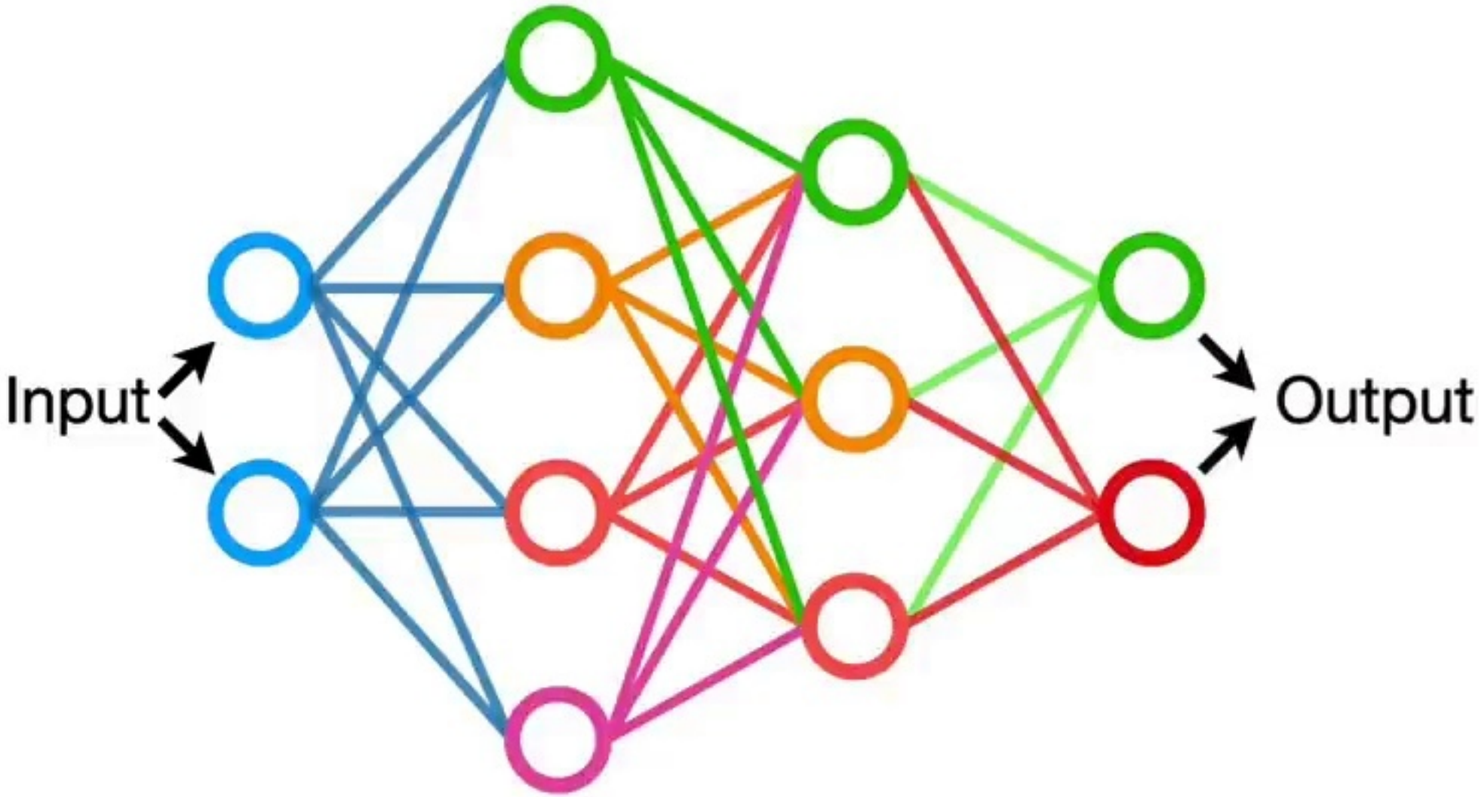
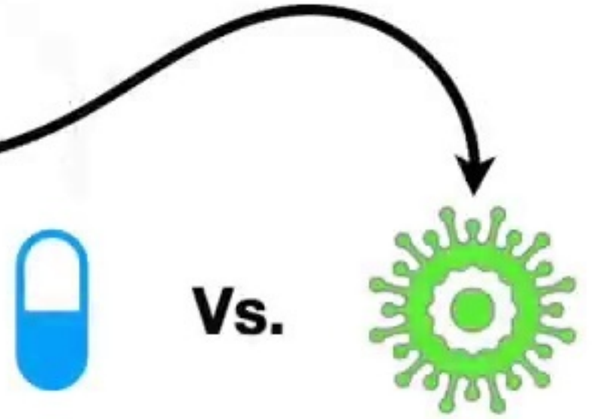
Neural Networks, one of the most popular algorithms in **Machine Learning**, cover a broad range of concepts and techniques.



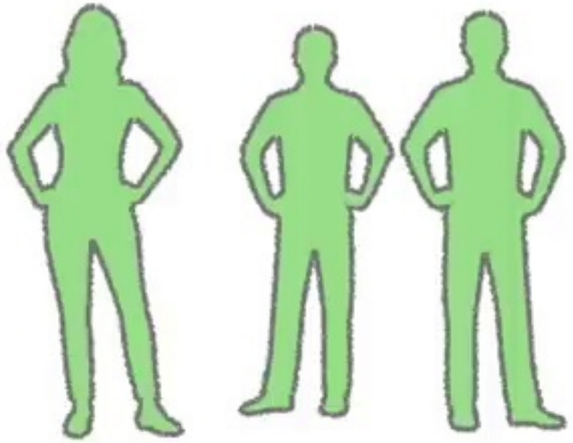
So, with that said, let's imagine we tested a drug that was designed to treat an illness…

So, with that said, let's imagine we tested a drug that was designed to treat an illness…

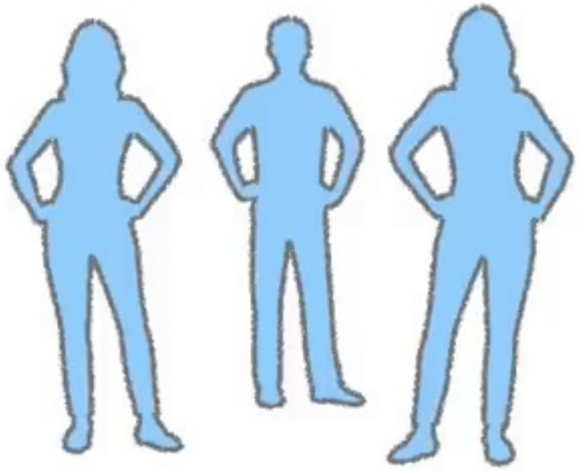


…and we gave the drug to **3** different groups of people with **3** different **Dosages**.

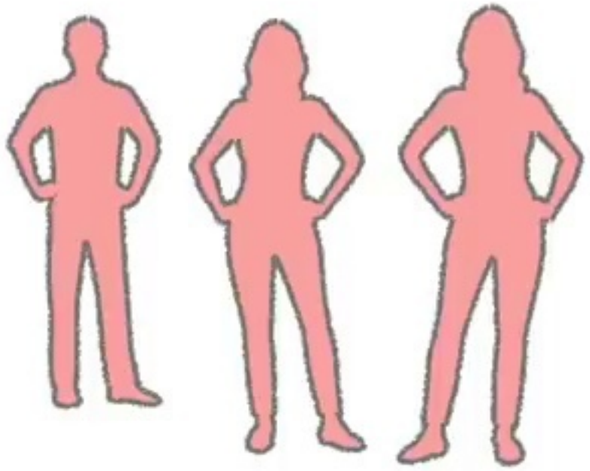
Low Dosage



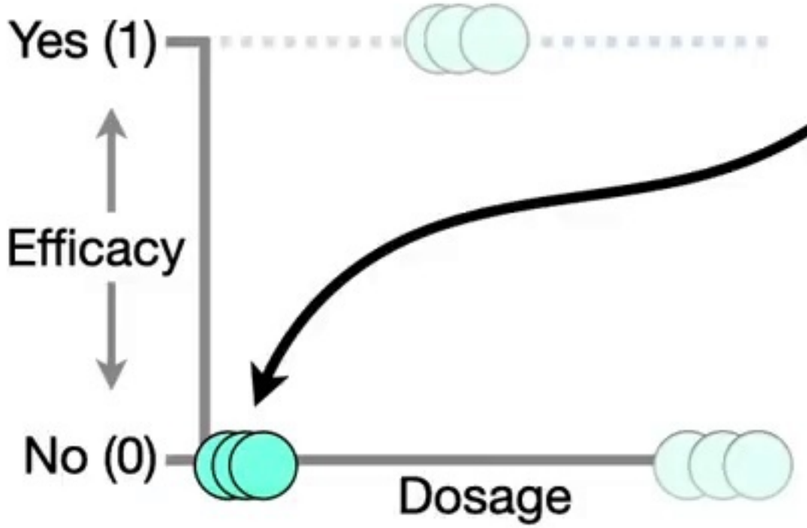
Medium Dosage



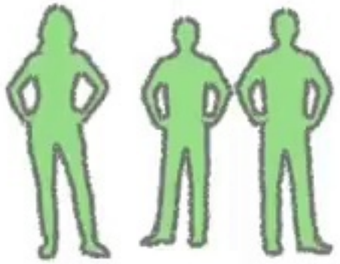
High Dosage



The low **Dosages** were ***not Effective***, so we set them to **0** on this graph.



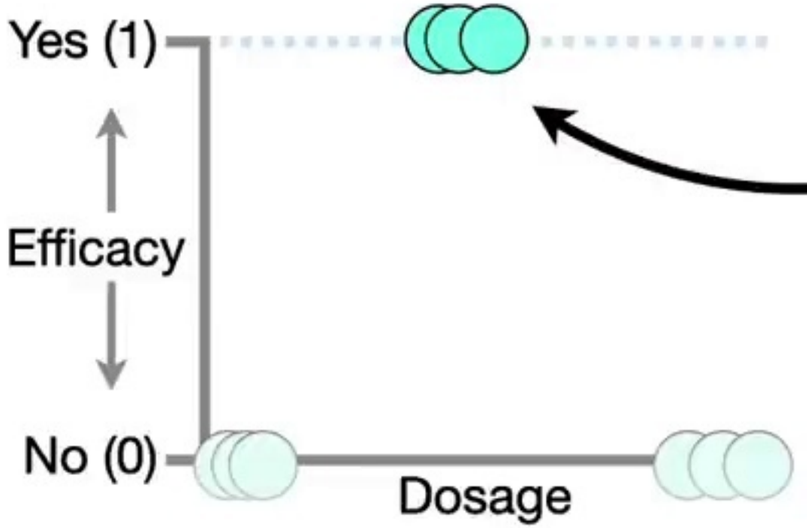
Low Dosage



Medium Dosage

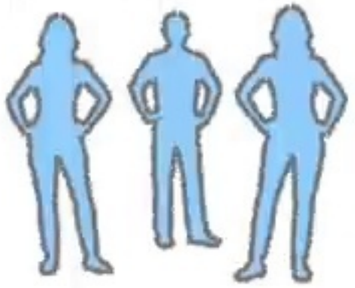
High Dosage

In contrast, the medium **Dosages** were ***Effective***, so we set them to **1**.



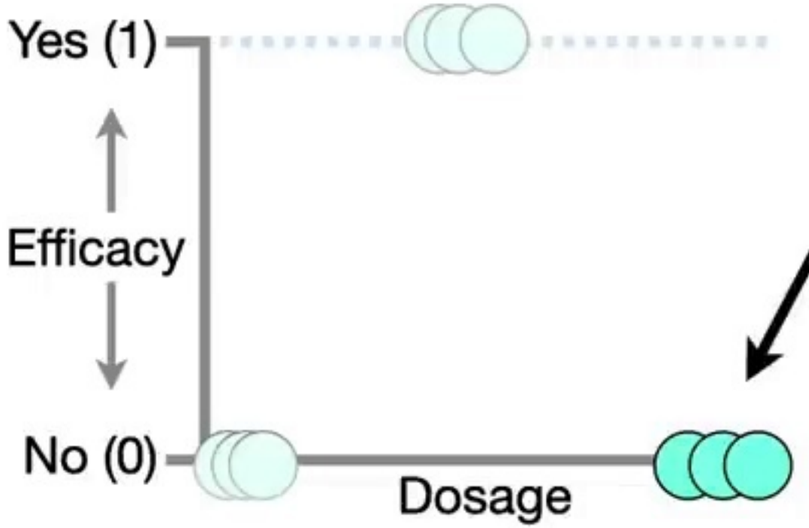
Low Dosage

Medium Dosage



High Dosage

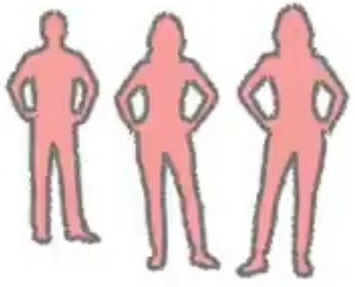
And the high **Dosages** were ***not Effective***, so those are set to **0**.



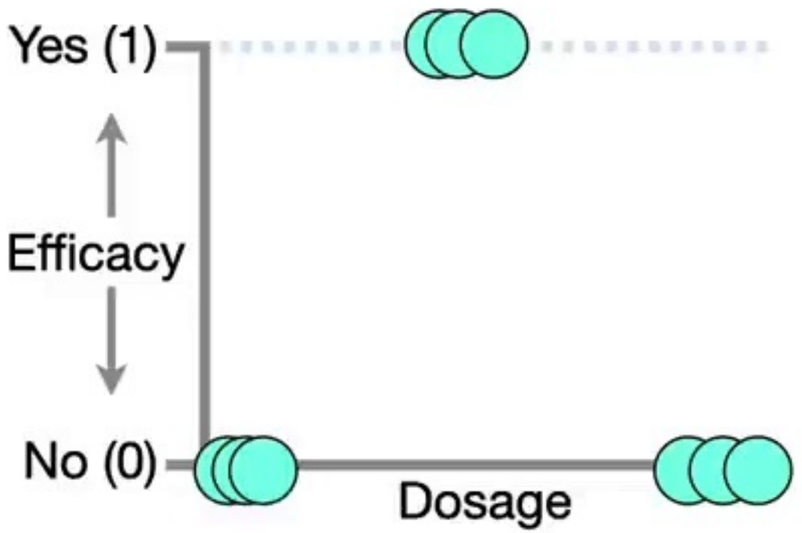
Low Dosage

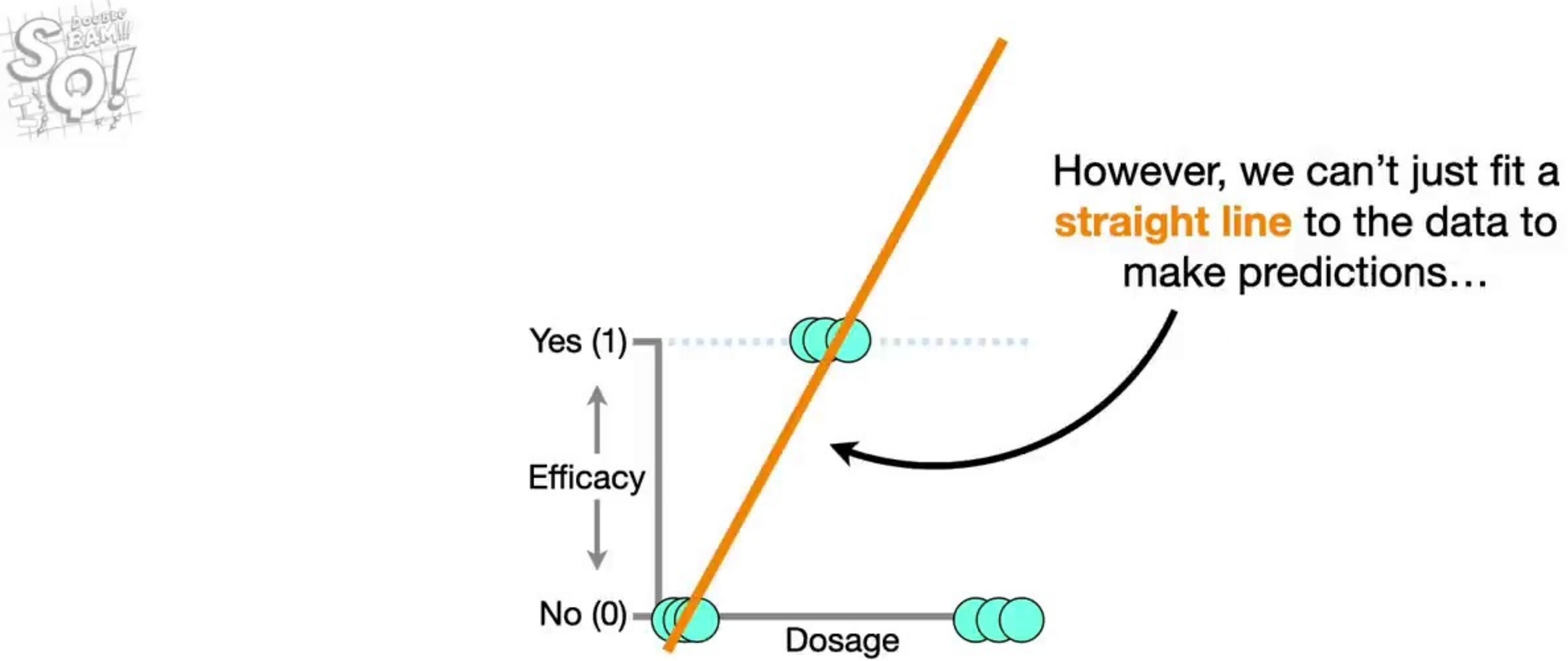
Medium Dosage

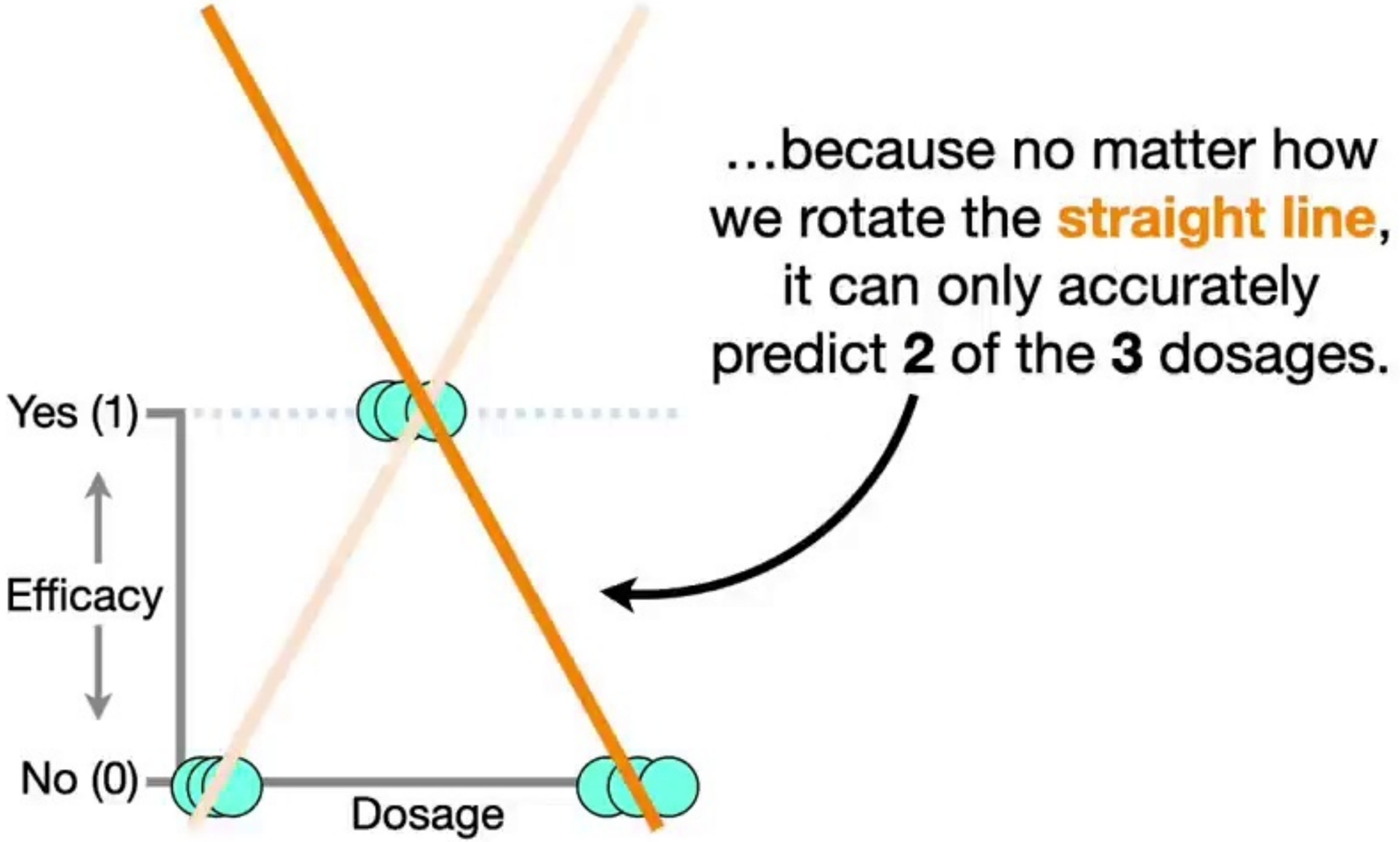
High Dosage

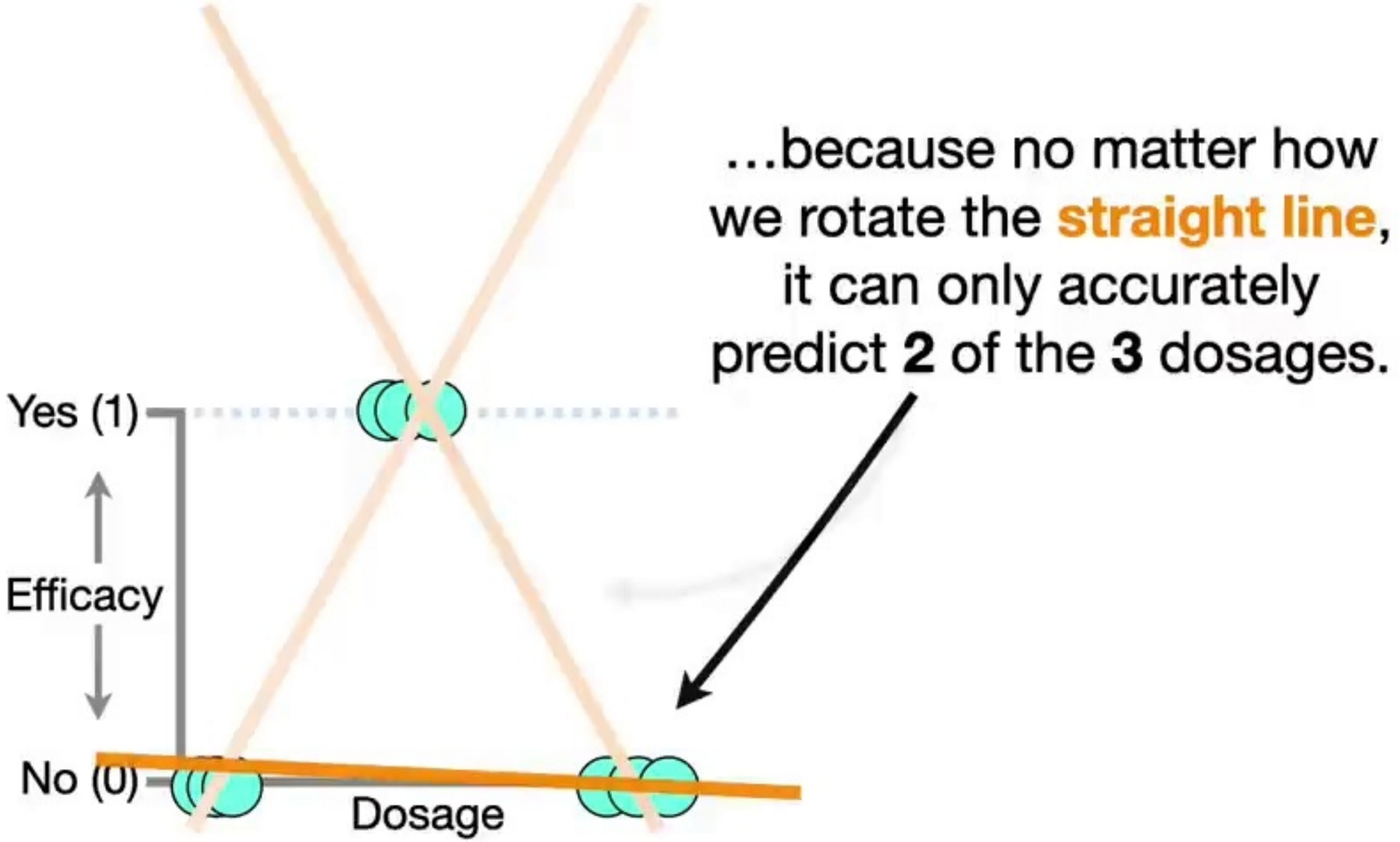


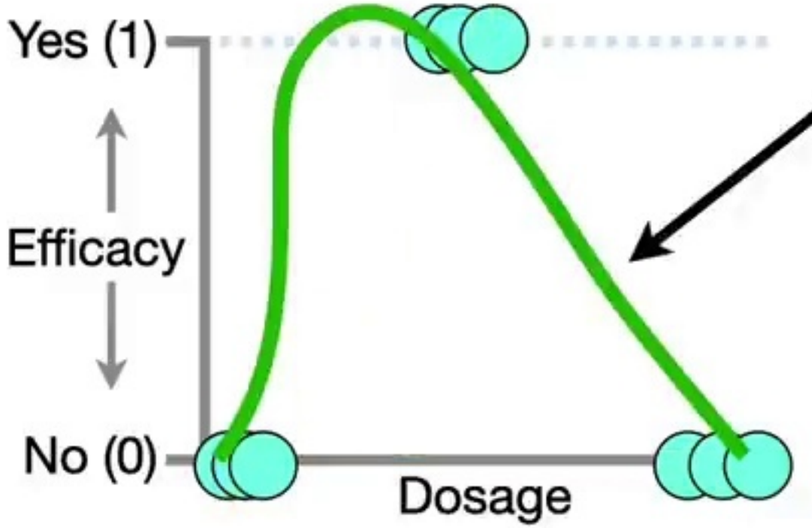
Now that we have this data, we would like to use it to predict whether or not a future **Dosage** will be Effective.



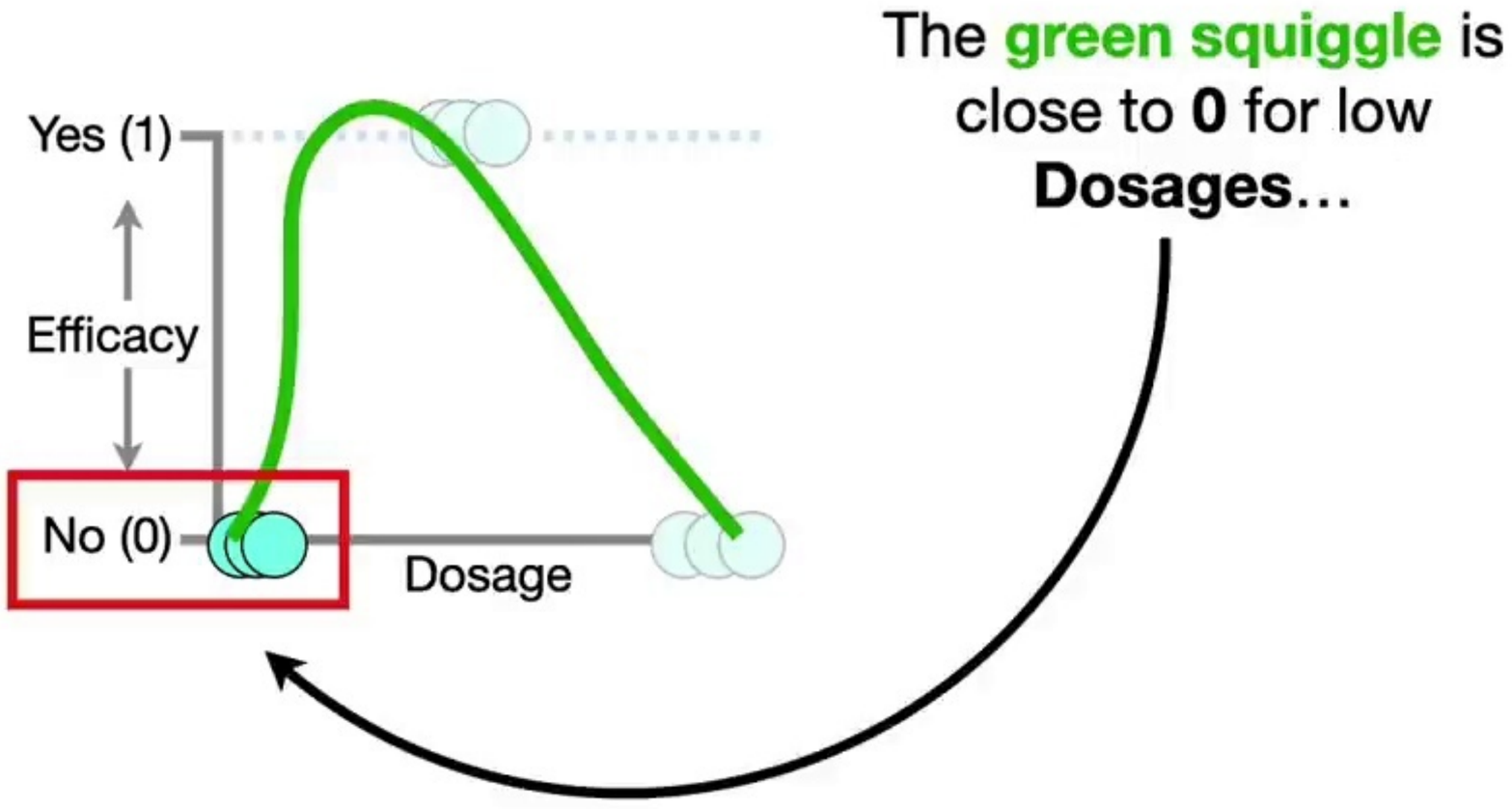

However, we can't just fit a straight line to the data to make predictions…
Yes (1)
Efficacy
No (0)
Dosage

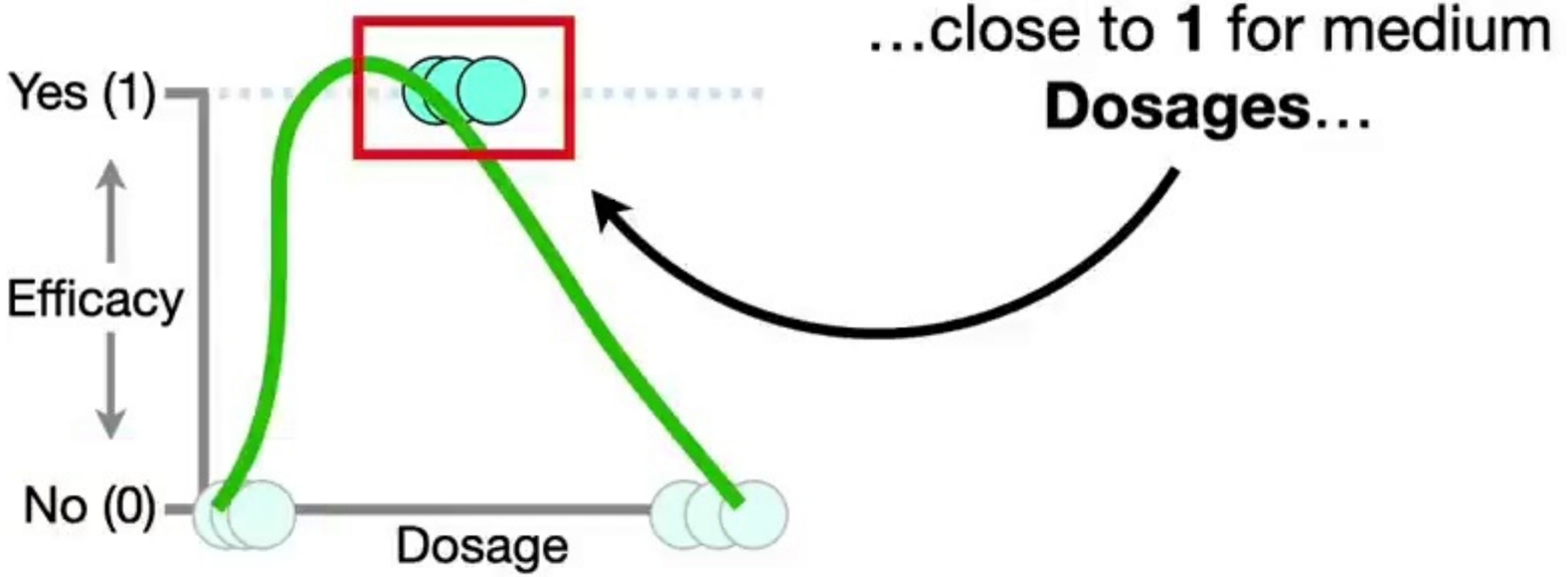

…because no matter how we rotate the straight line, it can only accurately predict 2 of the 3 dosages.
Yes (1)
Efficacy
No (0)
Dosage

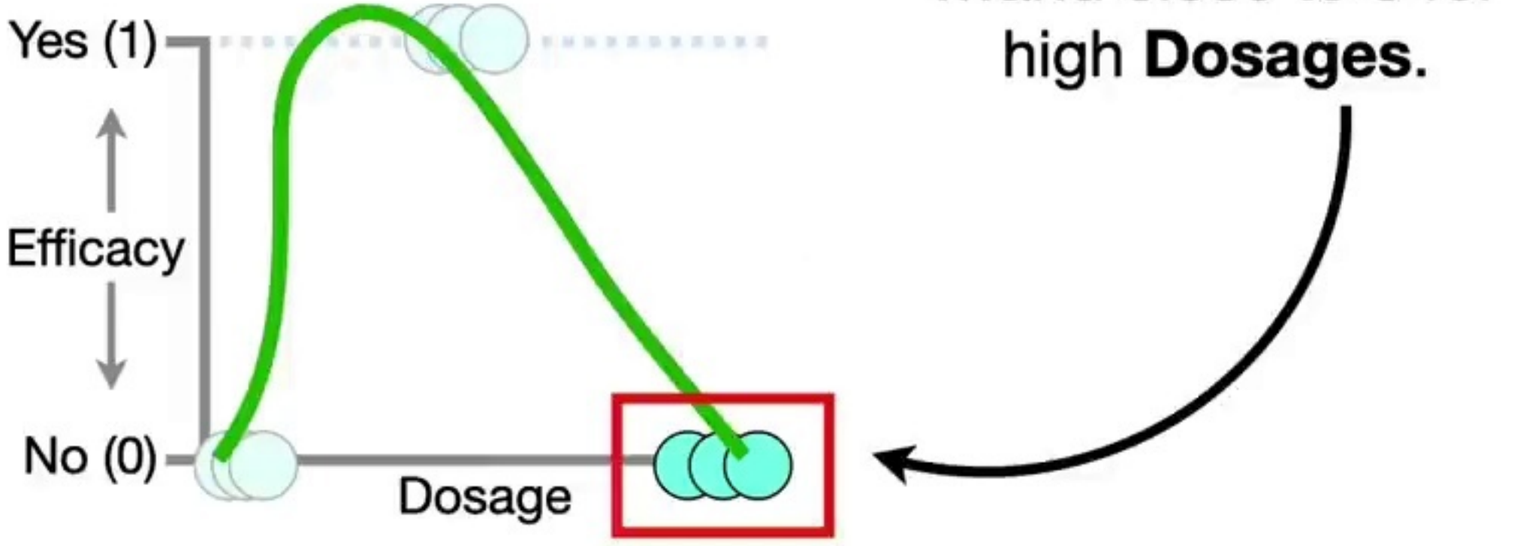

…because no matter how we rotate the straight line, it can only accurately predict 2 of the 3 dosages.
Yes (1)
Efficacy
No (0)
Dosage

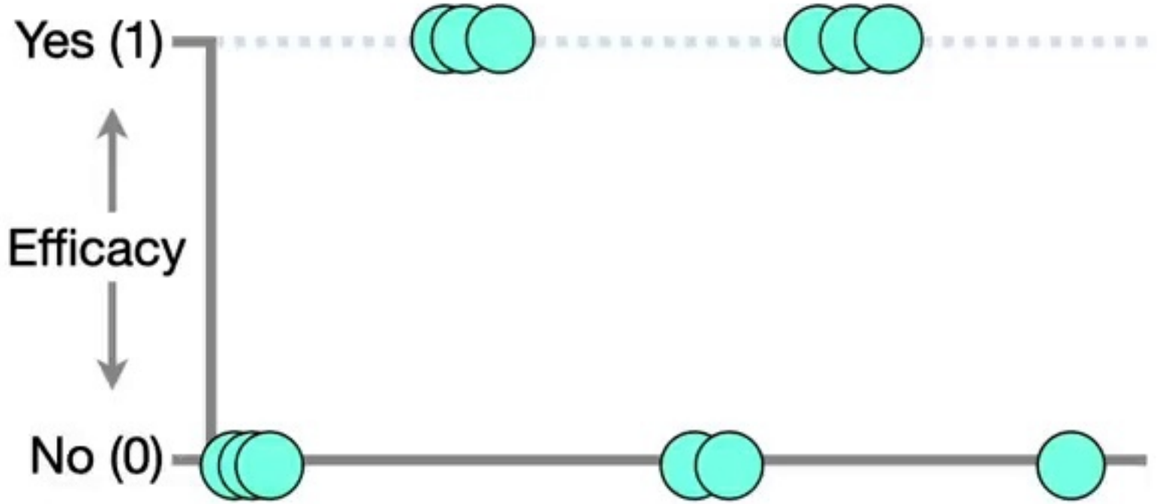


The good news is that a **Neural Network** can fit a **squiggle** to the data.

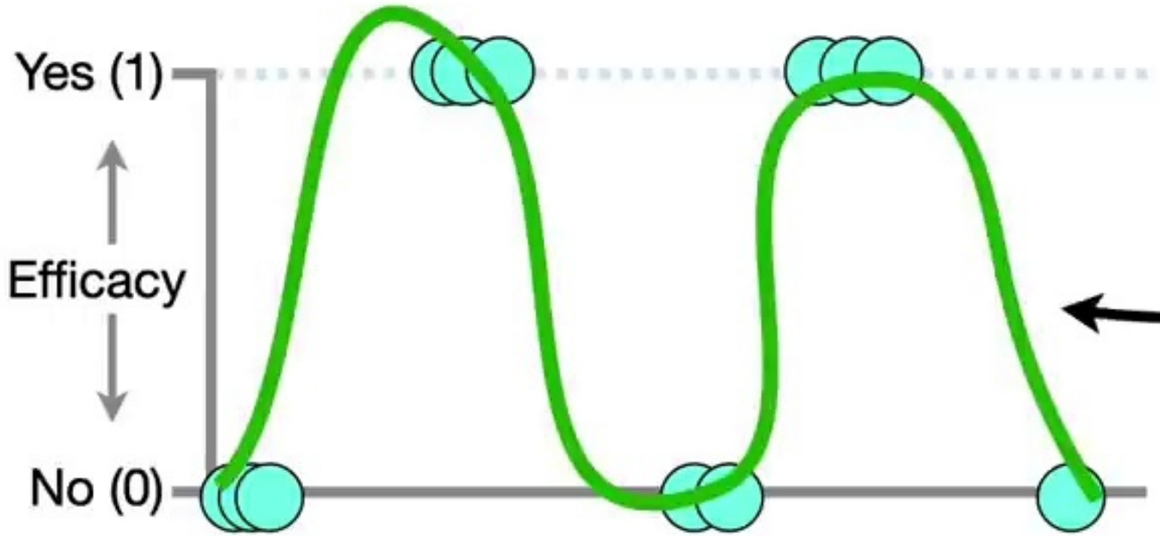

The green squiggle is close to 0 for low Dosages…
Yes (1)
Efficacy
No (0)
Dosage


…close to **1** for medium
Dosages…
Yes (1)
Efficacy
No (0)
Dosage


Yes (1)
Efficacy
No (0)
Dosage
…and close to **0** for high **Dosages**.

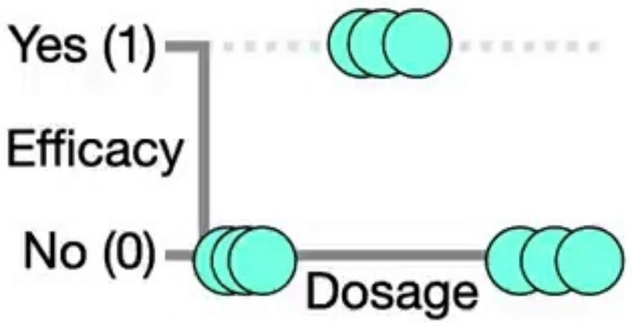


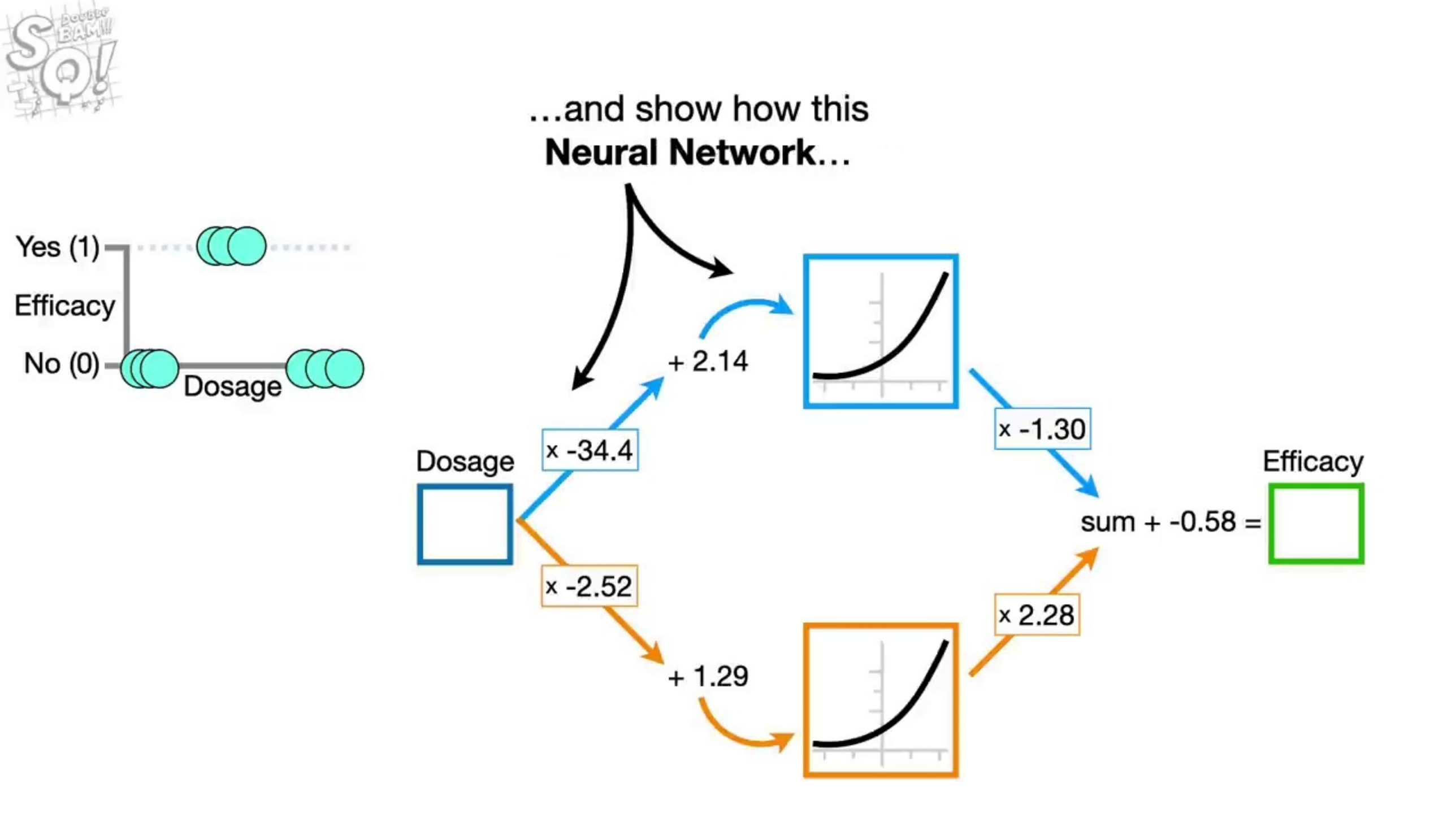
And even if we a have really complicated dataset like this…

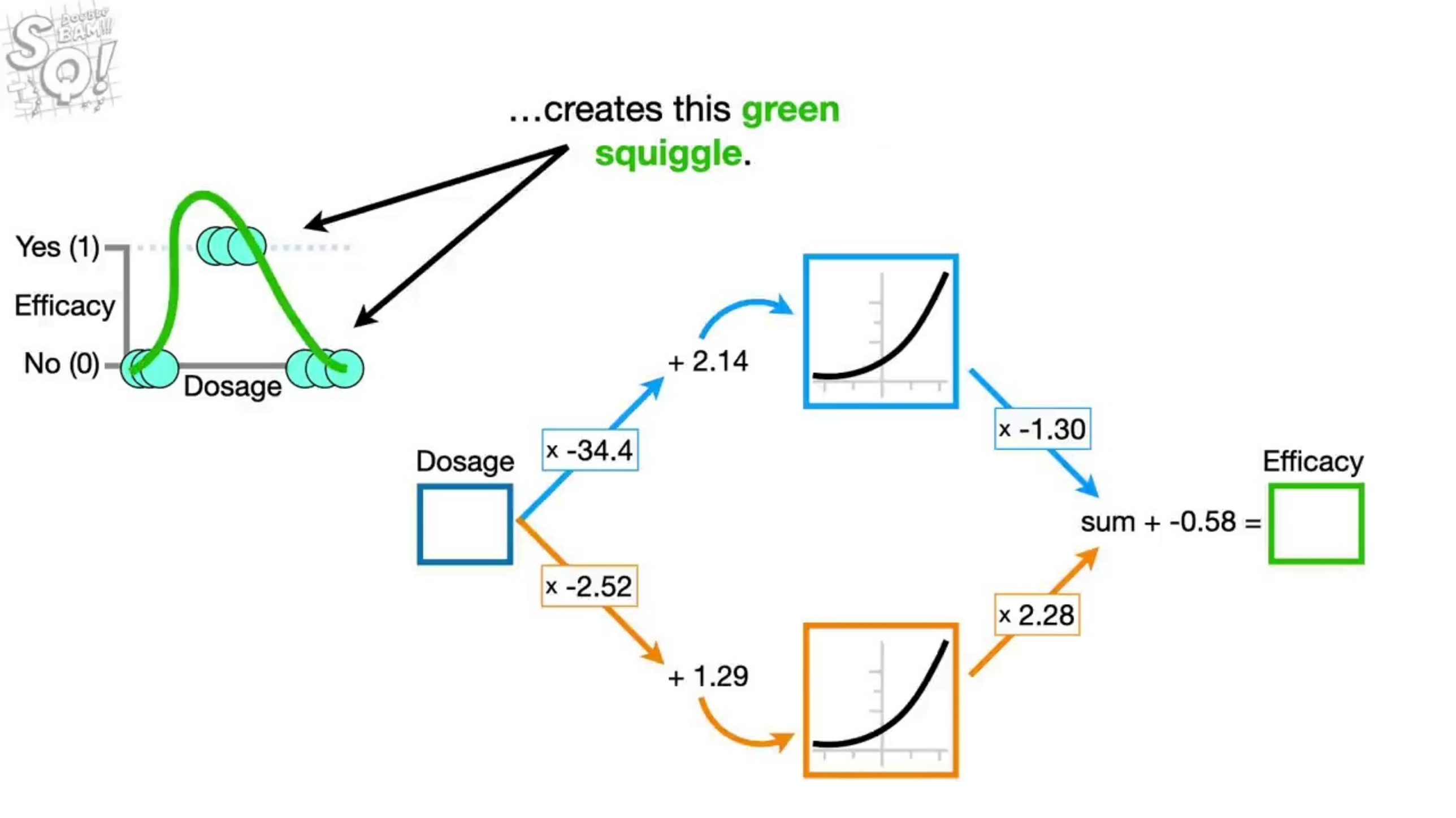


…a **Neural Network**
can fit a **squiggle** to it.

