### Essential Question
How does the graph of the linear function \( f(x) = x \) compare to the graphs of \( g(x) = f(x) + c \) and \( h(x) = f(cx) \)?

**Exploration 1**  
**Comparing Graphs of Functions**

**Work with a partner.** The graph of \( f(x) = x \) is shown. Sketch the graph of each function, along with \( f \), on the same set of coordinate axes. Use a graphing calculator to check your results. What can you conclude?

- a. \( g(x) = x + 4 \)
- b. \( g(x) = x + 2 \)
- c. \( g(x) = x - 2 \)
- d. \( g(x) = x - 4 \)

**Exploration 2**  
**Comparing Graphs of Functions**

**Work with a partner.** Sketch the graph of each function, along with \( f(x) = x \), on the same set of coordinate axes. Use a graphing calculator to check your results. What can you conclude?

- a. \( h(x) = \frac{1}{2}x \)
- b. \( h(x) = 2x \)
- c. \( h(x) = -\frac{1}{2}x \)
- d. \( h(x) = -2x \)

**Exploration 3**  
**Matching Functions with Their Graphs**

**Work with a partner.** Match each function with its graph. Use a graphing calculator to check your results. Then use the results of Explorations 1 and 2 to compare the graph of \( k \) to the graph of \( f(x) = x \).

- a. \( k(x) = 2x - 4 \)
- b. \( k(x) = -2x + 2 \)
- c. \( k(x) = \frac{1}{2}x + 4 \)
- d. \( k(x) = -\frac{1}{2}x - 2 \)

**Communicate Your Answer**

4. How does the graph of the linear function \( f(x) = x \) compare to the graphs of \( g(x) = f(x) + c \) and \( h(x) = f(cx) \)?

Section 3.6  
Transformations of Graphs of Linear Functions  
145
What You Will Learn

- Translate and reflect graphs of linear functions.
- Stretch and shrink graphs of linear functions.
- Combine transformations of graphs of linear functions.

Translations and Reflections

A **family of functions** is a group of functions with similar characteristics. The most basic function in a family of functions is the **parent function**. For nonconstant linear functions, the parent function is \( f(x) = x \). The graphs of all other nonconstant linear functions are **transformations** of the graph of the parent function. A **transformation** changes the size, shape, position, or orientation of a graph.

### Core Vocabulary

- family of functions, p. 146
- parent function, p. 146
- transformation, p. 146
- translation, p. 146
- reflection, p. 147
- horizontal shrink, p. 148
- horizontal stretch, p. 148
- vertical stretch, p. 148
- vertical shrink, p. 148

### Core Concept

A **translation** is a transformation that shifts a graph horizontally or vertically but does not change the size, shape, or orientation of the graph.

#### Horizontal Translations

The graph of \( y = f(x - h) \) is a horizontal translation of the graph of \( y = f(x) \), where \( h \neq 0 \).

<table>
<thead>
<tr>
<th>( h &lt; 0 )</th>
<th>( h &gt; 0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y = f(x - h) )</td>
<td>( y = f(x - h) )</td>
</tr>
</tbody>
</table>

Subtracting \( h \) from the inputs before evaluating the function shifts the graph left when \( h < 0 \) and right when \( h > 0 \).

#### Vertical Translations

The graph of \( y = f(x) + k \) is a vertical translation of the graph of \( y = f(x) \), where \( k \neq 0 \).

<table>
<thead>
<tr>
<th>( k &lt; 0 )</th>
<th>( k &gt; 0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y = f(x) + k )</td>
<td>( y = f(x) + k )</td>
</tr>
</tbody>
</table>

Adding \( k \) to the outputs shifts the graph down when \( k < 0 \) and up when \( k > 0 \).

### Example 1

**Horizontal and Vertical Translations**

Let \( f(x) = 2x - 1 \). Graph (a) \( g(x) = f(x) + 3 \) and (b) \( t(x) = f(x + 3) \). Describe the transformations from the graph of \( f \) to the graphs of \( g \) and \( t \).

