# Box Plots

## Goals

- Compare and contrast (orally) a dot plot and a box plot that represent the same data set.
- Create a box plot to represent a data set.
- Describe (orally) the parts of a box plot that correspond with each number in the five-number summary, the range, and the IQR of a data set.

## Learning Targets

- I can use the five-number summary to draw a box plot.
- I know what information a box plot shows and how it is constructed.

### Access for Students with Diverse Abilities

- Engagement (Activity 2)

### Access for Multilingual Learners

- MLR2: Collect and Display (Activity 2)

### Instructional Routines

- MLR2: Collect and Display
- Notice and Wonder

### Required Materials

**Materials to Gather**
- Index cards: Activity 1
- Tape: Activity 1

### Required Preparation

**Lesson:**
For the Human Box Plot activity:

- Each student will need the index card that shows their name and the number of letters in their name (used for the Finding the Middle activity), as well as a class data set.
- Compile the numbers on the cards into a single list or table. Prepare one copy of the data set for each student.
- Have some extra index cards available for students who might have been absent in that earlier lesson.
- Prepare five index cards that are labeled with "minimum," "maximum," "Q1," "Q2," and "Q3."
- Make a number line on the ground using thin masking tape (0.5 inch). It should show whole number intervals and span at least from the lowest data value to the highest. The intervals should be at least a student's shoulder's width.
- Prepare a roll of wide masking tape (2- or 3-inch wide) to create a box and two whiskers on the ground.

## Lesson Narrative

In this lesson, students use the five-number summary to construct a **box plot.** Similar to their first encounter with the median, students are introduced to the structure of a box plot through a kinesthetic activity. Using the class data set that contains the numbers of letters in their names, they first identify the numbers that make up the five-number summary. Then, they use their numbers to position themselves on a number line on the ground, and are guided through how a box plot would be constructed with them as the data points.

Later, students draw and make sense of the structure of a box plot on paper. They notice that, unlike the dot plot, it is not possible to know all the data points from a box plot. They understand that the box plot summarizes a data set by showing the range of the data, where the middle half of the data set is located, and how the values are divided into quarters by the quartiles.

## Student Learning Goal

Let's explore how box plots can help us summarize distributions.

## Lesson Timeline

| 5 min | 15 min | 15 min | 10 min |
|-------|--------|--------|--------|
| Warm-up | Activity 1 | Activity 2 | Lesson Synthesis |

## Assessment

| 5 min |
|-------|
| Cool-down |

## Warm-up

### Notice and Wonder: Puppy Weights

**5 min**

### Activity Narrative

The purpose of this *Warm-up* is to elicit the idea that it can be difficult to describe a distribution from the data alone, which will be useful when students visualize data using a box plot in a later activity. While students may notice and wonder many things about these data, the usefulness of data displays is the important discussion point.

When students articulate what they notice and wonder, they have an opportunity to attend to precision in the language that they use to describe what they see. They might first propose less formal or imprecise language, and then restate their observation with more precise language in order to communicate more clearly.

### Launch 👥

Arrange students in groups of 2. Display the table for all to see. Give students 1 minute of quiet time to look at the data set and to identify at least one thing they notice and at least one thing they wonder about the distribution of the data. Ask students to give a signal when they have noticed or wondered about something. When the minute is up, give students 1 minute to discuss their observations and questions with their partner. Follow with a whole-class discussion.

#### Student Task Statement

Here are the birth weights, in ounces, of all the puppies born at a kennel in the past month.

What do you notice? What do you wonder?

| 13 | 14 | 15 | 15 | 16 | 16 | 16 | 16 | 17 | 17 | 17 | 17 | 17 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 17 | 17 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 19 | 20 | |

Students may notice:

- The median birth weight is 17 ounces.
- The median looks like it's the same as the mean.
- Almost a third of the puppies weigh 18 ounces.
- There are no gaps in the data or values that are very far from the center.
- There are 25 puppies.

Students may wonder:

- If the IQR is less than 1.
- How a histogram could be used to represent the data.
- If a dot plot could be used to represent this data.

### Instructional Routines

**Notice and Wonder**

**ilclass.com/r/10694948**

Please log in to the site before using the QR code or URL.

### Student Workbook

**Activity Synthesis**

Ask students to share the things that they noticed and wondered. Record and display their responses for all to see, without editing or commentary. If possible, record the relevant reasoning on or near the data. Next, ask students,

💬 *"Is there anything on this list that you are wondering about now?"*

Encourage students to respectfully disagree, ask for clarification, or point out contradicting information.