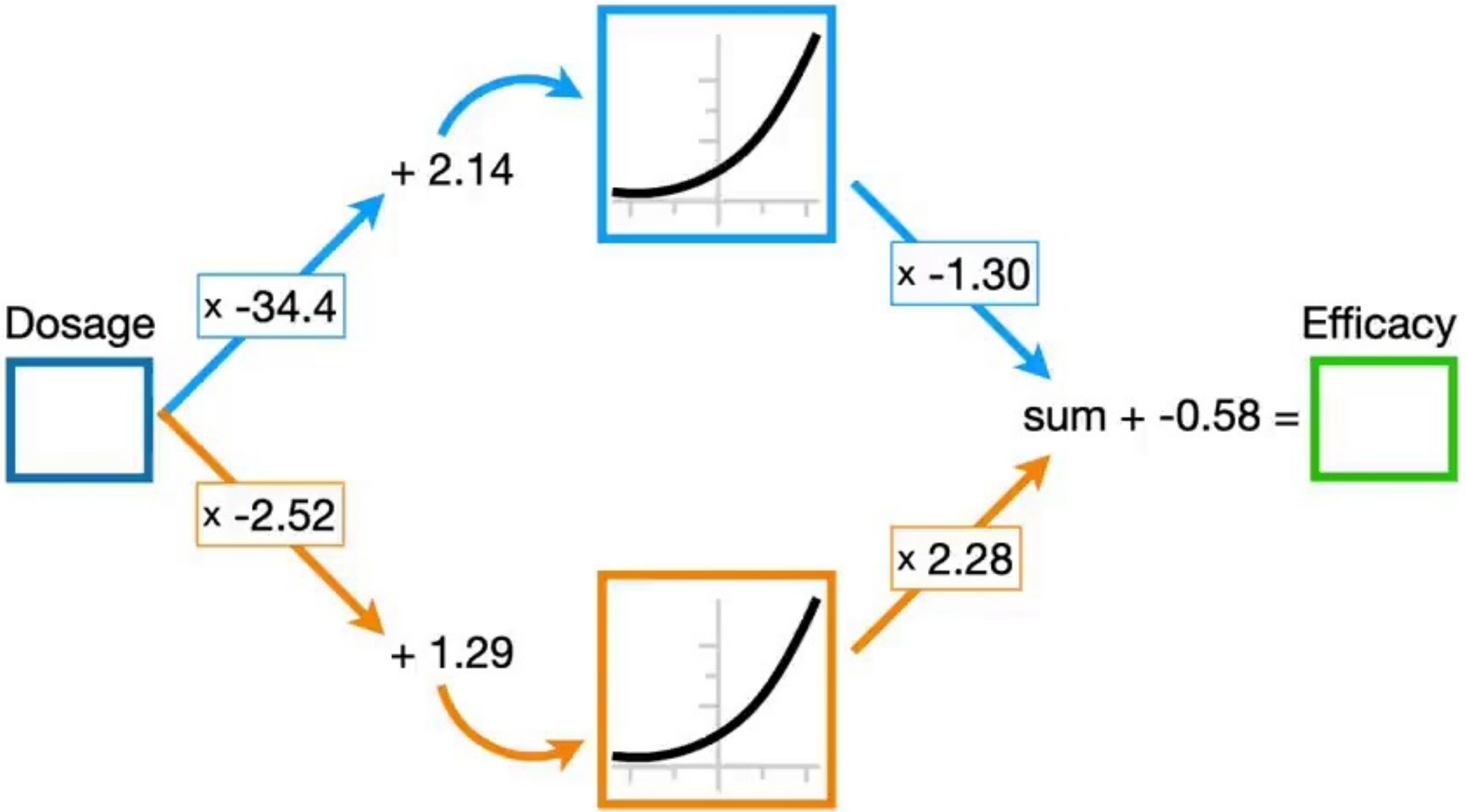
In this **StatQuest**, we're going to use this super simple dataset…

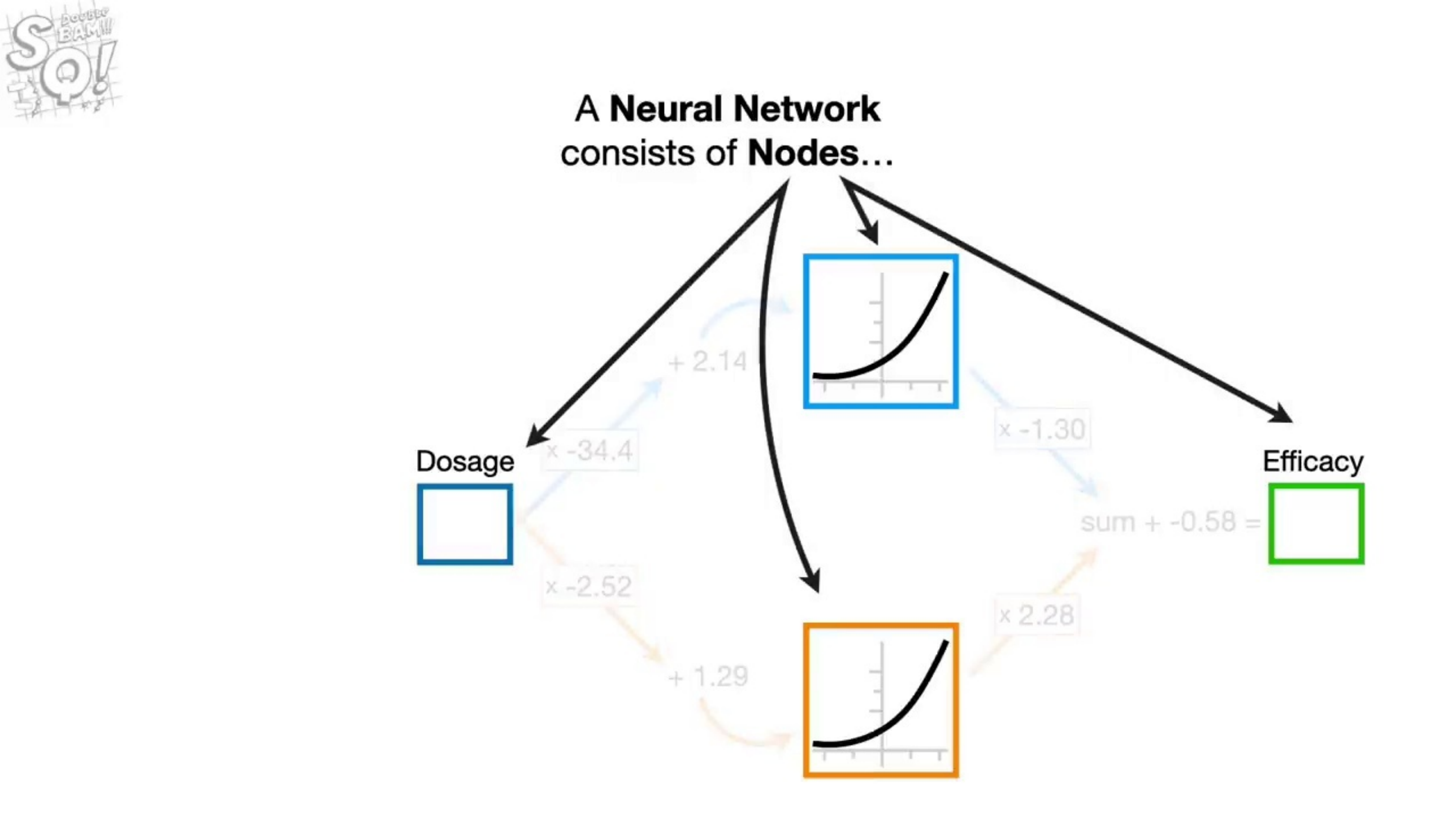


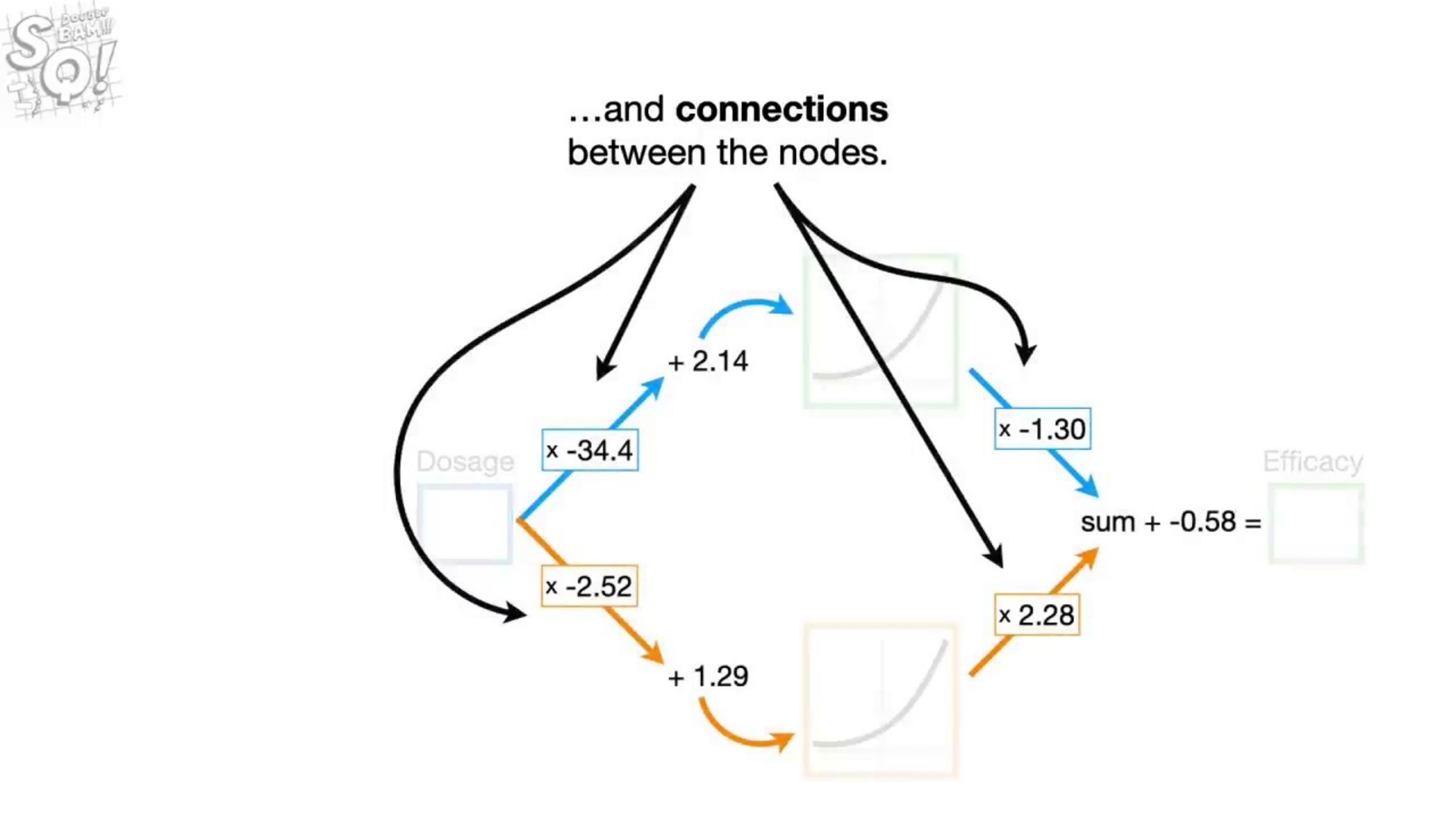

…and show how this
Neural Network…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28


…creates this green squiggle.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

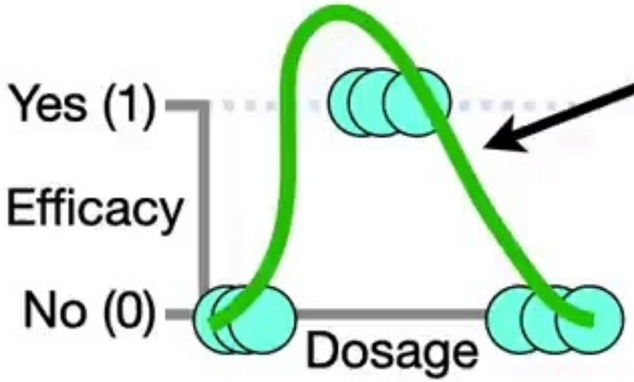
But first let's just talk about what a **Neural Network** is.

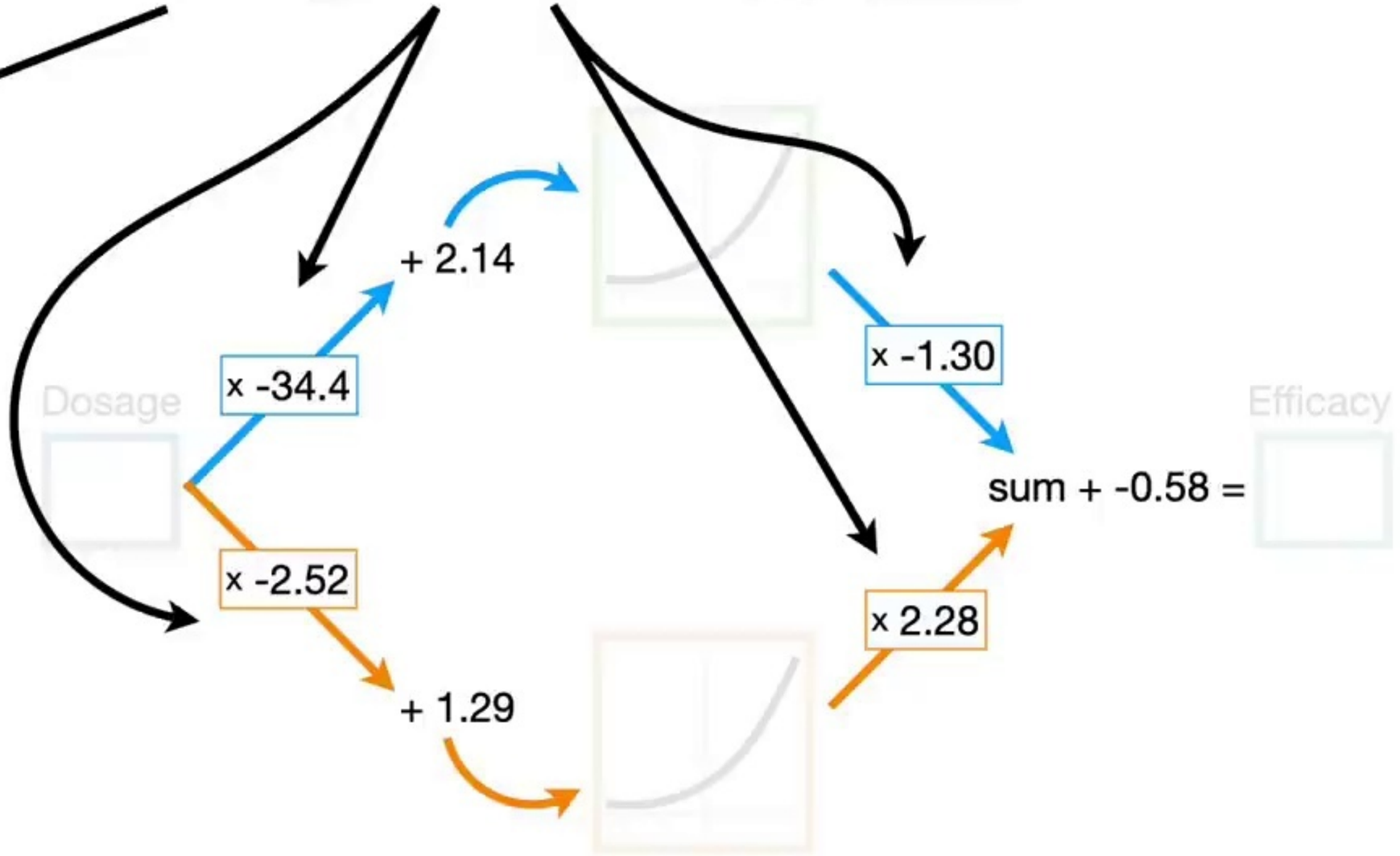



A Neural Network
consists of Nodes…
Dosage
Efficacy
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

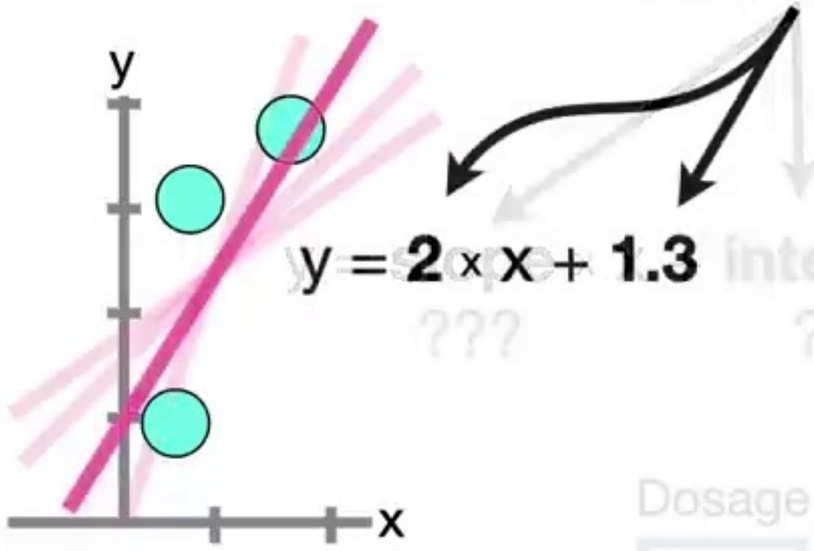

…and **connections**
between the nodes.
+ 2.14
x -34.4
Dosage
x -2.52
+ 1.29
x -1.30
sum + -0.58 =
Efficacy
x 2.28

NOTE: The numbers along each connection represent parameter values that were estimated when this **Neural Network** was fit to the data.



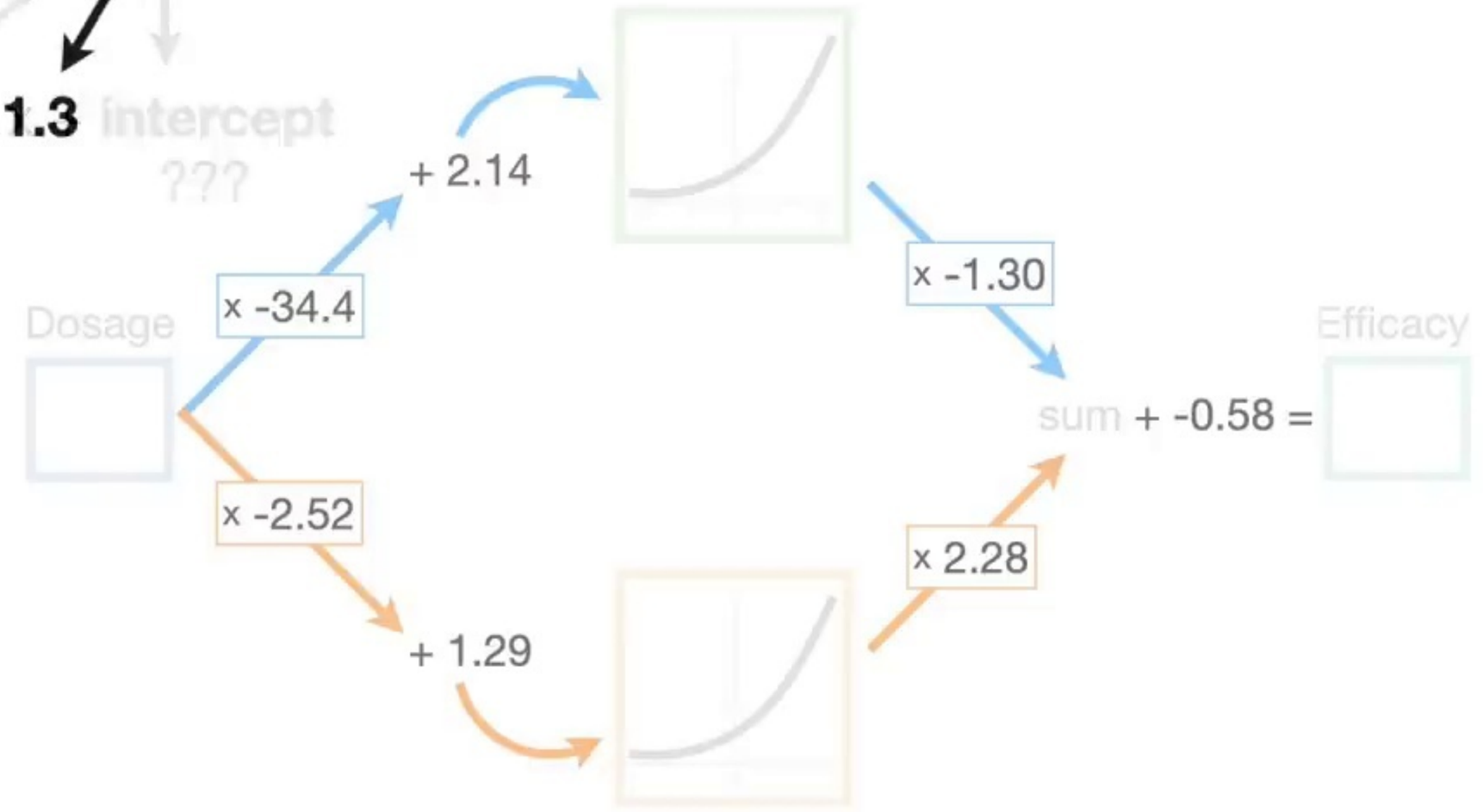


For now, just know that these parameter estimates are analogous to the **slope** and **intercept** values that we solve for when we fit a **straight line** to data.

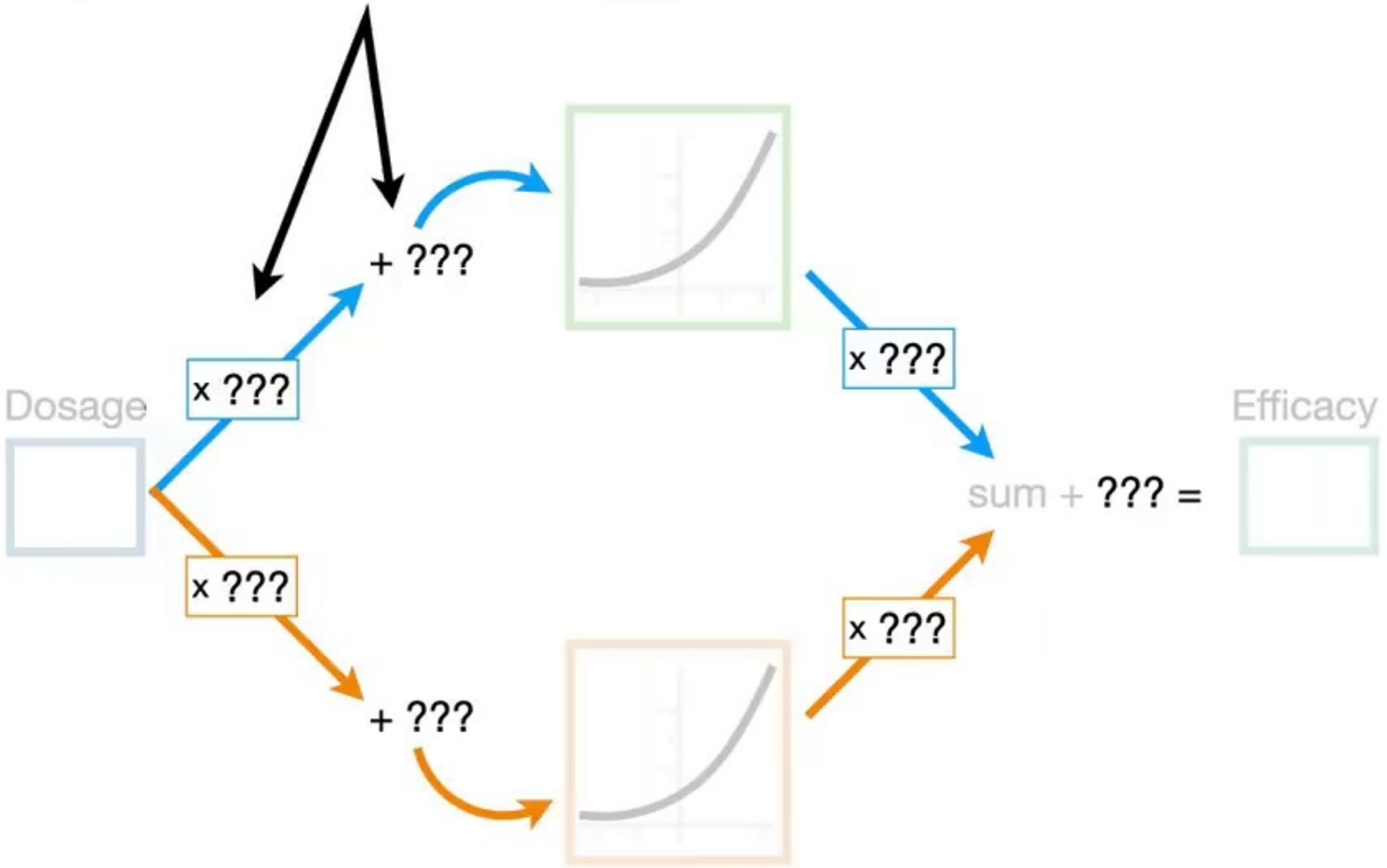


$$y = \mathbf{2} \times x + \mathbf{1.3}$$

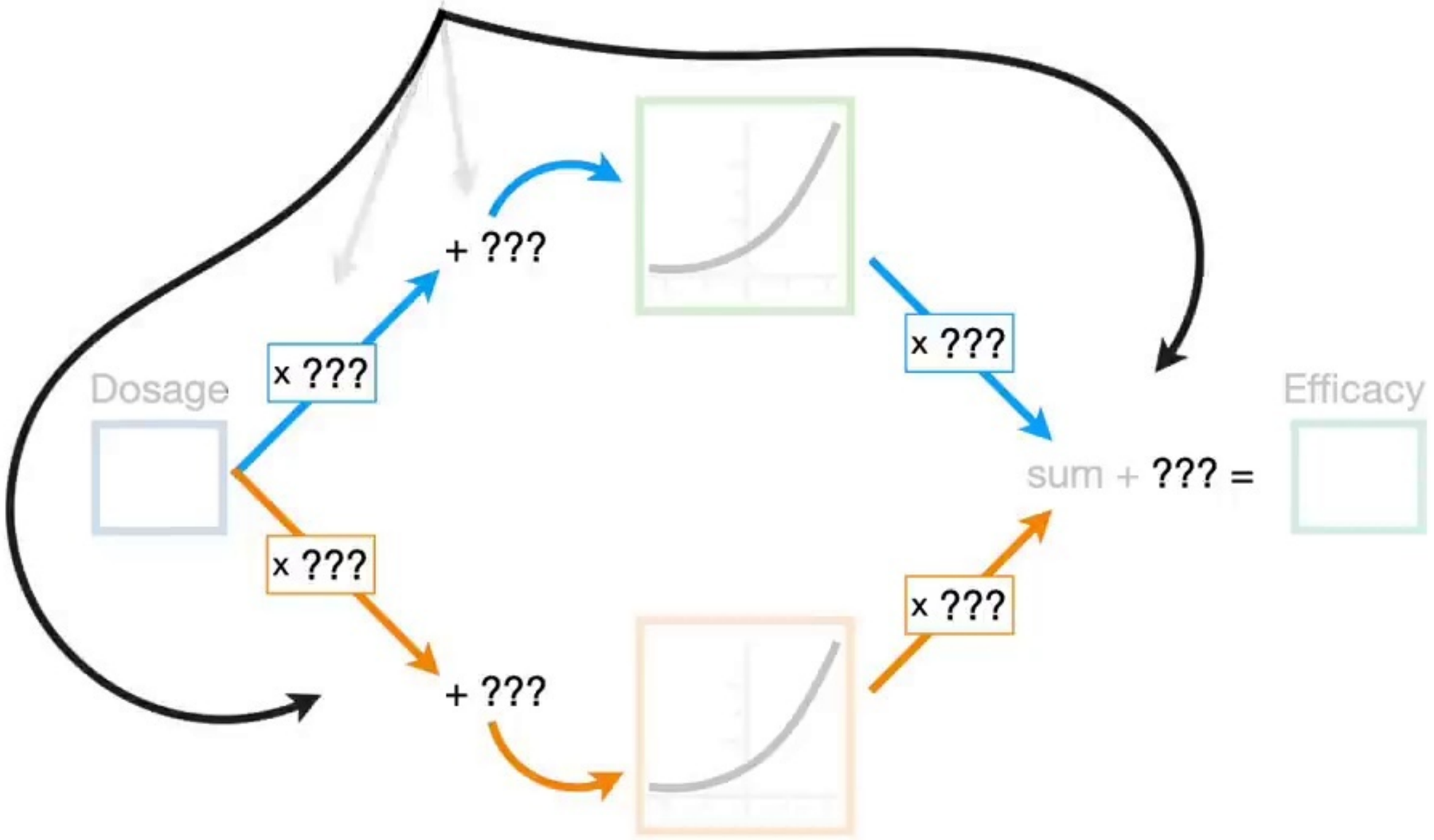
slope ??? intercept ???



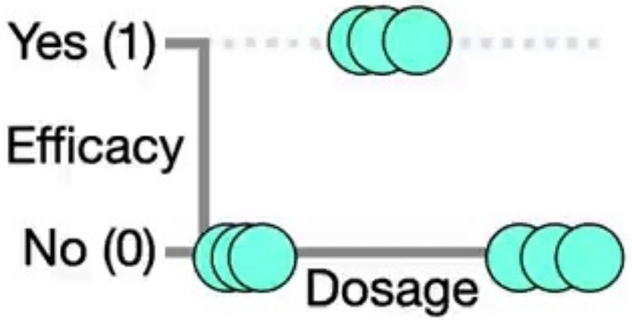
Likewise, a **Neural Network** starts out with unknown parameter values…

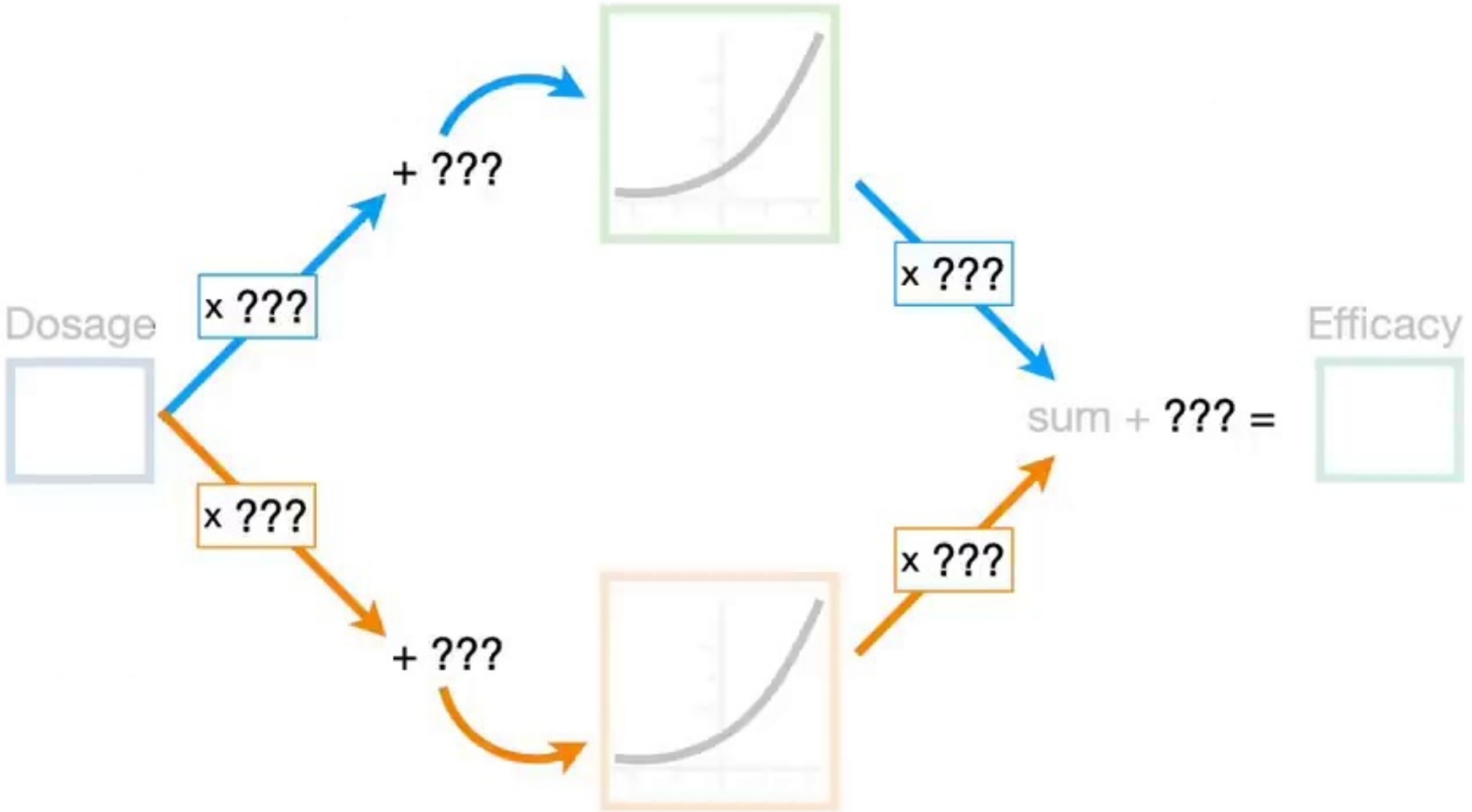


Likewise, a **Neural Network** starts out with unknown parameter values…

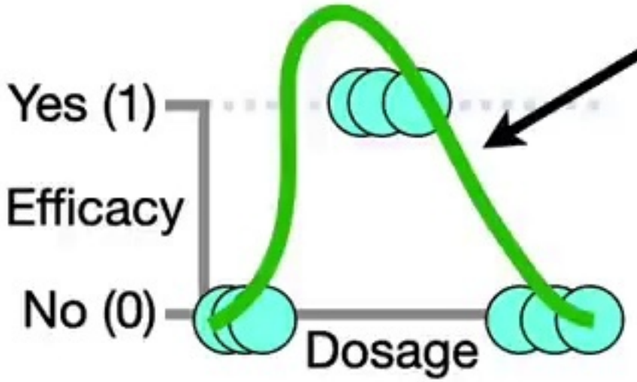


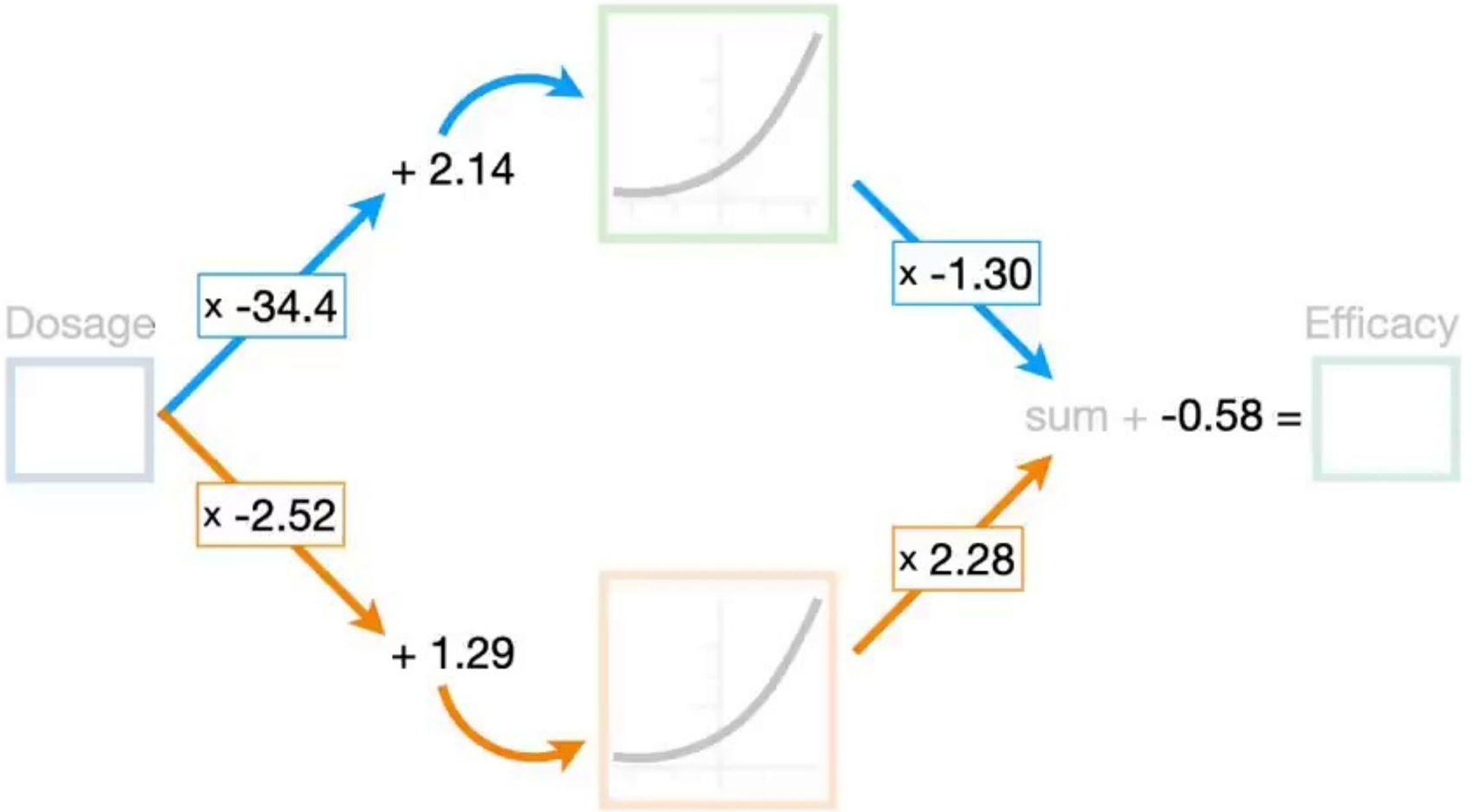
…that are estimated when we fit the **Neural Network** to a dataset using a method called **Backpropagation**.



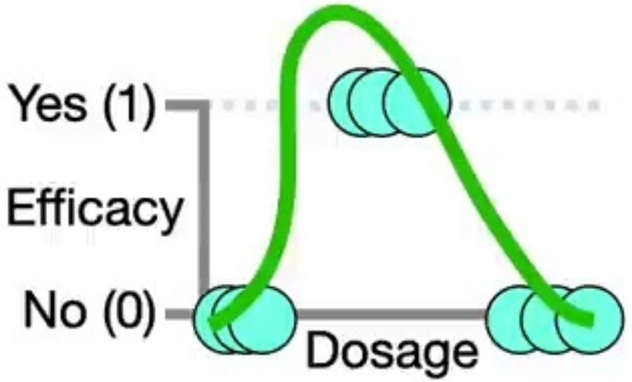


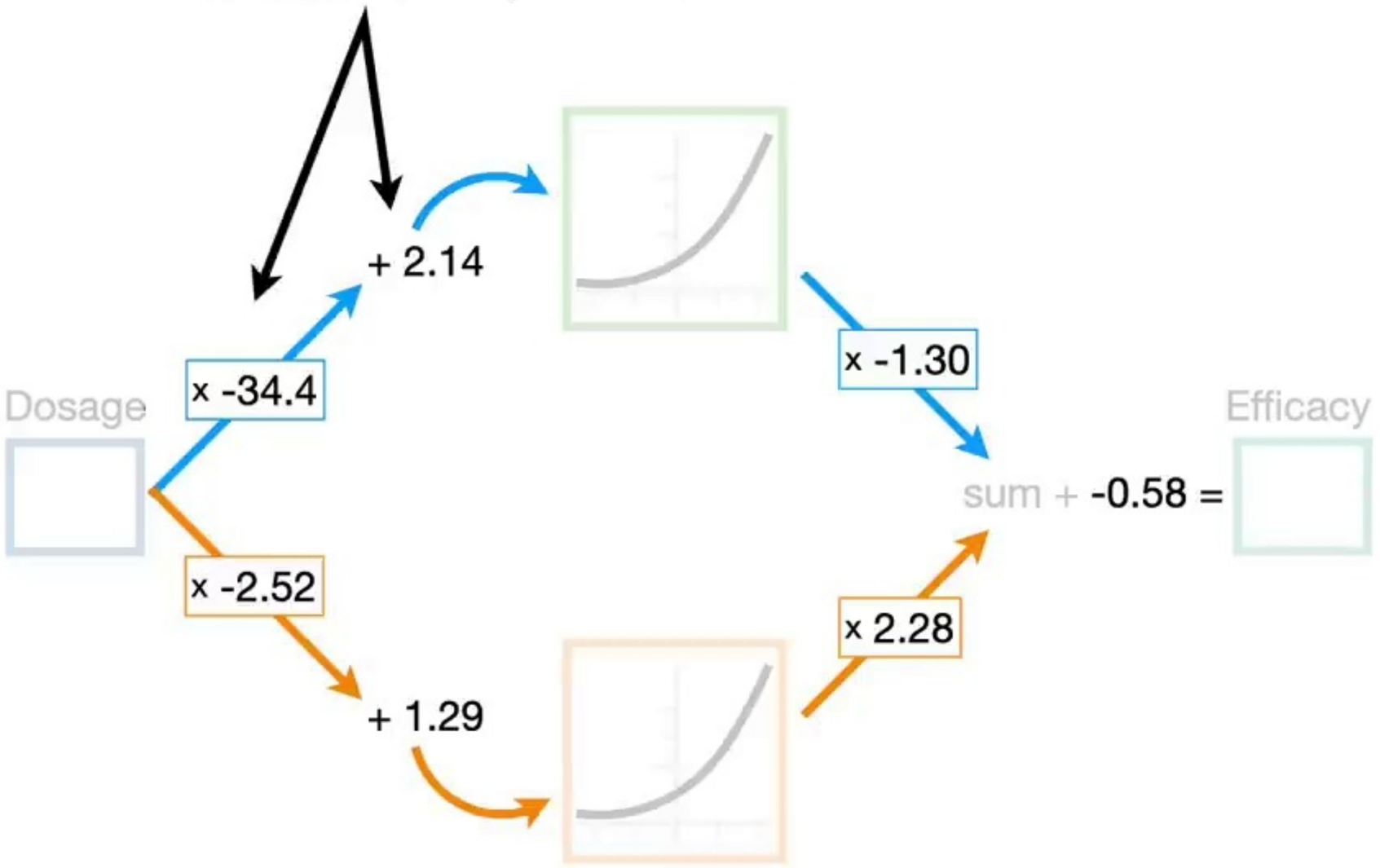
…but for now, just assume that we've already fit this **Neural Network** to this specific dataset…



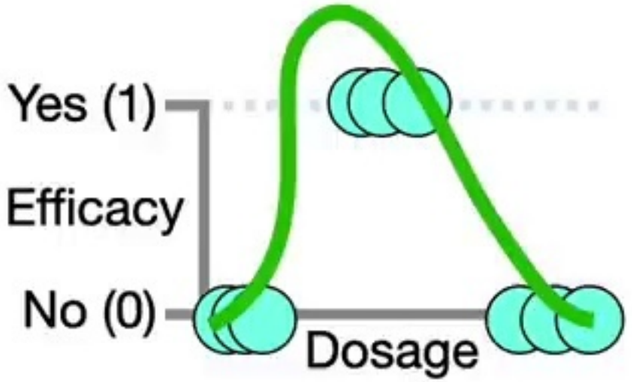


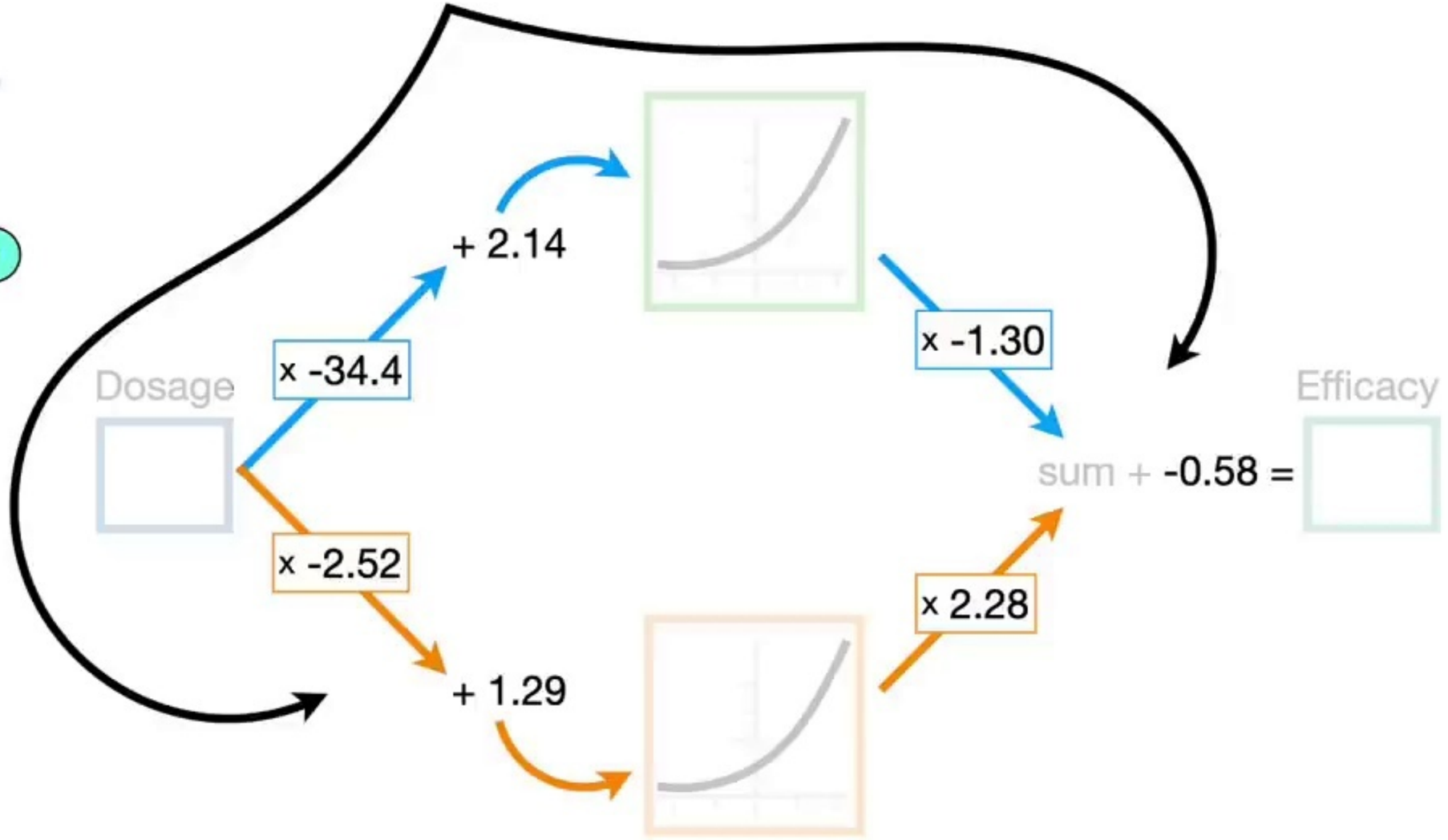
…and that means we have already estimated these parameters.