**SOLUTION**

a. The function \( g \) is of the form \( y = f(x) + k \), where \( k = 3 \). So, the graph of \( g \) is a vertical translation 3 units up of the graph of \( f \).

b. The function \( t \) is of the form \( y = f(x - h) \), where \( h = -3 \). So, the graph of \( t \) is a horizontal translation 3 units left of the graph of \( f \).
A reflection is a transformation that flips a graph over a line called the line of reflection.

**Reflections in the x-axis**
The graph of \( y = -f(x) \) is a reflection in the x-axis of the graph of \( y = f(x) \).

**Reflections in the y-axis**
The graph of \( y = f(-x) \) is a reflection in the y-axis of the graph of \( y = f(x) \).

Multiplying the outputs by \(-1\) changes their signs.

Multiplying the inputs by \(-1\) changes their signs.

**EXAMPLE 2  Reflections in the x-axis and the y-axis**

Let \( f(x) = \frac{1}{2}x + 1 \). Graph (a) \( g(x) = -f(x) \) and (b) \( t(x) = f(-x) \). Describe the transformations from the graph of \( f \) to the graphs of \( g \) and \( t \).

**SOLUTION**

a. To find the outputs of \( g \), multiply the outputs of \( f \) by \(-1\). The graph of \( g \) consists of the points \((x, -f(x))\).

<table>
<thead>
<tr>
<th>( x )</th>
<th>-4</th>
<th>-2</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f(x) )</td>
<td>-1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>(-f(x))</td>
<td>1</td>
<td>0</td>
<td>-1</td>
</tr>
</tbody>
</table>

The graph of \( g \) is a reflection in the x-axis of the graph of \( f \).

b. To find the outputs of \( t \), multiply the inputs by \(-1\) and then evaluate \( f \). The graph of \( t \) consists of the points \((x, f(-x))\).

<table>
<thead>
<tr>
<th>( x )</th>
<th>-2</th>
<th>0</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-x)</td>
<td>2</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>( f(-x) )</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

The graph of \( t \) is a reflection in the y-axis of the graph of \( f \).

**Monitoring Progress**

Using \( f \), graph (a) \( g \) and (b) \( h \). Describe the transformations from the graph of \( f \) to the graphs of \( g \) and \( h \).

1. \( f(x) = 3x + 1; g(x) = f(x) - 2; h(x) = f(x - 2) \)
2. \( f(x) = -4x - 2; g(x) = -f(x); h(x) = f(-x) \)
**Stretches and Shrinks**

You can transform a function by multiplying all the $x$-coordinates (inputs) by the same factor $a$. When $a > 1$, the transformation is a **horizontal shrink** because the graph shrinks toward the $y$-axis. When $0 < a < 1$, the transformation is a **horizontal stretch** because the graph stretches away from the $y$-axis. In each case, the $y$-intercept stays the same.

You can also transform a function by multiplying all the $y$-coordinates (outputs) by the same factor $a$. When $a > 1$, the transformation is a **vertical stretch** because the graph stretches away from the $x$-axis. When $0 < a < 1$, the transformation is a **vertical shrink** because the graph shrinks toward the $x$-axis. In each case, the $x$-intercept stays the same.

**STUDY TIP**

The graphs of $y = f(-ax)$ and $y = -a \cdot f(x)$ represent a stretch or shrink and a reflection in the $x$- or $y$-axis of the graph of $y = f(x)$.

---

**Core Concept**

**Horizontal Stretches and Shrinks**

The graph of $y = f(ax)$ is a horizontal **stretch** or **shrink** by a factor of $\frac{1}{a}$ of the graph of $y = f(x)$, where $a > 0$ and $a \neq 1$.

**Vertical Stretches and Shrinks**

The graph of $y = a \cdot f(x)$ is a vertical **stretch** or **shrink** by a factor of $a$ of the graph of $y = f(x)$, where $a > 0$ and $a \neq 1$.

**EXAMPLE 3** Horizontal and Vertical Stretches

Let $f(x) = x - 1$. Graph (a) $g(x) = f\left(\frac{1}{3}x\right)$ and (b) $h(x) = 3f(x)$. Describe the transformations from the graph of $f$ to the graphs of $g$ and $h$.