If a visual display of the distribution does not come up during the conversation, ask students to discuss that idea.

Display the dot plot of the same data.



weight in ounces
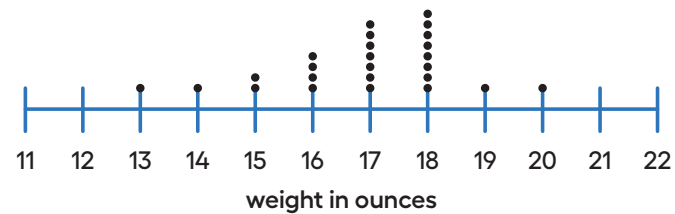
Ask students:

💬 *"How would a data display like a dot plot help describe the distribution?"*

It would be easier to see what is typical, estimate the center, and describe the spread.

💬 *"Is it easier to find the mean from the data list or the dot plot? What about the median?"*

It is easier to estimate the mean from the dot plot, but maybe a little easier to calculate it using the list. The median is probably a little easier to find from the list because this list is already organized.

**Activity 1**

**Human Box Plot**

**15 min**

**Activity Narrative**

Previously, students learned to identify the median, quartiles, and five-number summary of data sets. They also calculated the range and interquartile range of distributions. In this activity, students rely on those experiences to make sense of **box plots**. They explore this new representation of data kinesthetically: by creating a human box plot to represent class data on the lengths of student names, which they collected in the "Finding the Middle" activity in an earlier lesson.

**Launch**

Before the lesson, use thin painter's tape to make a number line on the ground. If the floor is tiled with equal-sized tiles, consider using the tiles for the intervals of the number line. Otherwise, mark off equal intervals on the tape. The number line should cover at least the distance between the least data value (the fewest number of letters in a student's name) and the greatest (the most number of letters).

Provide each student with a copy of the data on the lengths of students' names from the "Finding the Middle" activity. If any students were absent then, add their names and numbers of letters to the data set.

Give students 4–5 minutes to find the quartiles and write the five-number summary of the data. Then, invite several students to share their findings and come to an agreement on the five numbers. Record and display the summary for all to see.

Explain to students that the five-number summary can be used to make another visual representation of a data set called a "box plot." Tell students that they will create a human box plot in a way similar to the way they found the median.

- Return to students the index cards from the lesson on finding the median. If any students were absent when the cards were made, give them each an index card and ask them to record on the card their full name and the number of letters in their name. If any student who made a card is absent, have another student with the same number of letters in their name hold the card of the absent student.

- Ask students to stand up, holding their index card in front of them, and place themselves on the point on the number line that corresponds to their number. (Consider asking students to do so without speaking at all.) Emphasize: Students who have the same number of letters should stand one in front of the other.

- Hold up the index card that has been labeled with "minimum." Ask students who should claim the card, then hand the card to the appropriate student. Do the same for the other labels of a five-number summary. If any quartile falls between two students' numbers, write that number of the index card and have both students hold that card together.

Now that the five numbers are identified and each is associated with one or more students, use wide painter's tape to construct a box plot.

- Form a rectangle on the ground by affixing the tape around the group of students between Q1 and Q3. If a quartile is between two people, put the tape down between them. If a quartile has the value of a student's number, put the tape down at that value and have the student stand on it.

- Put a tape segment at Q2, from the top side of the rectangle to the bottom side, to subdivide the rectangle into two smaller rectangles. If Q2 is a student's number, have the student stand on the tape.

- For the left whisker, affix the end of the tape to the Q1 end of the rectangle, and extend it to where the student holding the "minimum" card is standing. Do the same for the right whisker, from Q3 to the maximum.

- Tape the five-number summary cards and students' cards that correspond to them in the correct locations.

This image shows an example of a completed human box plot.