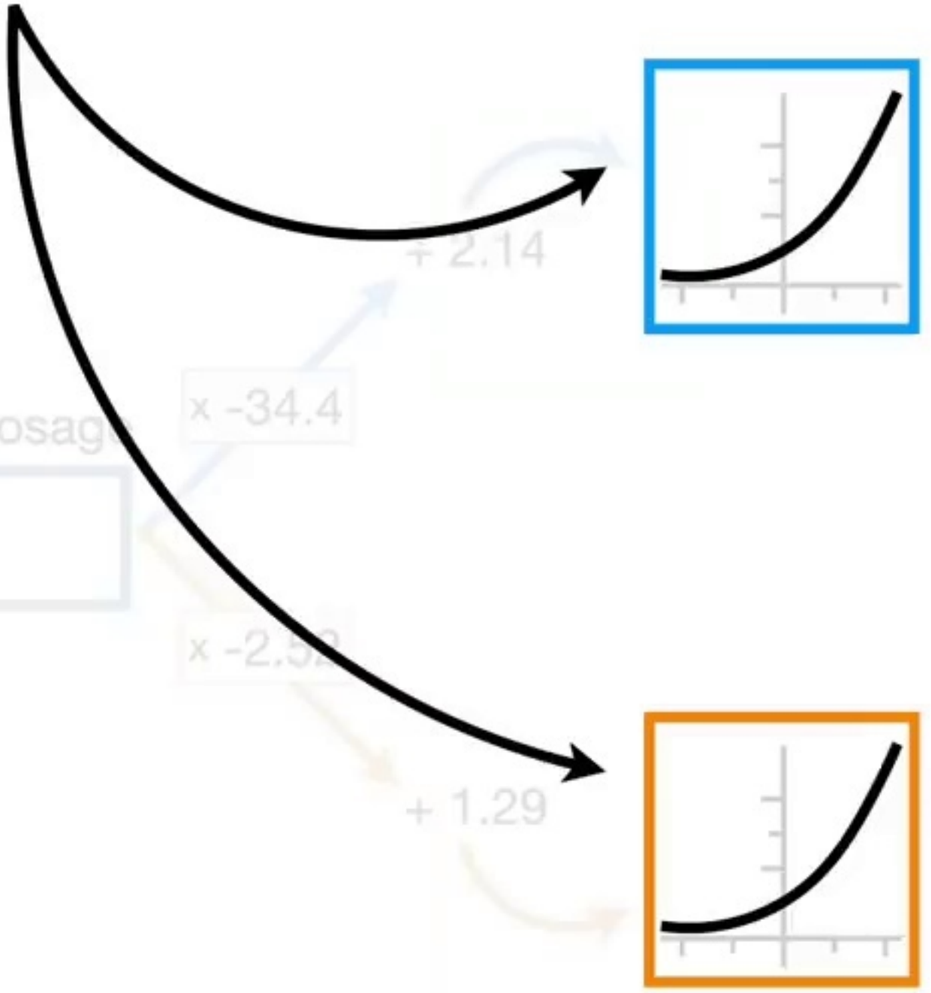


…and that means we have already estimated these parameters.

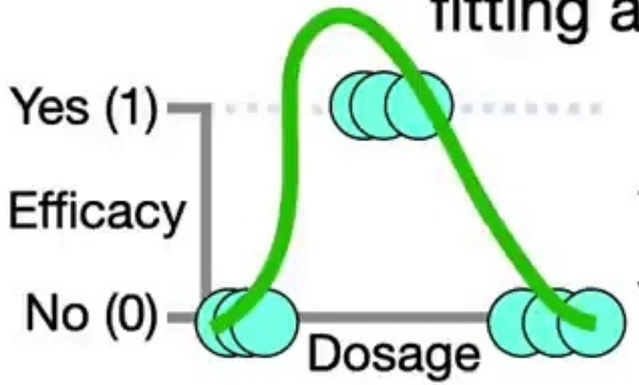




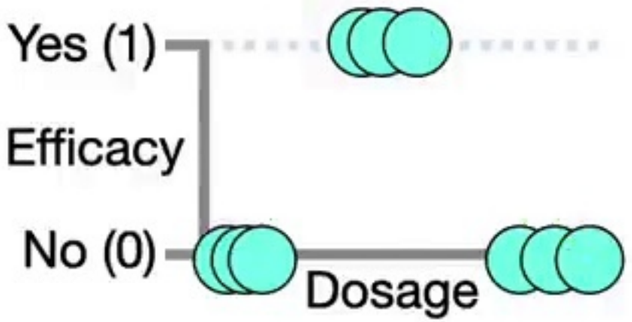
Also, you may have noticed that some of the **Nodes** have **curved lines** inside of them.



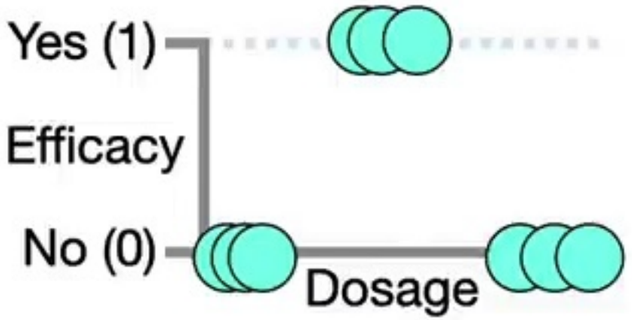
These **bent** or **curved lines** are the building blocks for fitting a **squiggle** to data.

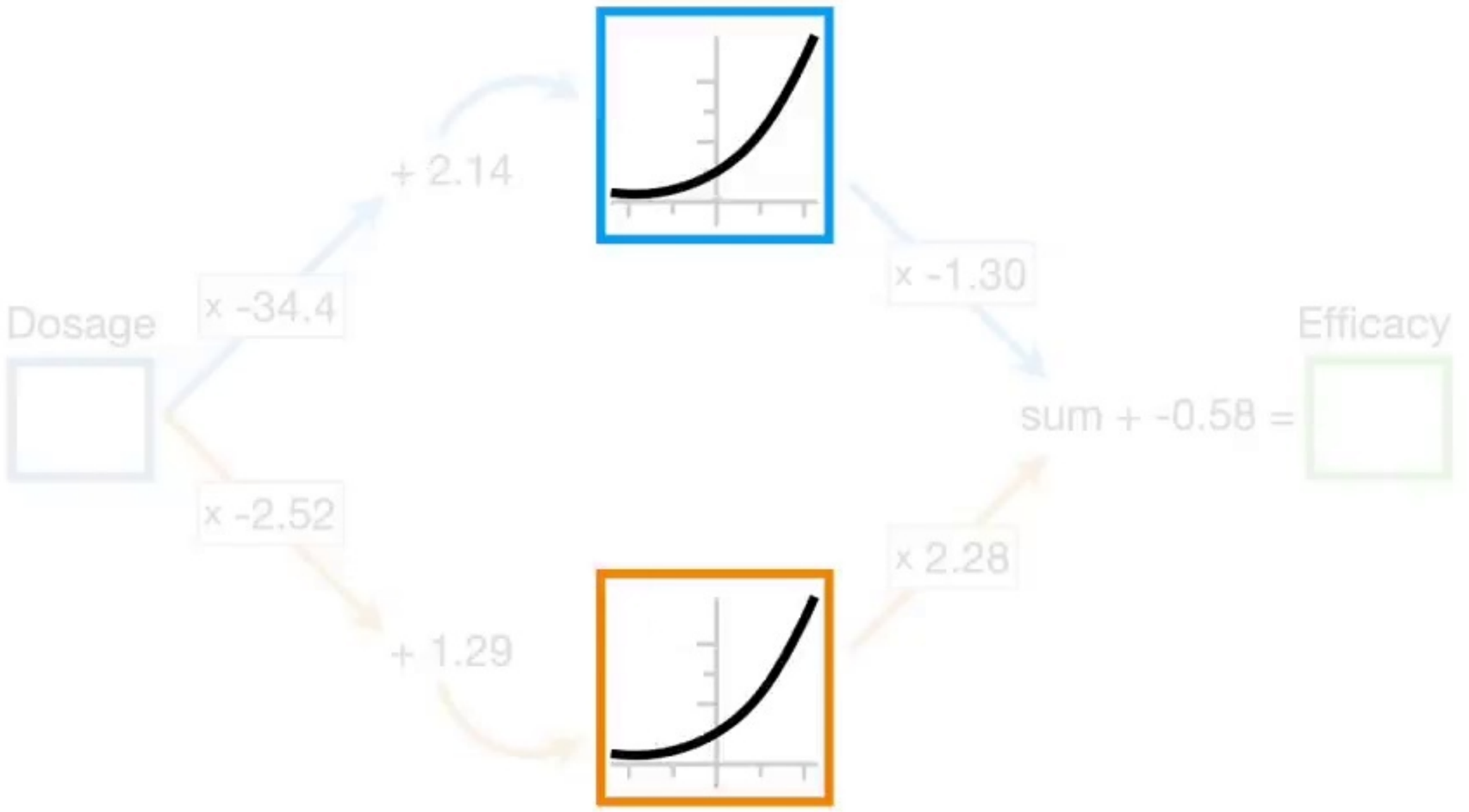


The goal of this **StatQuest** is to show you how these identical **curves**…

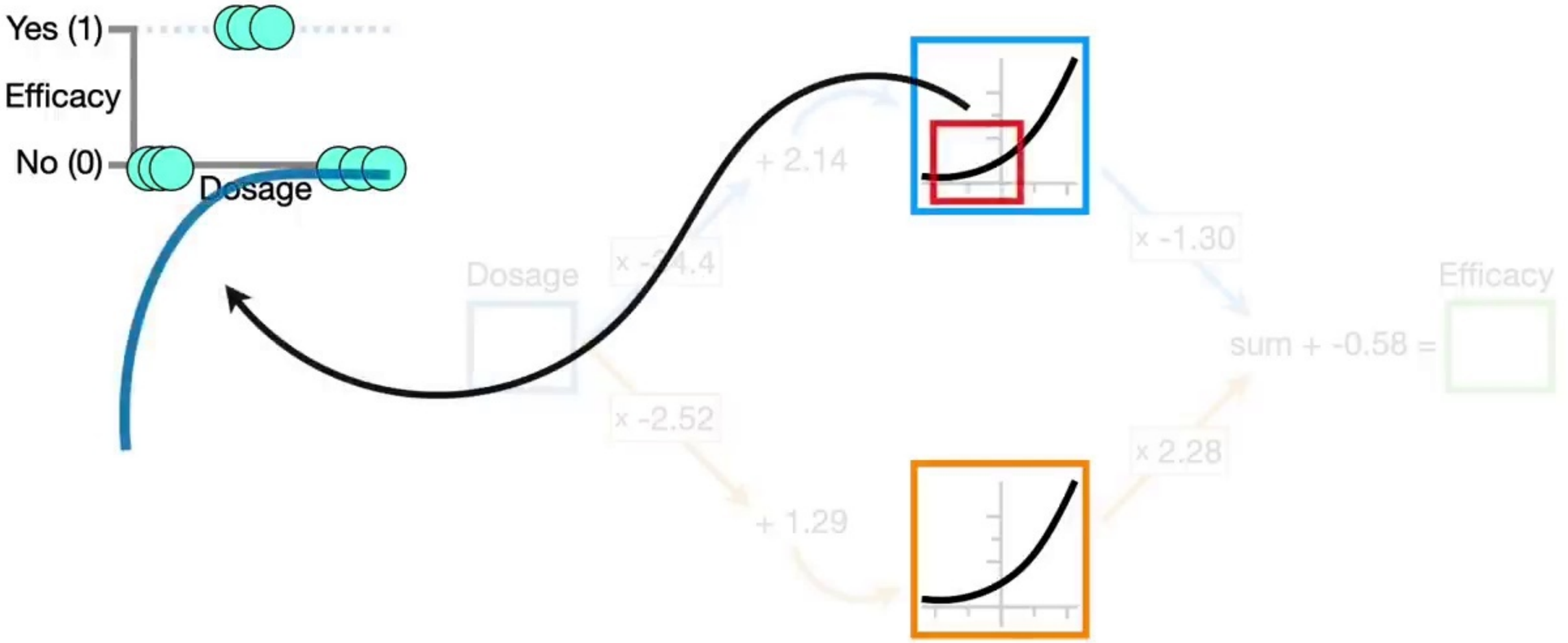


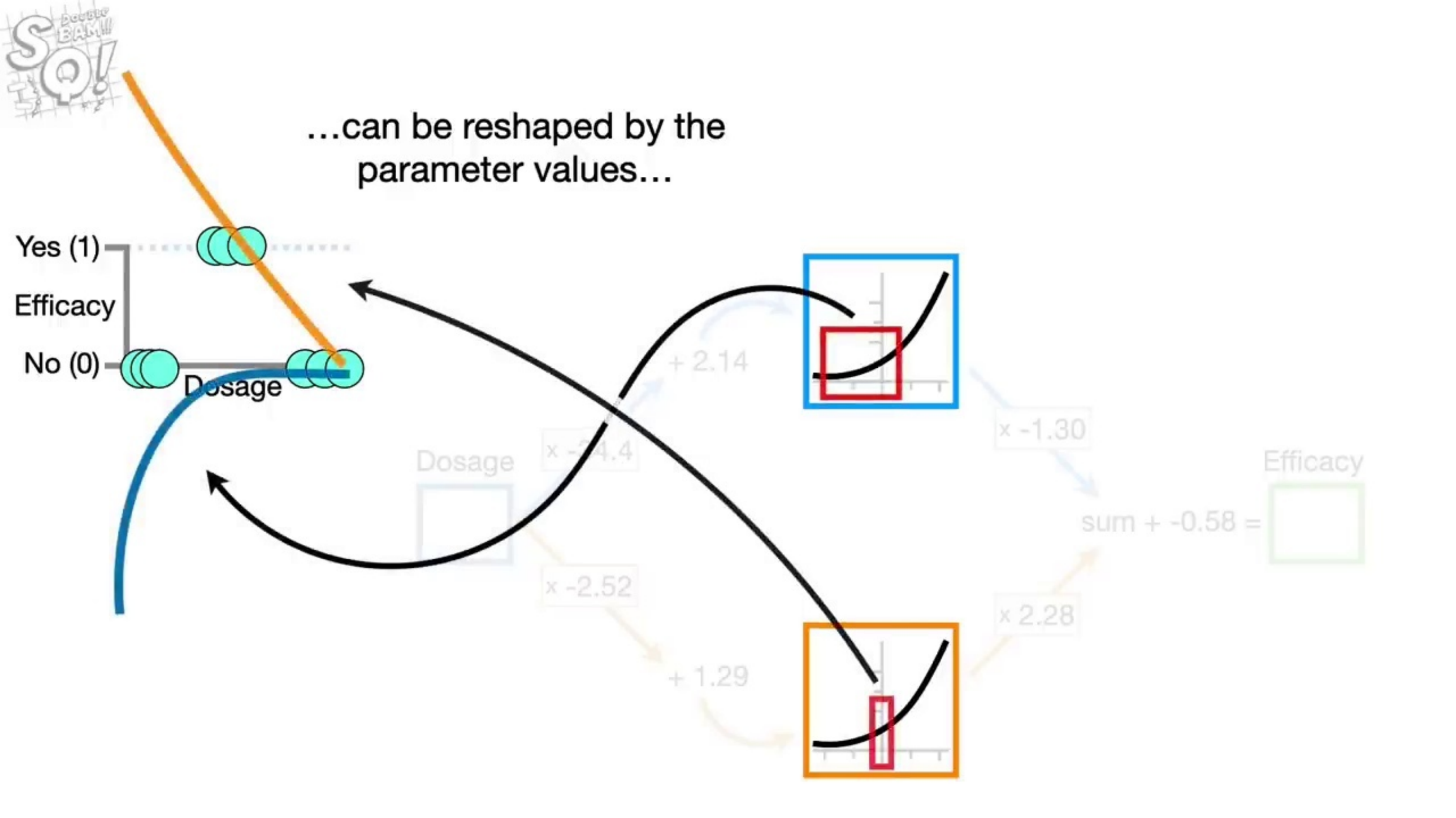
…can be reshaped by the parameter values…

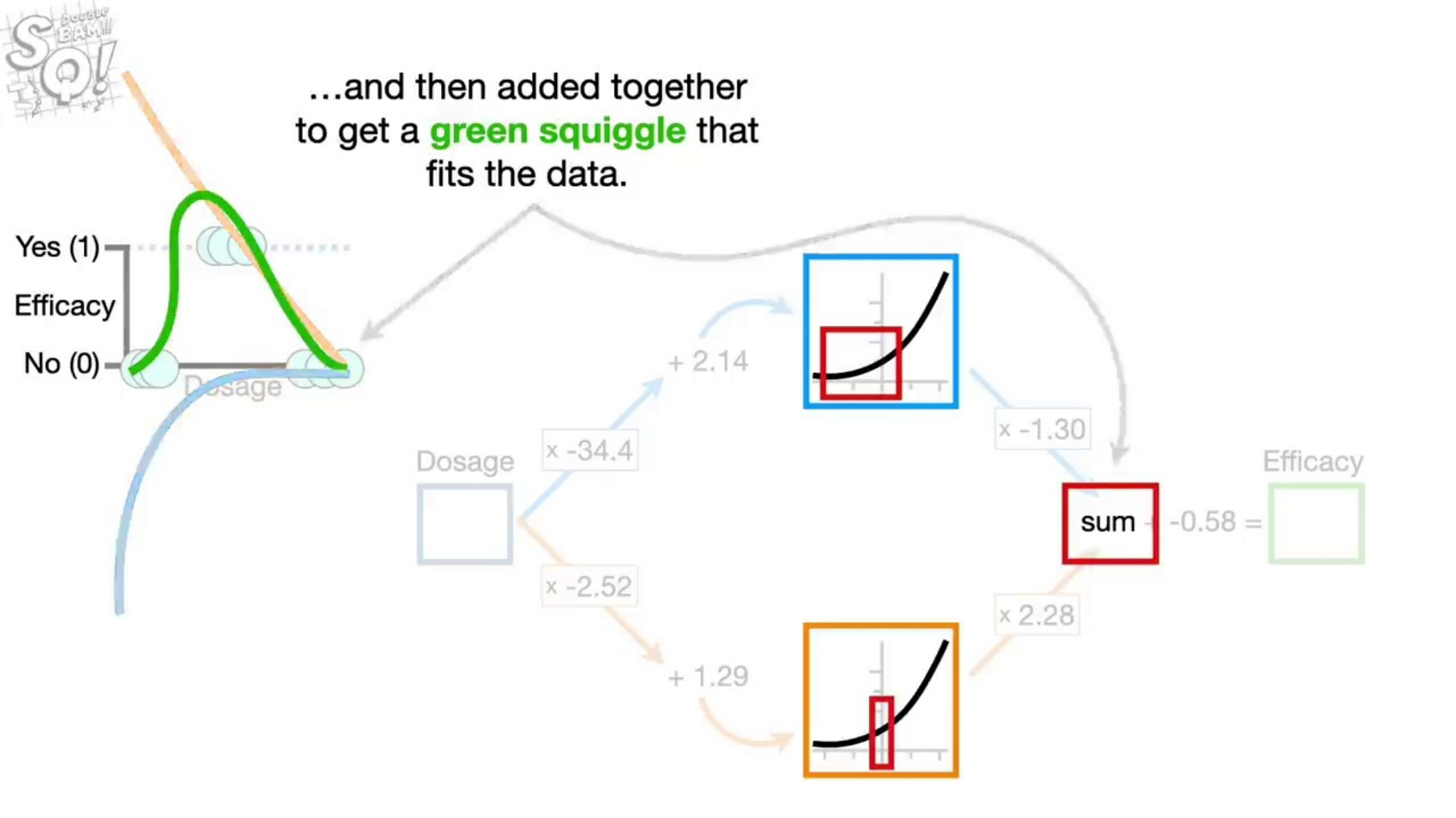




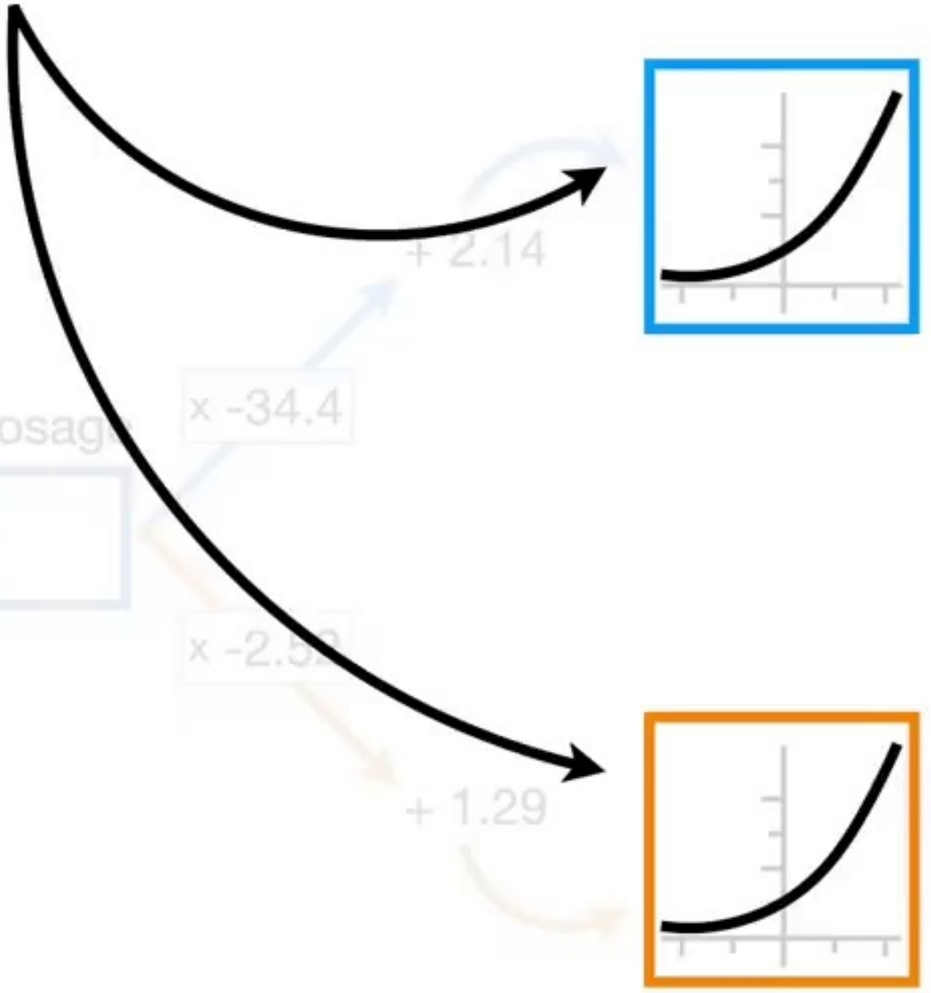
…can be reshaped by the parameter values…



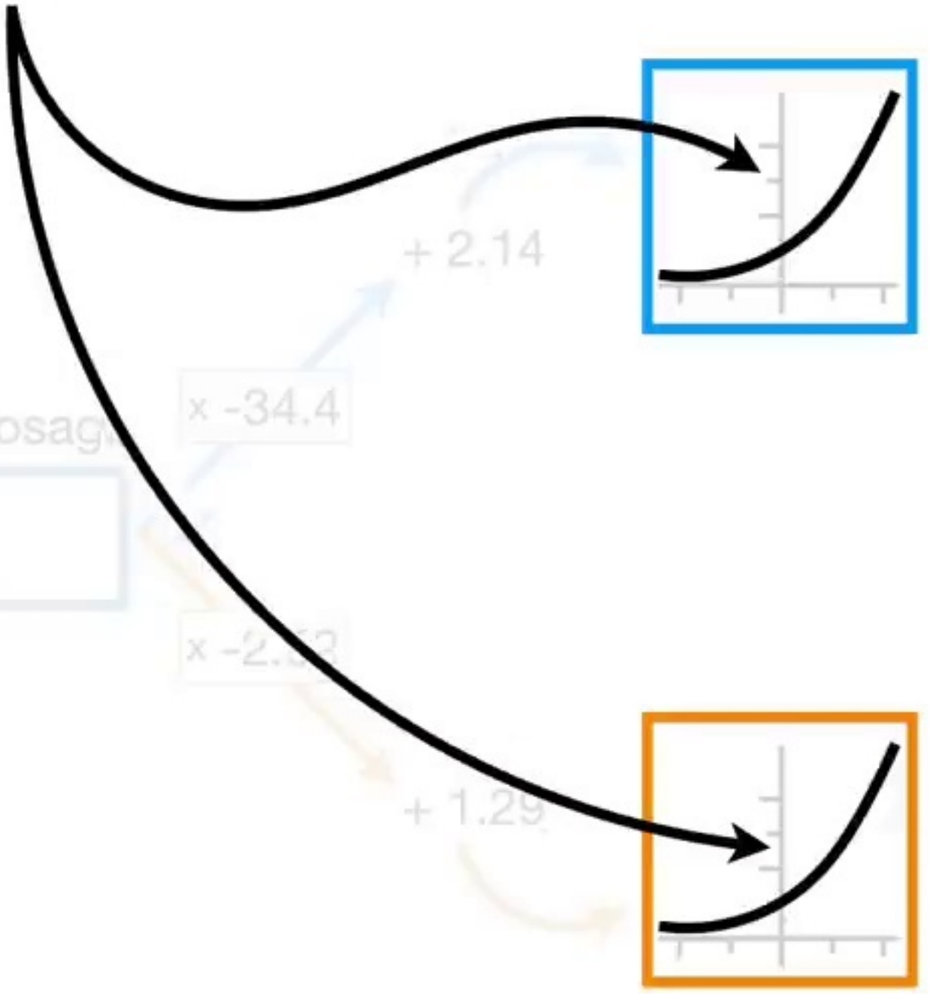

…can be reshaped by the parameter values…
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x -1.30
Dosage
x -24.4
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29


…and then added together
to get a green squiggle that
fits the data.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum
-0.58 =
Efficacy

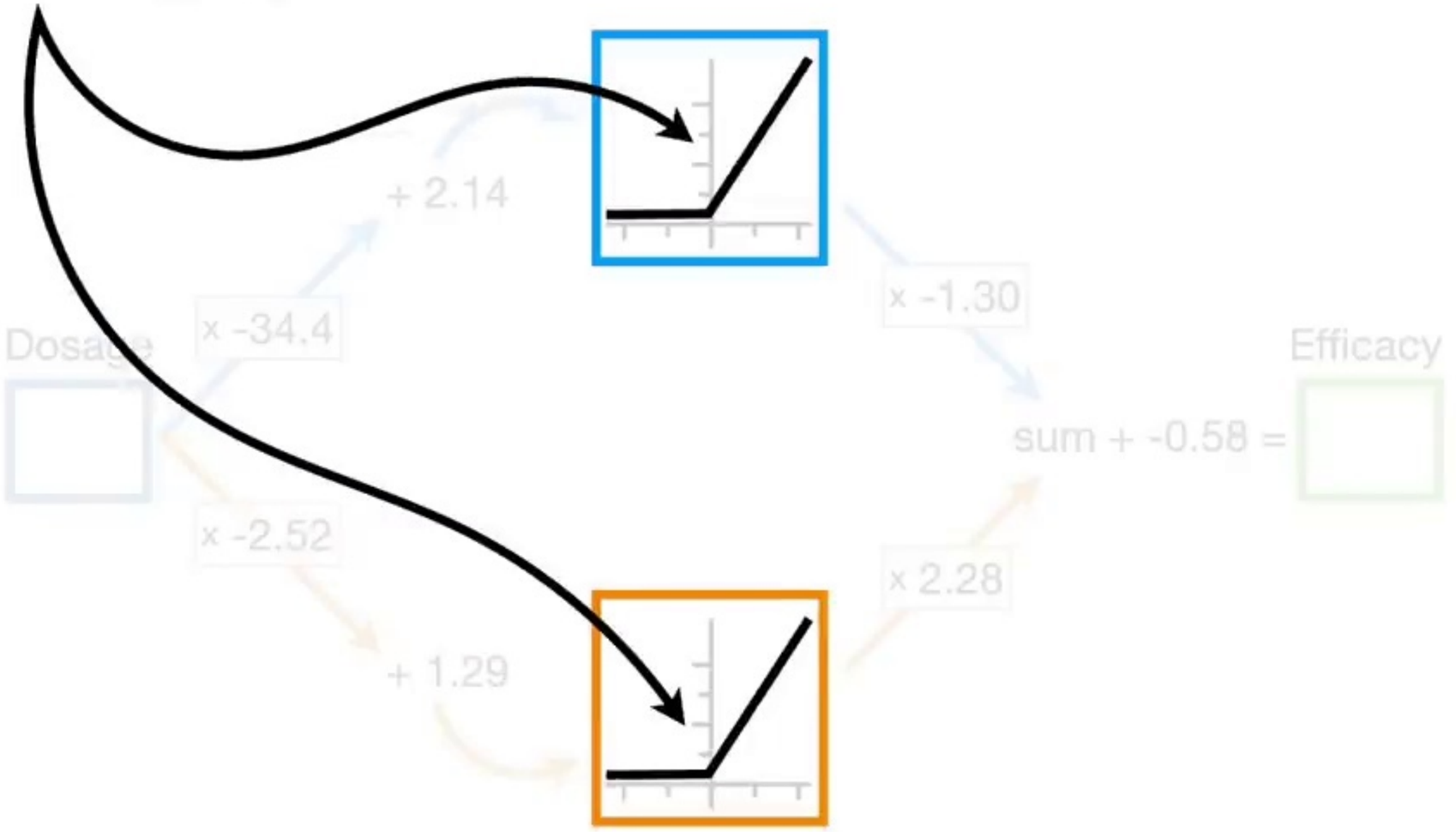
NOTE: There are many common **bent** or **curved lines** that we can choose for a **Neural Network**.



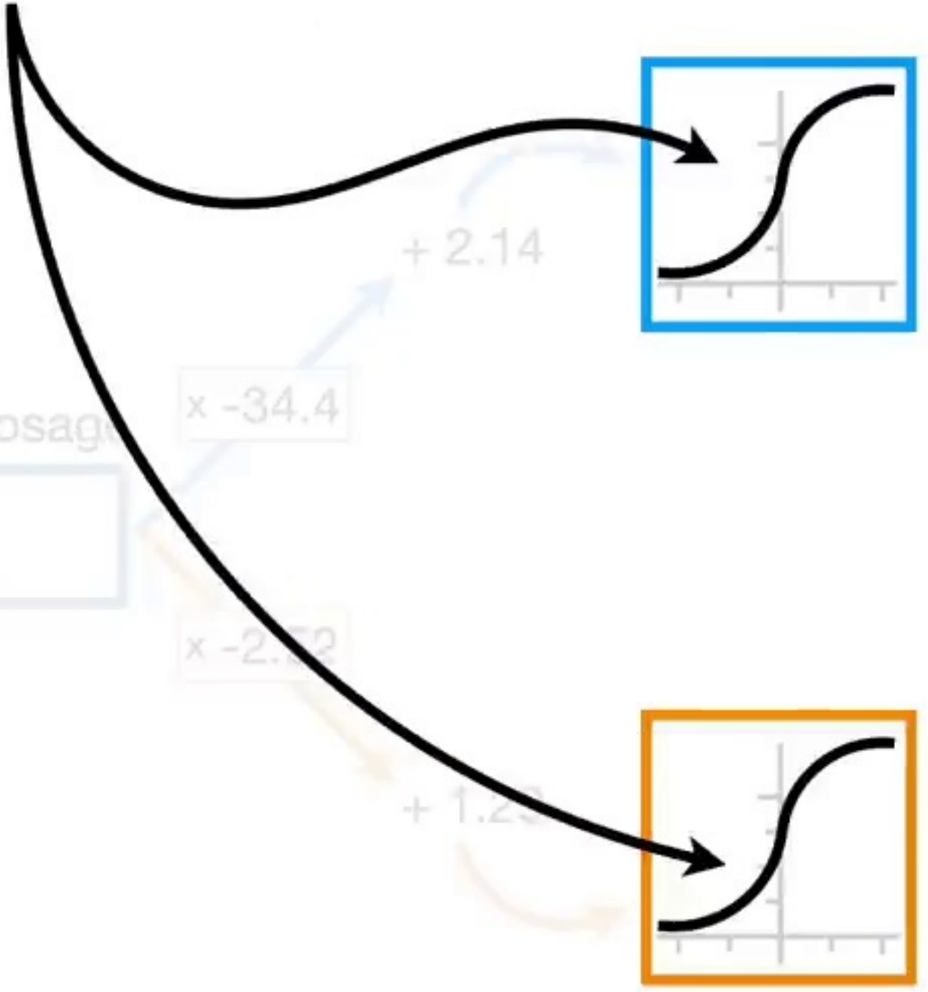
This specific **curved line** is called **softplus**, which sounds like a brand of toilet paper.



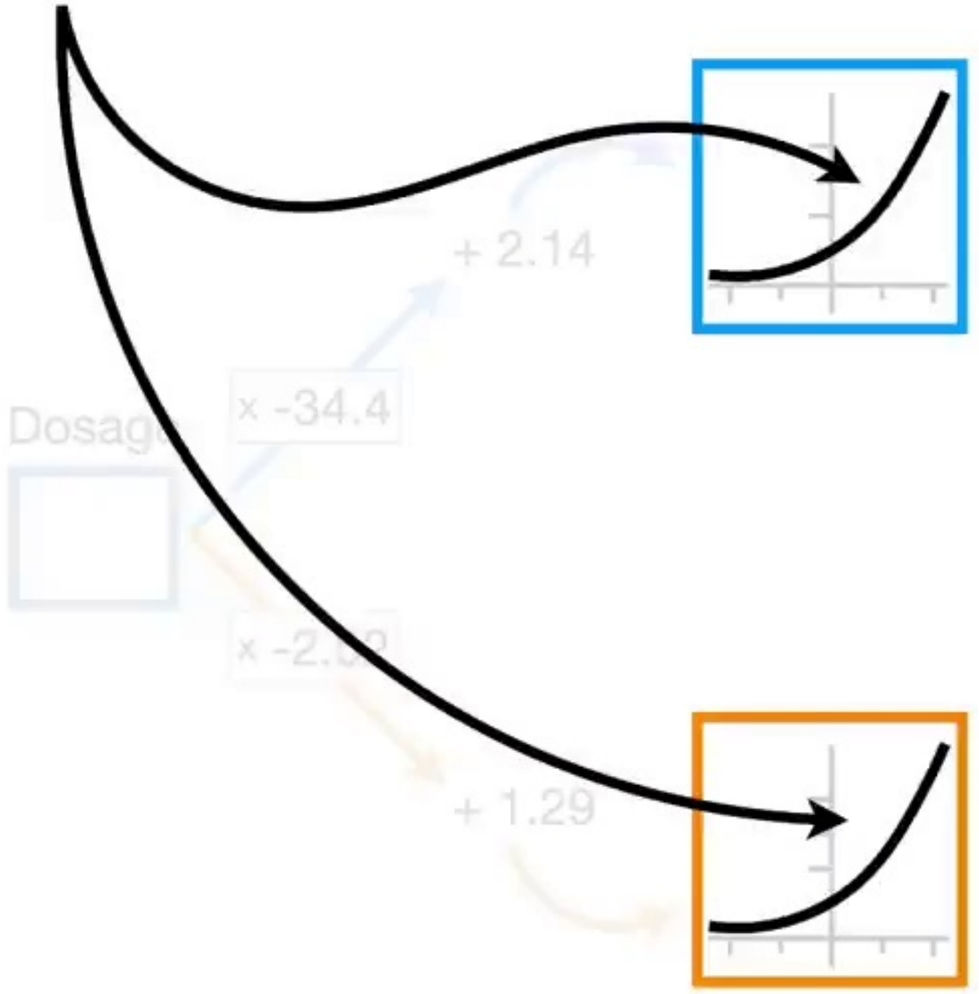
Alternatively, we could use this **bent line**, called, **ReLU**, which is short for **Rectified Linear Unit** and sounds like a robot.



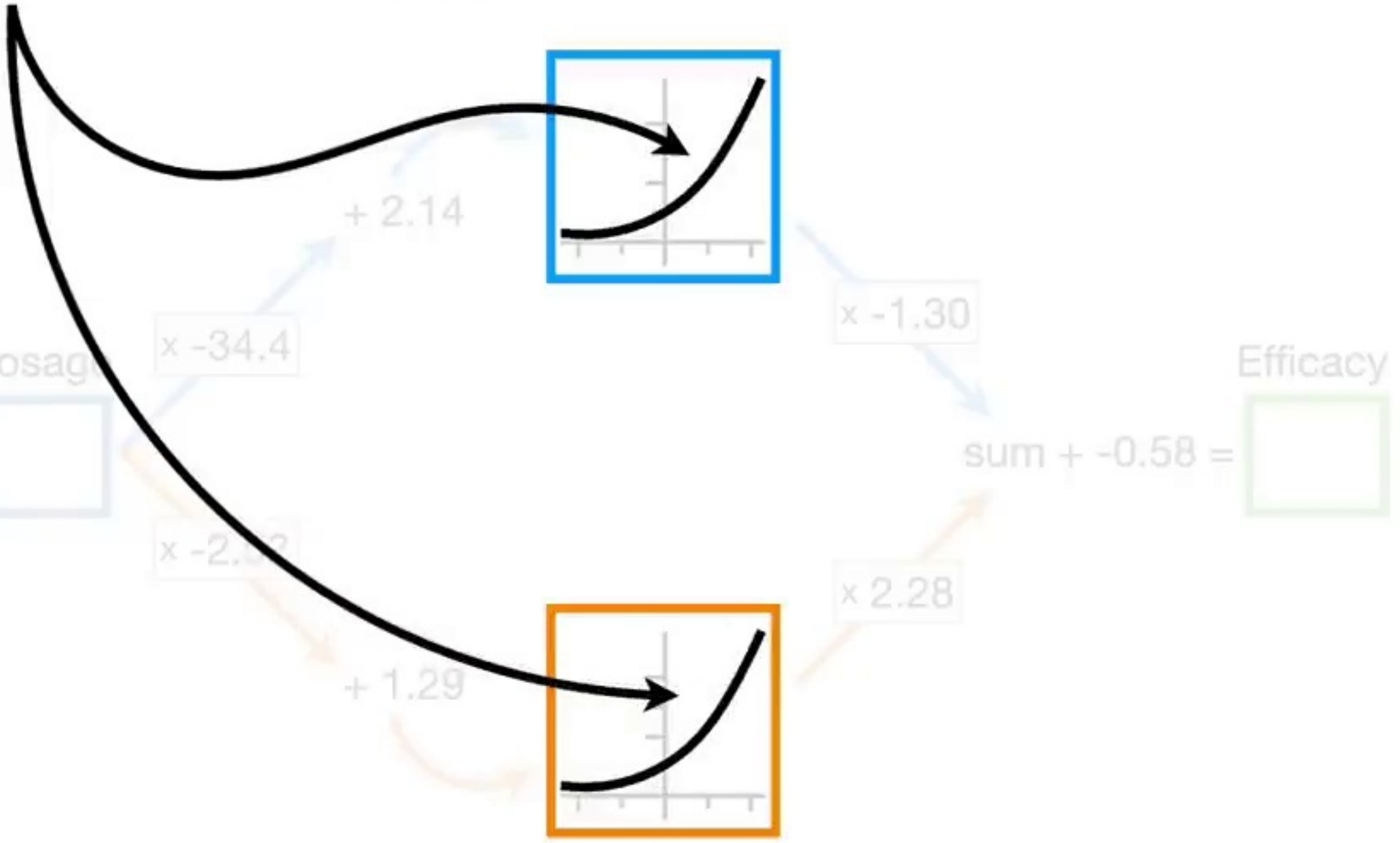
Or we could use a **sigmoid** shape or any other **bent** or **curved line**.



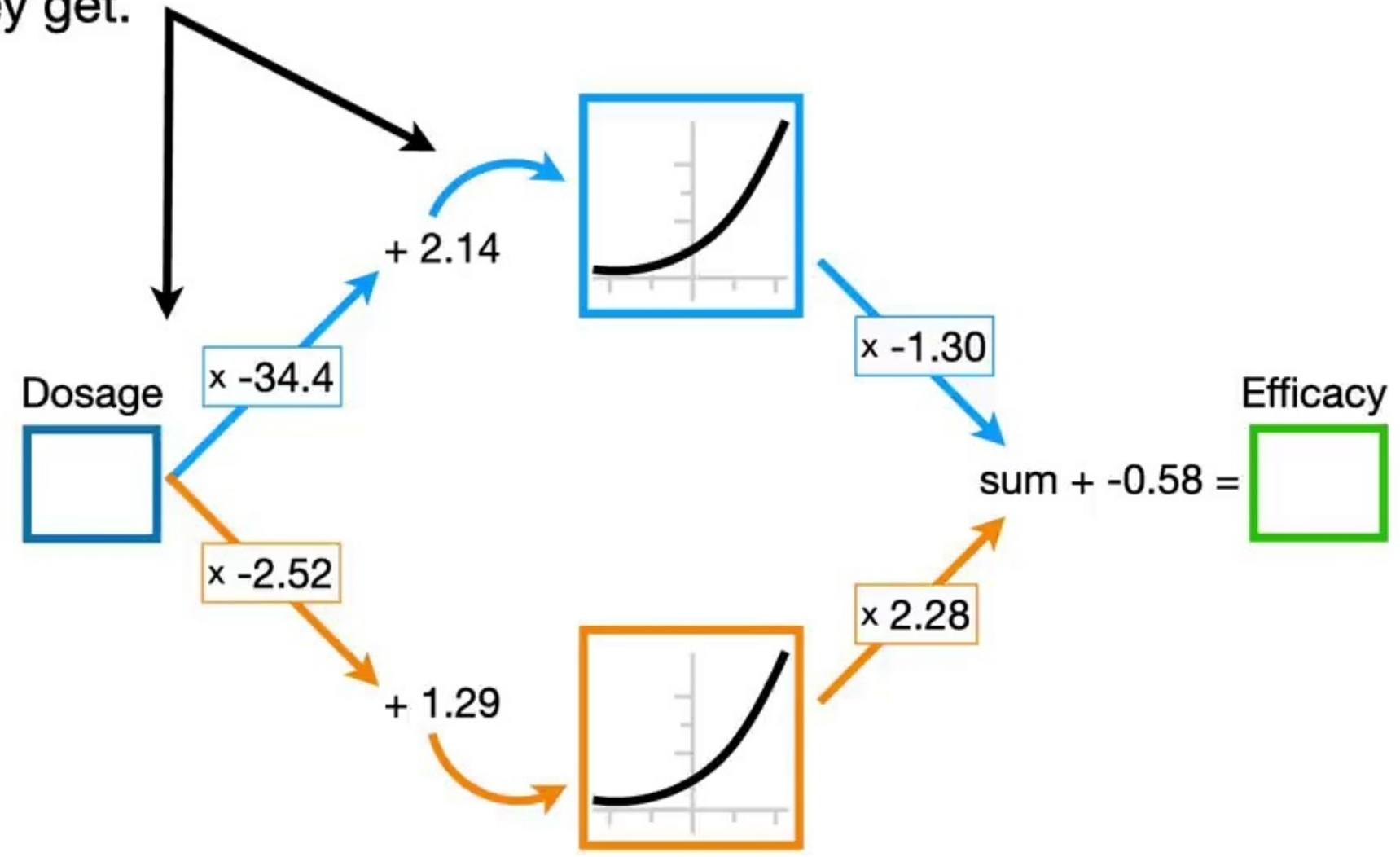
The **curved** or **bent lines** are called **Activation Functions.**



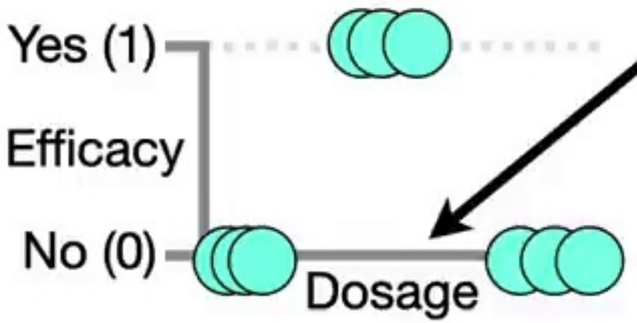
When you build a **Neural Network**, you have to decide which **Activation Function** or **Functions** you want to use.

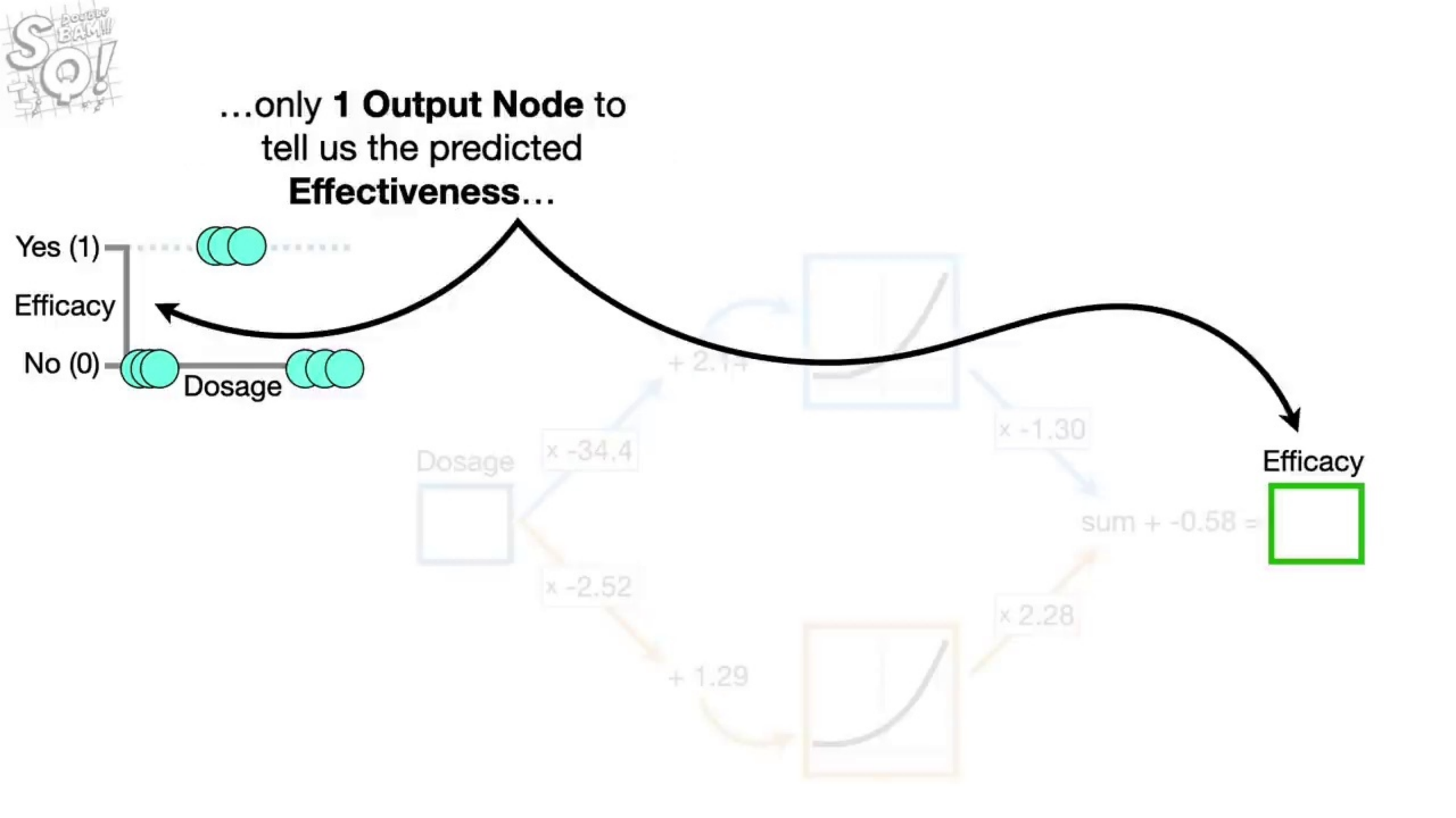


NOTE: This specific **Neural Network** is about as simple as they get.

