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The meaning of function inverse

In many applications, we need to reverse the function process, asking for the input $x$ associated with an output $y = f(x)$.

Given a function $f(x)$, with inputs $x$ and outputs $y$, we would like to reverse the process, taking outputs $y$ and restoring the original input $x$ to create $f^{-1}(x)$. 

![Diagram of function and its inverse](image)
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![Diagram showing function and its inverse with domains and ranges labeled X and Y.]
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In the picture above, we have a function $f$ from the set $X$ (the domain) to $Y$ (the codomain.) We would like to create an inverse function with domain $Y$ that maps back to $X$. We write $f^{-1}$ for the new function that reverses the process of function $f$.

Note that $f^{-1}$ is NOT the reciprocal of $f(x)$. It is NOT $\frac{1}{f}$!
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Suppose $f : \{a, b, c\} \rightarrow \{1, 2, 3\}$ is described in the first picture below (from Wikipedia.) Then $f^{-1}$ is described by the second picture. Notice how $f^{-1}$ reverses the inputs and outputs.
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Warning! The superscript $-1$ indicates the inverse function.

$$f^{-1} \text{ is not the same as } \frac{1}{f}.$$ 

Not every function has an inverse.

We will look at some examples of functions where we can reverse the process and some examples where we cannot.
Warning! The superscript $-1$ indicates the inverse function $f^{-1}$.

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Examples.

1 Let $f(x) = 3x + 5$. Write this function in the form $y = 3x + 5$. Suppose we are given a particular output $y$. Can we recover $x$? Yes. Let’s take the equation $y = 3x + 5$ and solve for $x$:

$$y = 3x + 5 \implies y - 5 = 3x \implies \frac{y - 5}{3} = x.$$ 

We have discovered that if we are given $y$ then $x = \frac{y - 5}{3}$.

$$g(y) = \frac{y - 5}{3}.$$ 

We follow custom and use $x$ for inputs and $y$ for outputs so we write

$$g(x) = \frac{x - 5}{3} \text{ or } f^{-1}(x) = \frac{x - 5}{3}.$$
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2 \( f(x) = x^2 \) with domain \( \mathbb{R} \) and codomain \( \mathbb{R} \).

If we write \( y = x^2 \), and we are given a particular value of \( y \), say \( y = 25 \), can we reverse the process and find \( x \)?

No, not in this case, for both \( x = -5 \) and \( x = 5 \) are mapped to \( y = 25 \) by this function.

There are two different inputs that are both mapped to 25 so we cannot reverse our process in a unique way.

The function \( f(x) = x^2 \), with domain \( \mathbb{R} \), does not have an inverse function.
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The function $f(x) = x^2$, with domain $\mathbb{R}$, does not have an inverse function.
Changing the domain to create an inverse function

Occasionally, if a function does not have an inverse, we may be able to change the domain of the function so that on this new domain the function is invertible.

We can do that in this last example.

We could change our function so that the domain is the interval \([0, \infty)\) instead of \((-\infty, \infty)\).

If we agree that no negative numbers are input into this function, then the ambiguity about \(x\) goes away.

If \(y = 25\) then \(x\) must be equal to 5, not \(-5\).

In this case, if \(f: [0, \infty) \to (-\infty, \infty)\) is defined by \(f(x) = x^2\) then the inverse function is \(f^{-1}(x) = \sqrt{x}\).

In the next presentation we will practice inverting functions.

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