**SOLUTION**

**a.** To find the outputs of $g$, multiply the inputs by $\frac{1}{3}$. Then evaluate $f$. The graph of $g$ consists of the points $\left(x, f\left(\frac{1}{3}x\right)\right)$.

- The graph of $g$ is a horizontal stretch of the graph of $f$ by a factor of $1 + \frac{1}{3} = 3$.

**b.** To find the outputs of $h$, multiply the outputs of $f$ by 3. The graph of $h$ consists of the points $(x, 3f(x))$.

- The graph of $h$ is a vertical stretch of the graph of $f$ by a factor of 3.
**EXAMPLE 4** Horizontal and Vertical Shrinks

Let \( f(x) = x + 2 \). Graph (a) \( g(x) = f(4x) \) and (b) \( h(x) = \frac{1}{4} f(x) \). Describe the transformations from the graph of \( f \) to the graphs of \( g \) and \( h \).

**SOLUTION**

a. To find the outputs of \( g \), multiply the inputs by 4. Then evaluate \( f \). The graph of \( g \) consists of the points \((x, f(4x))\).

<table>
<thead>
<tr>
<th>( x )</th>
<th>( f(4x) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

The graph of \( g \) is a horizontal shrink of the graph of \( f \) by a factor of \( \frac{1}{4} \).

b. To find the outputs of \( h \), multiply the outputs of \( f \) by \( \frac{1}{4} \). The graph of \( h \) consists of the points \((x, \frac{1}{4} f(x))\).

<table>
<thead>
<tr>
<th>( x )</th>
<th>( f(x) )</th>
<th>( \frac{1}{4} f(x) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

The graph of \( h \) is a vertical shrink of the graph of \( f \) by a factor of \( \frac{1}{4} \).

**Monitoring Progress**

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Using \( f \), graph (a) \( g \) and (b) \( h \). Describe the transformations from the graph of \( f \) to the graphs of \( g \) and \( h \).

3. \( f(x) = 4x - 2 \); \( g(x) = f(\frac{1}{2}x) \); \( h(x) = 2f(x) \)
4. \( f(x) = -3x + 4 \); \( g(x) = f(2x) \); \( h(x) = \frac{1}{2} f(x) \)

**STUDY TIP**

You can perform transformations on the graph of any function \( f \) using these steps.

**Core Concept**

**Transformations of Graphs**

The graph of \( y = a \cdot f(x - h) + k \) or the graph of \( y = f(ax - h) + k \) can be obtained from the graph of \( y = f(x) \) by performing these steps.

Step 1 Translate the graph of \( y = f(x) \) horizontally \( h \) units.

Step 2 Use \( a \) to stretch or shrink the resulting graph from Step 1.

Step 3 Reflect the resulting graph from Step 2 when \( a < 0 \).

Step 4 Translate the resulting graph from Step 3 vertically \( k \) units.
Combining Transformations

Graph \( f(x) = x \) and \( g(x) = -2x + 3 \). Describe the transformations from the graph of \( f \) to the graph of \( g \).

**SOLUTION**

Note that you can rewrite \( g \) as \( g(x) = -2f(x) + 3 \).

**Step 1** There is no horizontal translation from the graph of \( f \) to the graph of \( g \).

**Step 2** Stretch the graph of \( f \) vertically by a factor of 2 to get the graph of \( h(x) = 2x \).

**Step 3** Reflect the graph of \( h \) in the \( x \)-axis to get the graph of \( r(x) = -2x \).

**Step 4** Translate the graph of \( r \) vertically 3 units up to get the graph of \( g(x) = -2x + 3 \).

Solving a Real-Life Problem

A cable company charges customers $60 per month for its service, with no installation fee. The cost to a customer is represented by \( c(m) = 60m \), where \( m \) is the number of months of service. To attract new customers, the cable company reduces the monthly fee to $30 but adds an installation fee of $45. The cost to a new customer is represented by \( r(m) = 30m + 45 \), where \( m \) is the number of months of service. Describe the transformations from the graph of \( c \) to the graph of \( r \).