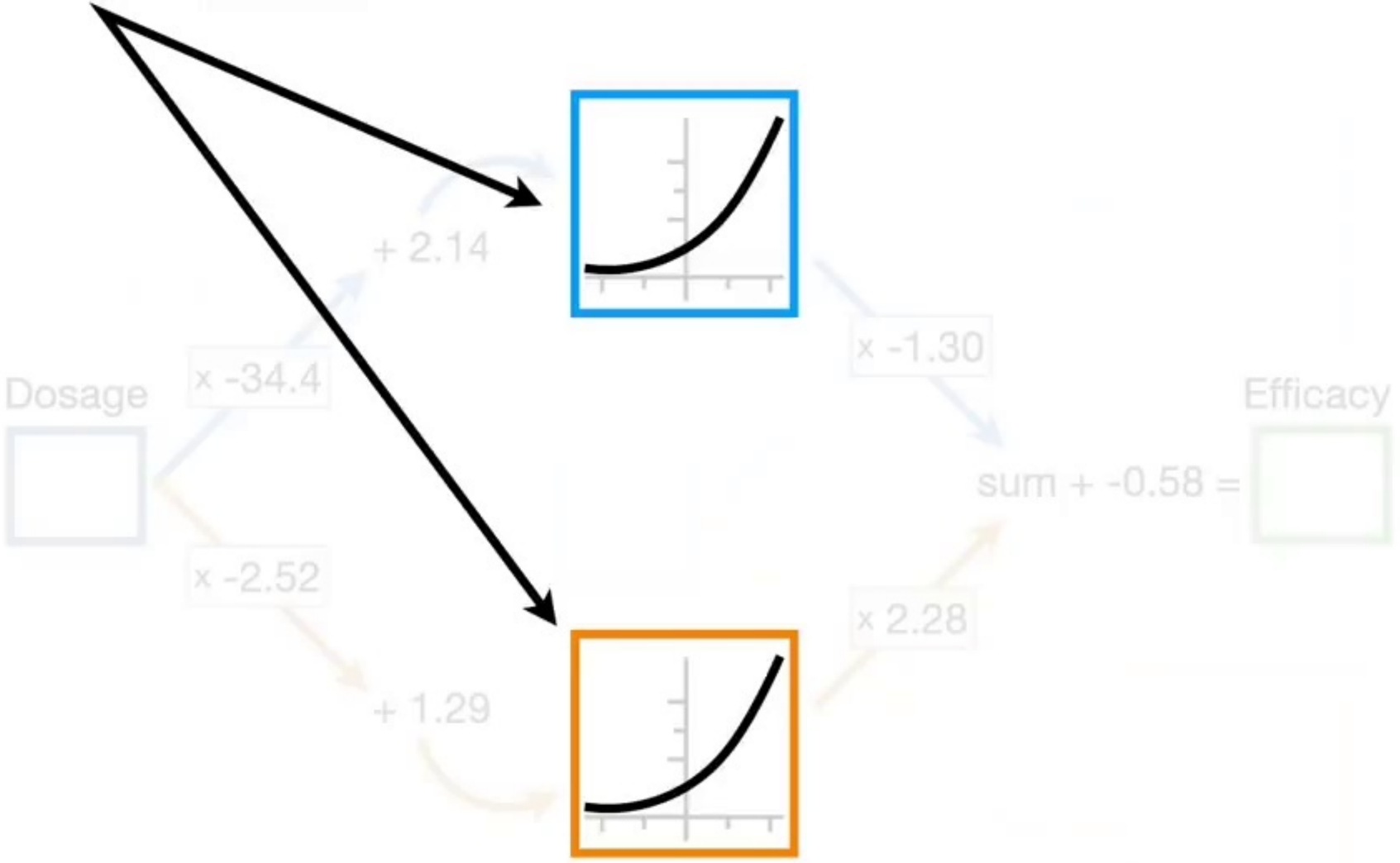


It only has **1 Input Node** where we plug in the **Dosage**…

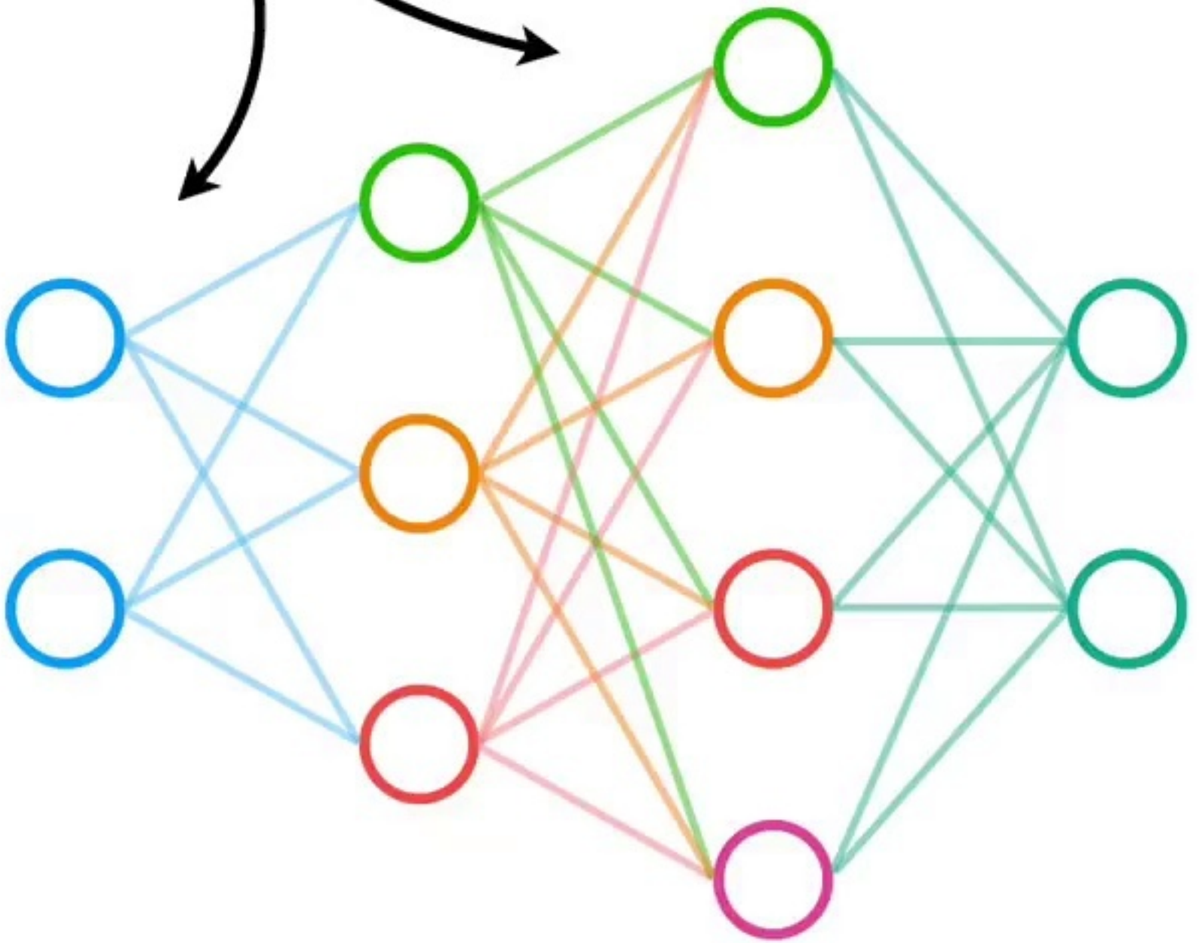



…only **1 Output Node** to tell us the predicted **Effectiveness**…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

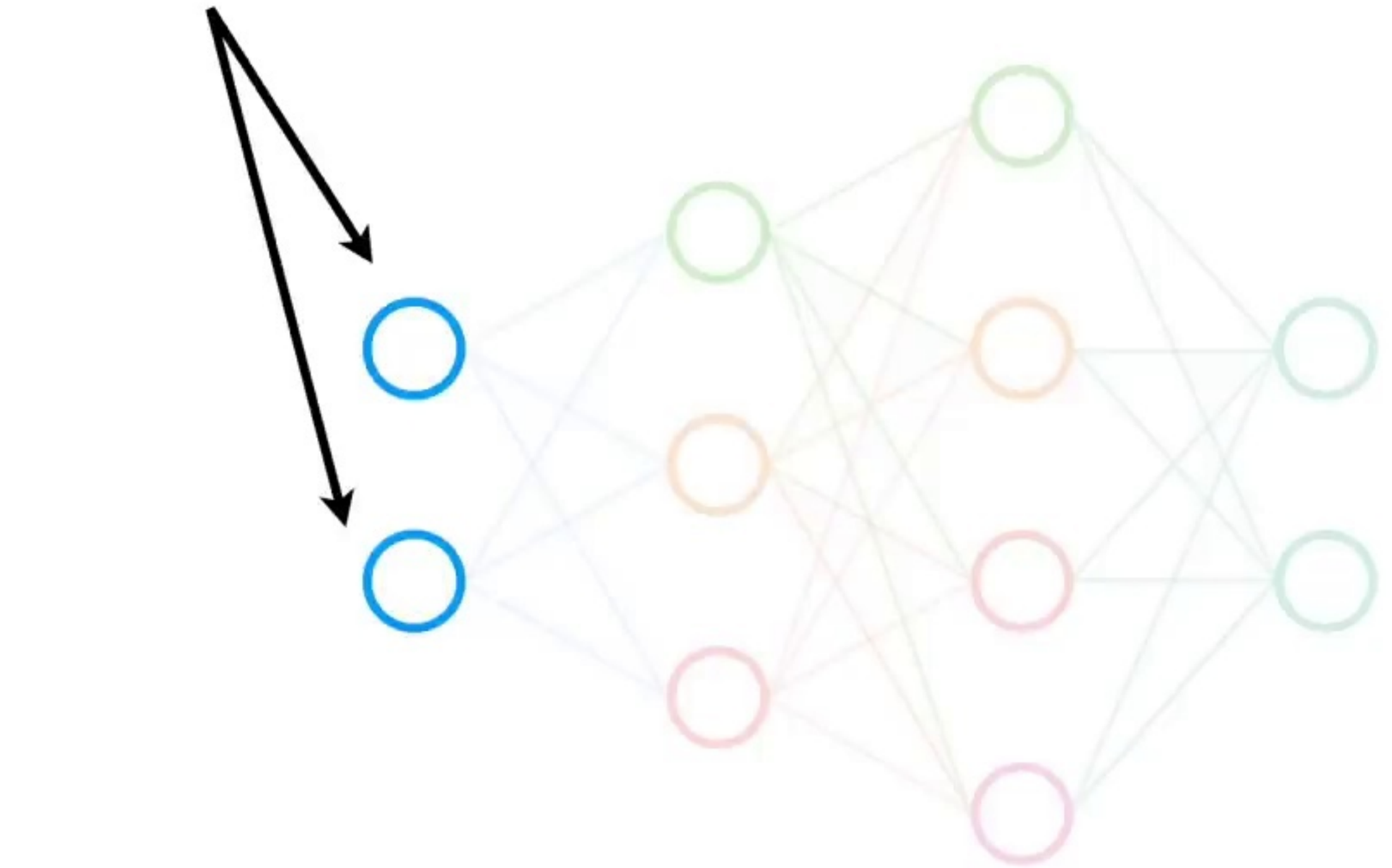
…and only **2 Nodes** between the **Input** and **Output Nodes**.



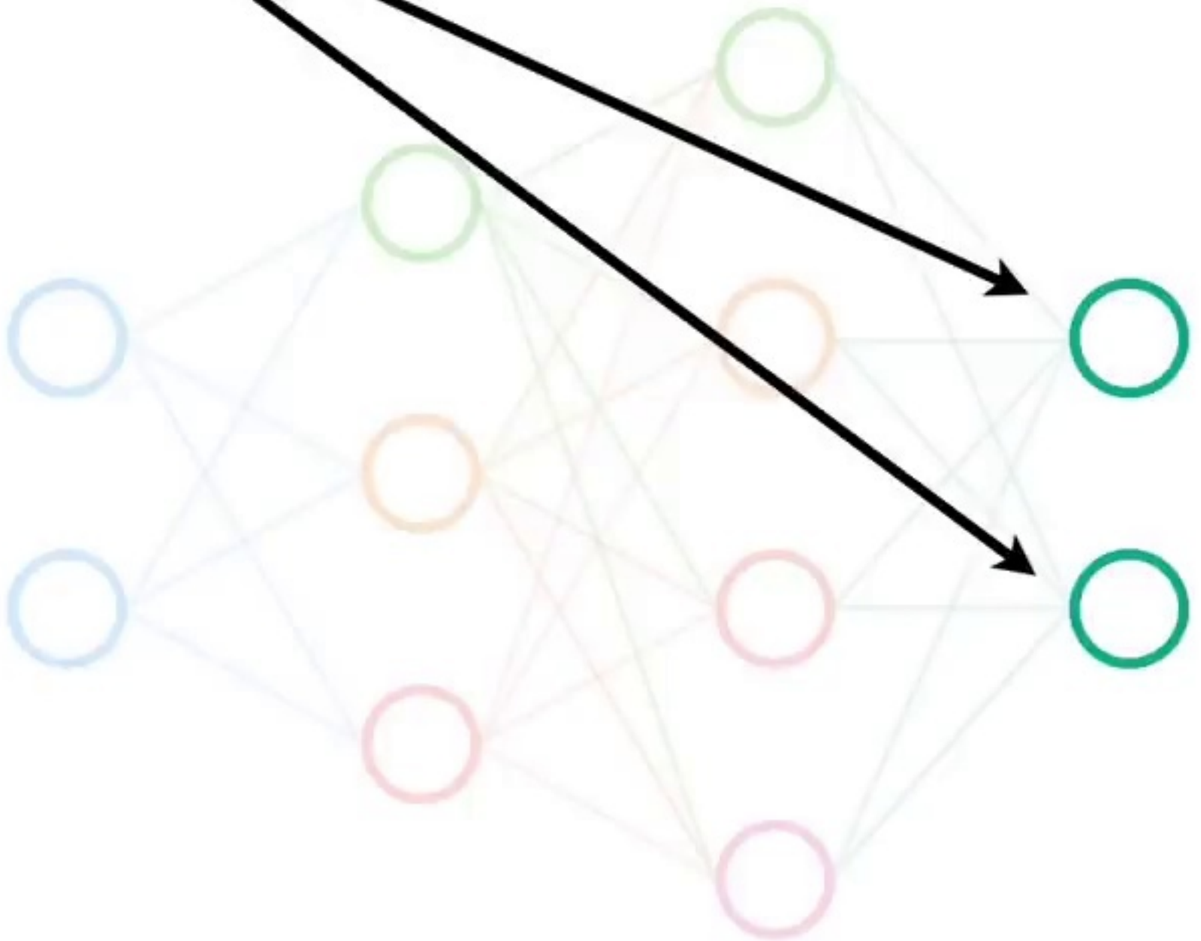
However, in practice, **Neural Networks** are usually much fancier…



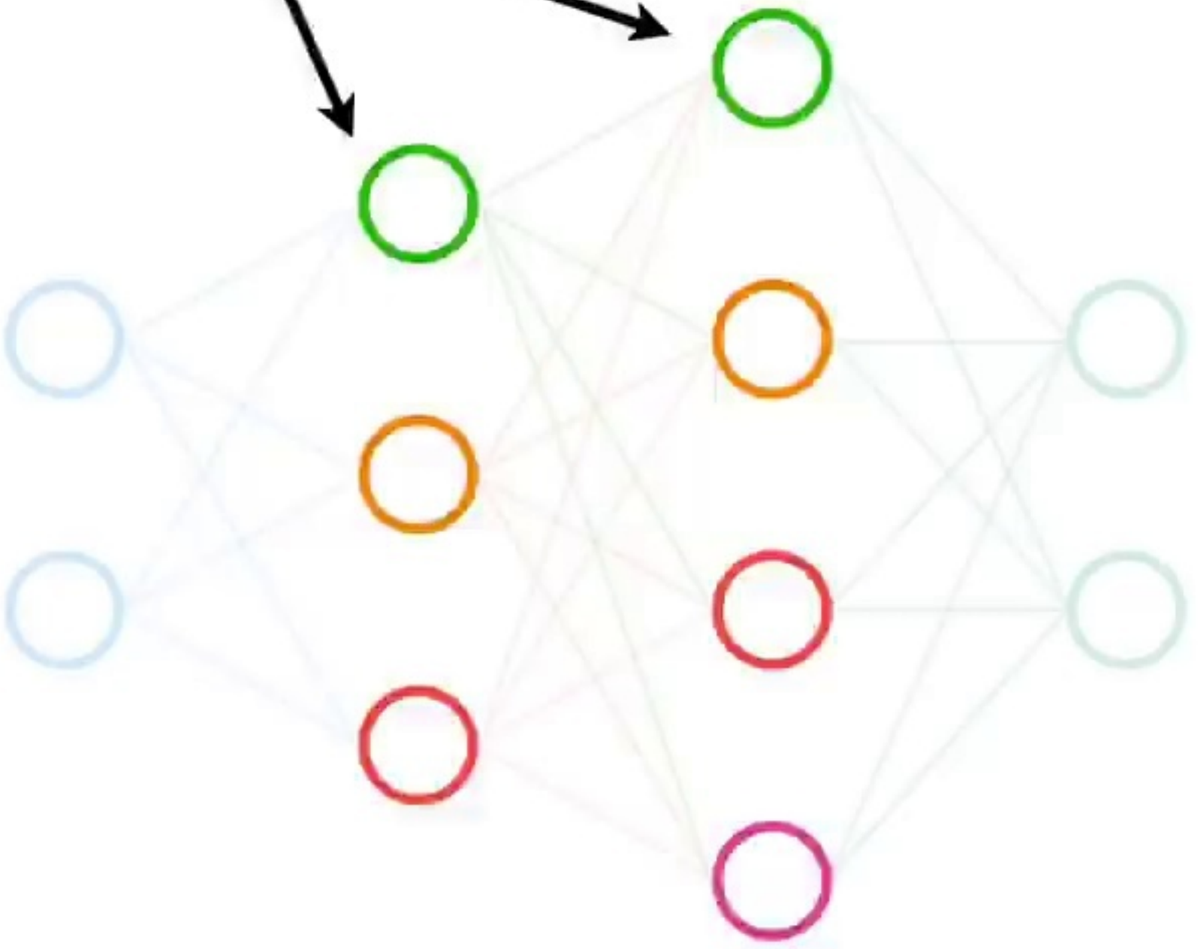
…and have more
than **1 Input Node**…



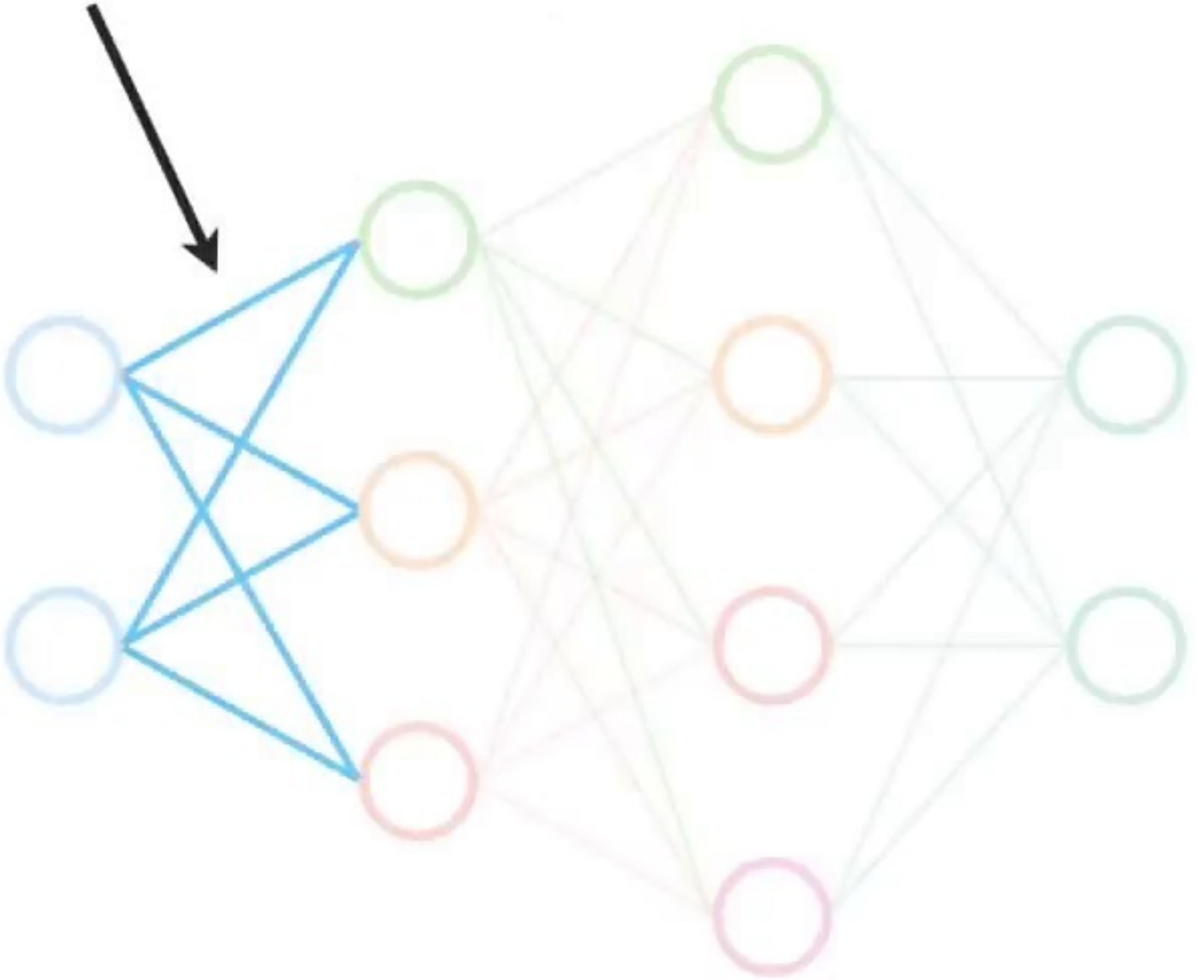
…more than **1 Output Node**…



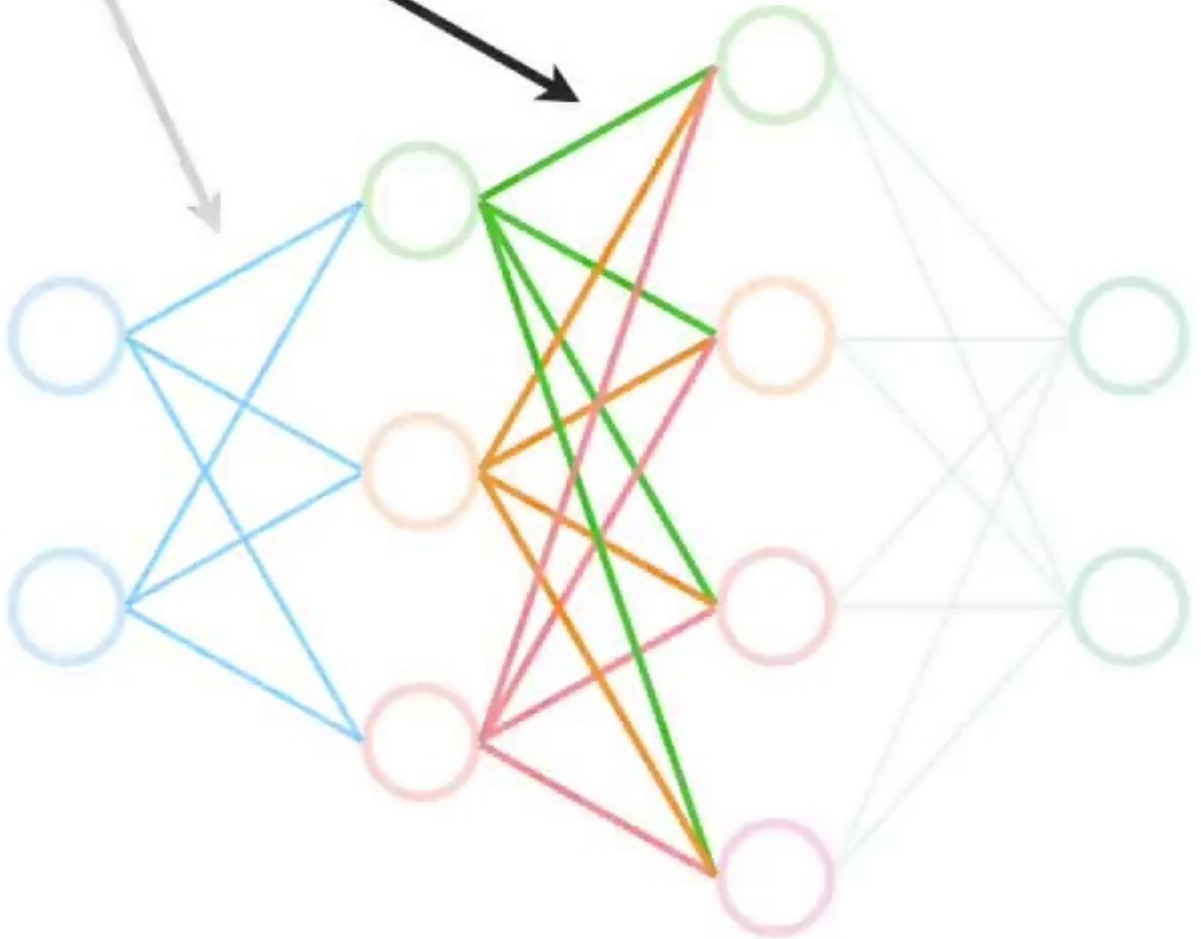
…different layers of **Nodes** between the **Input** and **Output Nodes**…



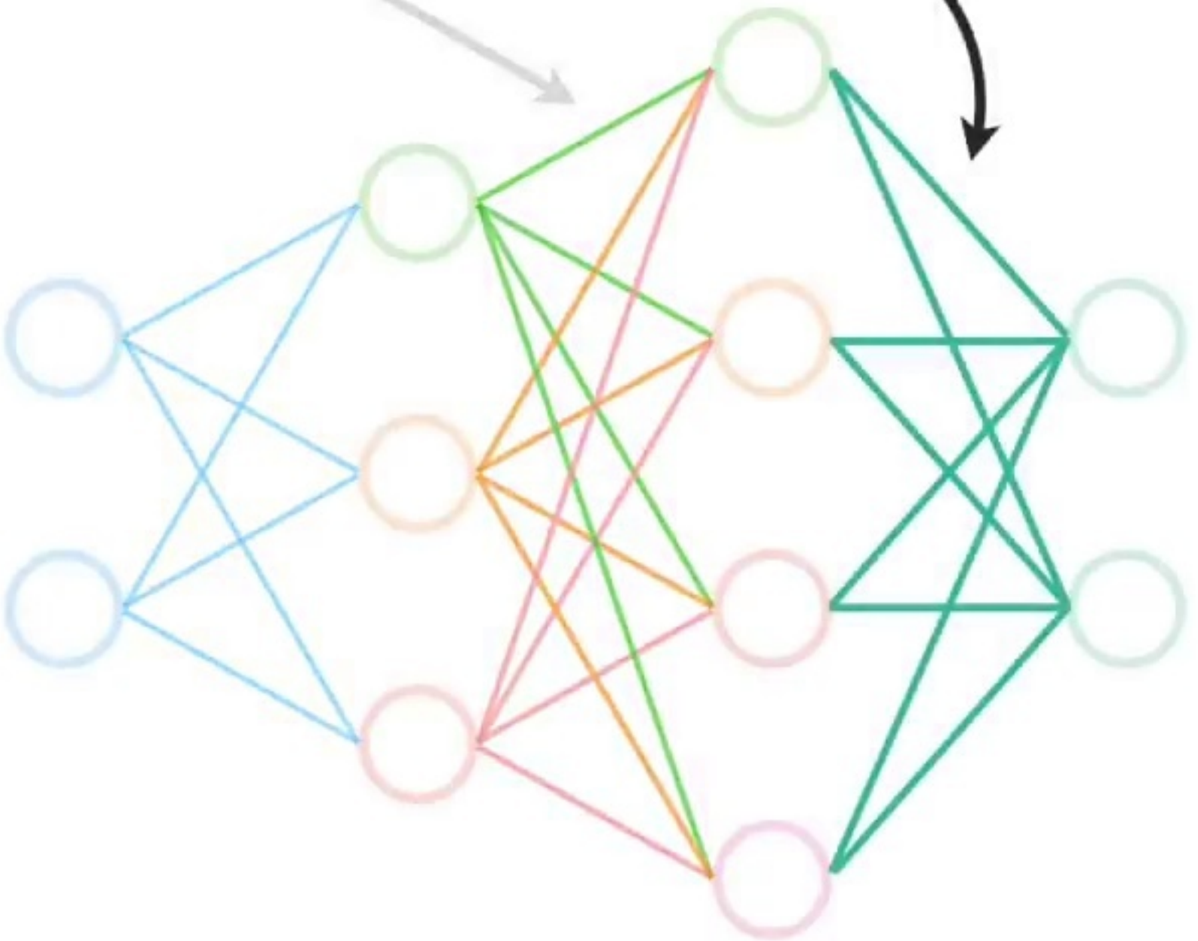
…and a spider web of connections between each layer of **Nodes**.



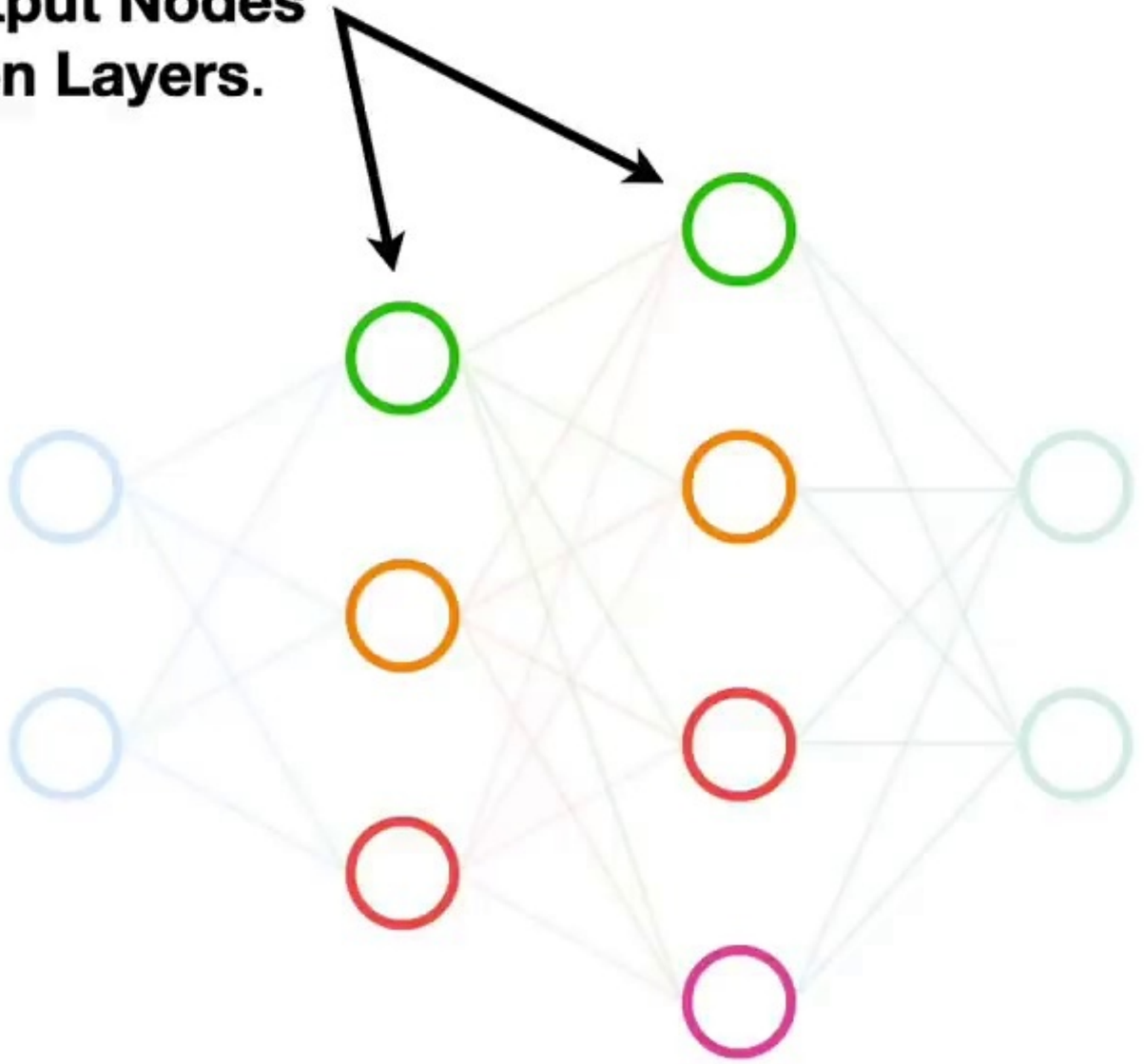
…and a spider web of connections between each layer of **Nodes**.



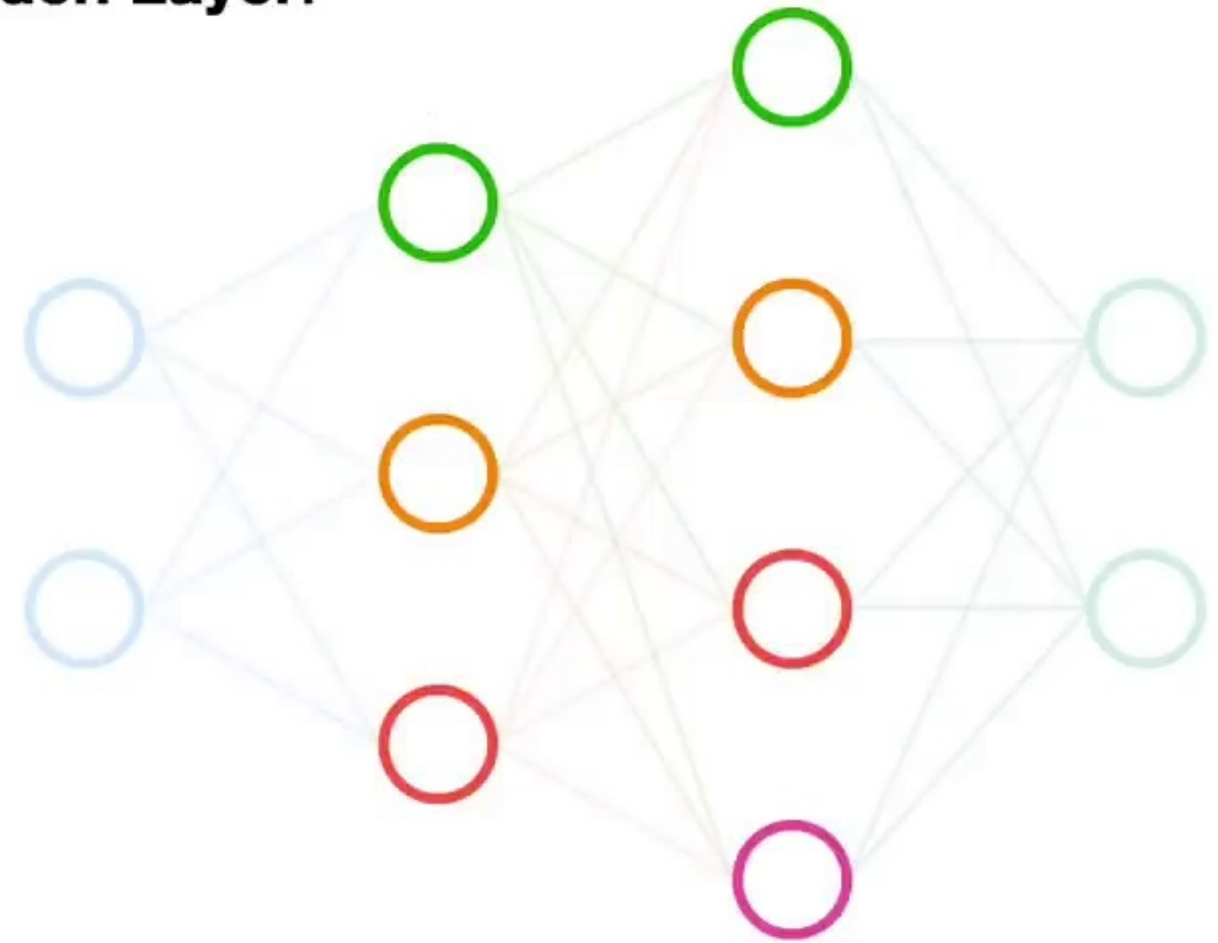
…and a spider web of connections between each layer of **Nodes**.



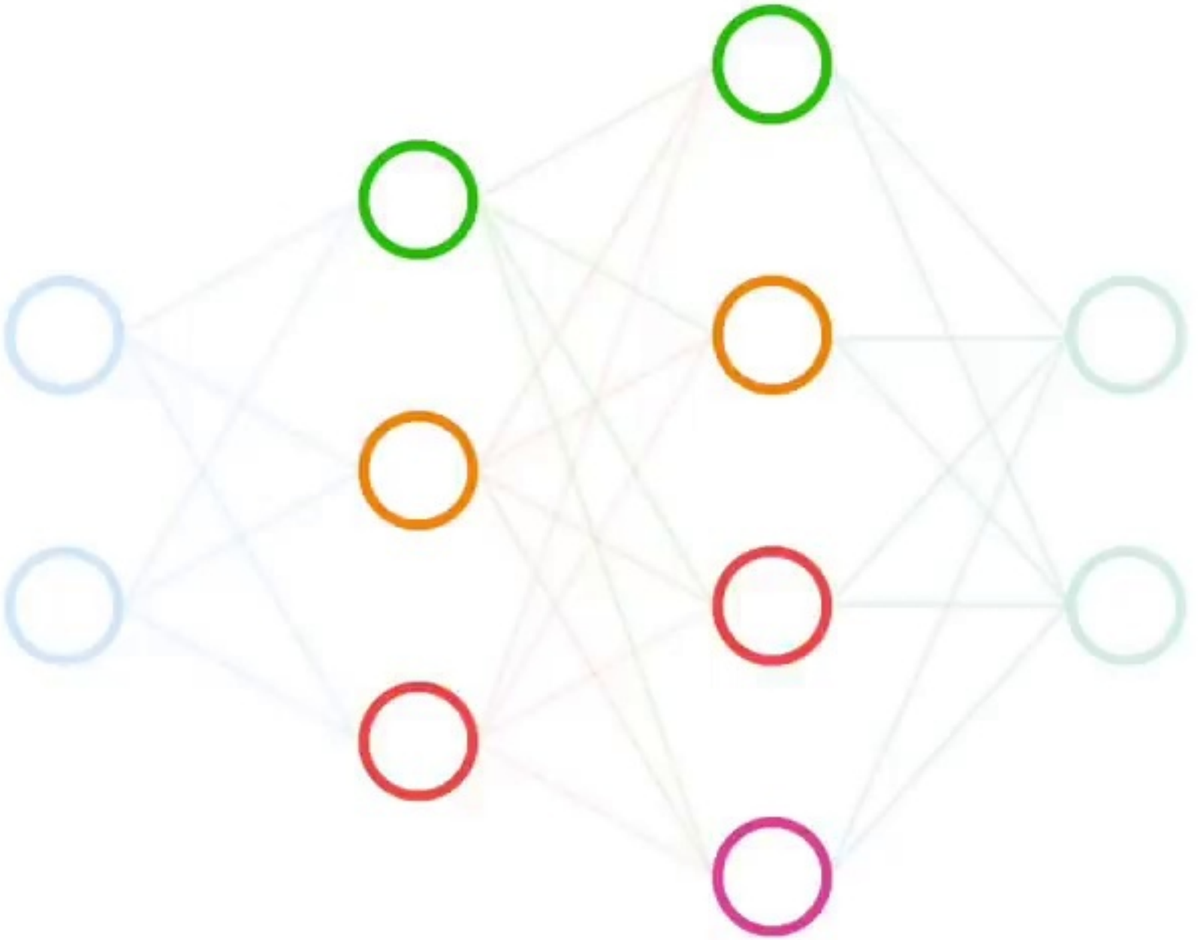
The layers of **Nodes** between the **Input** and **Output Nodes** are called **Hidden Layers**.



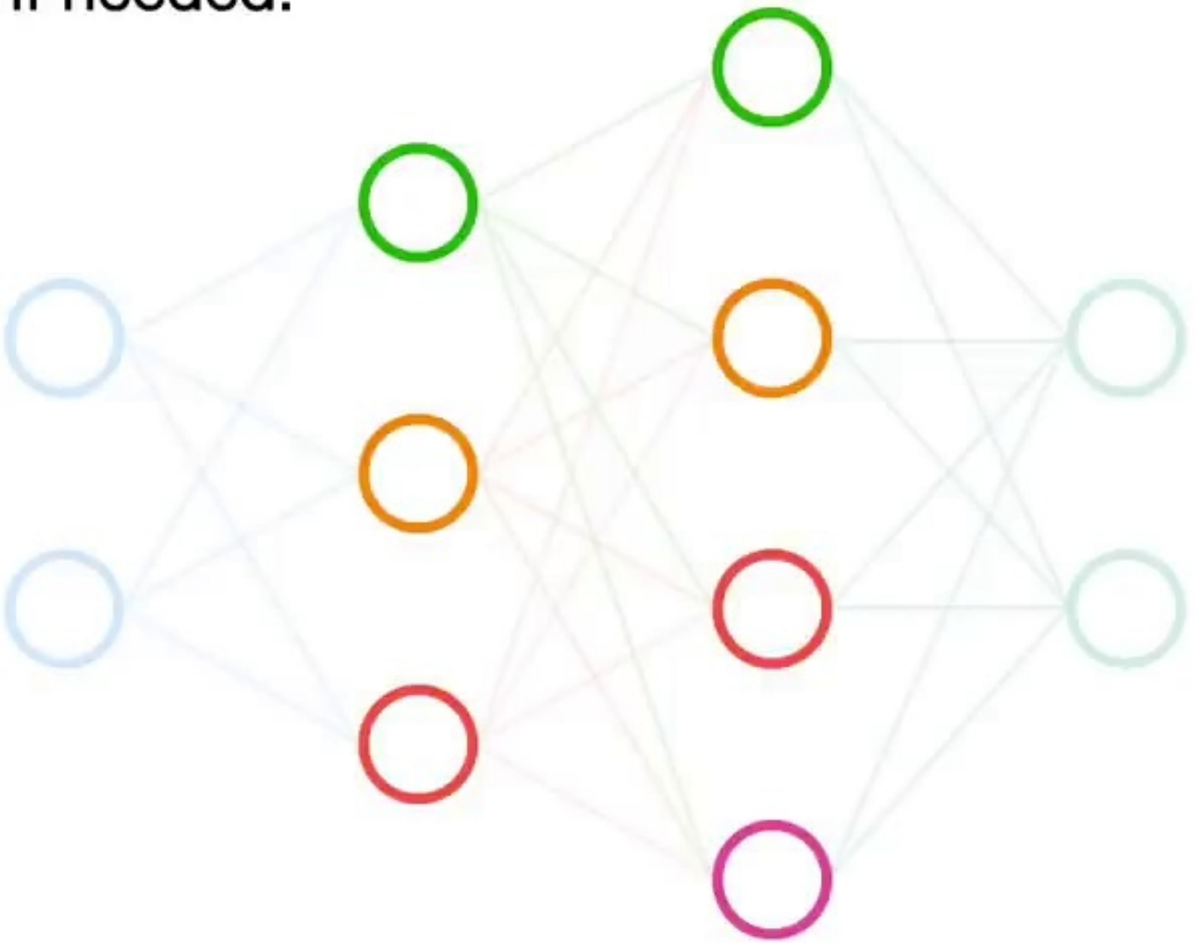
When you build a **Neural Network**, one of the first things you do is decide how many **Hidden Layers** you want, and how many **Nodes** go into each **Hidden Layer**.



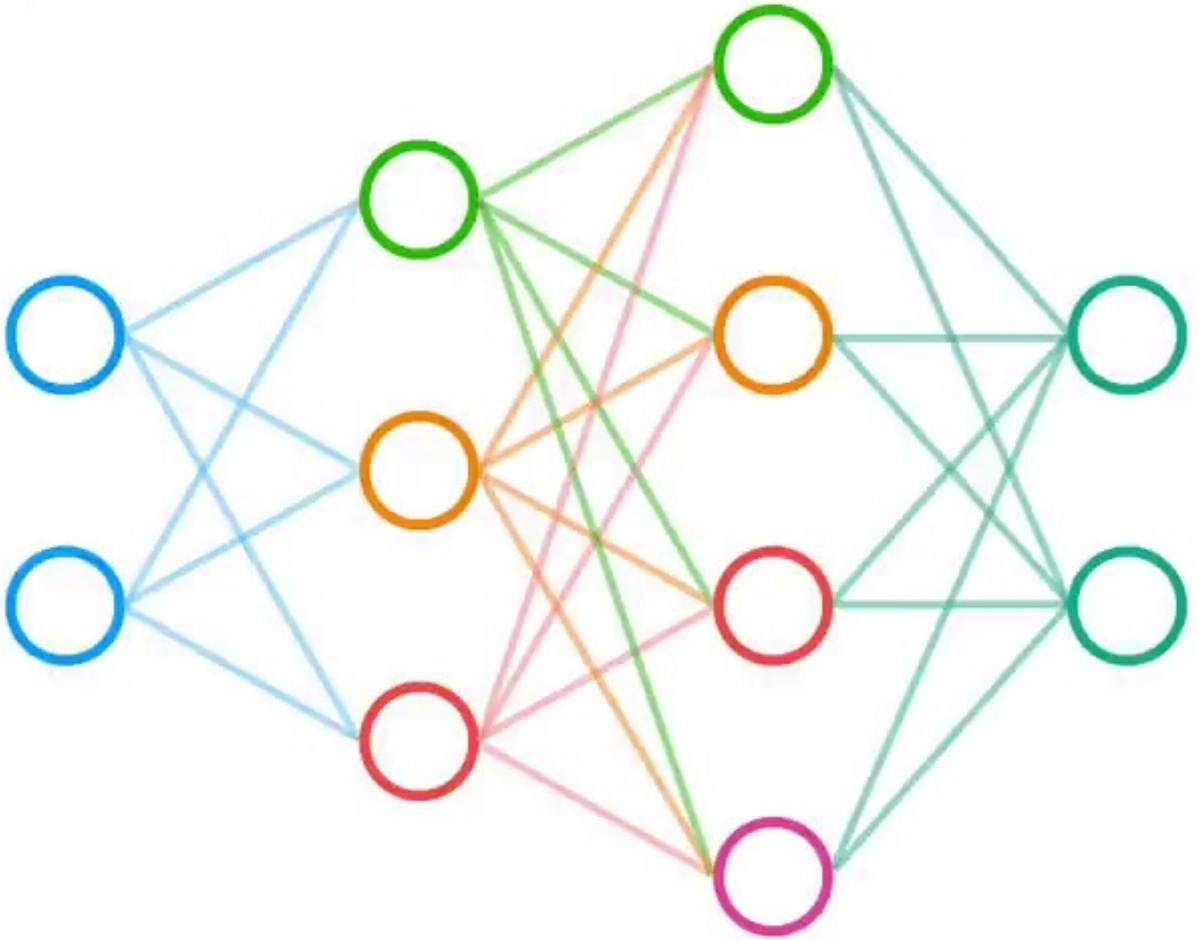
Although there are rules of thumb for making decisions about the **Hidden Layers**…



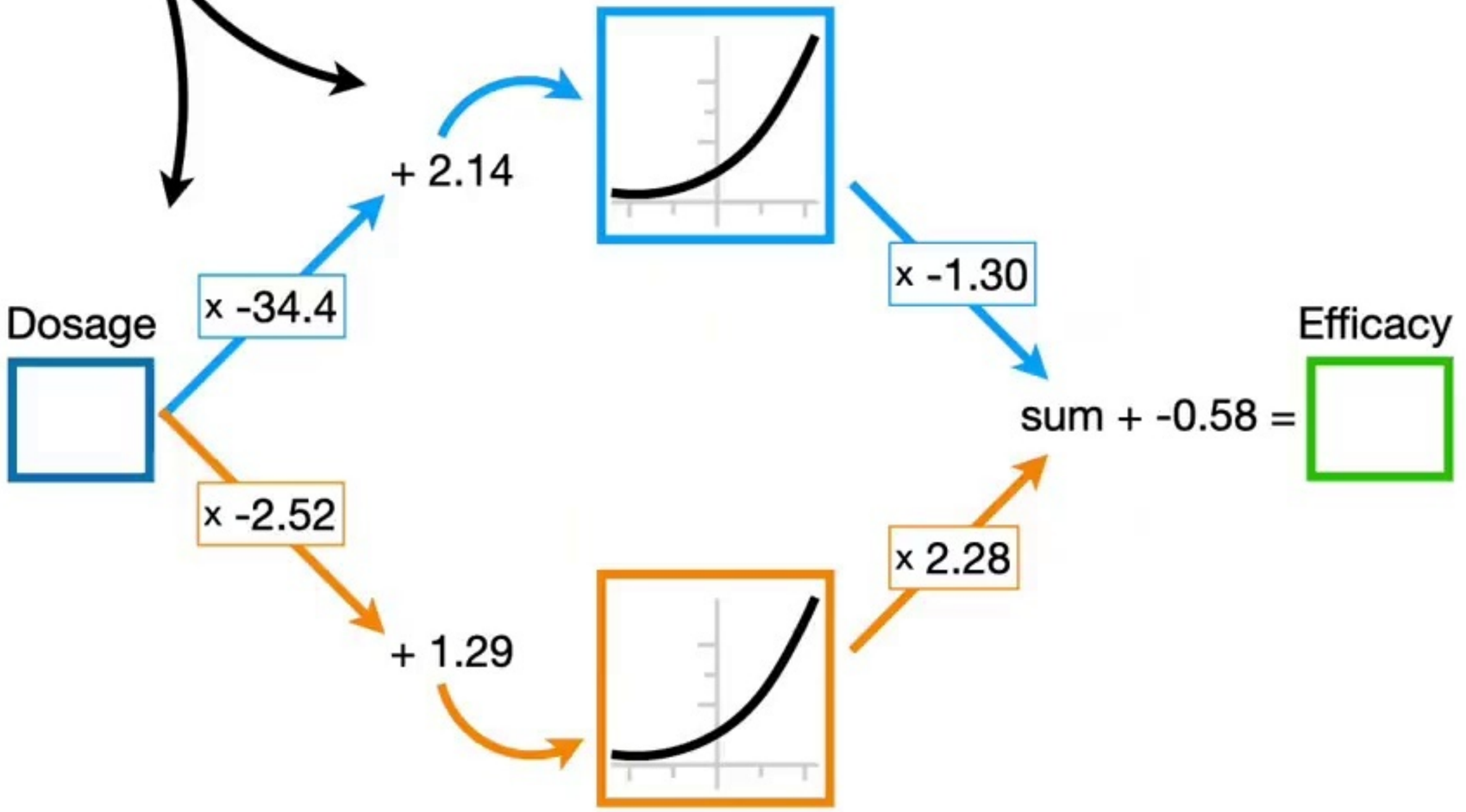
…you essentially make a guess and see how well the **Neural Network** performs, adding more layers and nodes if needed.



