ACTIVITY 1

Investigating Probabilistic Reasoning

CARD-BASED INVESTIGATION

Exposure to poor air quality
can result in symptoms similar
to those of other illnesses.

1 : INVESTIGATING PROBABILISTIC REASONING

GUIDING QUESTION

How do you make predictions with incomplete information?

INTRODUCTION

Since the middle of the 1900s, many countries have been working to improve air quality. In the United States, the first Clean Air Act was passed in 1963. This law helped reduce air pollutants such as ground-level ozone and sulfur dioxide. Another air pollutant is particulate matter (PM), microscopic particles suspended in the air that are so small that they can be inhaled. Sources of particulate matter include car emissions, oil and gas to heat homes, manufacturing processes, and power generation. Wildfire smoke is another source. Wildfire smoke particles vary in size, but about 90% are small enough to be called PM2.5—particulate matter in the air that has a diameter of 2.5 micrometers (μm) or less, also known as fine particles.

Studies show a strong link between breathing in particulate matter, especially PM2.5, and health risks. For many people, the symptoms of air pollution are similar to allergies, a cold, the flu, or COVID-19. So how can you figure out the likely cause of someone's symptoms? Probabilistic reasoning is a way of making predictions or drawing conclusions based on how likely something is to happen, especially when there is not enough clear data. In this activity, you will use probabilistic reasoning to figure out the most likely cause of a person's respiratory symptoms.

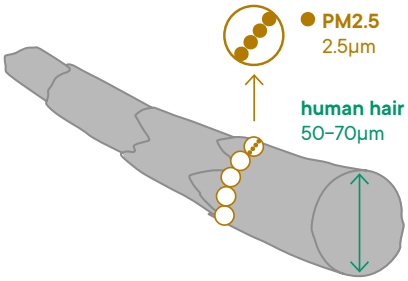


FIGURE 1.1
The size of PM2.5 particles is much smaller than a single human hair, which is typically 50–70 micrometers (μm) in diameter.

CONCEPTUAL TOOLS

If you need to review the concept of probability, you will find a Science Review at the end of this activity.

MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

- SET OF 4 STUDENT HEALTH CARDS
- SET OF 4 STUDENT FOLLOW-UP CARDS

FOR EACH PAIR OF STUDENTS

- SET OF COLORED PENCILS (2 DIFFERENT COLORS)

FOR EACH STUDENT

- 2 STUDENT SHEETS 1.1 "Analyzing Symptoms"
- STUDENT SHEET 1.2 "Symptom Chart"

PROCEDURE

1 With your group of four, read the following factual article.

INCREASE IN WILDFIRES MAY AFFECT RESPIRATORY HEALTH

Extreme wildfires are increasingly becoming a major cause of poor air quality in populated areas. Some wildfires occur naturally and create new habitats, stimulate new plant growth, and cycle nutrients. However, around the world, wildfire patterns are changing. Less than 10% of wildfires are now causing more than 90% of the total area burned each year. These events are known as extreme wildfires. In the last few years, extreme wildfires have occurred in many countries around the world, including Australia, Brazil, Canada, Russia, and the United States.

Children, teens, and the elderly are particularly vulnerable to poor air quality. One concern is the effect of particulate matter on those with asthma, a noninfectious condition that affects the lungs. Asthma can be controlled by taking medicine and avoiding triggers that can cause an attack such as air pollution, smoke, pet hair, and mold. Doctors suggest that the best thing to do when outdoor air quality is poor is to reduce your outdoor exposure.

2. Apply probabilistic reasoning to determine the most likely cause(s) of a person's respiratory symptoms. Your group will receive a set of 4 Student Health cards, and each pair will analyze 2 cards. Pick 1 card and read it aloud to your partner.

3. Work with your partner to identify the student's symptoms and record them on Student Sheet 1.1, "Analyzing Symptoms." As you work, your partner will also fill in their copy of Student Sheet 1.1.

4. Compare the student's symptoms to the symptoms on Student Sheet 1.2, "Symptom Chart."

   a. Identify the student's symptoms on Student Sheet 1.2, using a colored pencil to circle and/or underline symptoms. (You will use the other colored pencil for a second fictional student.)

   b. Determine the student's two most probable causes and explain your reasoning on Student Sheet 1.1. While you do not need to agree with your partner, remember to listen to and consider the ideas of others. If you disagree, explain why you disagree.

5. Brainstorm two questions to ask the student about their health to improve your diagnoses. Record those questions on Student Sheet 1.1.

6. Based on your diagnoses, work with your partner to recommend one or more actions for the student from the following list. Record your recommendations on Student Sheet 1.1.