**SOLUTION**

Note that you can rewrite \( r \) as \( r(m) = \frac{1}{2}c(m) + 45 \). In this form, you can use the order of operations to get the outputs of \( r \) from the outputs of \( c \). First, multiply the outputs of \( c \) by \( \frac{1}{2} \) to get \( h(m) = 30m \). Then add 45 to the outputs of \( h \) to get \( r(m) = 30m + 45 \).

The transformations are a vertical shrink by a factor of \( \frac{1}{2} \) and then a vertical translation 45 units up.

**Monitoring Progress**

5. Graph \( f(x) = x \) and \( h(x) = \frac{1}{2}x - 2 \). Describe the transformations from the graph of \( f \) to the graph of \( h \).
### Vocabulary and Core Concept Check

1. **WRITING** Describe the relationship between \( f(x) = x \) and all other nonconstant linear functions.

2. **VOCABULARY** Name four types of transformations. Give an example of each and describe how it affects the graph of a function.

3. **WRITING** How does the value of \( a \) in the equation \( y = f(ax) \) affect the graph of \( y = f(x) \)? How does the value of \( a \) in the equation \( y = af(x) \) affect the graph of \( y = f(x) \)?

4. **REASONING** The functions \( f \) and \( g \) are linear functions. The graph of \( g \) is a vertical shrink of the graph of \( f \). What can you say about the \( x \)-intercepts of the graphs of \( f \) and \( g \)? Is this always true? Explain.

### Monitoring Progress and Modeling with Mathematics

In Exercises 5–10, use the graphs of \( f \) and \( g \) to describe the transformation from the graph of \( f \) to the graph of \( g \). (See Example 1.)

5. \[ g(x) = f(x) + 2 \]

6. \[ g(x) = f(x + 4) \]

7. \( f(x) = \frac{1}{2}x + 3; \ g(x) = f(x) - 3 \)

8. \( f(x) = -3x + 4; \ g(x) = f(x) + 1 \)

9. \( f(x) = -x - 2; \ g(x) = f(x + 5) \)

10. \( f(x) = \frac{1}{2}x - 5; \ g(x) = f(x - 3) \)

11. **MODELING WITH MATHEMATICS** You and a friend start biking from the same location. Your distance \( d \) (in miles) after \( t \) minutes is given by the function \( d(t) = \frac{1}{4}t \). Your friend starts biking 5 minutes after you. Your friend’s distance \( f \) is given by the function \( f(t) = d(t - 5) \). Describe the transformation from the graph of \( d \) to the graph of \( f \).

12. **MODELING WITH MATHEMATICS** The total cost \( C \) (in dollars) to cater an event with \( p \) people is given by the function \( C(p) = 18p + 50 \). The set-up fee increases by $25. The new total cost \( T \) is given by the function \( T(p) = C(p) + 25 \). Describe the transformation from the graph of \( C \) to the graph of \( T \).

#### Pricing

- $50 set-up fee + $18 per person

In Exercises 13–16, use the graphs of \( f \) and \( h \) to describe the transformation from the graph of \( f \) to the graph of \( h \). (See Example 2.)

13. \[ f(x) = \frac{2}{3}x + 4, \quad h(x) = f(-x) \]

14. \[ f(x) = -3x + 1, \quad h(x) = -f(x) \]

15. \( f(x) = -5 - x; \ h(x) = f(-x) \)

16. \( f(x) = \frac{1}{4}x - 2; \ h(x) = -f(x) \)
In Exercises 17–22, use the graphs of \( f \) and \( r \) to describe the transformation from the graph of \( f \) to the graph of \( r \).
(See Example 3.)

17. \( f(x) = \frac{3}{2}x - 1 \)
18. \( f(x) = -x \)
19. \( f(x) = -2x - 4; r(x) = f\left(\frac{1}{2}x\right) \)
20. \( f(x) = 3x + 5; r(x) = f\left(\frac{1}{3}x\right) \)
21. \( f(x) = \frac{2}{3}x + 1; r(x) = 3f(x) \)
22. \( f(x) = -\frac{1}{3}x - 2; r(x) = 4f(x) \)

In Exercises 23–28, use the graphs of \( f \) and \( h \) to describe the transformation from the graph of \( f \) to the graph of \( h \).
(See Example 4.)