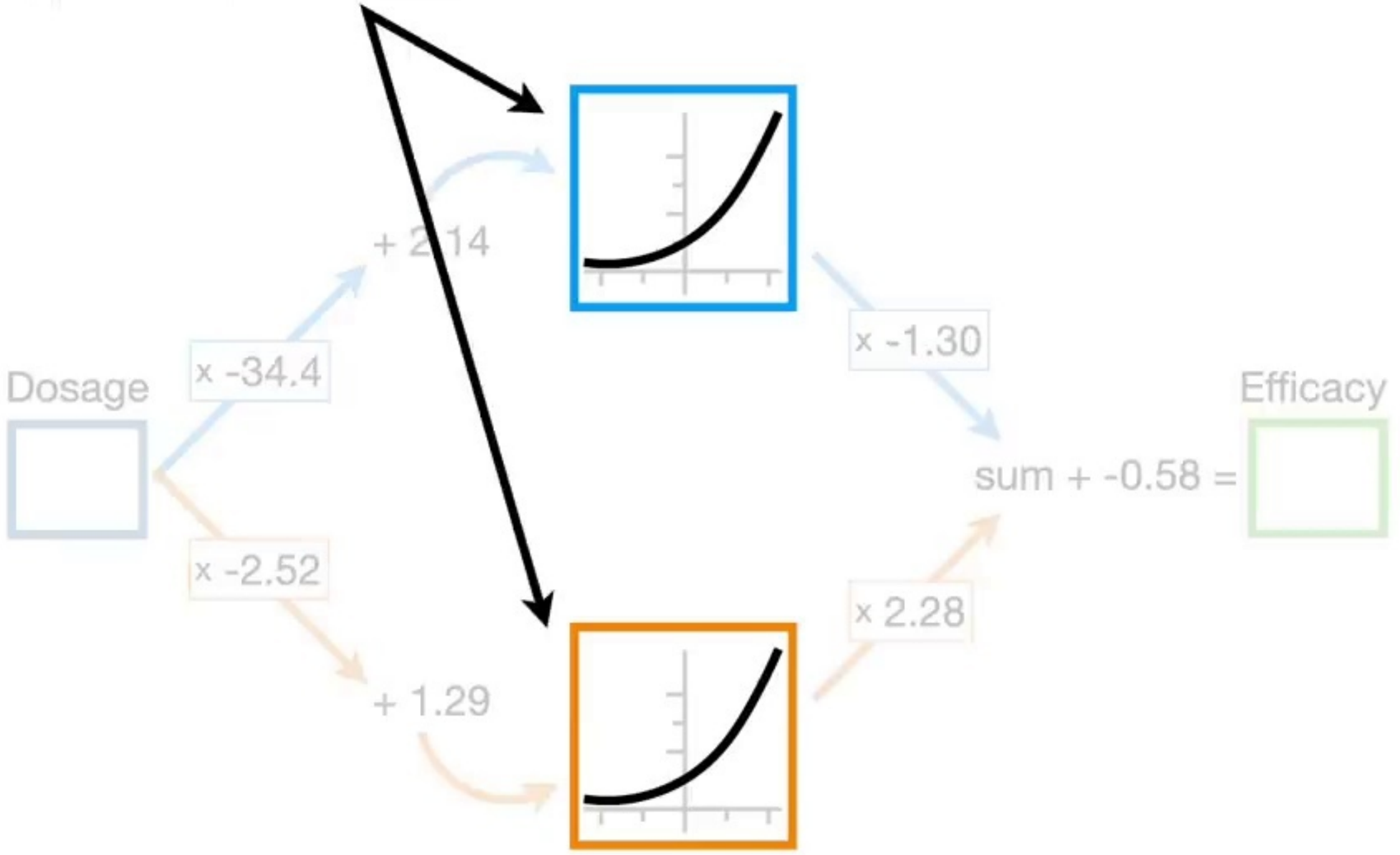
Now, even though this **Neural Network** looks fancy, it is still made from the same parts…



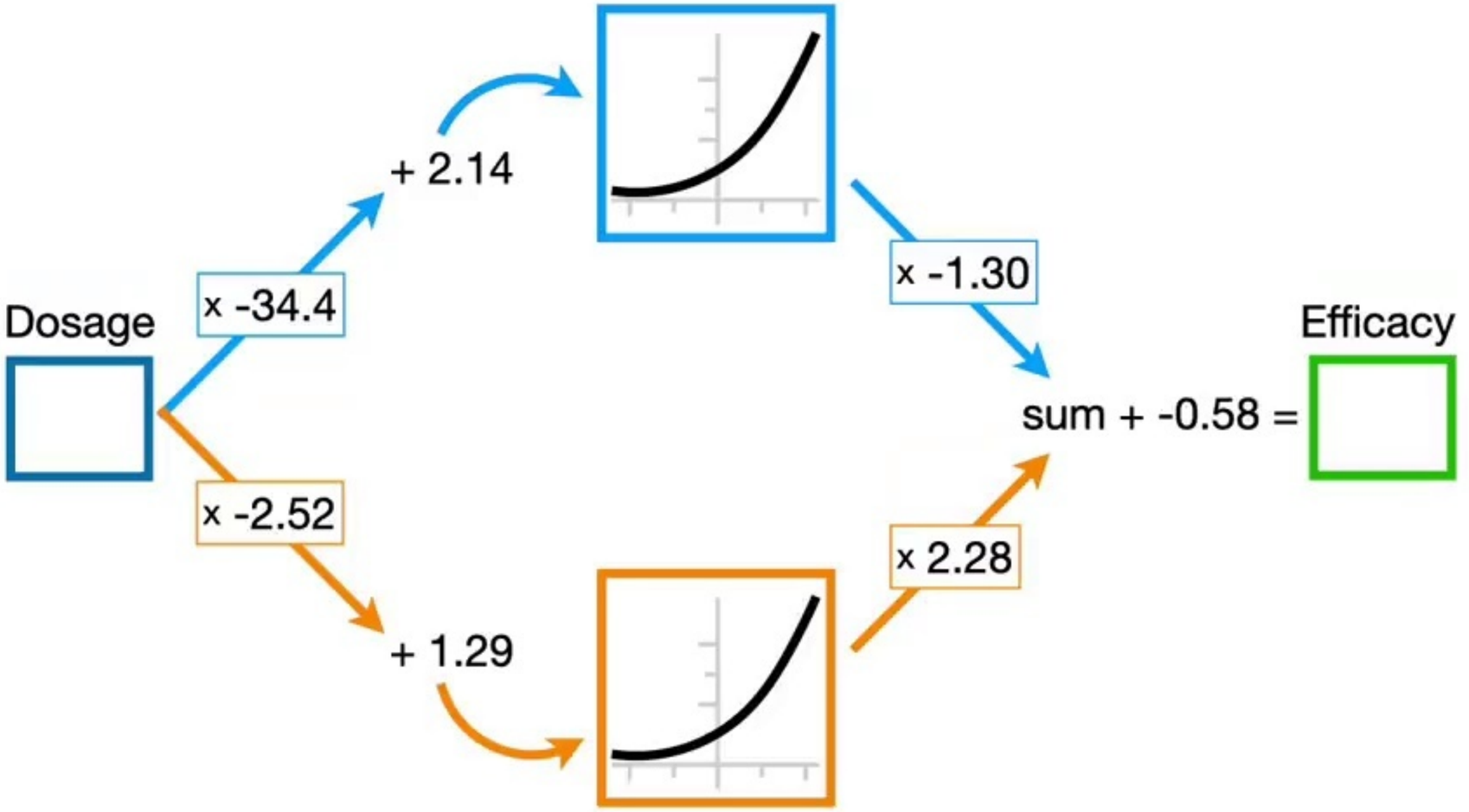
…used in this simple
Neural Network…



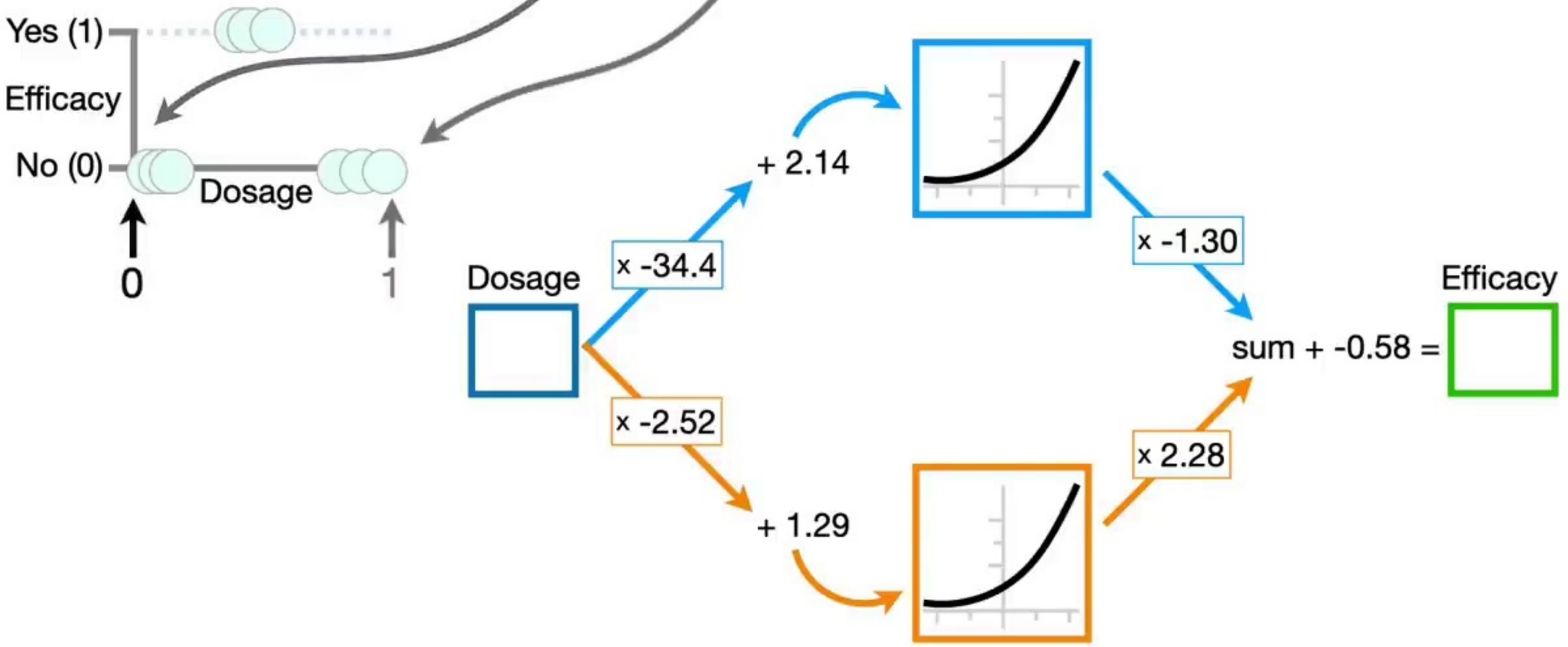
…which only has **1 Hidden Layer** with **2 Nodes**.



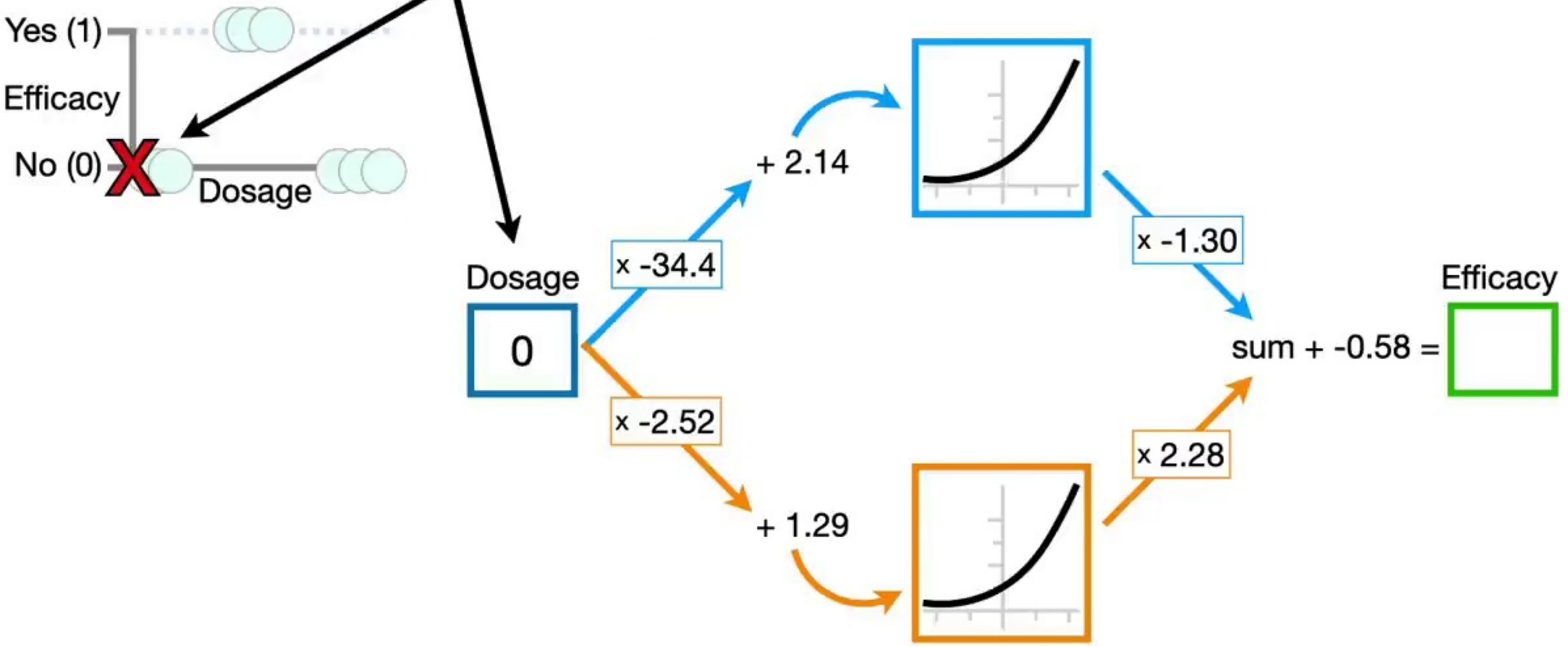
So let's learn how this **Neural Network** creates new shapes from the **curved** or **bent lines** in the **Hidden Layer**…

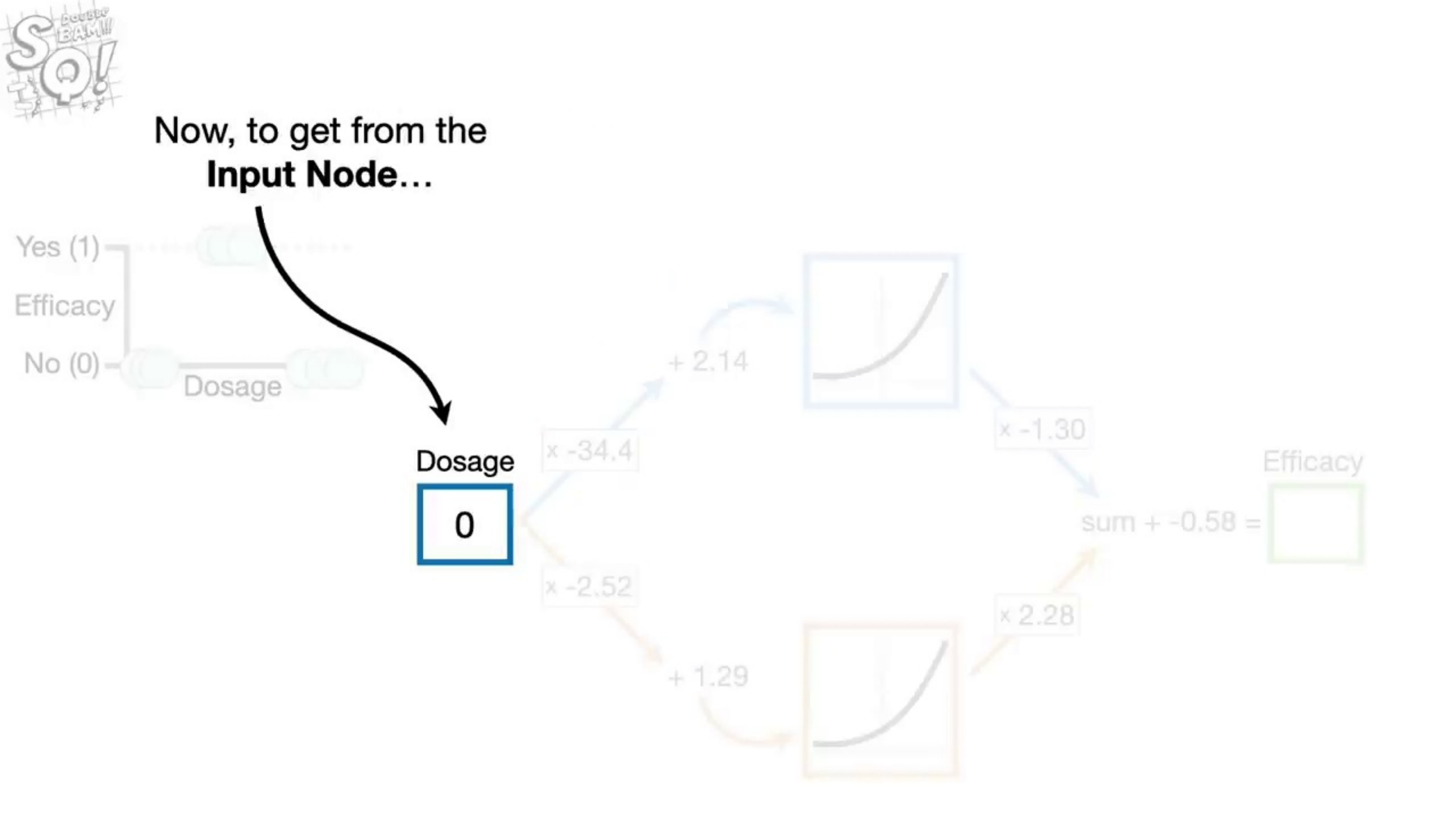


NOTE: To keep the math simple, let's assume **Dosages** go from **0** (low) to **1** (high).



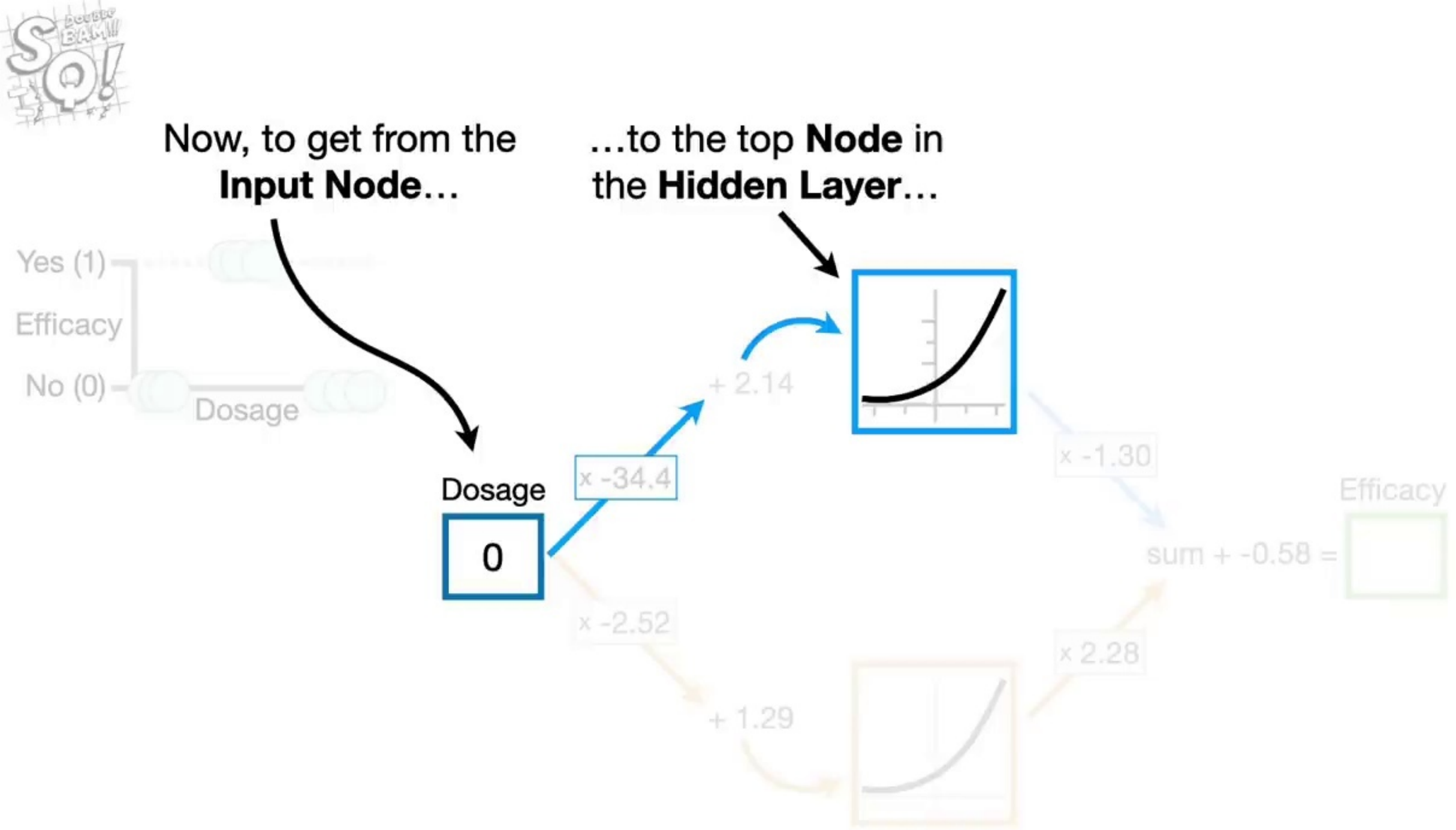
The first thing we are going to do is plug the lowest **Dosage**, **0**, into the **Neural Network**.




Now, to get from the
Input Node…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

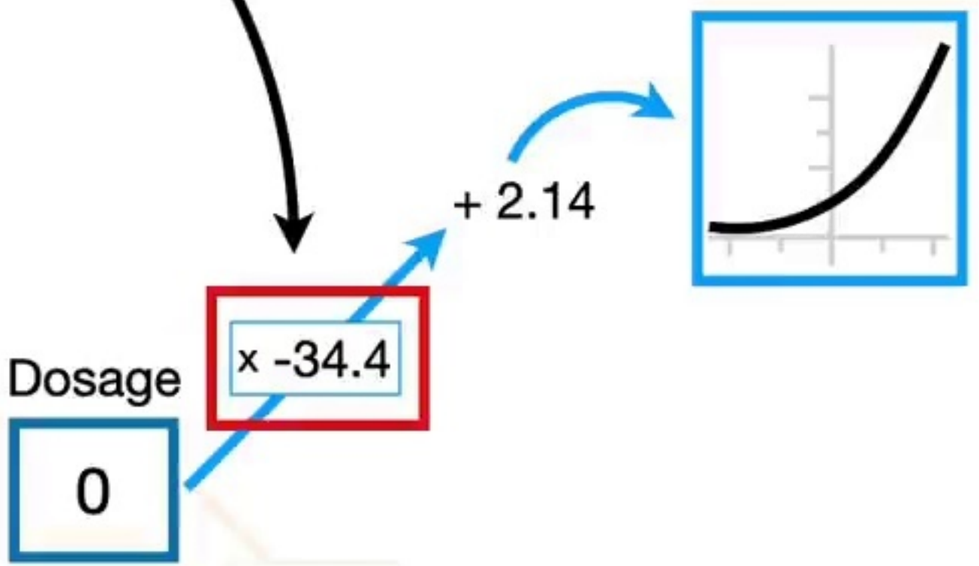
Now, to get from the **Input Node**…

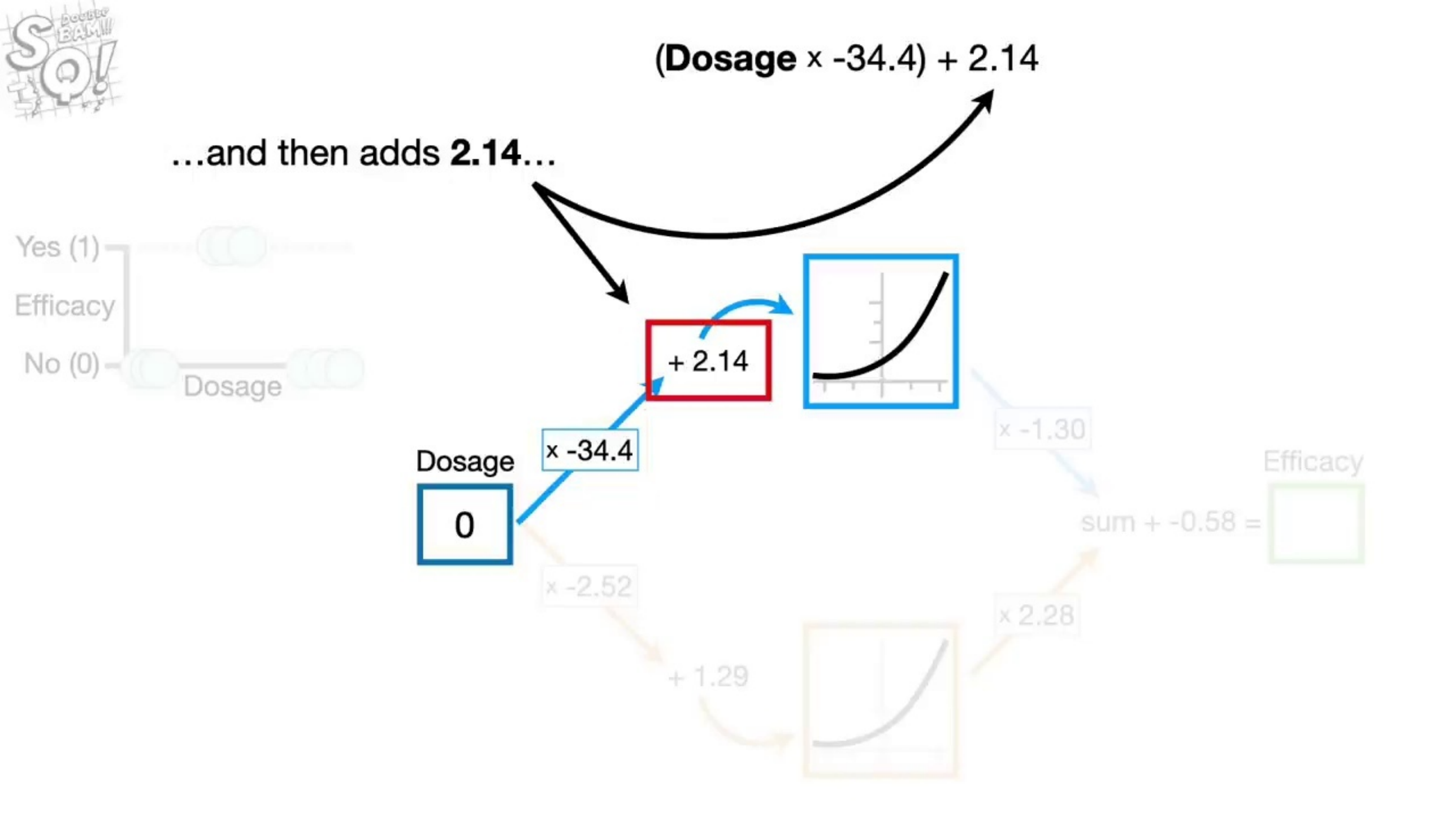
…to the top **Node** in the **Hidden Layer**…

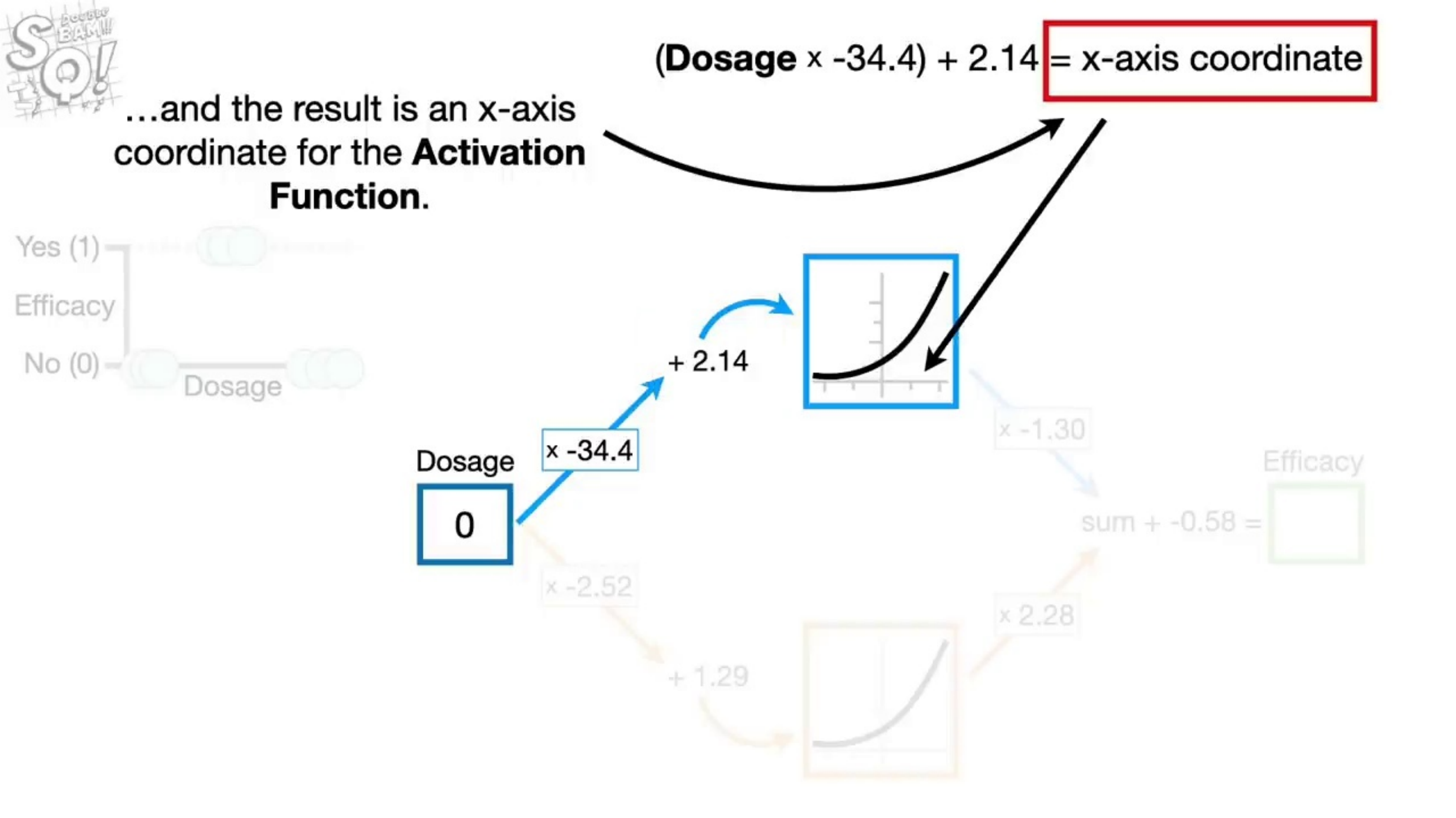


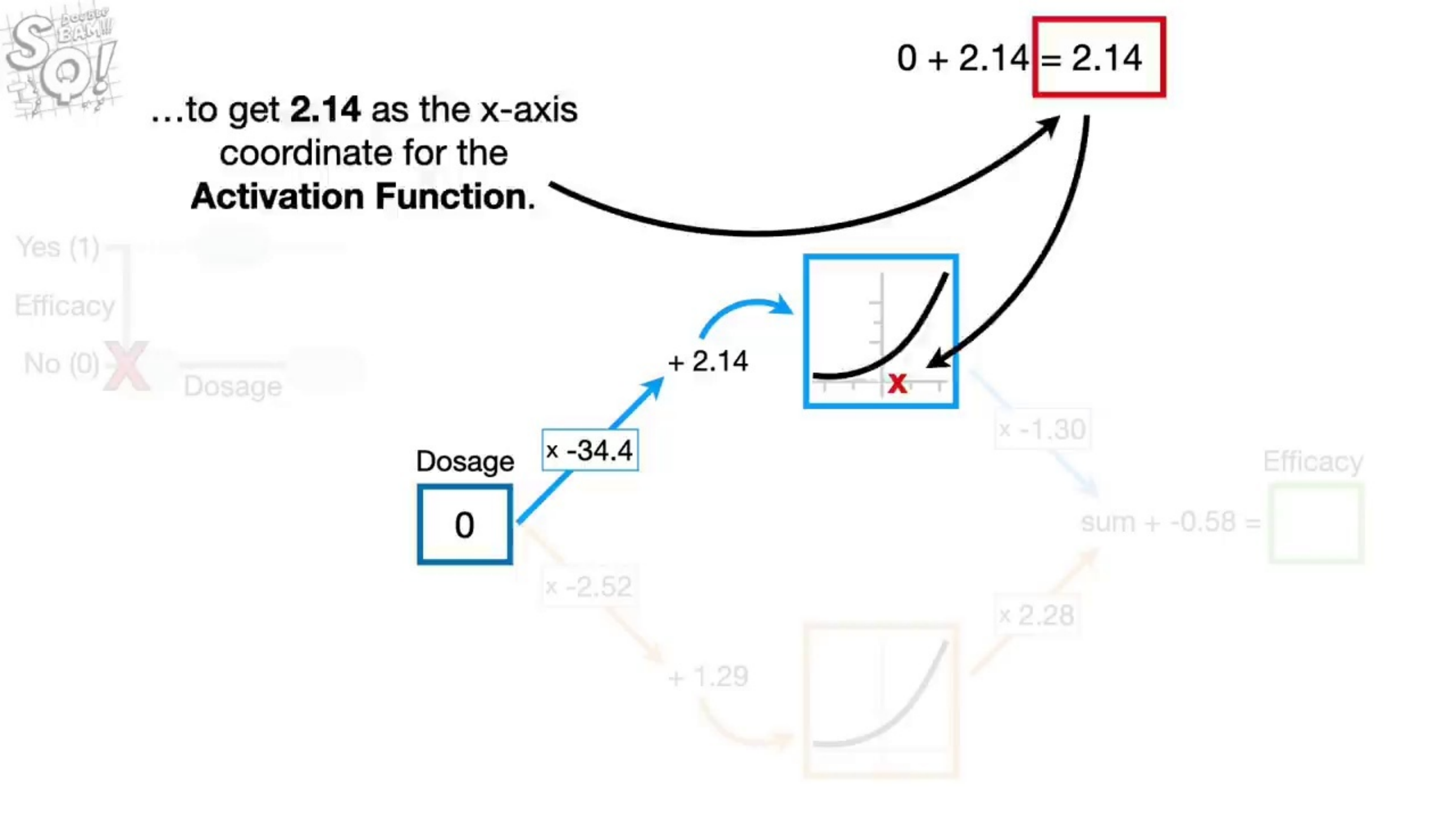
(**Dosage** x -34.4)

…this connection multiplies the **Dosage** by **-34.4**…



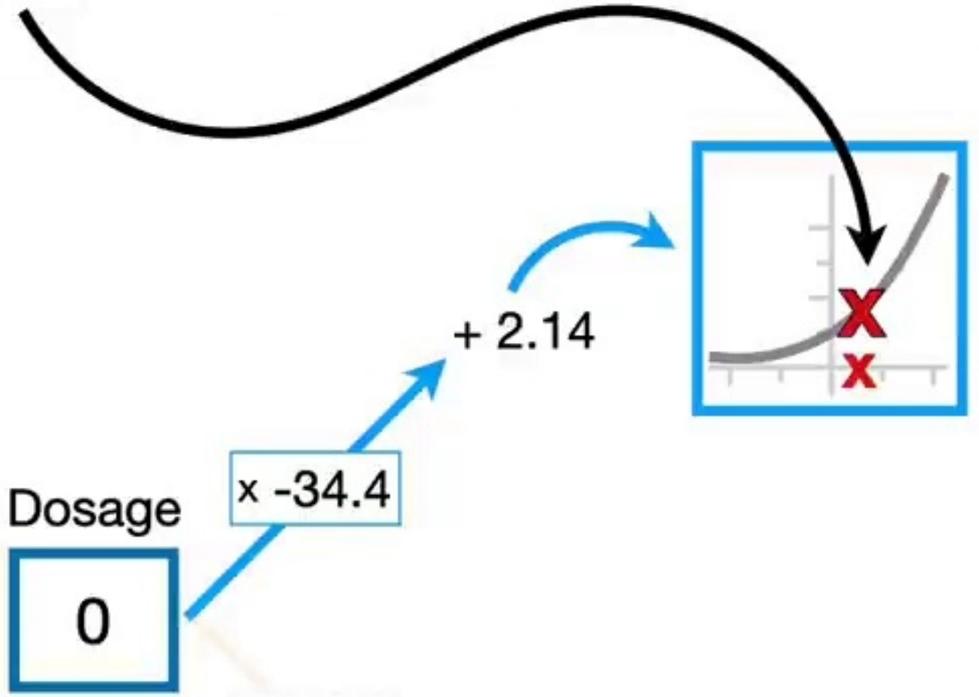

(Dosage x -34.4) + 2.14
…and then adds 2.14…
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

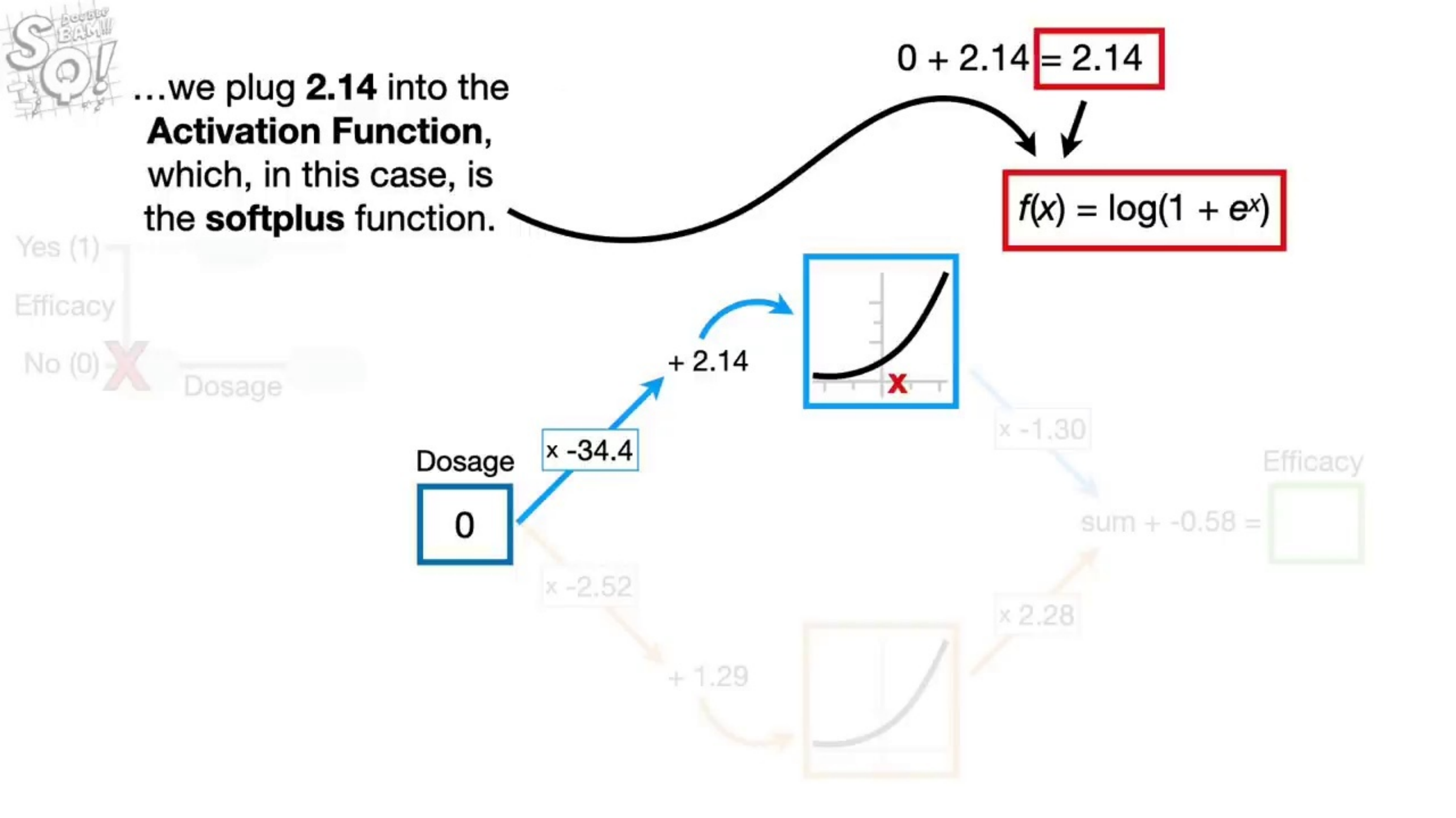

(Dosage x -34.4) + 2.14 = x-axis coordinate
…and the result is an x-axis coordinate for the Activation Function.
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

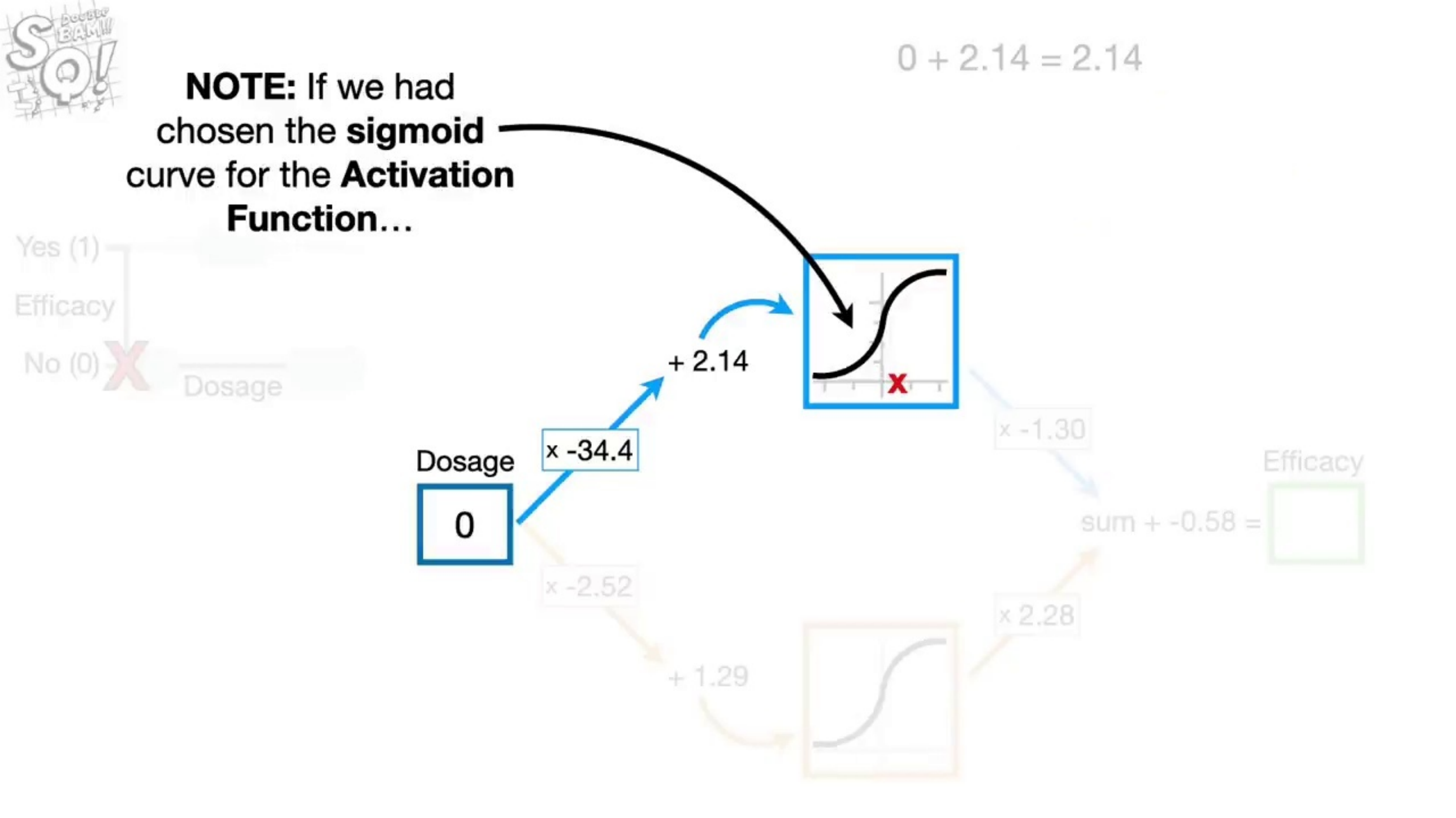

…to get **2.14** as the x-axis coordinate for the **Activation Function**.
0 + 2.14 = 2.14
+ 2.14
x
Dosage
0
x -34.4
Yes (1)
Efficacy
No (0)
Dosage
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

