (96.8)	11,679 (93.7)
8	11,727	37 (0.3)	65 (0.6)	380 (3.2)		11,304 (96.4)	11,385 (97.1)	11,382 (97.1)	11,368 (96.9)	11,211 (95.6)
9	11,839	20 (0.2)	47 (0.4)	388 (3.3)		11,359 (95.9)	11,485 (97.0)	11,470 (96.9)	11,444 (96.7)	11,343 (95.8)
10	11,314	18 (0.2)	57 (0.5)	341 (3.0)		10,857 (96.0)	10,957 (96.8)	10,885 (96.2)	10,861 (96.0)	10,881 (96.2)
11	10,595	22 (0.2)	61 (0.6)	309 (2.9)		10,154 (95.8)	10,312 (97.3)	10,257 (96.8)	10,229 (96.5)	10,218 (96.4)
12	9,912	13 (0.1)	73 (0.7)	293 (3.0)		9,481 (95.7)	9,707 (97.9)	9,640 (97.3)	9,622 (97.1)	9,630 (97.2)

*Students in Pre-K are required to have at least on dose of Hib vaccine administered on or after their first birthday, unless the student is older than 59 months.

**Tdap = tetanus toxoid, diphtheria, and acellular pertussis for 7-12th grades.

‡Varicella was added to school vaccination requirements beginning in the 2015-2016 academic year. The rate includes those reported as having a verified history of disease