Explain to students that they have made a human box plot. Consider taking a picture of the box plot for reference and discussion later.
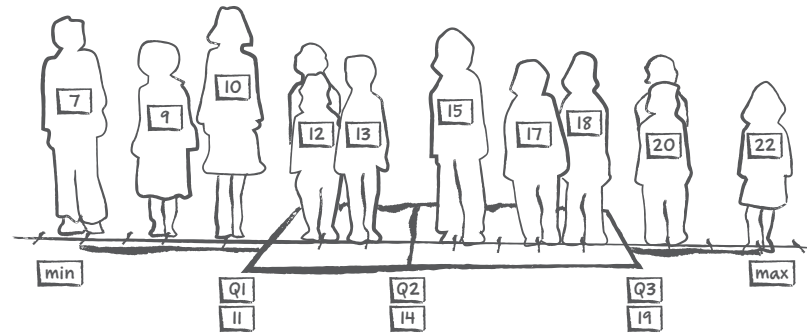
### Student Task Statement

Your teacher will give you the data on the lengths of names of students in your class. Write the five-number summary by finding the data set's minimum, Q1, Q2, Q3, and the maximum.

Pause for additional instructions from your teacher.

Answers vary.

### Activity Synthesis

Tell students that a box plot is a representation that shows the five-number summary of a data set. Discuss:

- *"Where can the median be seen in the box plot? What about the first and third quartiles?"*

  The median is the line inside the box. The left and right sides of the box represent the first and third quartiles.

- *"Where can the IQR be seen in the box plot?"*

  It is the length of the box.

- *"The two segments of tape on the two ends are called 'whiskers.' What do they represent?"*

  The lower one-fourth of the data and the upper one-fourth of data.

- *"How many people are part of the box, between Q1 and Q3? Approximately what fraction of the data set is that number?"*

  About half. Note that the number of people that are part of the box may not be exactly one half of the total number of people, depending on whether the number of data points is odd or even, and depending on how the values are distributed.

- *"Why might it be helpful to summarize a data set with a box plot?"*

  It could help us see how close together or spread out the values are, and where they are concentrated.

## Activity 2
## Studying Blinks

**15 min**

### Activity Narrative

In this activity, students learn to draw a box plot, and they explore the connections between a dot plot and a box plot of the same data set. Then they compare the representations by commenting on what information can be quickly understood from each, based on the structure of the representations.

### Launch 👥

Arrange students in groups of 2. Give students 8–10 minutes to complete the questions, and then follow with a whole-class discussion.

Tell students that they will now draw a box plot to represent another set of data. For their background information, explain that scientists believe people blink their eyes to keep the surface of the eye moist and also to give the brain a brief rest. On average, people blink between 15 and 20 times a minute.

Display the box plot for all to see. Tell students that their box plot will have all of these features, but will not look exactly like this because their data is different from the one used to make this box plot.
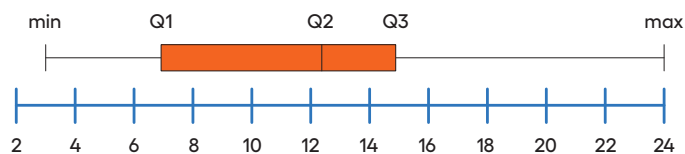


Use *Collect and Display* to create a shared reference that captures students' developing mathematical language. Collect the language that students use to compare the representations. Display words and phrases such as "median," "quartiles," "five-number summary," "estimate," and "exact."

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### Student Task Statement

Twenty people participate in a study about blinking. The number of times each person blinked while watching a video for one minute is recorded. The data values are shown here, in order from smallest to largest.

| 3 | 6 | 8 | 11 | 11 | 13 | 14 | 14 | 14 | 14 |
|---|---|---|----|----|----|----|----|----|----|
| 16 | 18 | 20 | 20 | 20 | 22 | 24 | 32 | 36 | 51 |

1. Here is a dot plot showing these data.



    a. Find the median (Q2) and mark its location on the dot plot. **15**

    b. Find the first quartile (Q1) and the third quartile (Q3). Mark their locations on the dot plot. **Q1: 12, Q3: 21**

    c. What are the minimum and maximum values? **minimum: 3, maximum: 51**

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### Access for Multilingual Learners (Activity 2)

**MLR2: Collect and Display.** This activity uses the *Collect and Display* math language routine to advance conversing and reading as students clarify, build on, or make connections to mathematical language.

### Access for Students with Diverse Abilities (Activity 2, Student Task)

**Engagement: Develop Effort and Persistence.** Chunk this task into more manageable parts. Within the first 3–5 minutes, check in with students to provide feedback and encouragement. Check to see if they were able to find Q1, Q2, and Q3. If necessary, remind students how to find each quartile.