   - Rest and wait to see if symptoms improve.
   - Ignore the symptoms and maintain routine activities.
   - Stay indoors.
   - Avoid strenuous outdoor activities such as sports.
   - Isolate from other people as much as possible.
   - Wear a face mask.
   - Go to an emergency room as soon as possible.
   - Make an appointment to see a doctor in a few days.
   - Take an over-the-counter allergy medicine.
   - See a doctor about getting an inhaler prescribed for asthma.
   - Take an at-home COVID–19 test.
   - Take an over-the-counter headache medicine.
   - Take an over-the-counter cough suppressant.
   - Take an over-the-counter fever reducer.
   - Another course of action not listed here.

7. Collect a Student Follow-Up card for this fictional student. On Student Sheet 1.1, record what happened to your student.

8. Discuss with your partner whether the information from the Student Follow-Up card supported your recommended course(s) of action. Record your ideas on Student Sheet 1.1.

9. Revisit your diagnoses to determine if you would like to revise it. If you make revisions, record them on Student Sheet 1.1, along with your reasoning for the likelihood of each illness.

10 Scientific uncertainty is an understanding that there are limits to data and conclusions about the natural world, and additional data and/or investigations can lead to increased surety or new questions. Discuss and record how sure you are of your diagnosis, using a scale of 0–100%, where:

0% = there is no chance your diagnosis is correct
50% = your diagnosis is just as likely to be wrong as it is to be correct
100% = you are absolutely sure that your diagnosis is correct

11 Choose another Student Health card and repeat Steps 2–10. This time, have your partner read aloud the card. Each of you should use a different colored pencil to mark the symptoms on your copies of Student Sheet 1.2 for this second fictional student.

12 Share your findings with the other half of your group. Discuss how sure you were of your diagnoses and what additional information you would have liked to have known.

BUILD UNDERSTANDING

The Build Understanding and Connections to Everyday Life items are intended to guide your understanding. Some of these items may be discussed with a partner, be part of a class discussion, or require an individual written response. Your teacher will guide you as to how these items will be used in your class.

① Doctors, like other scientists, try to identify and reduce sources of uncertainty in science.

- **a** What factors caused you to be uncertain about your diagnoses?
- **b** What factors caused you to reduce uncertainty in your diagnoses?

② Examine the data in the following table.

TABLE 1.1
Evaluation of Over-the-Counter COVID-19 Tests, 2021

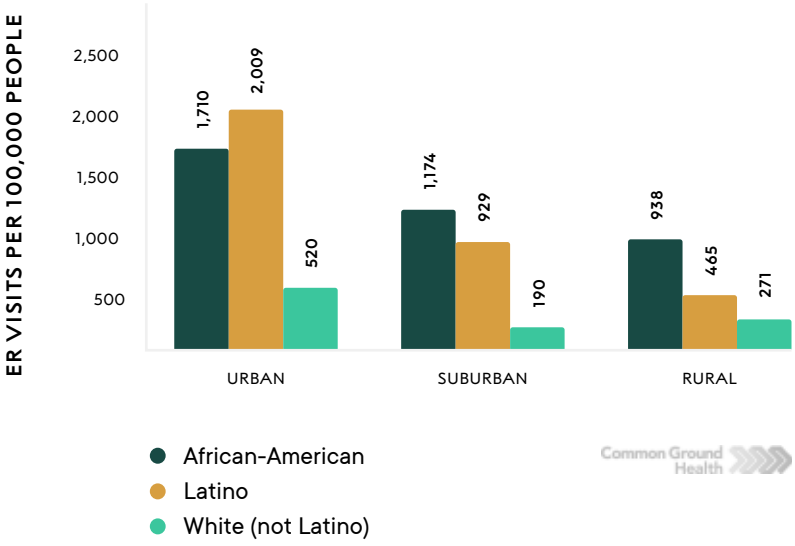
BRAND	PERCENT OF POSITIVE COVID-19 CASES CORRECTLY IDENTIFIED	PERCENT OF NEGATIVE COVID-19 CASES CORRECTLY IDENTIFIED
1	49.4%	100%
2	44.6%	100%
3	45.8%	97%
4	54.9%	100%

a A false positive is a type of error when something is incorrectly identified as present—for example, a positive COVID–19 test result when someone does not have COVID–19. A false negative is a type of error when something is incorrectly identified as absent but is actually present—for example, a negative COVID–19 test result when someone does have COVID–19. Based on Table 1.1, are over-the-counter COVID–19 tests more likely to result in a false positive or a false negative? Explain your reasoning.

b Imagine that you were feeling unwell and had symptoms similar to those of COVID–19. You take an over-the-counter COVID–19 test, and the test result is negative. Use probabilistic reasoning to explain whether or not you should go to a friend's birthday party.

③ Examine the graph in Figure 1.2, which provides data about emergency room visits for a three-year period.