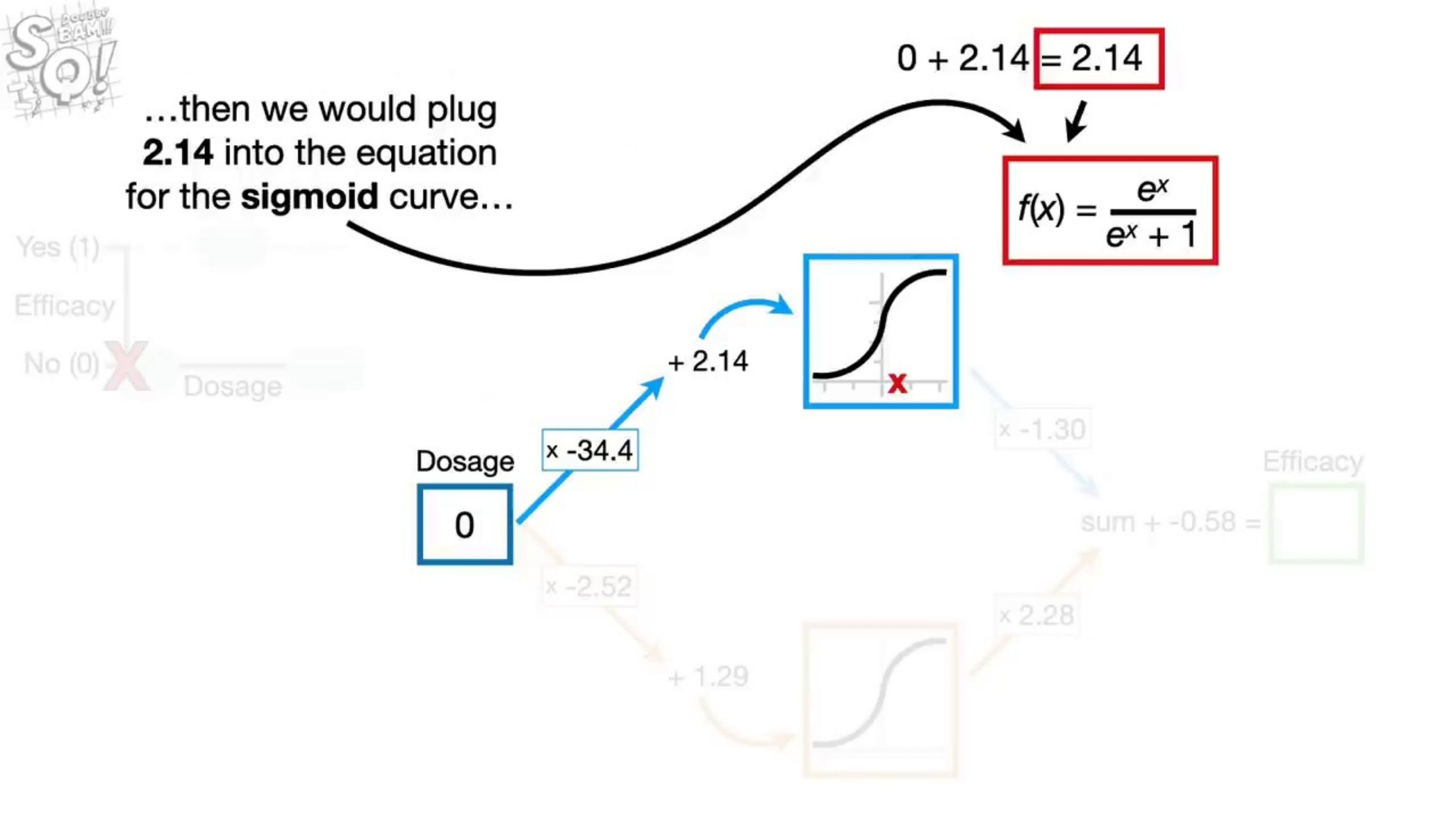
0 + 2.14 = 2.14

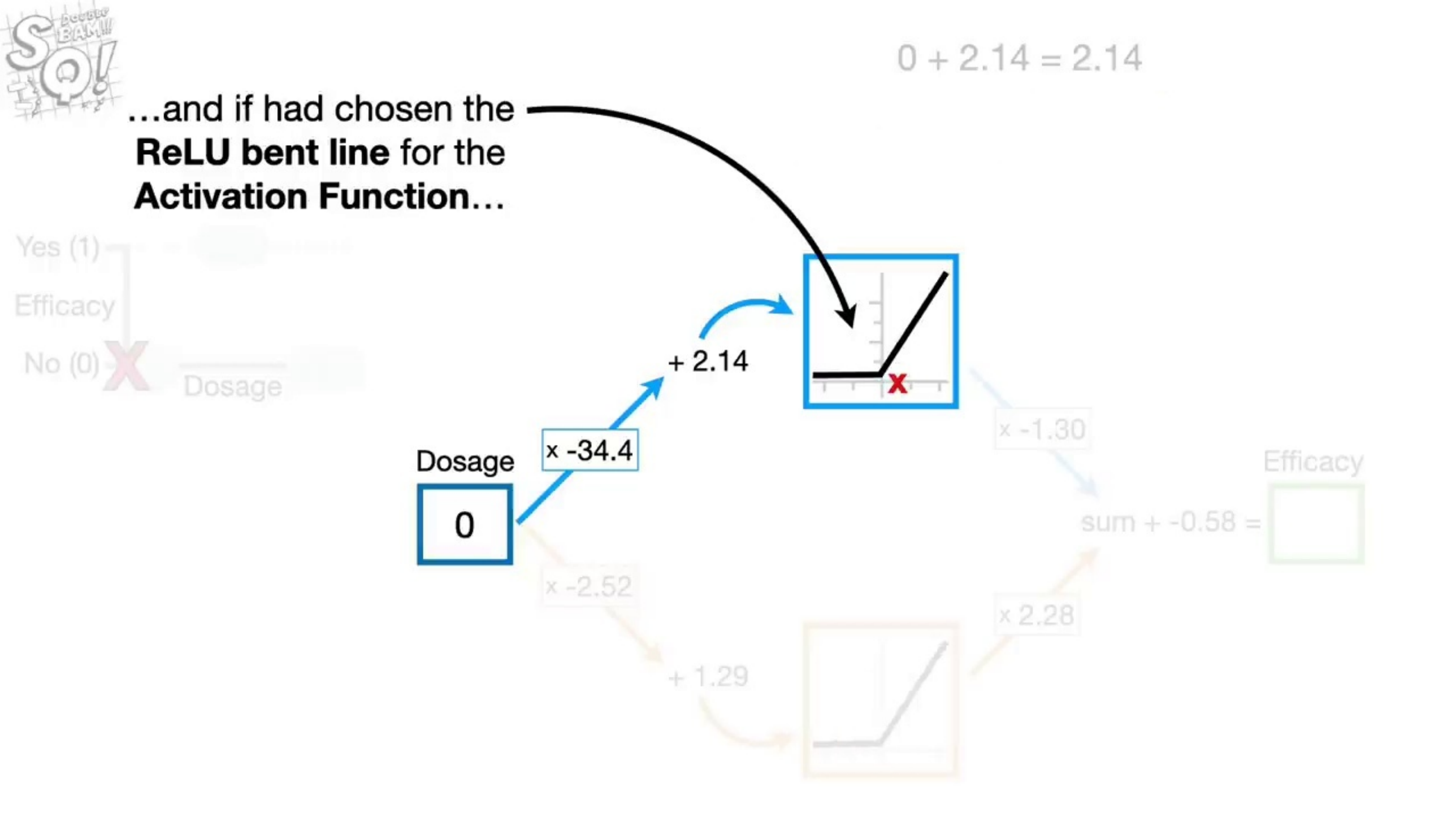
To get the corresponding y-axis value…

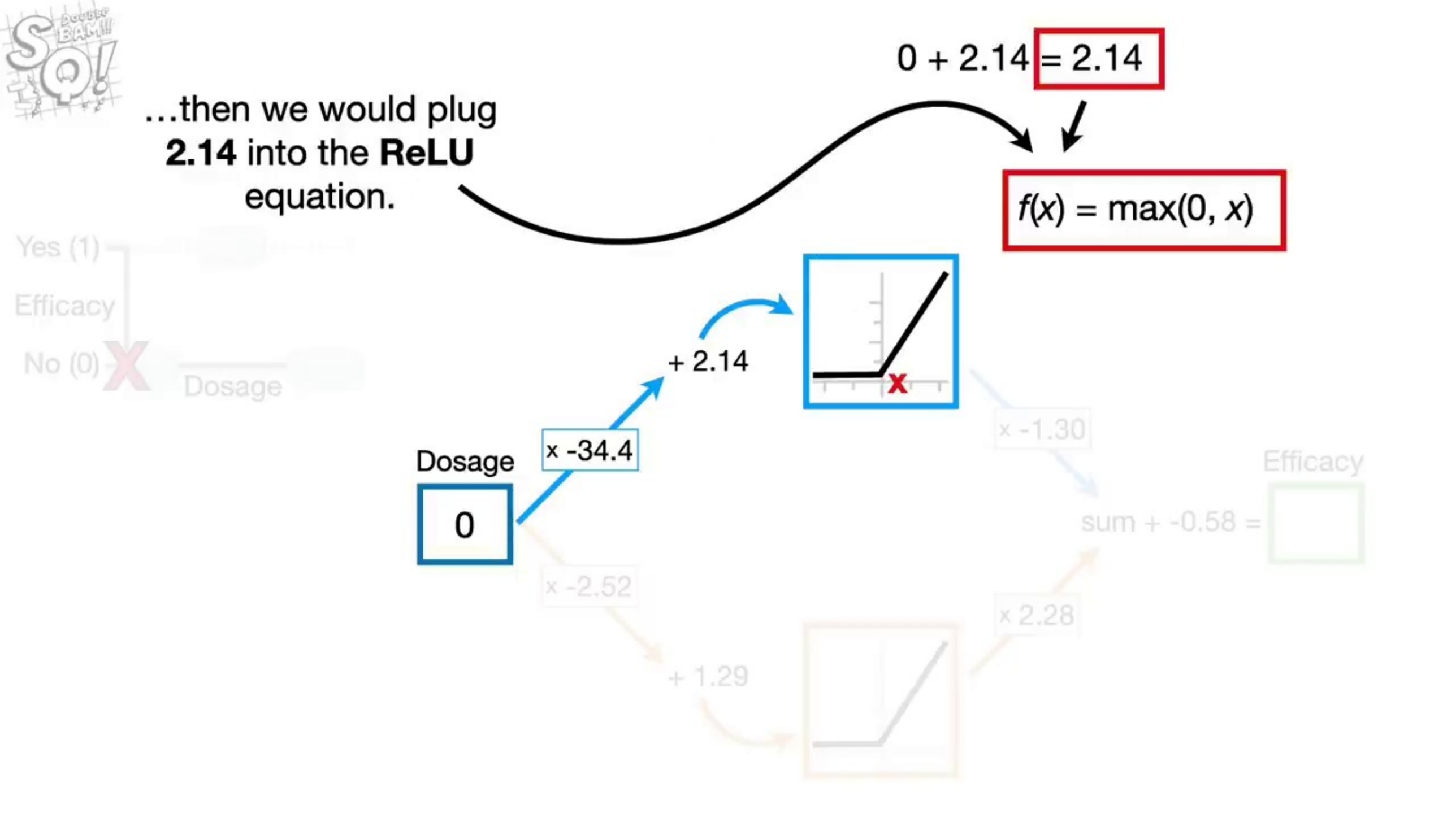


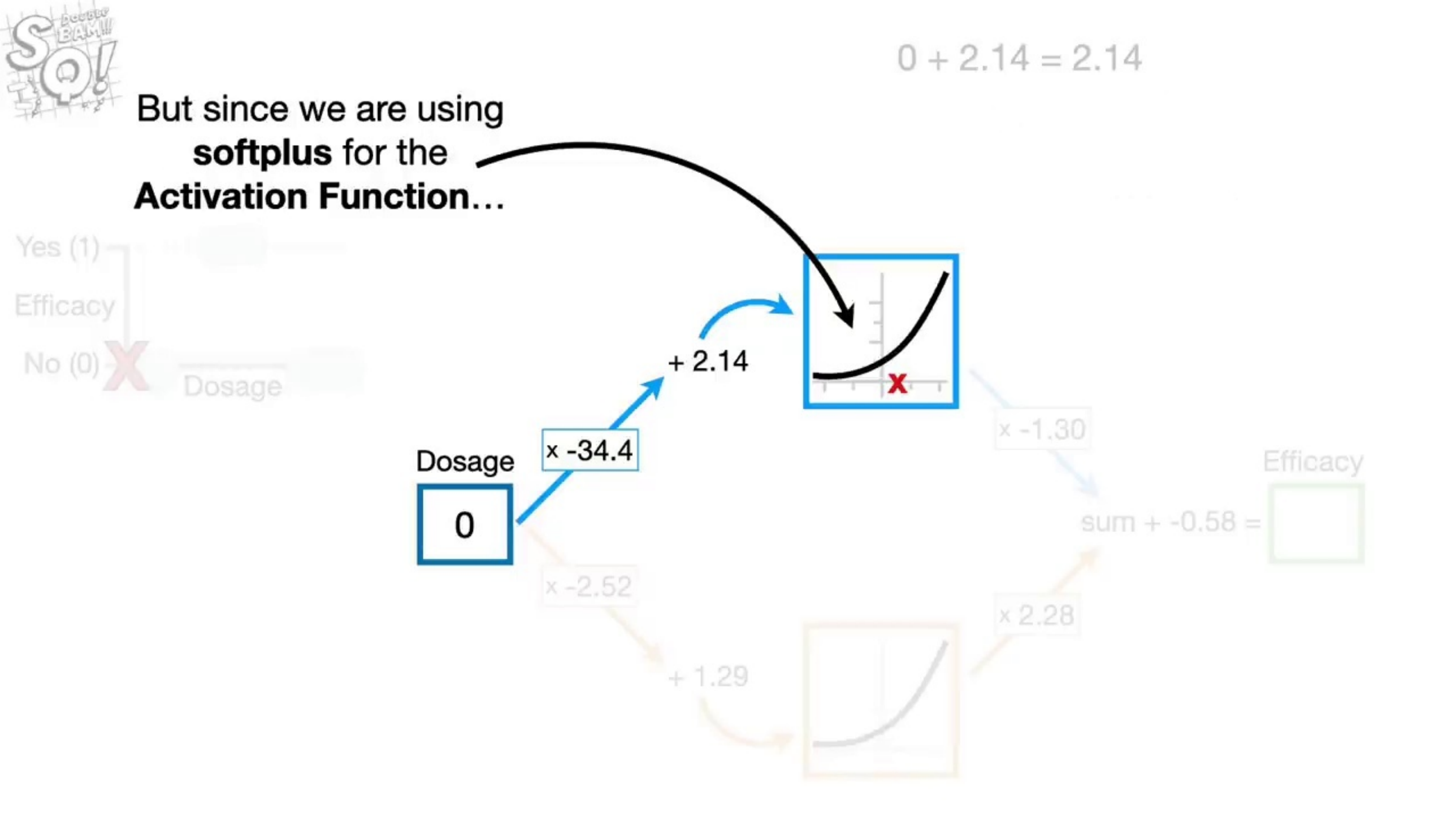

…we plug **2.14** into the **Activation Function**, which, in this case, is the **softplus** function.
0 + 2.14 = 2.14
$f(x) = \log(1 + e^x)$
Dosage
0
x -34.4
+ 2.14
x
Yes (1)
Efficacy
No (0)
Dosage
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

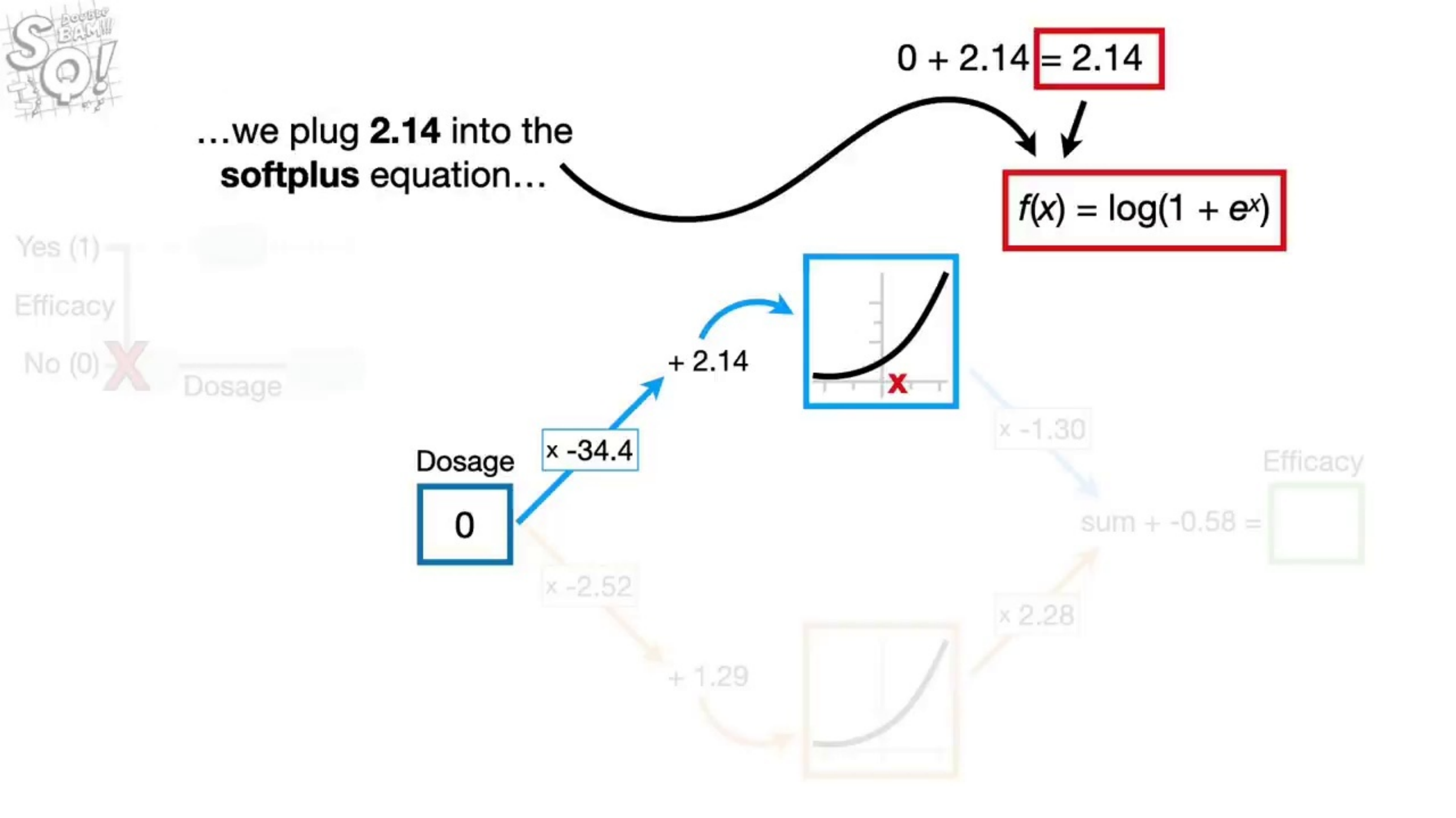

NOTE: If we had chosen the sigmoid curve for the Activation Function…
0 + 2.14 = 2.14
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x
Dosage
0
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

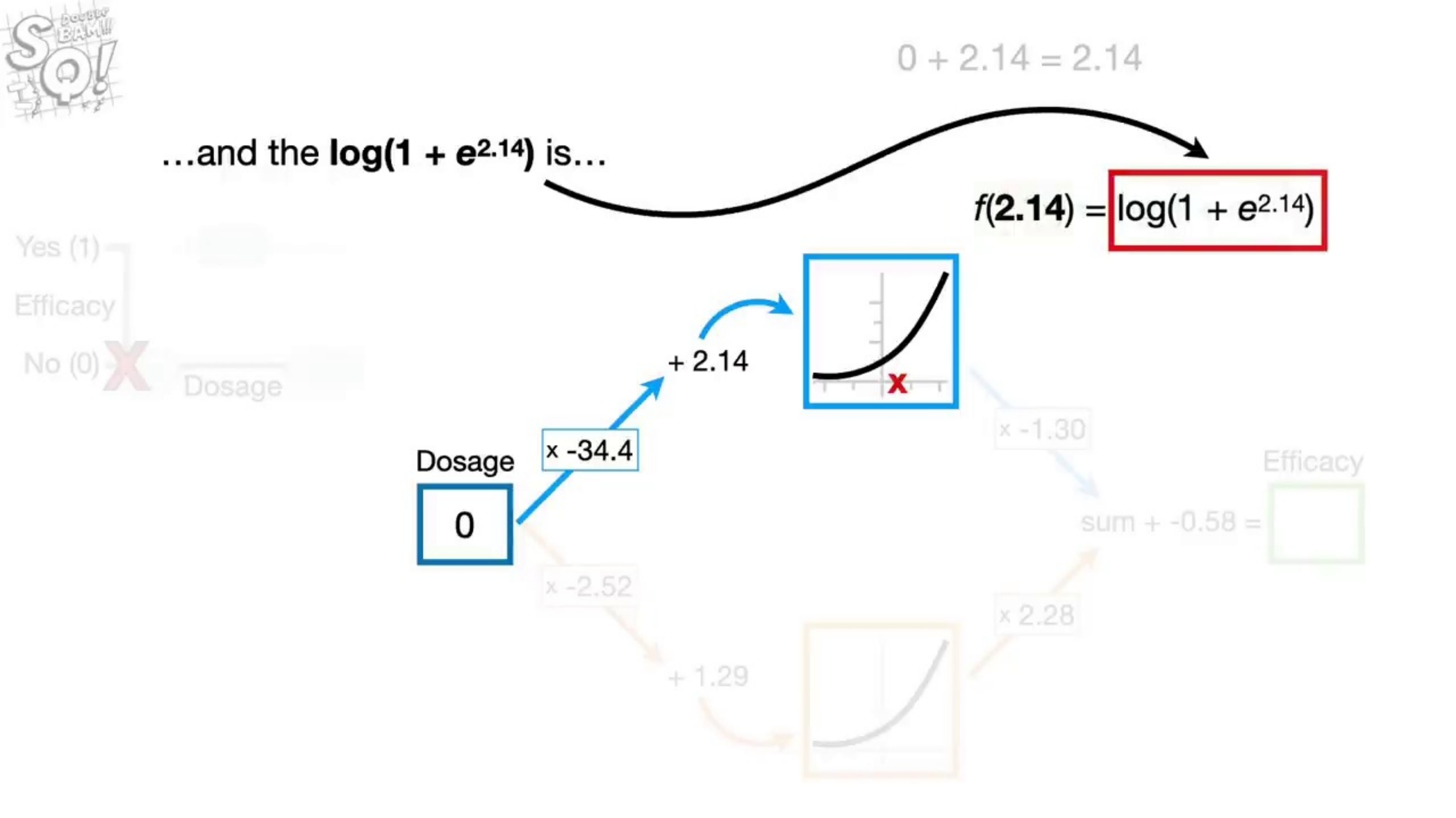

…then we would plug **2.14** into the equation for the **sigmoid** curve…
0 + 2.14 = 2.14
$f(x) = \frac{e^x}{e^x + 1}$
Dosage
0
x -34.4
+ 2.14
x
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28
Yes (1)
Efficacy
No (0)
Dosage

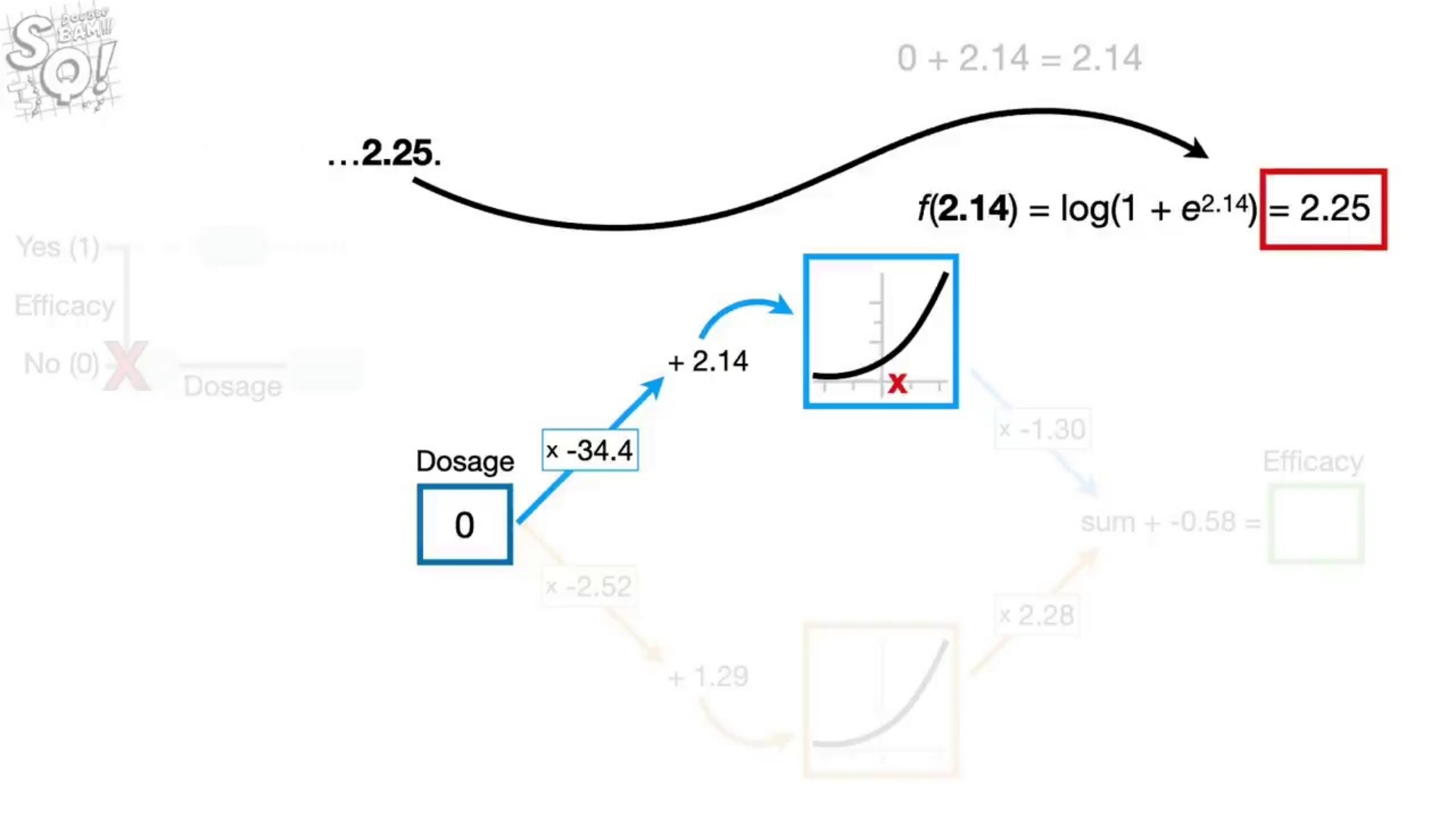

…and if had chosen the
ReLU bent line for the
Activation Function…
Dosage
0
x -34.4
+ 2.14
x
0 + 2.14 = 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28
Yes (1)
Efficacy
No (0)
Dosage


…then we would plug **2.14** into the **ReLU** equation.
0 + 2.14 = 2.14
f(x) = max(0, x)
Dosage
0
x -34.4
+ 2.14
x
x -1.30
sum + -0.58 =
Efficacy
x 2.28
+ 1.29
x -2.52
Yes (1)
Efficacy
No (0)
Dosage


But since we are using
softplus for the
Activation Function…
Dosage
0
x -34.4
+ 2.14
x

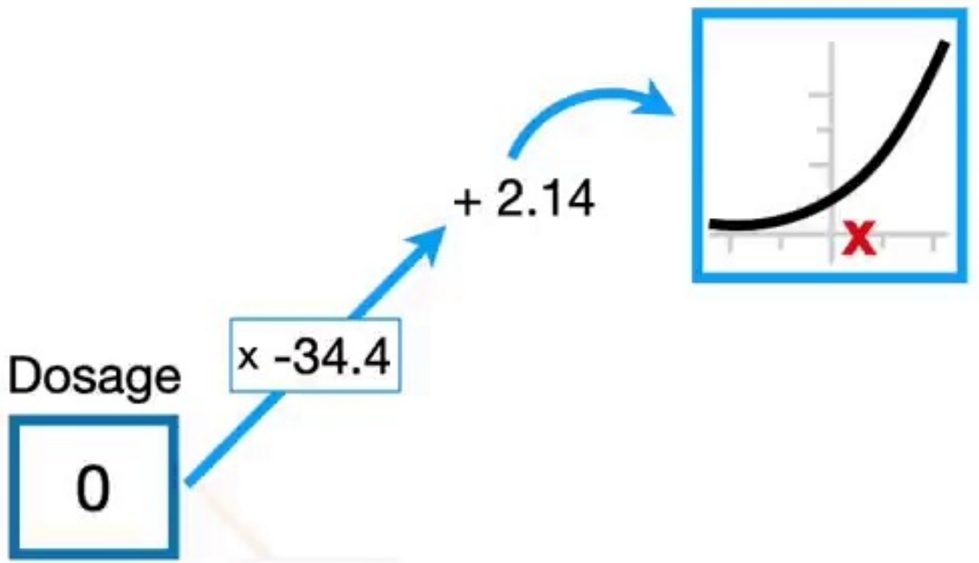

0 + 2.14 = 2.14
…we plug **2.14** into the **softplus** equation…
$f(x) = \log(1 + e^x)$
+ 2.14
Dosage
x -34.4
0
x -2.52
+ 1.29
x 2.28
x -1.30
sum + -0.58 =
Efficacy
Yes (1)
Efficacy
No (0)
Dosage


0 + 2.14 = 2.14
…and the log(1 + e^2.14) is…
f(2.14) = log(1 + e^2.14)
Yes (1)
Efficacy
No (0)
X
Dosage
+ 2.14
x
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29


0 + 2.14 = 2.14
…2.25.
$f(2.14) = \log(1 + e^{2.14}) = 2.25$
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x
x -1.30
Efficacy
Dosage
x -34.4
0
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

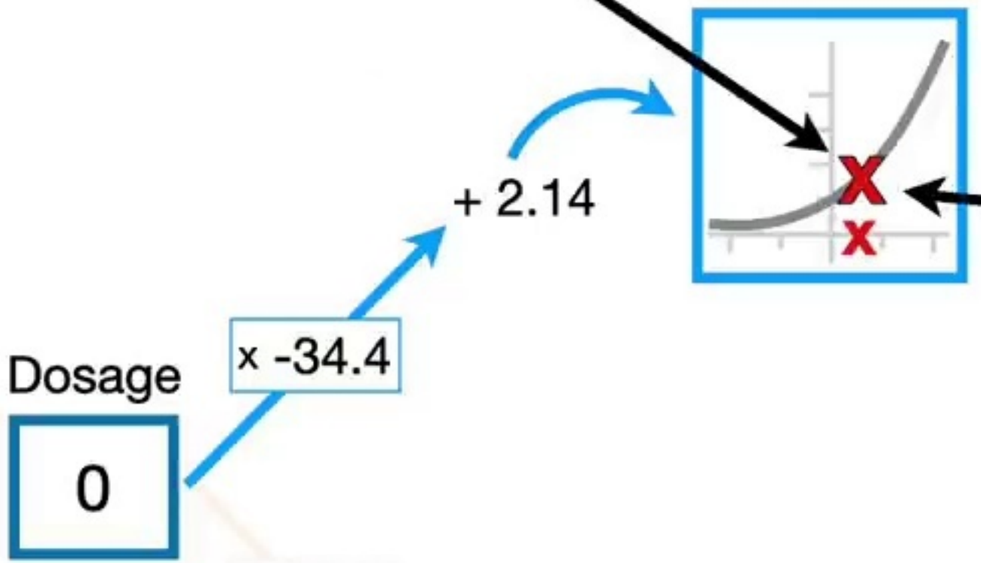
NOTE: In statistics, machine learning and most programming languages, **log()** implies the **natural log** (**ln**), or the log base ***e***.

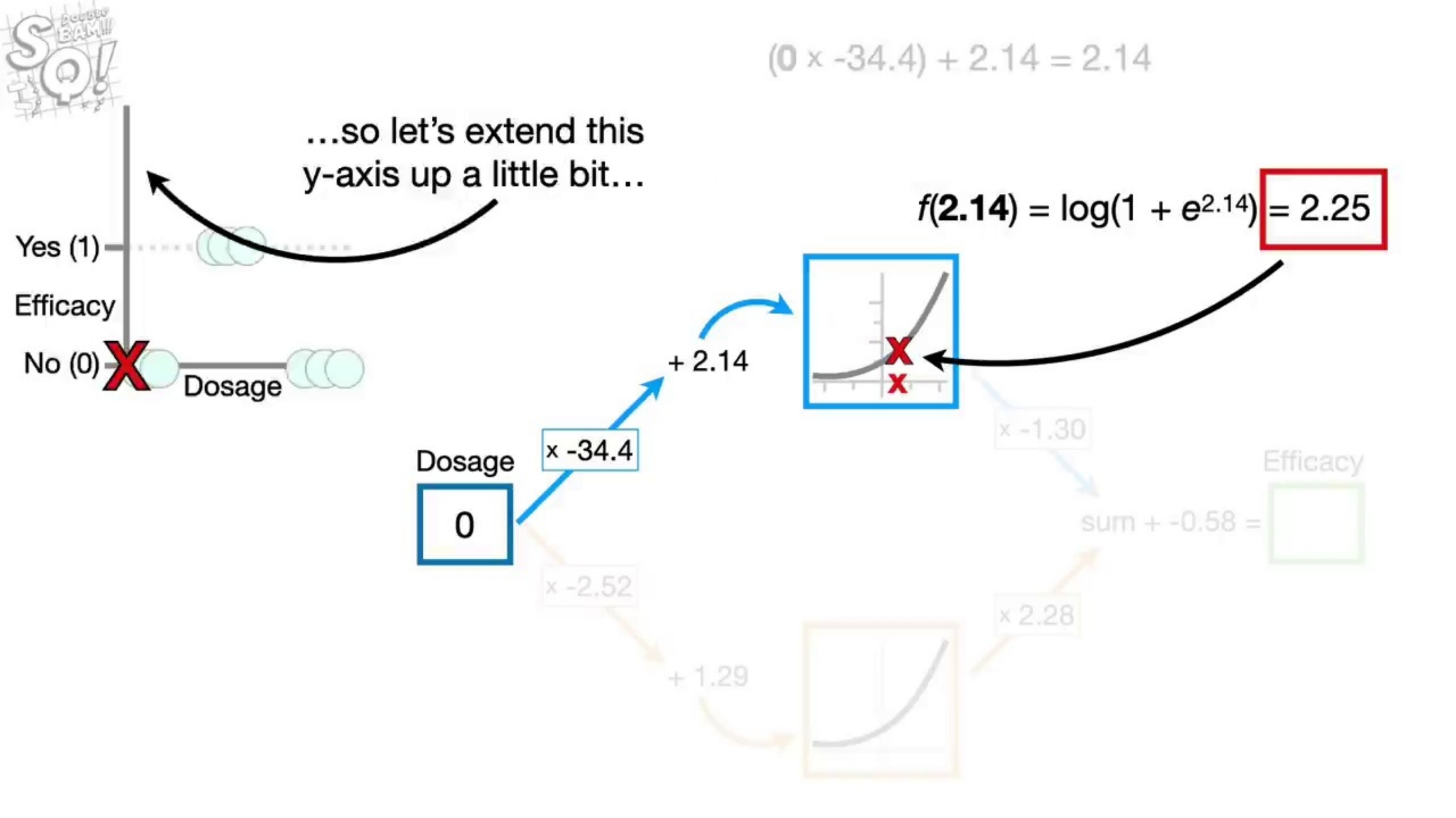
$$f(\mathbf{2.14}) = \log(1 + e^{2.14}) = 2.25$$

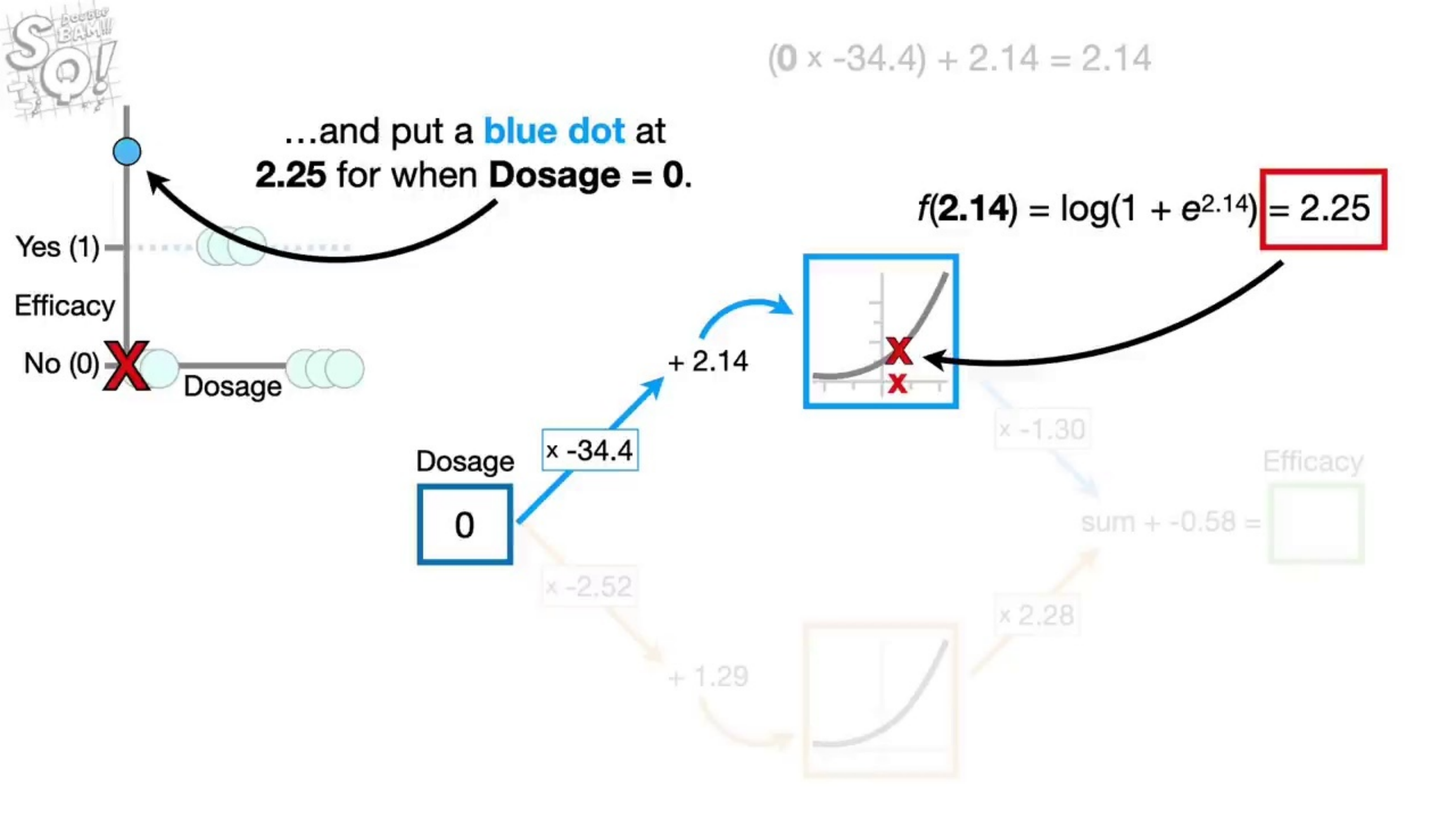


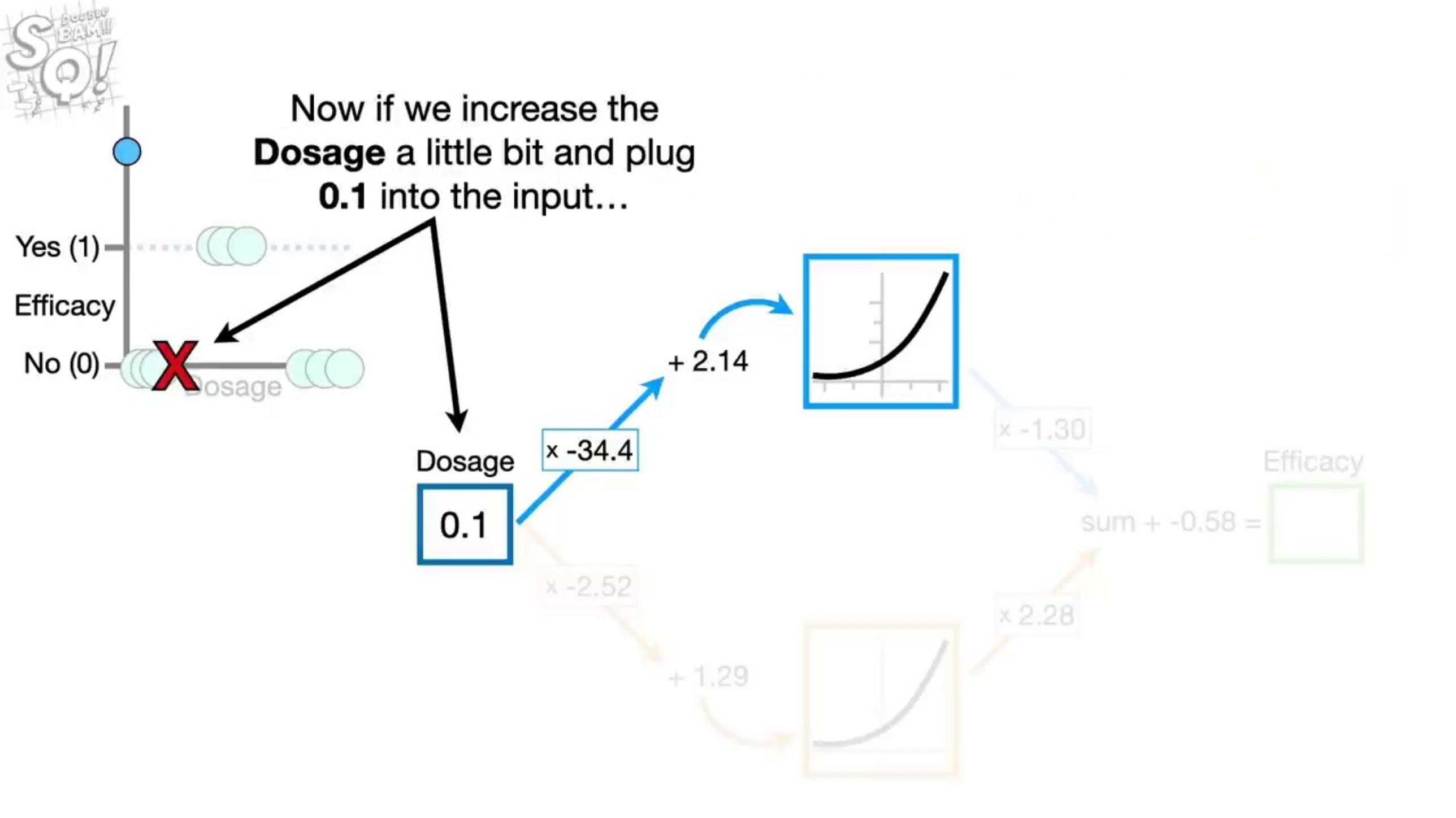
Anyway, the y-axis coordinate for the **Activation Function** is **2.25**.

