# Let the Transformations Begin!

5.3

## Translations of Linear and Exponential Functions

Turn to page 313 in your book and open Desmos.com on your Chromebook.

**PROBLEM 1 Vertical translations**

Consider the three linear functions shown.

- $g(x) = x$
- $c(x) = (x) + 3$
- $d(x) = (x) - 3$

The first function is the ***basic function.*** A basic function is the simplest function of its type.

In this case, $g(x) = x$ is the simplest linear function. It is in the form $f(x) = ax + b$, where $a = 1$ and $b = 0$.

You can write the given functions $c(x)$ and $d(x)$ in terms of the basic function $g(x)$.

For example, because $g(x) = x$, you can substitute $g(x)$ for $x$ in the equation for $c(x)$, as shown.

$$c(x) = (x) + 3$$

$$c(x) = g(x) + 3$$

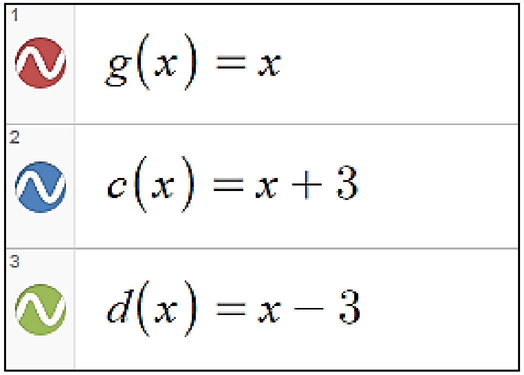
1. Write the function ***d*(*x*)** in terms of the basic function ***g*(*x*).**

$d(x) = g(x) - 3$

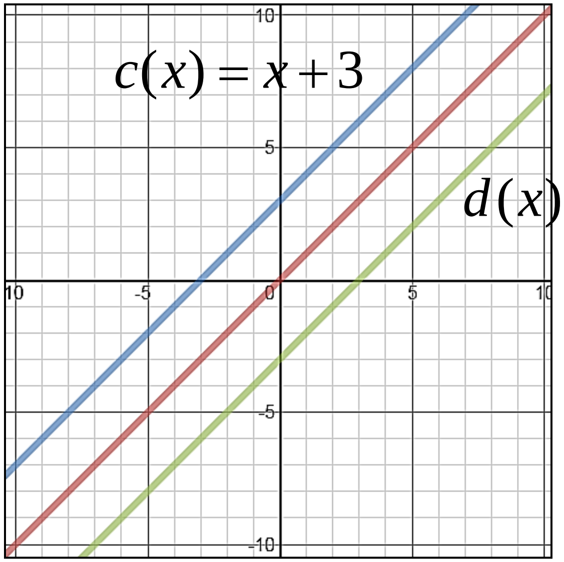
2. Describe the operation performed on the basic function ***g*(*x*)** to result in each of the equations for ***c*(*x*)** and ***d*(*x*).**

**You are adding 3 to one function and subtracting 3 from the other.**

3. Use desmos.com to graph each function on the same graph. You don't need to change the parameters for your graph. Sketch each graph and label.




$g(x) = x$



4. Compare the *y*-intercepts of the graphs of *c*(*x*) and *d*(*x*) to the *y*-intercept of the basic function *g*(*x*). What do you notice?

**The *y*-intercept for *c*(*x*) is 3 units above the *y*-intercept of the basic function.**
**The *y*-intercept for *d*(*x*) is 3 units below the *y*-intercept of the basic function.**

5. Write the *y*-value of each ordered pair for the three given functions.

| $g(x) = x$ | $c(x) = (x) + 3$ | $d(x) = (x) - 3$ |
|---|---|---|
| (−2, -2) | (−2, 1) | (−2, -5) |
| (−1, -1) | (−1, 2) | (−1, -4) |
| (0, 0) | (0, 3) | (0, -3) |
| (1, 1) | (1, 4) | (1, -2) |
| (2, 2) | (2, 5) | (2, -1) |

6. Use the table to compare the ordered pairs of the graphs of $c(x)$ and $d(x)$ to the ordered pairs of the graph of the basic function $g(x)$. What do you notice?

For the same $x$-coordinate, the $y$-coordinate of $c(x)$ is 3 more than the $y$-coordinate of $g(x)$. For the same $x$-coordinate, the $y$-coordinate of $d(x)$ is 3 less than the $y$-coordinate of $g(x)$.

**A vertical translation is a type of transformation that shifts the entire graph up or down. A vertical translation affects the *y*-coordinate of each point on the graph.**

Vertical shift occurs when a number is added or subtracted to the whole basic function!