23. \( h(x) = f(3x) \)
24. \( h(x) = \frac{1}{3}f(x) \)
25. \( f(x) = 3x - 12; h(x) = \frac{1}{6}f(x) \)
26. \( f(x) = -x + 1; h(x) = f(2x) \)
27. \( f(x) = -2x - 2; h(x) = f(5x) \)
28. \( f(x) = 4x + 8; h(x) = \frac{3}{4}f(x) \)

In Exercises 29–34, use the graphs of \( f \) and \( g \) to describe the transformation from the graph of \( f \) to the graph of \( g \).

29. \( f(x) = x - 2; g(x) = \frac{1}{2}f(x) \)
30. \( f(x) = -4x + 8; g(x) = -f(x) \)
31. \( f(x) = -2x - 7; g(x) = f(x - 2) \)
32. \( f(x) = 3x + 8; g(x) = f\left(\frac{1}{3}x\right) \)
33. \( f(x) = x - 6; g(x) = 6f(x) \)
34. \( f(x) = -x; g(x) = f(x) - 3 \)

In Exercises 35–38, write a function \( g \) in terms of \( f \) so that the statement is true.

35. The graph of \( g \) is a horizontal translation 2 units right of the graph of \( f \).
36. The graph of \( g \) is a reflection in the \( y \)-axis of the graph of \( f \).
37. The graph of \( g \) is a vertical stretch by a factor of 4 of the graph of \( f \).
38. The graph of \( g \) is a horizontal shrink by a factor of \( \frac{1}{3} \) of the graph of \( f \).

**ERROR ANALYSIS** In Exercises 39 and 40, describe and correct the error in graphing \( g \).

39. 

In Exercises 41–46, graph \( f \) and \( h \). Describe the transformations from the graph of \( f \) to the graph of \( h \).
(See Example 5.)

41. \( f(x) = x; h(x) = \frac{1}{3}x + 1 \)
42. \( f(x) = x; h(x) = 4x - 2 \)
43. \( f(x) = x; h(x) = -3x - 4 \)
44. \( f(x) = x; h(x) = -\frac{1}{2}x + 3 \)
45. \( f(x) = 2x; h(x) = 6x - 5 \)
46. \( f(x) = 3x; h(x) = -3x - 7 \)
47. **MODELING WITH MATHEMATICS** The function \( t(x) = -4x + 72 \) represents the temperature from 5 P.M. to 11 P.M., where \( x \) is the number of hours after 5 P.M. The function \( d(x) = 4x + 72 \) represents the temperature from 10 A.M. to 4 P.M., where \( x \) is the number of hours after 10 A.M. Describe the transformation from the graph of \( t \) to the graph of \( d \).

48. **MODELING WITH MATHEMATICS** A school sells T-shirts to promote school spirit. The school’s profit is given by the function \( P(x) = 8x - 150 \), where \( x \) is the number of T-shirts sold. During the play-offs, the school increases the price of the T-shirts. The school’s profit during the play-offs is given by the function \( Q(x) = 16x - 200 \), where \( x \) is the number of T-shirts sold. Describe the transformations from the graph of \( P \) to the graph of \( Q \).

49. **USING STRUCTURE** The graph of \( g(x) = a \cdot f(x - b) + c \) is a transformation of the graph of the linear function \( f \). Select the word or value that makes each statement true.

<table>
<thead>
<tr>
<th>Reflection</th>
<th>Translation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflection</td>
<td>Translation</td>
<td>-1</td>
</tr>
<tr>
<td>Stretch</td>
<td>Shrink</td>
<td>0</td>
</tr>
<tr>
<td>Left</td>
<td>Right</td>
<td>1</td>
</tr>
<tr>
<td>Y-axis</td>
<td>X-axis</td>
<td></td>
</tr>
</tbody>
</table>

a. The graph of \( g \) is a vertical ______ of the graph of \( f \) when \( a = 1 \), \( b = 1 \), \( c = 0 \), and \( d = 0 \).

b. The graph of \( g \) is a horizontal translation ______ of the graph of \( f \) when \( a = 1 \), \( b = 1 \), \( c = 0 \), and \( d = 0 \).

c. The graph of \( g \) is a vertical translation 1 unit up of the graph of \( f \) when \( a = 1 \), \( b = 0 \), and \( c = 0 \).