$f(\mathbf{2.14}) = \log(1 + e^{2.14}) = 2.25$



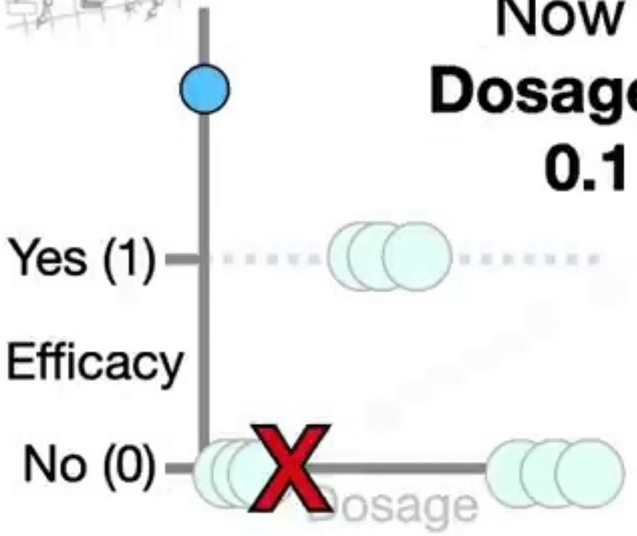

(0 x -34.4) + 2.14 = 2.14
…so let's extend this y-axis up a little bit…
f(2.14) = log(1 + e^2.14) = 2.25
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29


(0 x -34.4) + 2.14 = 2.14
…and put a blue dot at
2.25 for when Dosage = 0.
Yes (1)
Efficacy
No (0)
Dosage
f(2.14) = log(1 + e^2.14) = 2.25
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29


Now if we increase the
Dosage a little bit and plug
0.1 into the input…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.1
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

(**Dosage** x -34.4) + 2.14 = x-axis coordinate

Now if we increase the **Dosage** a little bit and plug **0.1** into the input…



Dosage

0.1

x -34.4

+ 2.14

x -1.30

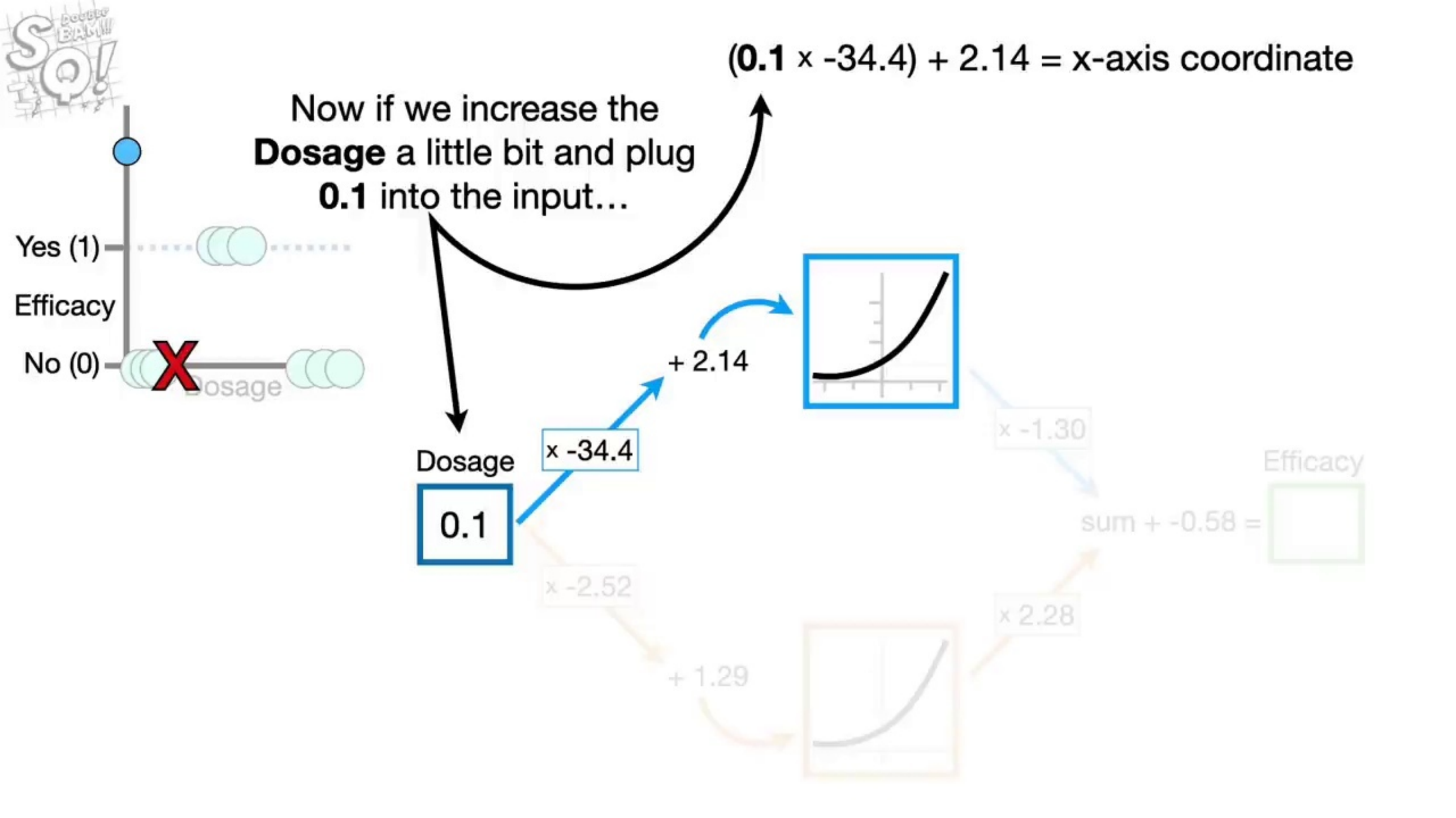
Efficacy

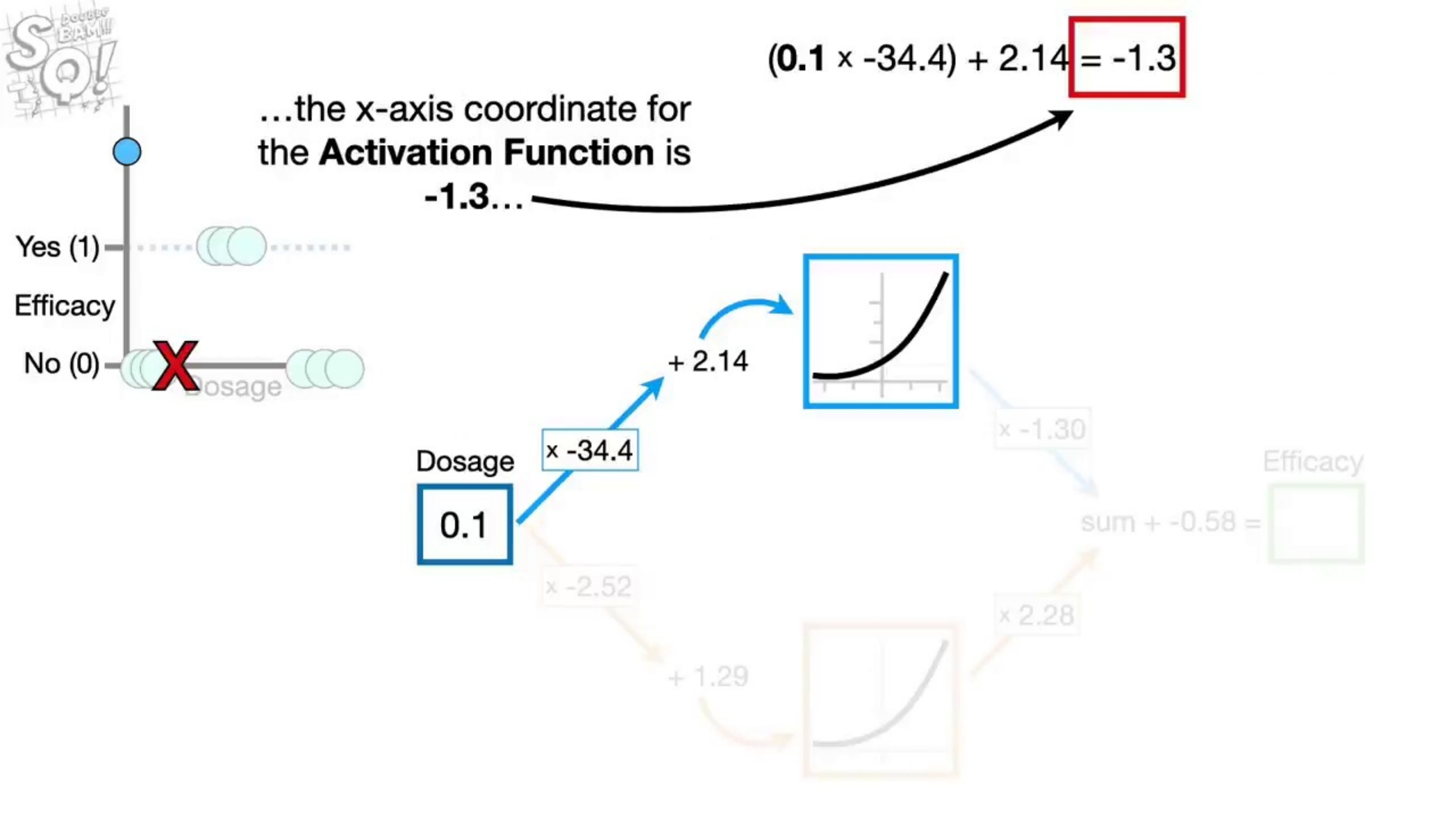
sum + -0.58 =

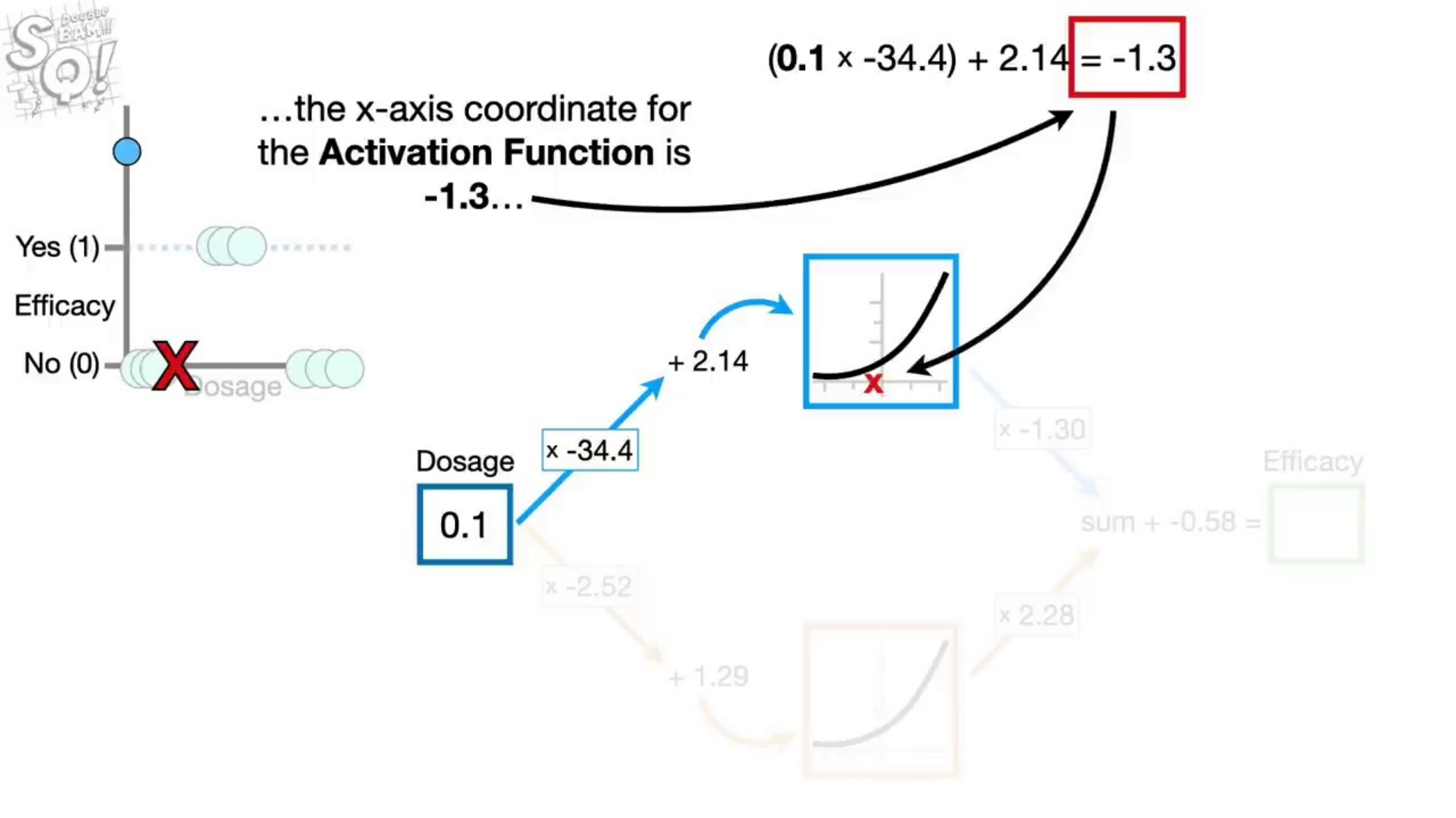
x -2.52

+ 1.29

x 2.28


(0.1 x -34.4) + 2.14 = x-axis coordinate
Now if we increase the Dosage a little bit and plug 0.1 into the input…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.1
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

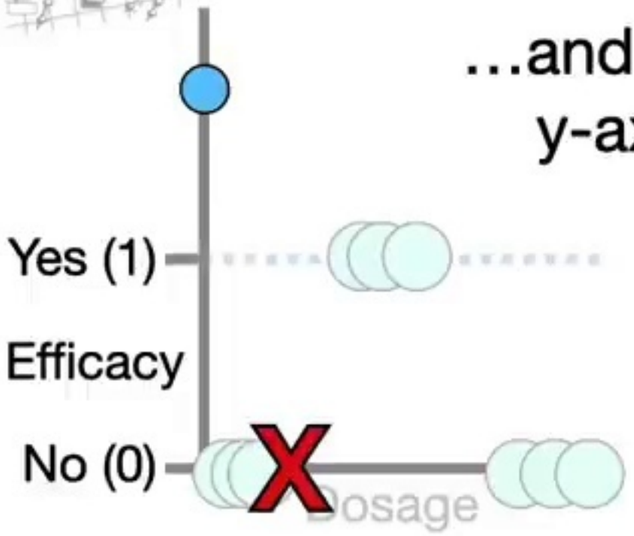

So!
…the x-axis coordinate for the **Activation Function** is **-1.3**…
(**0.1** x -34.4) + 2.14 = -1.3
Yes (1)
Efficacy
No (0)
X
Dosage
Dosage
0.1
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

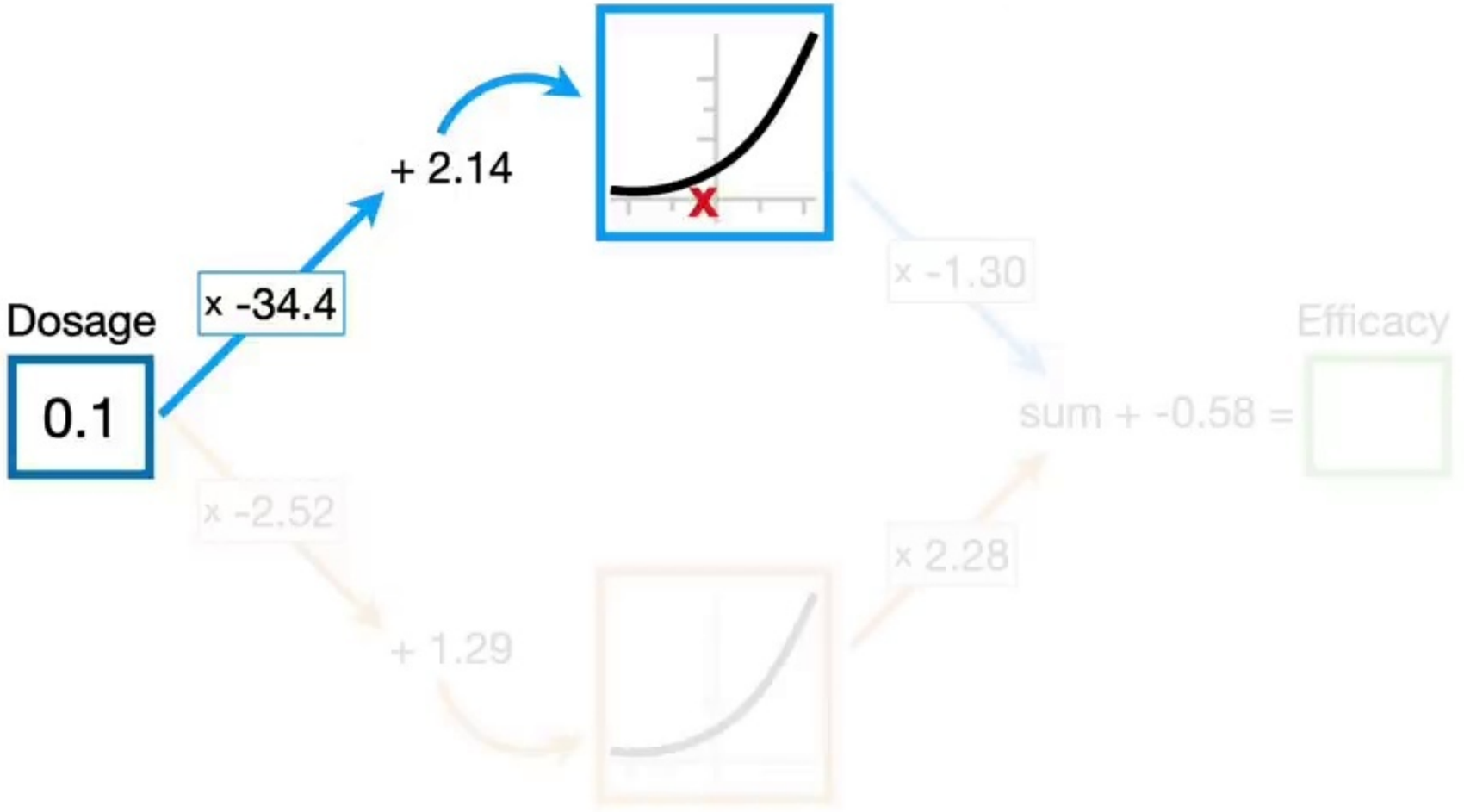

(0.1 x -34.4) + 2.14 = -1.3
…the x-axis coordinate for the Activation Function is -1.3…
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0.1
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

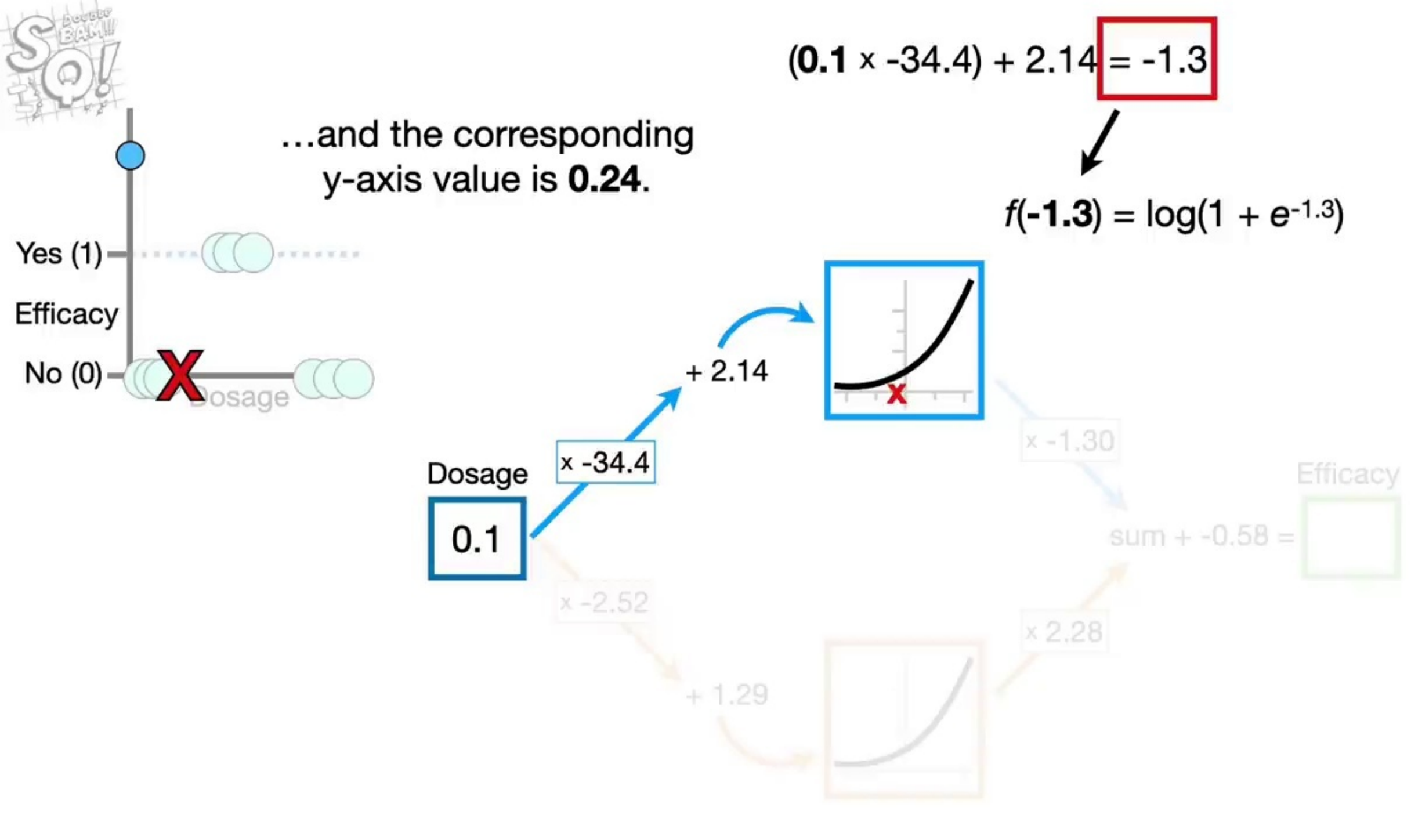
$(\mathbf{0.1} \times -34.4) + 2.14 = -1.3$

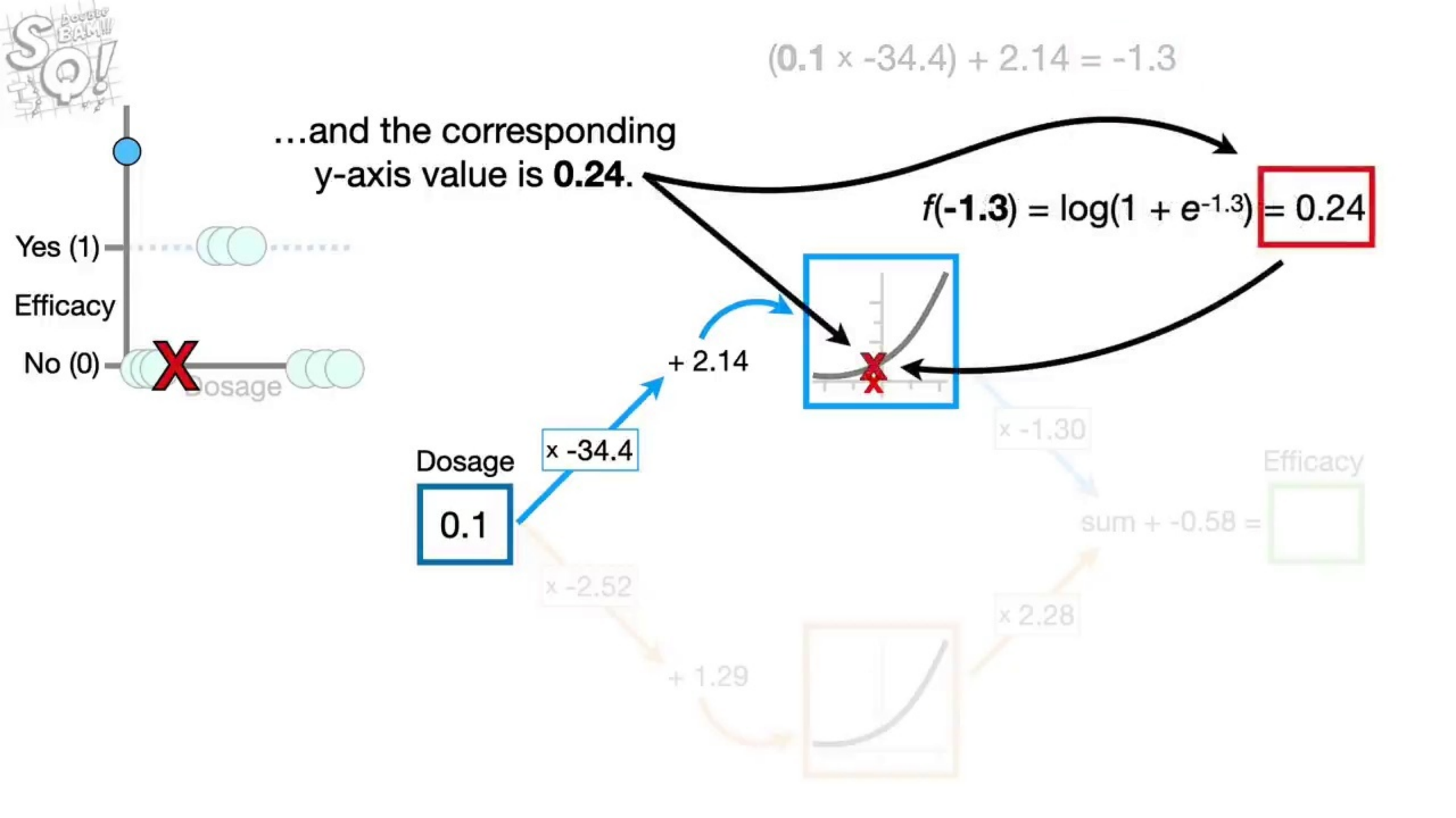
$f(x) = \log(1 + e^x)$

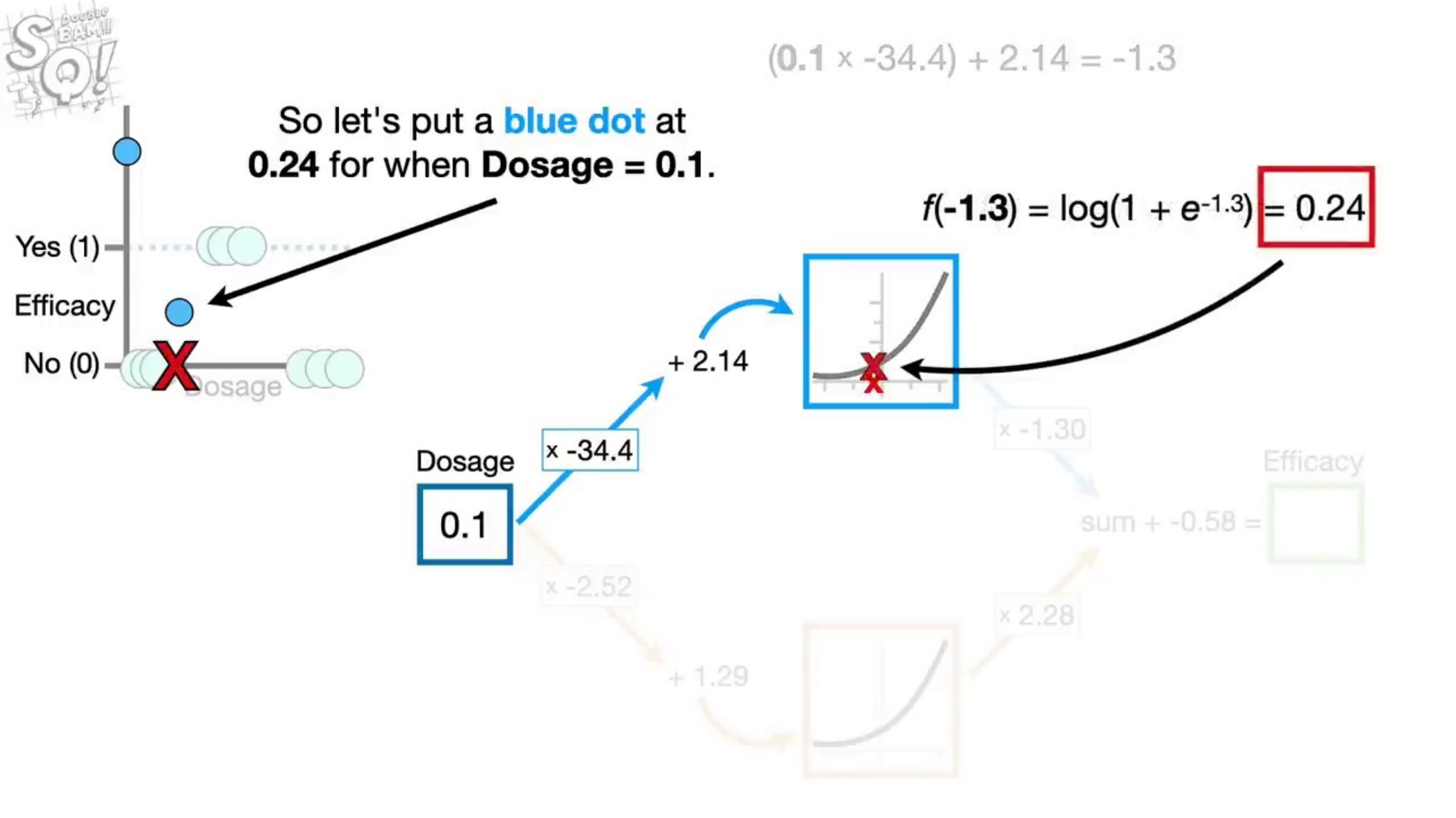
…and the corresponding y-axis value is **0.24**.

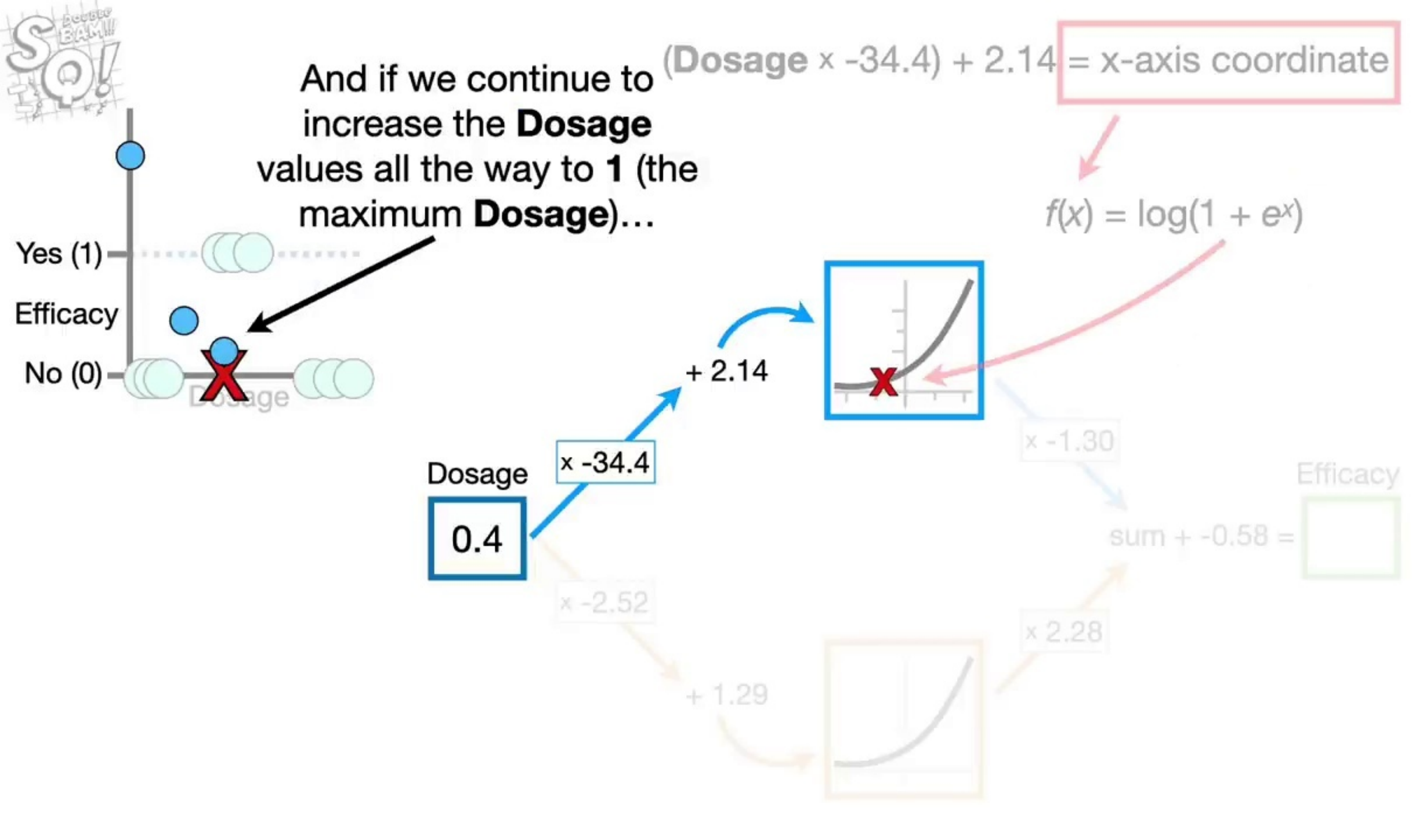


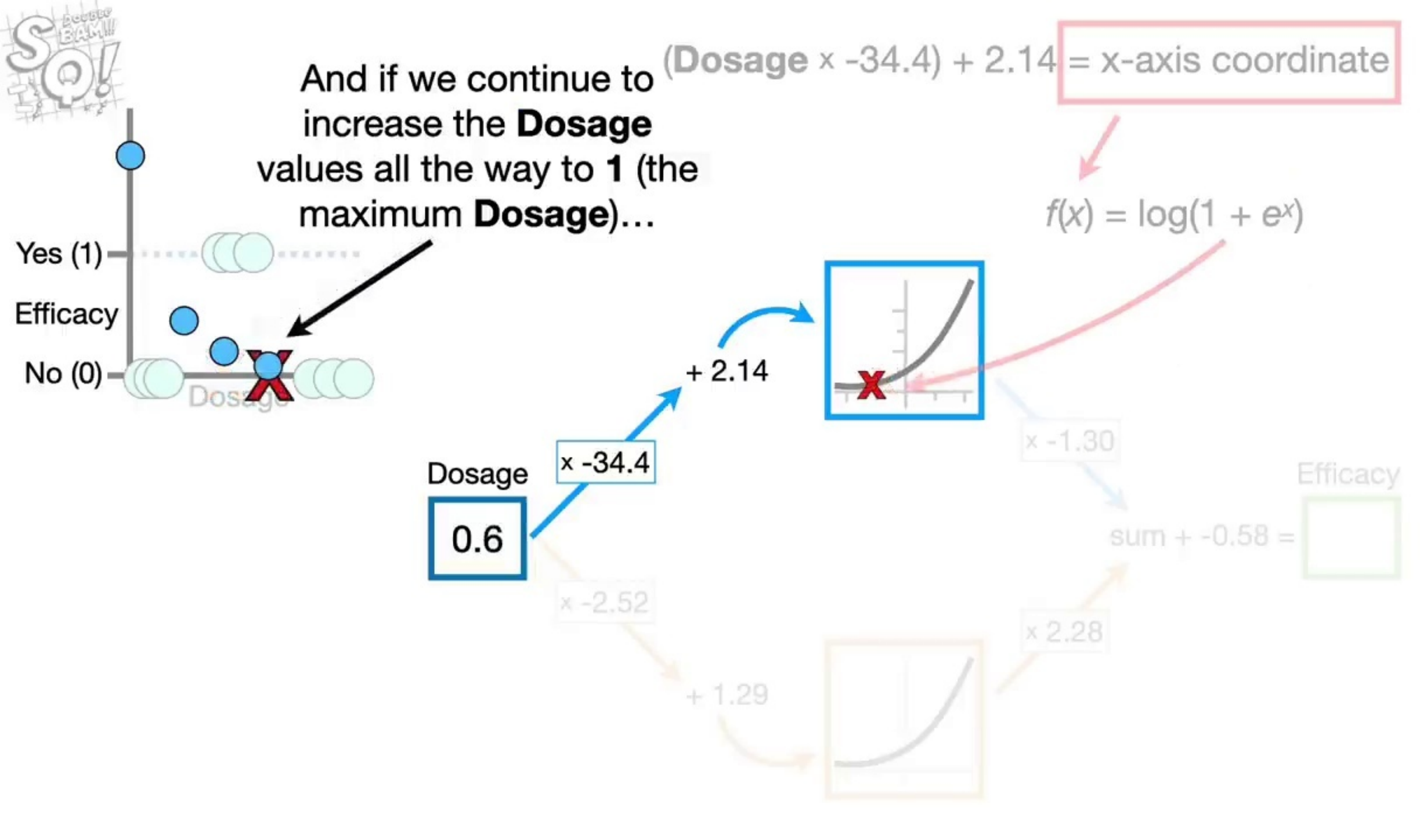


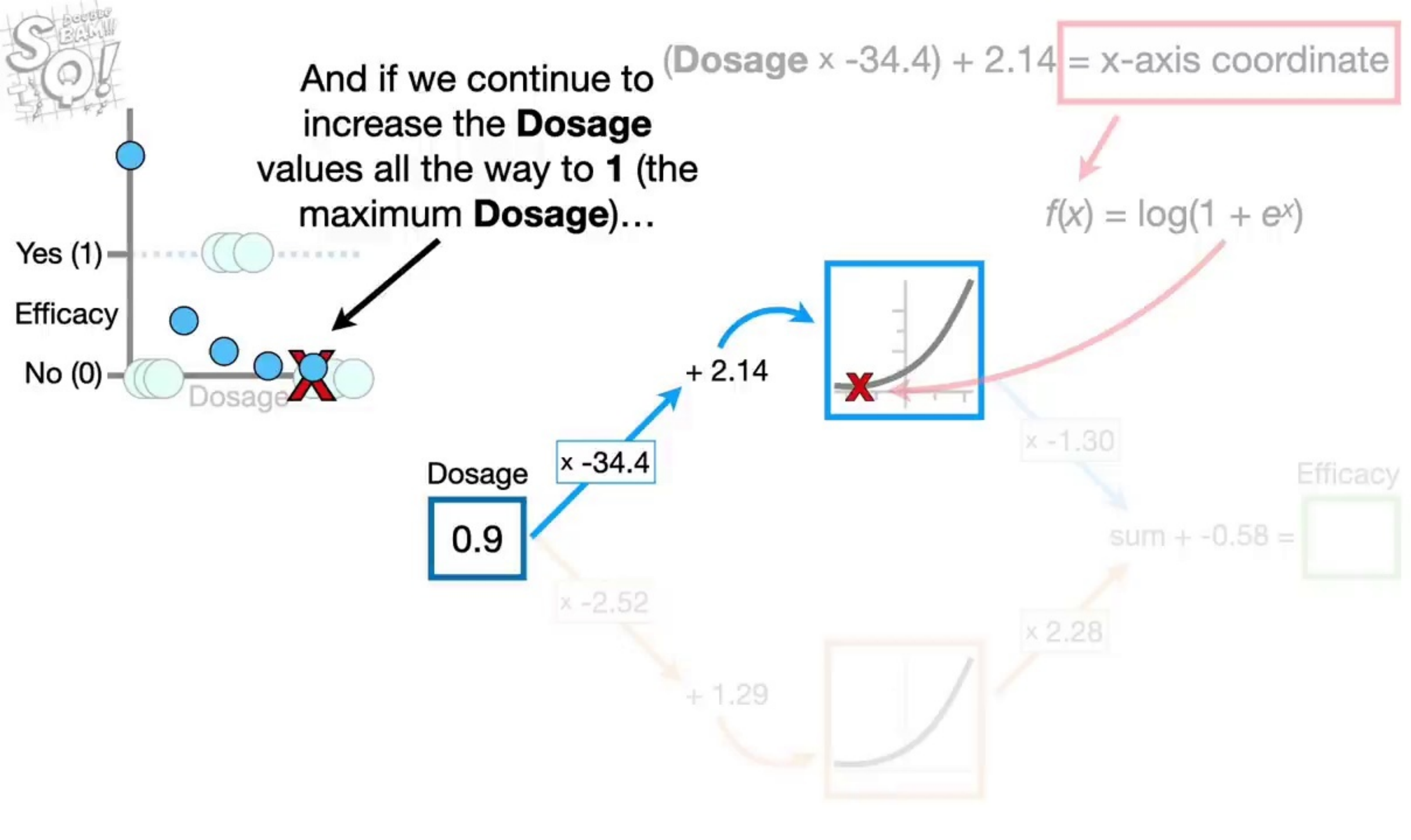

(0.1 x -34.4) + 2.14 = -1.3
f(-1.3) = log(1 + e^-1.3)
…and the corresponding y-axis value is 0.24.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.1
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

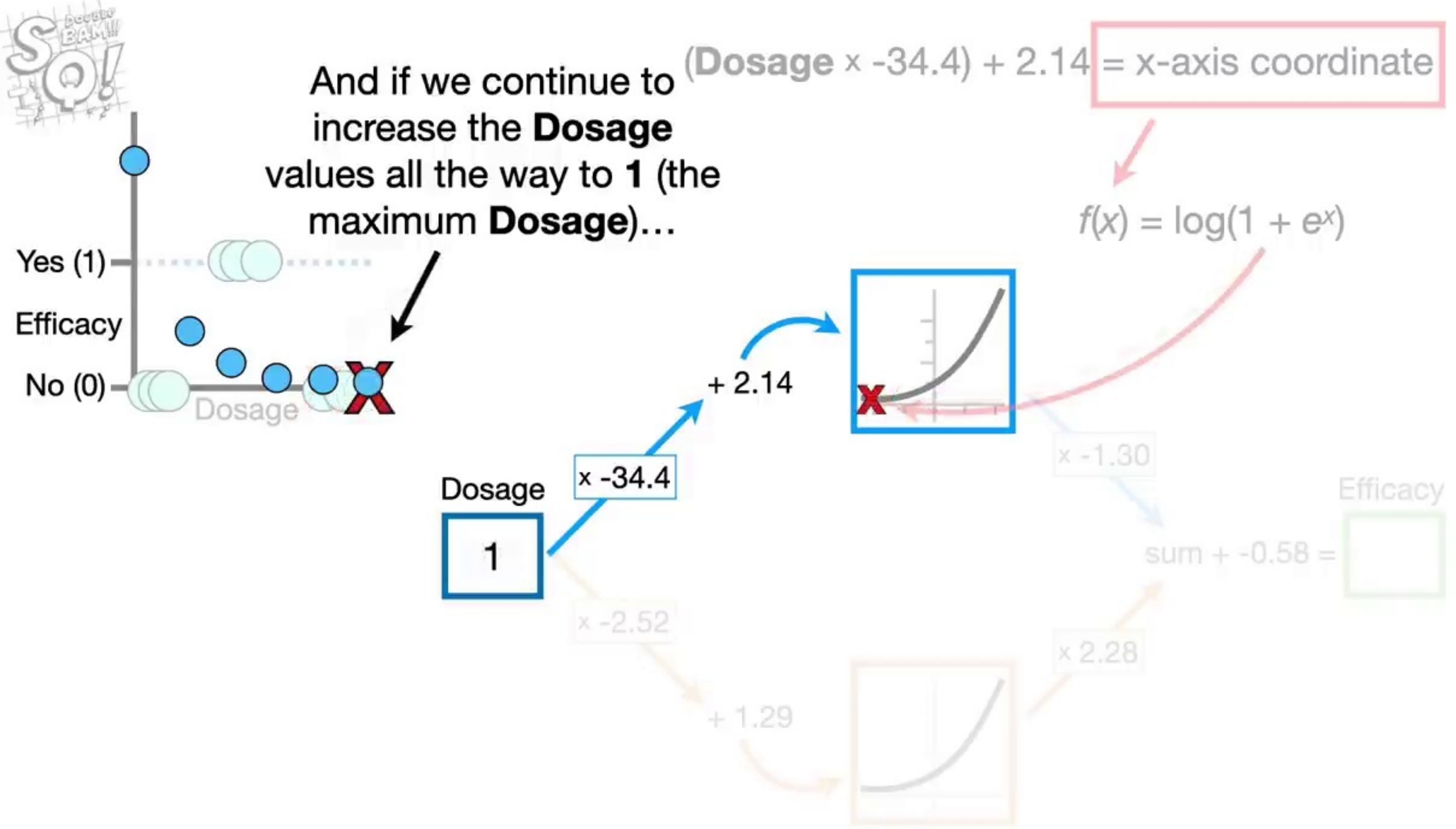

(0.1 x -34.4) + 2.14 = -1.3
…and the corresponding y-axis value is 0.24.
f(-1.3) = log(1 + e^-1.3) = 0.24
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0.1
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

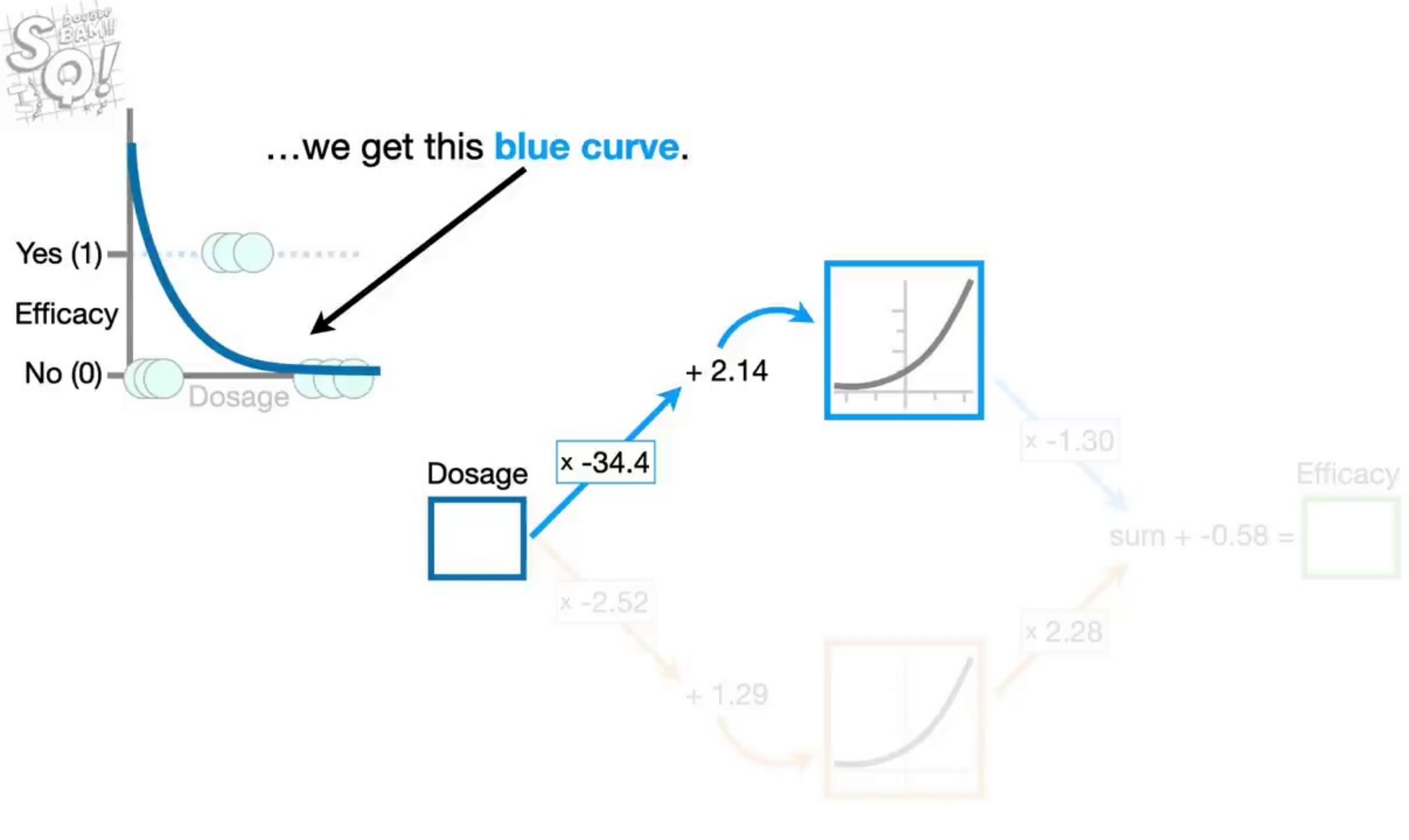

(0.1 x -34.4) + 2.14 = -1.3
So let's put a blue dot at
0.24 for when Dosage = 0.1.
Yes (1)
Efficacy
No (0)
Dosage
f(-1.3) = log(1 + e^-1.3) = 0.24
+ 2.14
Dosage
x -34.4
0.1
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29


So!
Double BAM!!!
And if we continue to increase the **Dosage** values all the way to **1** (the maximum **Dosage**)…
Yes (1)
Efficacy
No (0)
Dosage
(**Dosage** x -34.4) + 2.14 = x-axis coordinate
$f(x) = \log(1 + e^x)$
Dosage
0.4
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

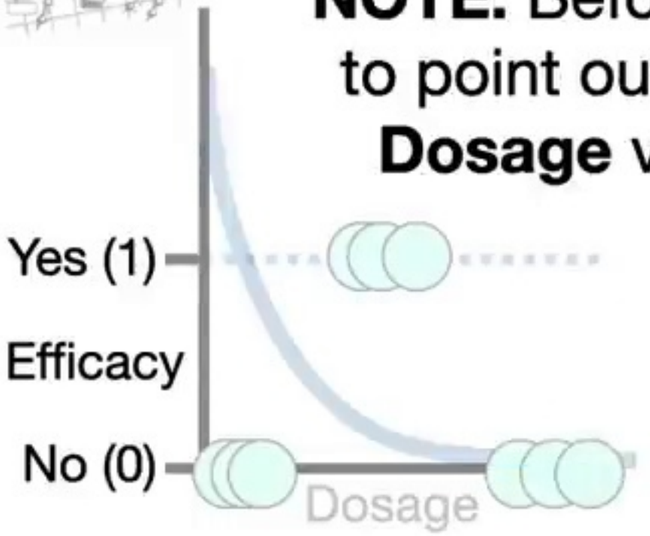

So!
Double BAM!!!
And if we continue to increase the **Dosage** values all the way to **1** (the maximum **Dosage**)…
Yes (1)
Efficacy
No (0)
Dosage
(Dosage x -34.4) + 2.14 = x-axis coordinate
$f(x) = \log(1 + e^x)$
+ 2.14
Dosage
x -34.4
0.6
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

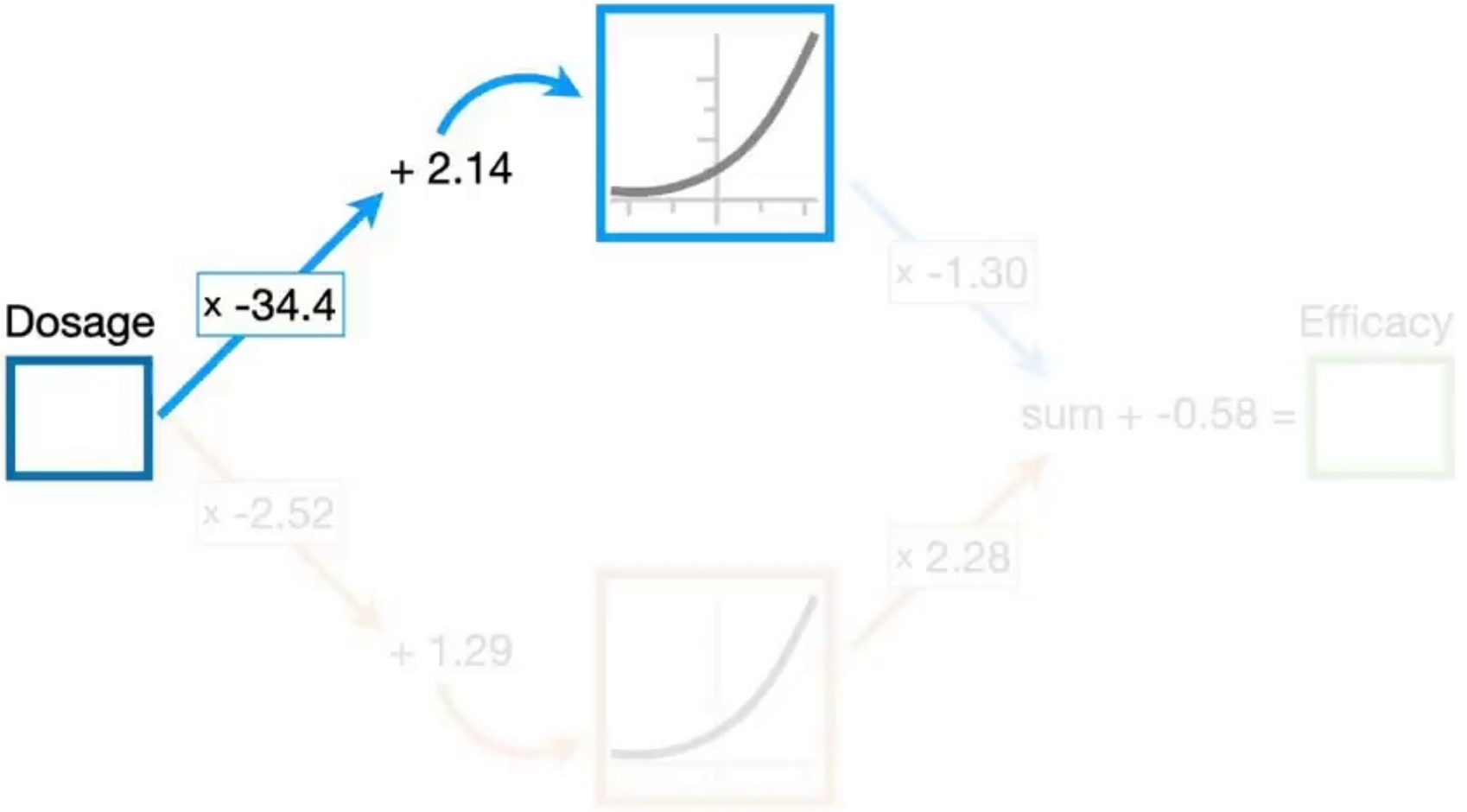

And if we continue to increase the **Dosage** values all the way to **1** (the maximum **Dosage**)…
Yes (1)
Efficacy
No (0)
Dosage
(Dosage x -34.4) + 2.14 = x-axis coordinate
$f(x) = \log(1 + e^x)$
Dosage
0.9
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28