Now, let's consider the three exponential functions shown. (Page 316)

- $h(x) = 2^x$
- $s(x) = 2^x + 3$
- $t(x) = 2^x - 3$

In this case, $h(x) = 2^x$ is the basic function because it is the simplest exponential function with a base of 2. It is in the form $f(x) = ab^x$, where $a = 1$ and $b = 2$.

*With your group answer questions 8-10*

8. Write the functions $s(x)$ and $t(x)$ in terms of the basic function $h(x)$. Then, describe the operation performed on the basic function $h(x)$ to result in each of the equations for $s(x)$ and $t(x)$.

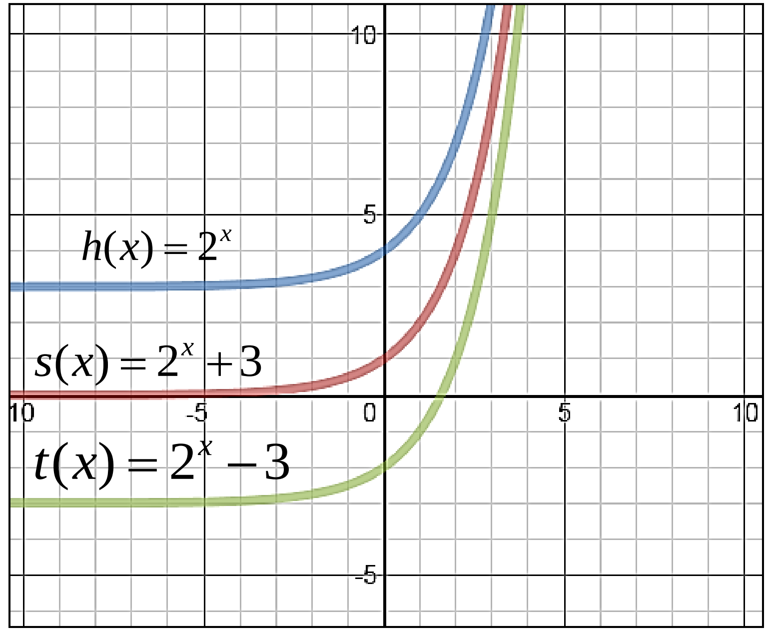
$s(x) = h(x) + 3$

$t(x) = h(x) - 3$

A constant, 3, is added to $h(x)$ to result in the function $s(x)$. A constant, 3, is subtracted from $h(x)$ to result in the function $t(x)$.

9. Using desmos.com, graph each function. Then, sketch the graph of each function and label.

1. $h(x) = 2^x$
2. $s(x) = \left(2^x\right) + 3$
3. $t(x) = \left(2^x\right) - 3$




10. Compare the *y*-intercepts of the graphs of *s*(*x*) and *t*(*x*) to the *y*-intercept of the graph of the basic function *h*(*x*). What do you notice? Are the results the same as when you compared the graphs of the linear functions in Question 4?

**The graph of *s*(*x*) is 3 units above the graph of the basic function. The graph of *t*(*x*) is 3 units below the graph of the basic function. Yes.**

11. Write the *y*-value of each ordered pair for the three given functions.

| $h(x) = 2^x$ | $s(x) = (2^x) + 3$ | $t(x) = (2^x) - 3$ |
|---|---|---|
| (−2, ¼ or .25) | (−2, 13/4 or 3.25) | (−2, -11/4 or -2.75) |
| (−1, ½ or .5) | (−1, 7/2 or 3.5) | (−1, -5/2 or -2.5) |
| (0, 1) | (0, 4) | (0, -2) |
| (1, 2) | (1, 5) | (1, -1) |
| (2, 4) | (2, 7) | (2, 1) |

12. Use the table to compare the ordered pairs of the graphs of $s(x)$ and $t(x)$ to the ordered pairs of the graph of the basic function $h(x)$. What do you notice? Are the results the same as when you compared the $y$-values for the linear functions in Question 6?

**For the same *x*-coordinate, the *y*-coordinate of *s*(*x*) is 3 more than the *y*-coordinate of *h*(*x*). For the same *x*-coordinate, the *y*-coordinate of *t*(*x*) is 3 less than the *y*-coordinate of *h*(*x*). Yes.**

13. Explain how you know that the graphs of $s(x)$ and $t(x)$ are vertical translations of the graph of $h(x)$.

**Because every point is either shifted up the same amount or down the same amount.**

# Homework: Worksheet