50. **USING STRUCTURE** The graph of \( h(x) = a \cdot f(bx - c) + d \) is a transformation of the graph of the linear function \( f \). Select the word or value that makes each statement true.

<table>
<thead>
<tr>
<th>Vertical</th>
<th>Horizontal</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretch</td>
<td>Shrink</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>Y-axis</td>
<td>X-axis</td>
<td>5</td>
</tr>
</tbody>
</table>

a. The graph of \( h \) is a ______ shrink of the graph of \( f \) when \( a = \frac{1}{2} \), \( b = 1 \), \( c = 0 \), and \( d = 0 \).

b. The graph of \( h \) is a reflection in the ______ of the graph of \( f \) when \( a = 1 \), \( b = -1 \), \( c = 0 \), and \( d = 0 \).

c. The graph of \( h \) is a horizontal stretch of the graph of \( f \) by a factor of 5 when \( a = 1 \), \( b = \ ______ \), \( c = 0 \), and \( d = 0 \).

51. **ANALYZING GRAPHS** Which of the graphs are related by only a translation? Explain.

52. **ANALYZING RELATIONSHIPS** A swimming pool is filled with water by a hose at a rate of 1020 gallons per hour. The amount \( v \) (in gallons) of water in the pool after \( t \) hours is given by the function \( v(t) = 1020t \). How does the graph of \( v \) change in each situation?

a. A larger hose is found. Then the pool is filled at a rate of 1360 gallons per hour.

b. Before filling up the pool with a hose, a water truck adds 2000 gallons of water to the pool.
53. **ANALYZING RELATIONSHIPS** You have $50 to spend on fabric for a blanket. The amount $m$ (in dollars) of money you have after buying $y$ yards of fabric is given by the function $m(y) = -9.98y + 50$. How does the graph of $m$ change in each situation?

a. You receive an additional $10 to spend on the fabric.

b. The fabric goes on sale, and each yard now costs $4.99.

54. **THOUGHT PROVOKING** Write a function $g$ whose graph passes through the point $(4, 2)$ and is a transformation of the graph of $f(x) = x$.

In Exercises 55–60, graph $f$ and $g$. Write $g$ in terms of $f$. Describe the transformation from the graph of $f$ to the graph of $g$.

55. $f(x) = 2x - 5; g(x) = 2x - 8$

56. $f(x) = 4x + 1; g(x) = -4x - 1$

57. $f(x) = 3x + 9; g(x) = 3x + 15$

58. $f(x) = -x - 4; g(x) = x - 4$

59. $f(x) = x + 2; g(x) = \frac{2}{3}x + 2$

60. $f(x) = x - 1; g(x) = 3x - 3$

61. **REASONING** The graph of $f(x) = x + 5$ is a vertical translation 5 units up of the graph of $f(x) = x$. How can you obtain the graph of $f(x) = x + 5$ from the graph of $f(x) = x$ using a horizontal translation?

62. **HOW DO YOU SEE IT?** Match each function with its graph. Explain your reasoning.

- $a(x) = f(-x)$
- $g(x) = f(x - 4)$
- $h(x) = f(x) + 2$
- $k(x) = f(3x)$

63. **REASONING** In Exercises 63–66, find the value of $r$.

64. $g(x) = f(rx)$

65. $f(x) = 3x - 6$

66. $f(x) = \frac{1}{2}x + 8$

67. **CRITICAL THINKING** When is the graph of $y = f(x) + w$ the same as the graph of $y = f(x + w)$ for linear functions? Explain your reasoning.

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**Maintaining Mathematical Proficiency**

Reviewing what you learned in previous grades and lessons

**Solve the formula for the indicated variable.**

68. Solve for $h$.

$$V = \pi r^2 h$$

69. Solve for $w$.

$$P = 2l + 2w$$

**Solve the inequality. Graph the solution, if possible.**

70. $|x - 3| \leq 14$

71. $|2x + 4| > 16$

72. $|x + 7| < 25$

73. $-2|x + 1| \geq 18$