FIGURE 1.2
Emergency Room (ER) Visits for Asthma
in New York Finger Lakes Region, 2014–2016



a What can you conclude about the likelihood of emergency room visits for asthma?

b Imagine your state has the funds to build one urgent care asthma center. Would you recommend they build it in an urban, suburban, or rural area? Support your answer with evidence and identify the trade-offs of your decision. A trade-off is a desirable outcome given up to gain another desirable outcome.

CONNECTIONS TO EVERYDAY LIFE

4. Which of the following are examples of probabilistic reasoning? Explain.
   - **a** estimating the chance of getting stuck in a traffic jam based on the time of day
   - **b** deciding on where to have dinner based on your favorite food and the cost of the meal
   - **c** a basketball player calculating the odds of making a shot based on their past performance and the current situation on the court
   - **d** a doctor considering the likelihood of a specific disease based on a patient's symptoms and test results
   - **e** selecting a concert to attend based on which concert venue is the closest to where you live
   - **f** figuring out your chances of getting a job offer based on your qualifications and the competition for the position
5. Choose one example of probabilistic reasoning from item 4 and describe one action you could take to reduce scientific uncertainty in that example.

EXTENSION

Learn how scientists handle uncertainty in science and use probabilistic reasoning by watching a 9–minute video narrated by Saul Perlmutter, who won the Nobel Prize in Physics in 2011. Consider the advantages and disadvantages of using probabilistic reasoning, as explained in the video.

KEY SCIENTIFIC TERMS

false negative
false positive
particulate matter (PM)
PM2.5
probabilistic reasoning
scientific uncertainty
trade-off

SCIENCE REVIEW

Probability

In this unit, you will be learning about probabilistic reasoning. You may also be familiar with the concept of probability, a mathematical measure of the likelihood that a specific event will happen. Probability can be expressed as a percentage. For example, a 25% chance of rain represents a 1 out of 4 (¼) chance that it will rain. The probability of an event depends on the number of successful outcomes divided by the number of total possible outcomes:

$$\text{probability of an event} = \frac{\text{number of successful outcomes}}{\text{total number of possible outcomes}}$$

Probability can be converted between fractions and percentages by using formulas:

FRACTION TO %

$$\frac{A}{B} \times 100 = C\%$$

EXAMPLE

$$\frac{4}{5} \times 100 = 80\%$$

% TO FRACTION

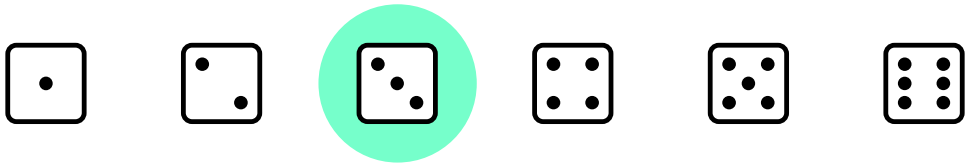
$$C\% = \frac{C}{100}$$

EXAMPLE

$$80\% = \frac{80}{100} = \frac{4}{5}$$

Consider a number cube. When you roll a number cube, there are 6 possible outcomes:

If you wanted to calculate the probability of rolling a 3, only one of the rolls would be a successful outcome:

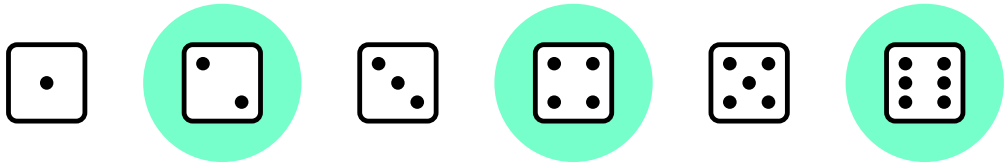


The calculation would be as follows:

$$\text{probability of rolling a } \square = \frac{\text{1 successful outcome}}{\text{6 possible outcomes}} = \frac{1}{6}$$

Expressed as a fraction, the chance of rolling a 3 is 1 out of 6 times, or 17%. But this does not guarantee that 1 out of every 6 rolls will be a 3! The chance of any given event occurring is independent of the previous events. So every roll is independent of the rolls you did before. It is sometimes only after many, many events that you will start to see the probability—for example, after calculating the average of many rolls.

Probability can be determined when there is more than one possible event that counts as a successful outcome. The following example shows the probability of rolling an even number on the cube. In this case, there are three possible events that count as successful outcomes:



So, the probability of rolling an even number is:

$$\text{probability of rolling a } \square\square\square = \frac{\text{3 successful outcome}}{\text{6 possible outcomes}} = \frac{3}{6} = \frac{1}{2}$$

On average, you will roll an even number 1 out of 2 times, or 50%.