*Supports accessibility for: Attention, Social-Emotional Functioning*

### Student Workbook

**Student Workbook**

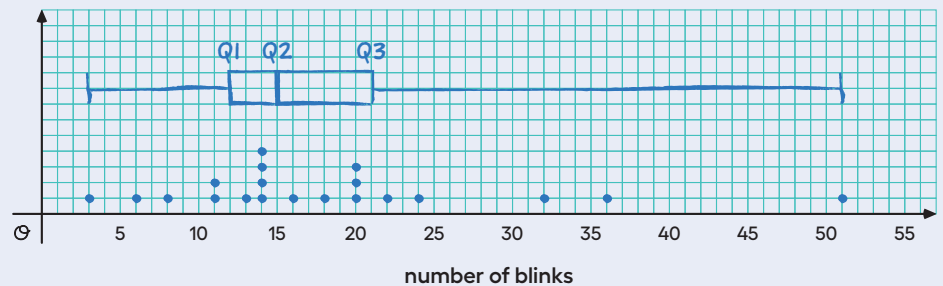2 Studying Blinks

**Are You Ready for More?**

Suppose there were some errors in the data set: the smallest value should have been 6 instead of 3, and the largest value should have been 41 instead of 51. Determine if any part of the five-number summary would change. If you think so, describe how it would change. If not, explain how you know.

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2. A **box plot** can be used to represent the five-number summary graphically. Let's draw a box plot for the number-of-blinks data. Above the dot plot:

   **a.** Draw a box that extends from the first quartile (Q1) to the third quartile (Q3). Label the quartiles.

   **b.** At the median (Q2), draw a vertical line from the top of the box to the bottom of the box. Label the median.

   **c.** From the left side of the box (Q1), draw a horizontal line (a whisker) that extends to the minimum of the data set. On the right side of the box (Q3), draw a similar line that extends to the maximum of the data set.



number of blinks

3. Compare the information that can be quickly understood from each representation.

Sample response: From the box plot, it is easy to see the five-number summary as well as some information about the variability of the data. The dot plot shows the actual values, but none of the statistics are calculated, so only estimates are easy to get.

**Are You Ready for More?**

Suppose there were some errors in the data set: the smallest value should have been 6 instead of 3, and the largest value should have been 41 instead of 51. Determine if any part of the five-number summary would change. If you think so, describe how it would change. If not, explain how you know.

Sample reasonings:

- Minimum: Yes. The minimum would change from 3 to 6.
- First quartile (Q1): No. The lower quartile would still be the average of 11 and 13, because the number of data points in the set has not changed.
- Median (Q2): No. The median would still be the average of 14 and 16, because the number of data points in the set has not changed.
- Third Quartile (Q3): No. The upper quartile would still be the average of 20 and 22, because the number of data points in the set has not changed.
- Maximum: Yes. The maximum would change from 51 to 41.

**Activity Synthesis**

Display the dot plot and the box plot for all to see.



number of blinks
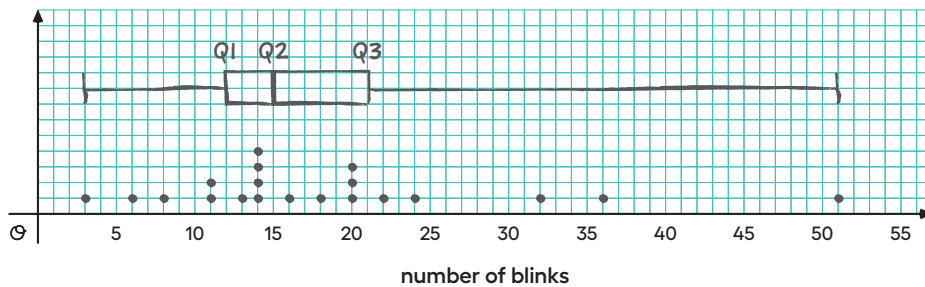
Direct students' attention to the reference created using *Collect and Display*. Ask students to share their comparison of the representations. Invite students to borrow language from the display as needed, and update the reference to include additional phrases as they respond. (For example, "The box plot shows the five-number summary easily, but the exact data are lost. The dot plot shows the shape of the distribution better, but there are no calculated values shown.")

Discuss:

💬 *"How many data values are included in each part of the box plot?"*

　　5 data values in each part

💬 *"What percentage of data is included in the boxed portion of the box plot?"*

　　50%

The focus of this activity is on constructing a box plot and understanding its parts, rather than on interpreting it in context. If students seem to have a good grasp of the drawing process and what the parts entail and mean, consider asking them to interpret the plots in the context of the research study. Ask:

💬 *"Suppose you are the scientist who conducted the research and are writing an article about it. Write 2–3 sentences that summarize your findings, based on your analyses of the dot plot and the box plot."*

　　Half of the participants blink between 12 and 21 times per minute. A person blinked as few as 3 times and another as many as 51 times, but these values were unusual in this group.

**Lesson Synthesis**

For the "Human Box Plot" activity:

- Each student will need the index card that shows their name and the number of letters in their name (used for the "Finding the Middle" activity), as well as a class data set.

- Compile the numbers on the cards into a single list or table. Prepare one copy of the data set for each student.

- Have some extra index cards available for students who might have been absent in that earlier lesson.

- Prepare five index cards that are labeled with "minimum," "maximum," "Q1," "Q2," and "Q3."

**Student Workbook**

- Make a number line on the ground using thin masking tape (0.5 inch). It should show whole number intervals and span at least from the lowest data value to the highest. The intervals should be at least a student's shoulder's width.

- Prepare a roll of wide masking tape (2- or 3-inch wide) to create a box and two whiskers on the ground.

### Lesson Summary

A **box plot** represents the five-number summary of a data set.

It shows the first quartile (Q1) and the third quartile (Q3) as the left and right sides of a rectangle, or a box. The median (Q2) is shown as a vertical segment inside the box. On the left side, a horizontal line segment, sometimes called a whisker, extends from Q1 to the minimum value. On the right, a whisker extends from Q3 to the maximum value.

The rectangle in the middle represents the middle half of the data. Its width is the IQR. The whiskers represent the bottom quarter and the top quarter of the data set.

Here are data about pug and beagle weights represented as both dot plots and box plots.

pug weights in kilograms        beagle weights in kilograms
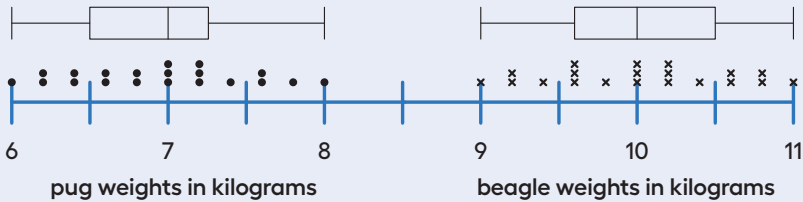
We can tell from the box plots that, in general, the pugs in the group are lighter than the beagles. The median weight of pugs is 7 kilograms and the median weight of beagles is 10 kilograms. Because the two box plots are on the same scale and the rectangles have similar widths, we can also tell that the IQRs for the two breeds are very similar. This suggests that the variability in the beagle weights is very similar to the variability in the pug weights.
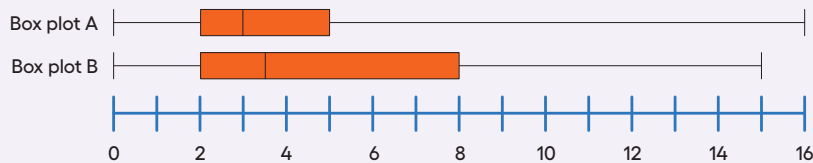
**Cool-down**

**Boxes and Dots**                                                                        **5 min**

**Student Task Statement**

1. Here are two box plots that summarize two data sets. Do you agree with each of the following statements?



a. Both data sets have the same range. Disagree

b. Both data sets have the same minimum value. Agree

c. The IQR shown in box plot B is twice the IQR shown in box plot A. Agree

d. Box plot A shows a data set that has a quarter of its values between 2 and 5. Disagree

2. These dot plots show the same data sets as those represented by the box plots. Decide which box plot goes with each dot plot. Explain your reasoning.

**data set 1**
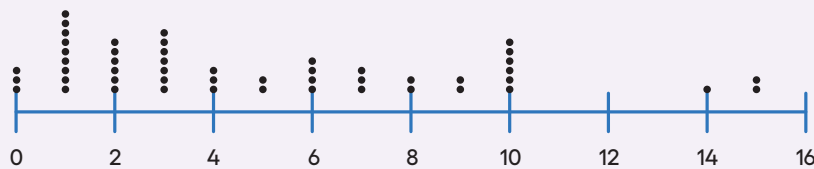


**data set 2**
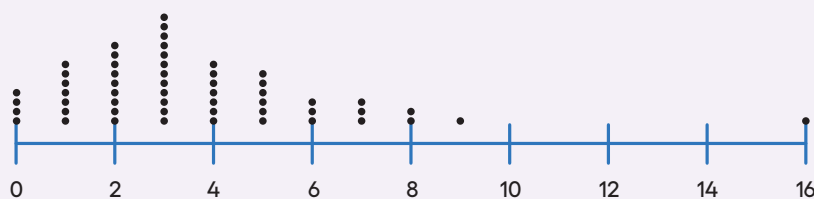


Box plot A goes with Data set 2. Box plot B goes with Data set 1. Sample reasonings:

• The maximum values tell which box plot goes with which dot plot.

• The middle half of the points in data set 1 are more spread out compared to those in data set 2, so box plot B, which has a longer box, goes with data set 1.

• Three quarters of the points in data set 2 are between 0 and 5, which matches the box and left whisker in Box plot A.

**Responding To Student Thinking**

**Points to Emphasize**
If students struggle with specific vocabulary in context or with creating a box plot, clarify any areas of difficulty during this activity: Unit 8, Lesson 17, Warm-up Hours of Slumber

**Practice Problems**                                        6 Problems

## Problem 1

Each student in a class recorded how many books they read during the summer. Here is a box plot that summarizes their data.
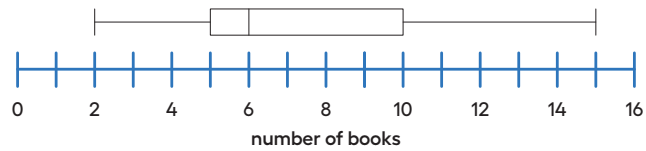


number of books

**a.** What is the greatest number of books read by a student in this group?

15

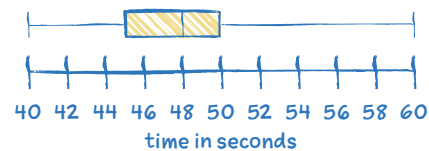**b.** What is the median number of books read by the students?

6

**c.** What is the interquartile range (IQR)?

5

## Problem 2

Use this five-number summary to draw a box plot. All values are in seconds.

- Minimum: 40
- First quartile (Q1): 45
- Median: 48
- Third quartile (Q3): 50
- Maximum: 60



40 42 44 46 48 50 52 54 56 58 60
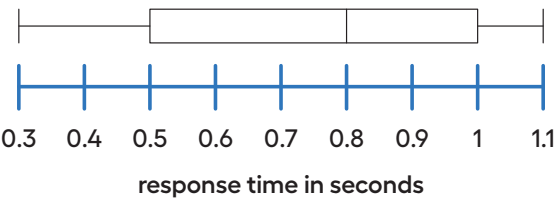
time in seconds

## Problem 3

The data shows the number of hours per week that each of 13 seventh-grade students spent doing homework. Create a box plot to summarize the data.

3    10    12    4    7    9    5    5    11    11    5    12    11



0  1  2  3  4  5  6  7  8  9  10  11  12  13

time in hours
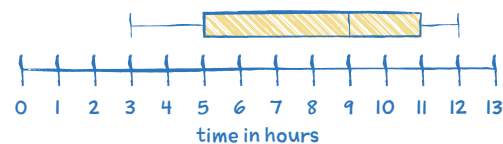
## Problem 4

The box plot displays the data on the response times of 100 mice to seeing a flash of light.



response time in seconds

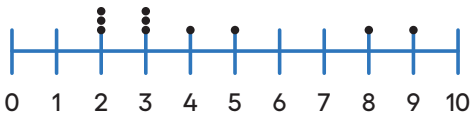How many mice are represented by the rectangle between 0.5 and 1 second?

50

## Problem 5                                              from Unit 8, Lesson 14

Here is a dot plot that represents a data set. Explain why the mean of the data set is greater than its median.



Sample explanation: The dot plot has a peak on the left and the median is near that peak. The values 8 and 9 are much larger than the other values. These large values make the mean larger than the median.

## Problem 6                                              from Unit 8, Lesson 9

Jada earns money from babysitting, walking her neighbor's dogs, and running errands for her aunt. Every four weeks, she combines her earnings and divides them into three equal parts—one for spending, one for saving, and one for donating to a charity. Jada donated $26.00 of her earnings from the past four weeks to charity.

How much could she have earned from each job? Make two lists of how much she could have earned from the three jobs during the past four weeks.

Sample response:

o  $15, $16, $19, $28

o  $17, $23, $12.50, $25.50

Any correct response will have a total of $78.