And if we continue to increase the **Dosage** values all the way to **1** (the maximum **Dosage**)…
Yes (1)
Efficacy
No (0)
Dosage
(Dosage x -34.4) + 2.14 = x-axis coordinate
$f(x) = \log(1 + e^x)$
Dosage
1
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

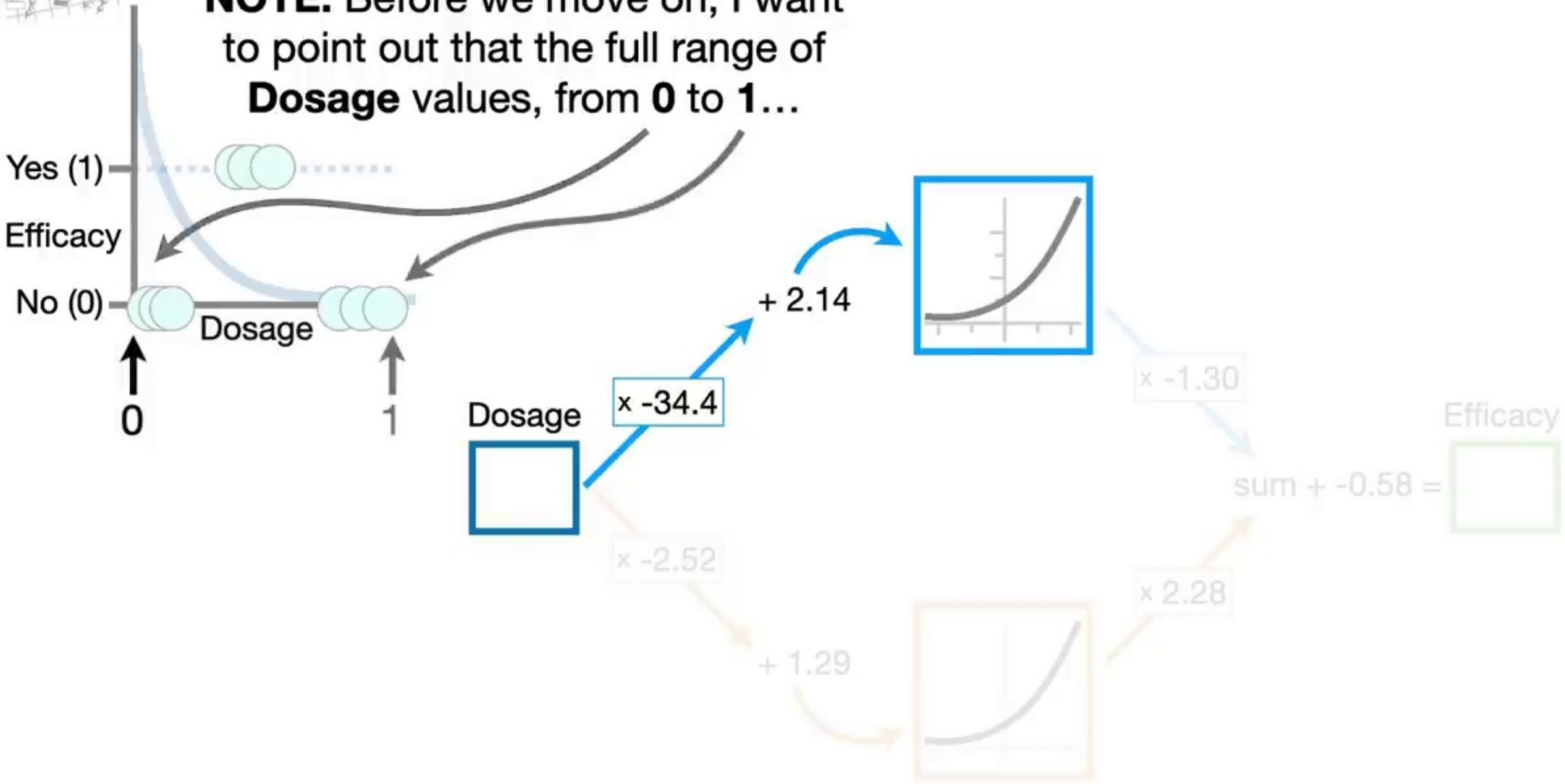

…we get this blue curve.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

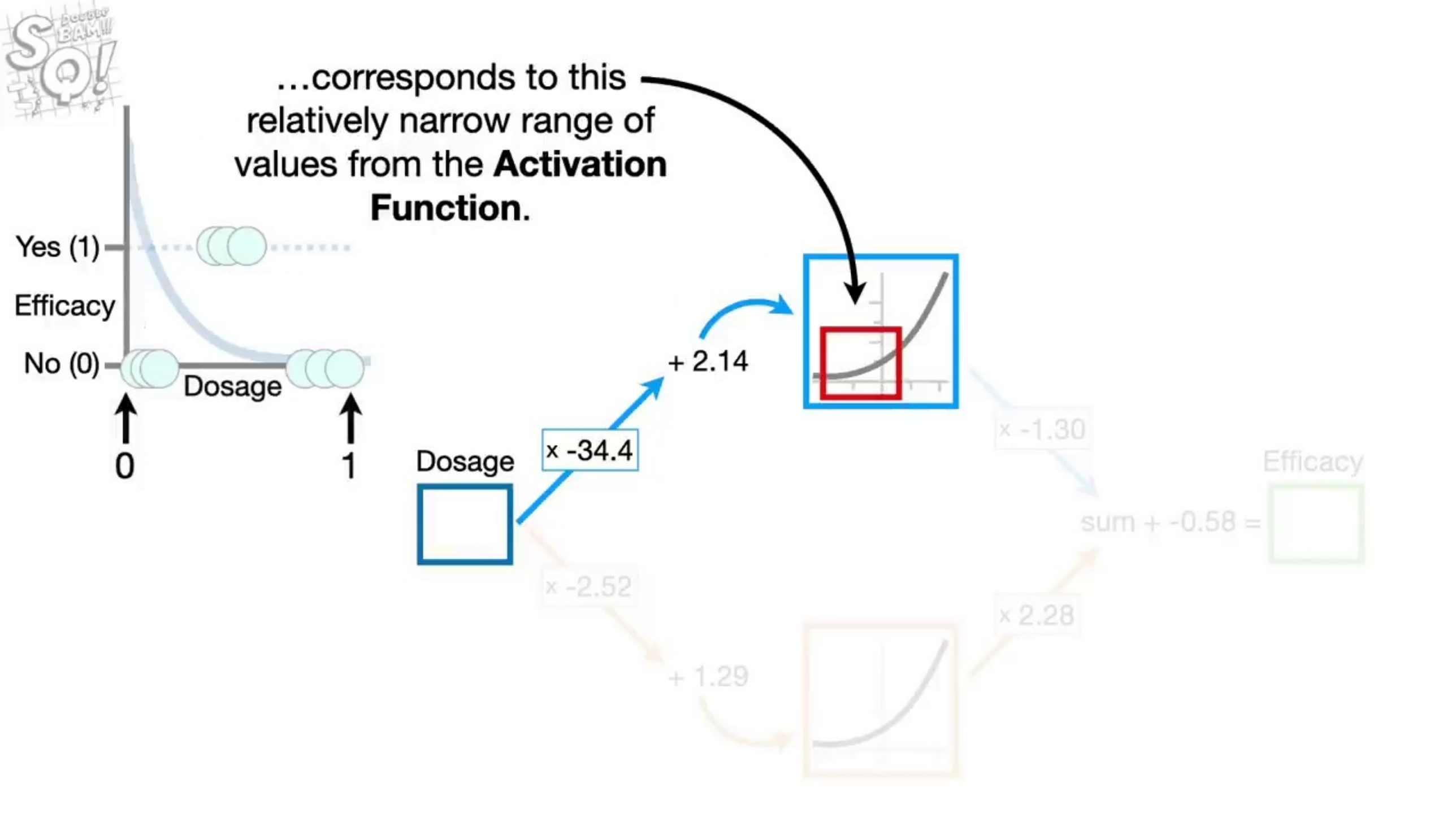
NOTE: Before we move on, I want to point out that the full range of **Dosage** values, from **0** to **1**...

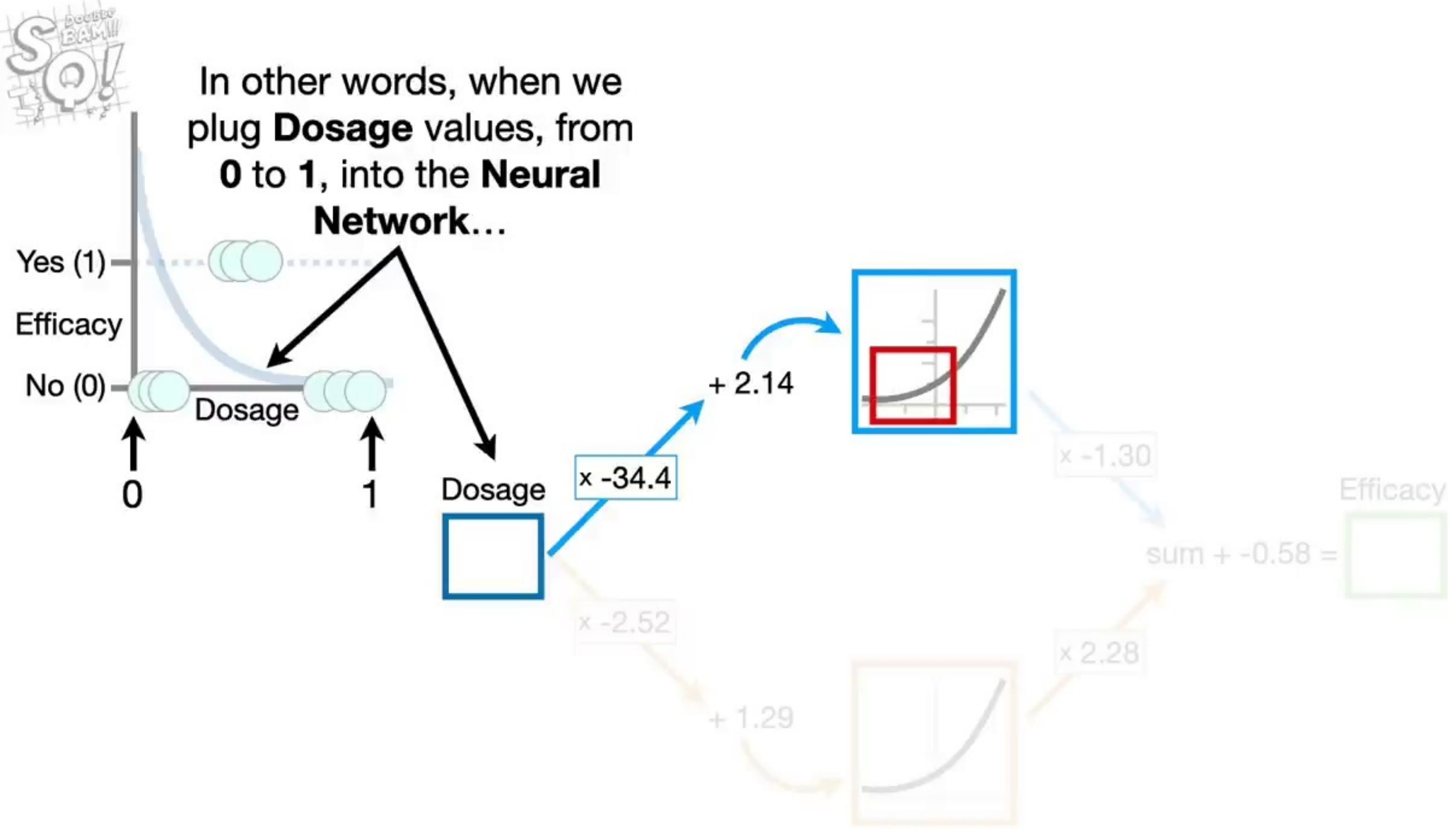


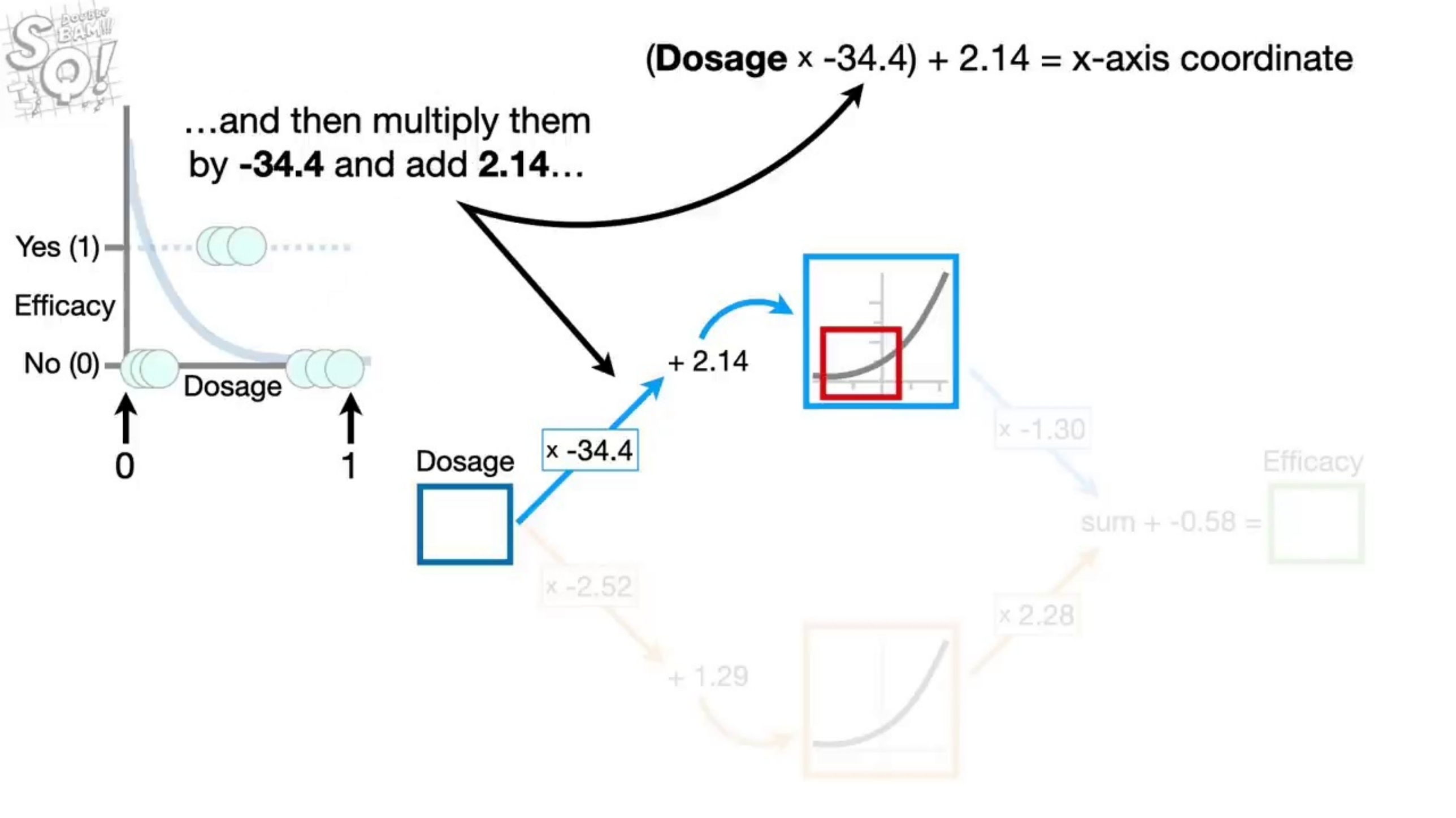


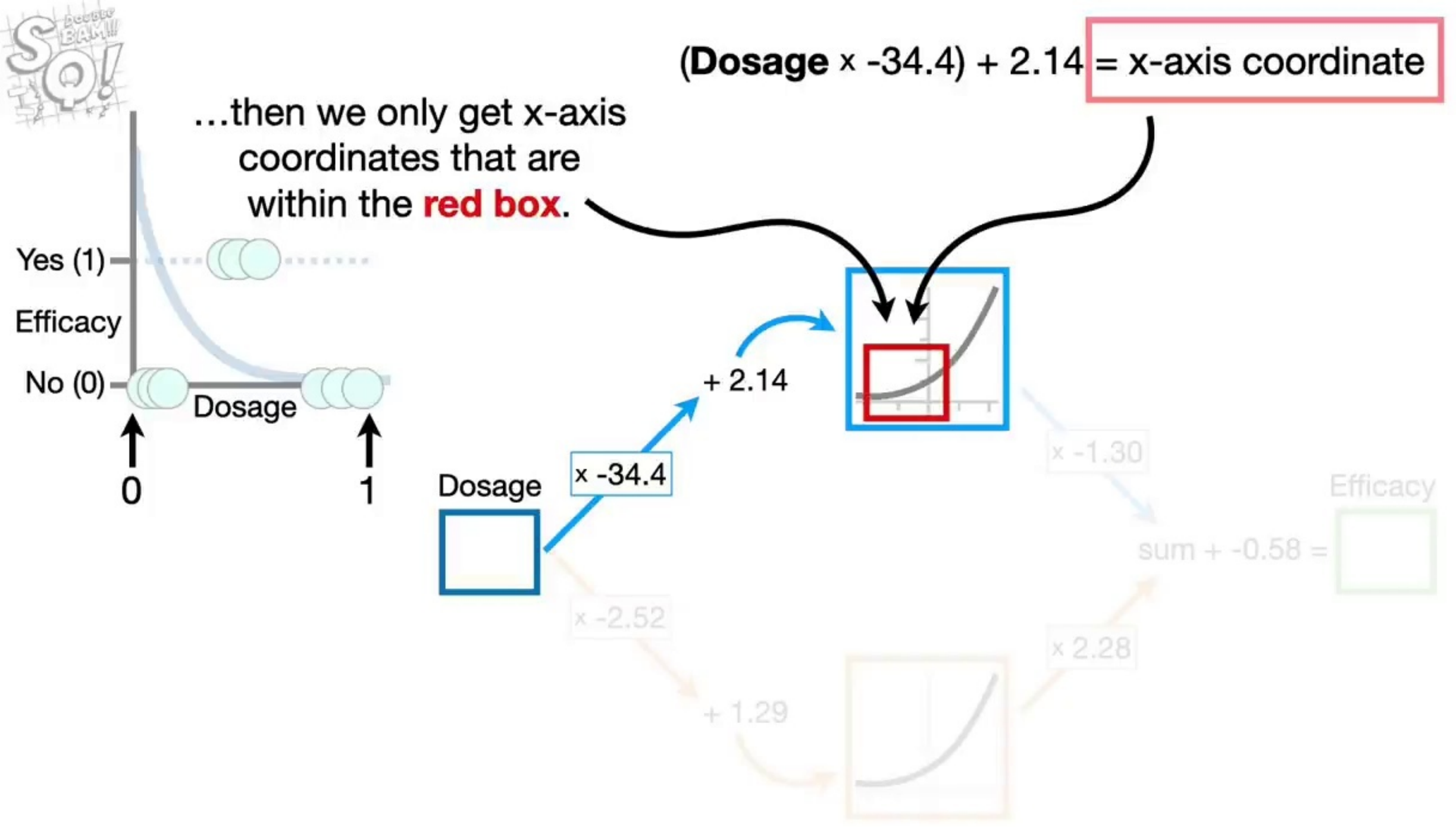
NOTE: Before we move on, I want to point out that the full range of **Dosage** values, from **0** to **1**...

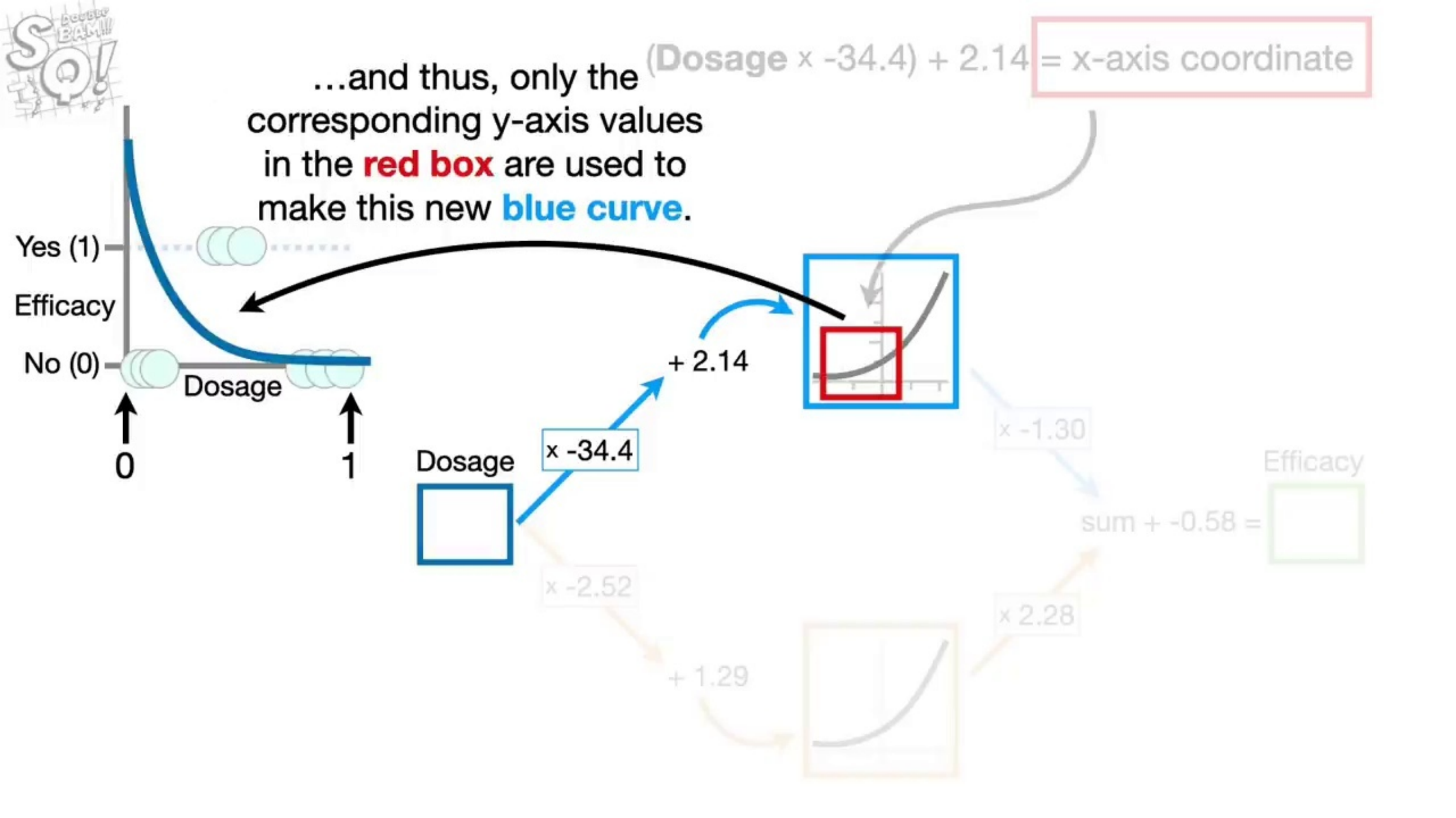


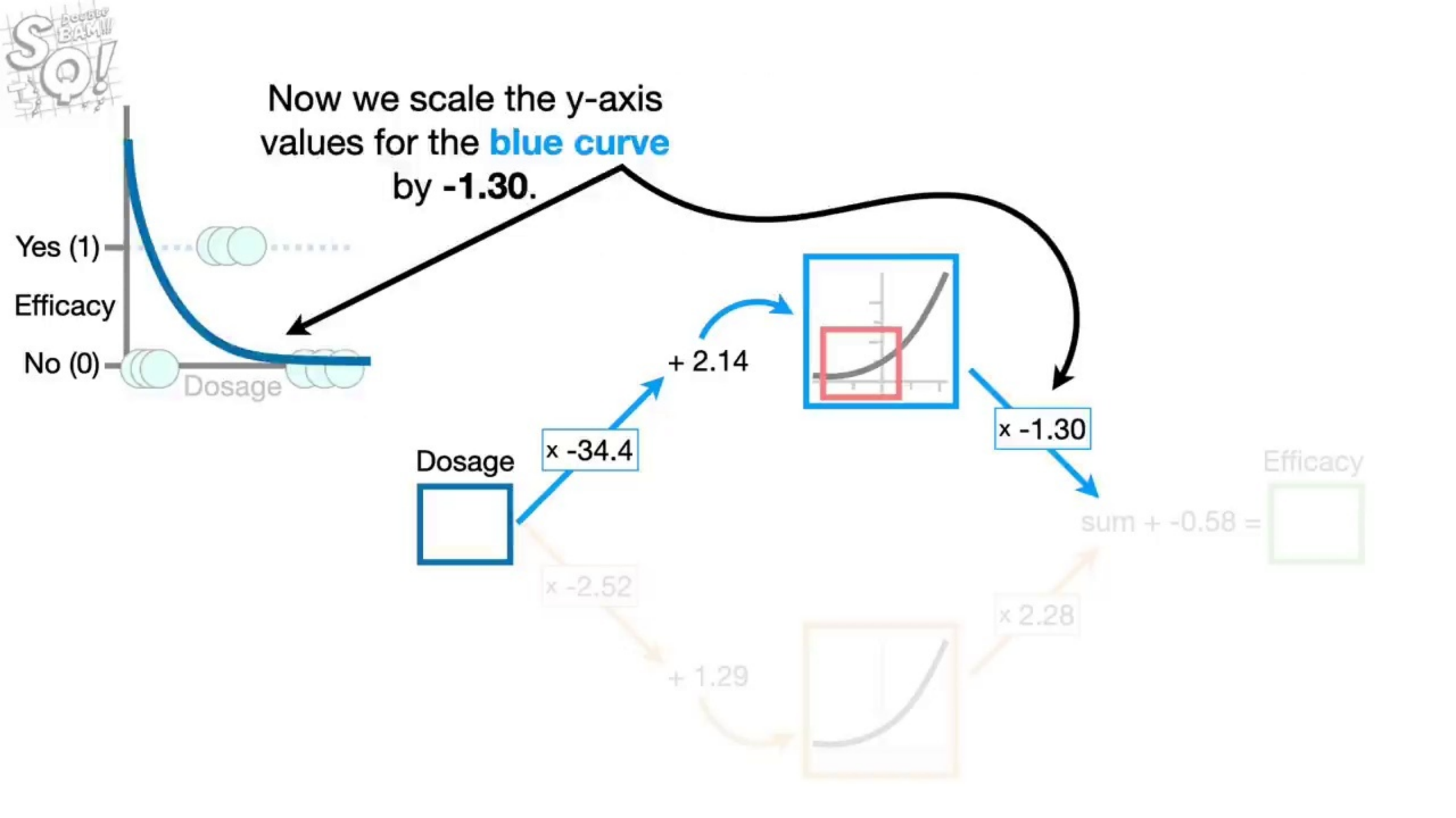

…corresponds to this relatively narrow range of values from the **Activation Function**.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

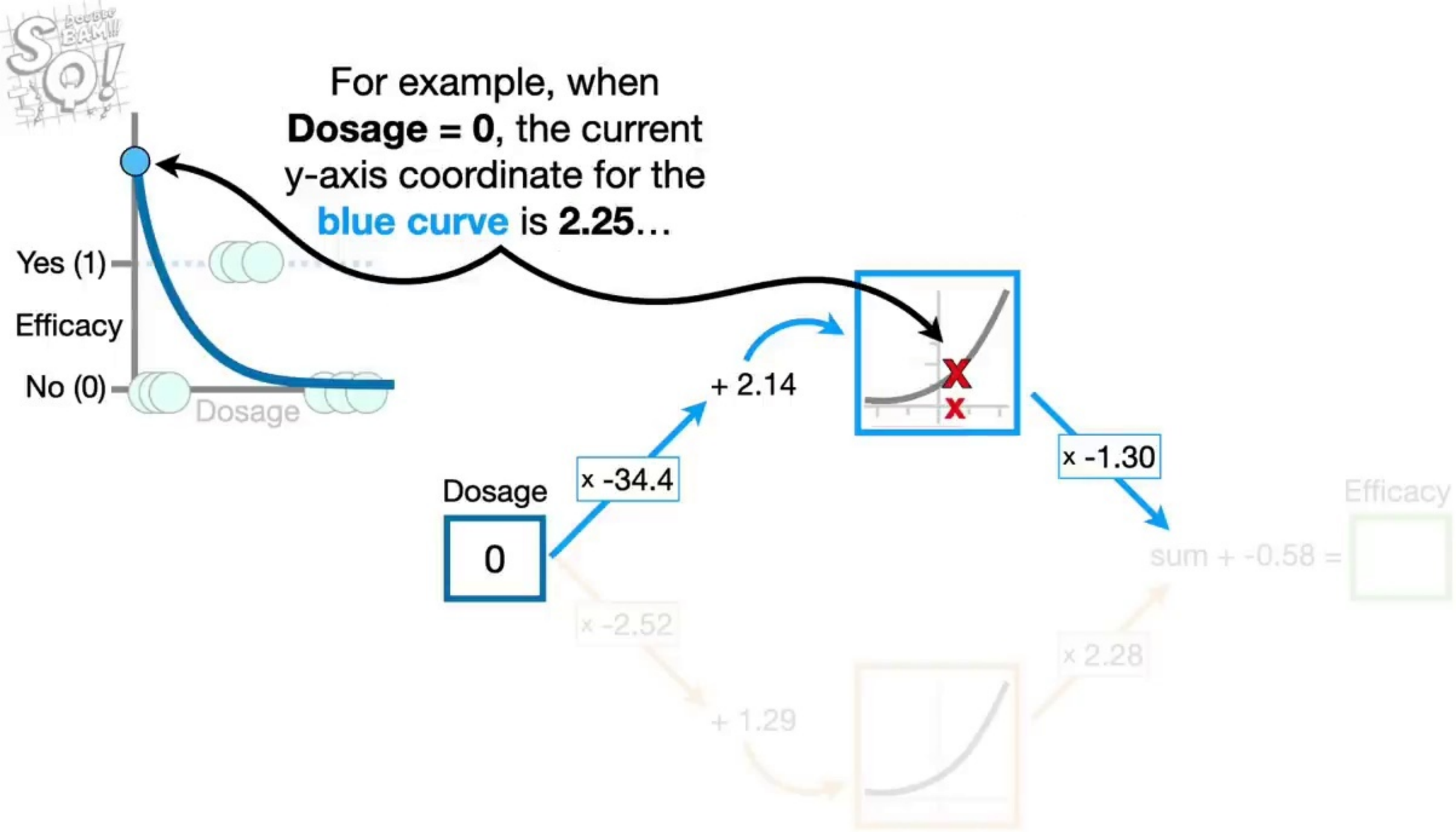

In other words, when we plug **Dosage** values, from **0** to **1**, into the **Neural Network**…
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

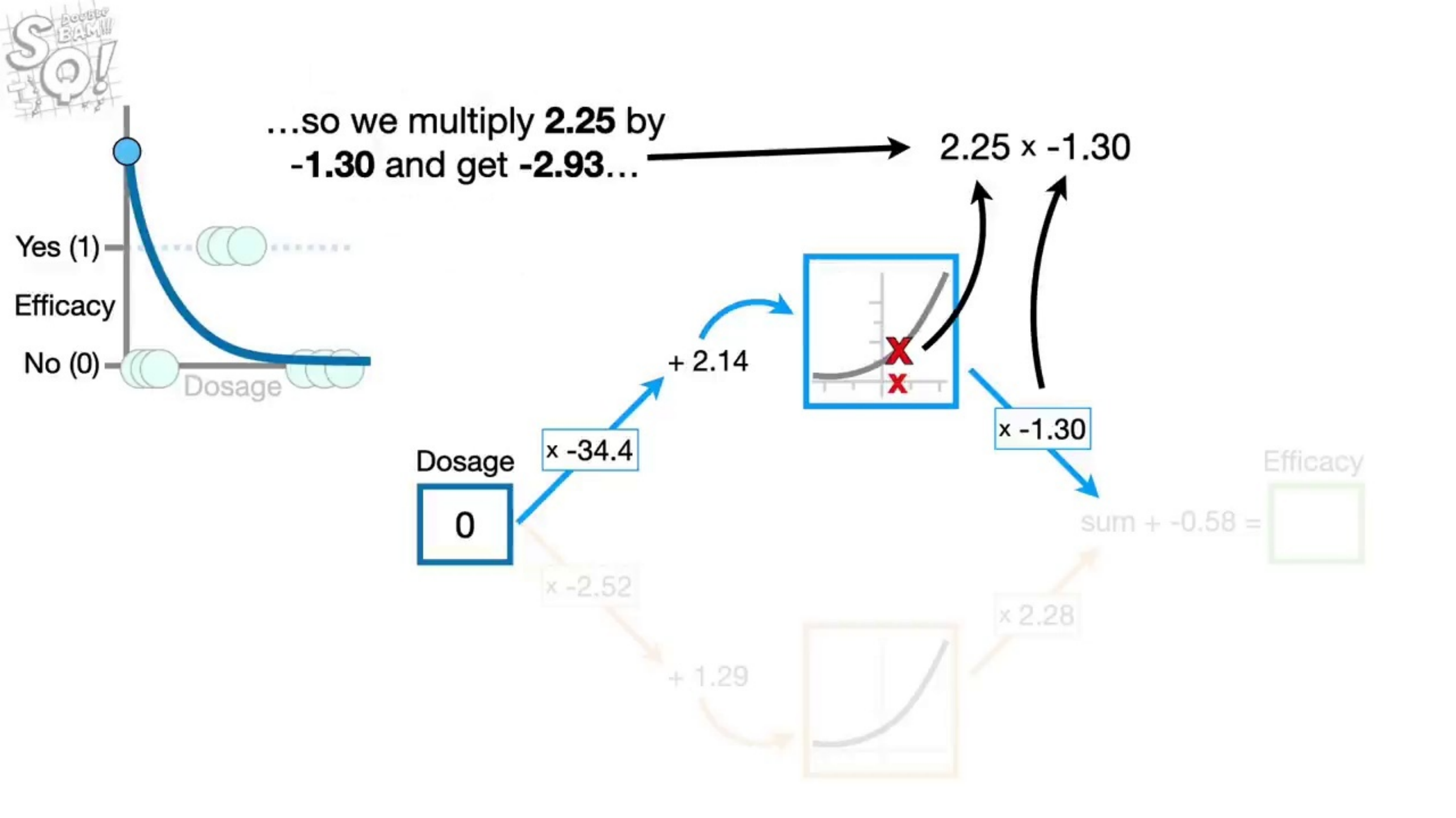

(Dosage x -34.4) + 2.14 = x-axis coordinate
…and then multiply them by -34.4 and add 2.14…
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

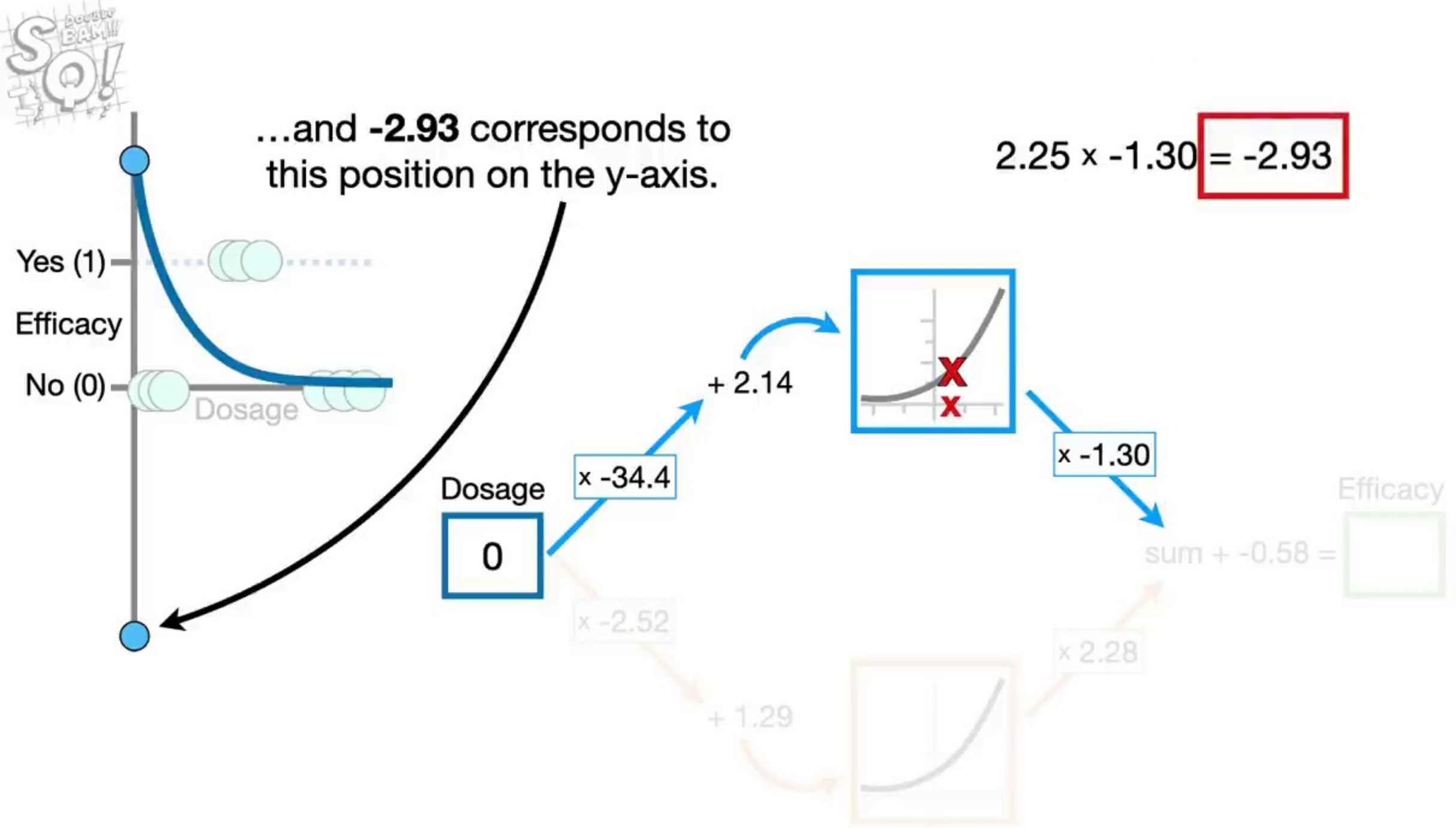

(Dosage x -34.4) + 2.14 = x-axis coordinate
…then we only get x-axis coordinates that are within the red box.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

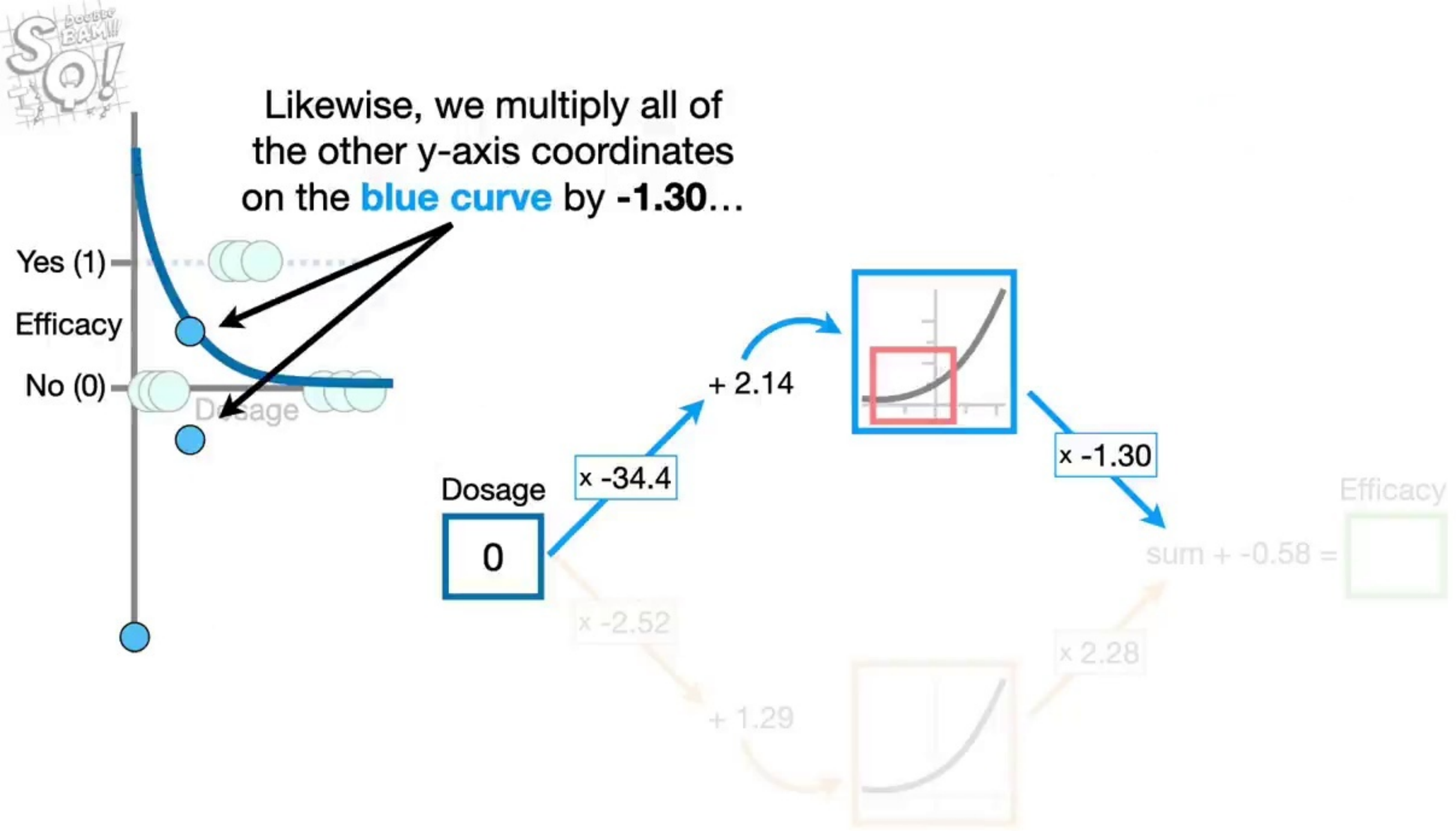

…and thus, only the corresponding y-axis values in the red box are used to make this new blue curve.
(Dosage x -34.4) + 2.14 = x-axis coordinate
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

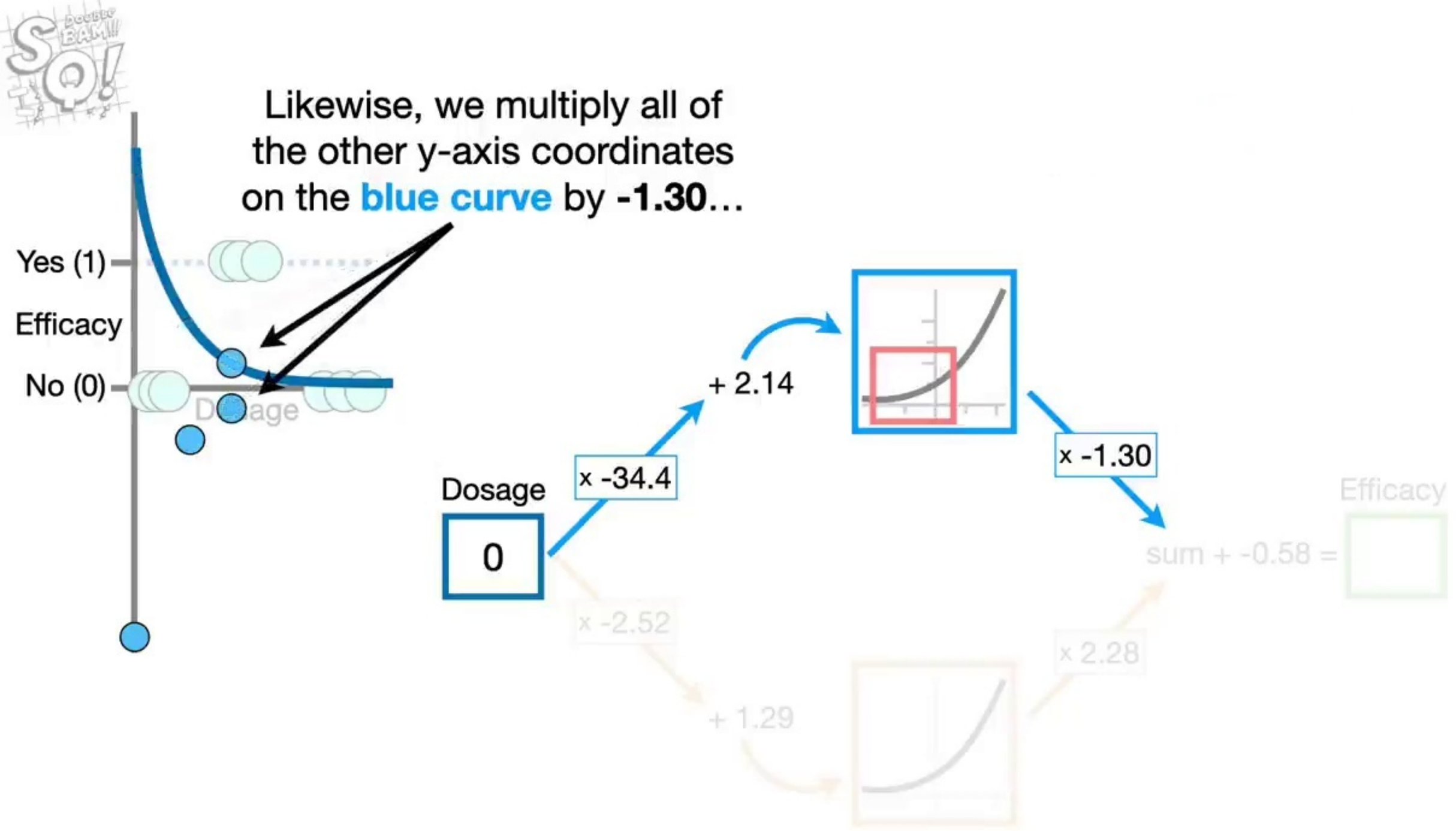

Now we scale the y-axis values for the blue curve by -1.30.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

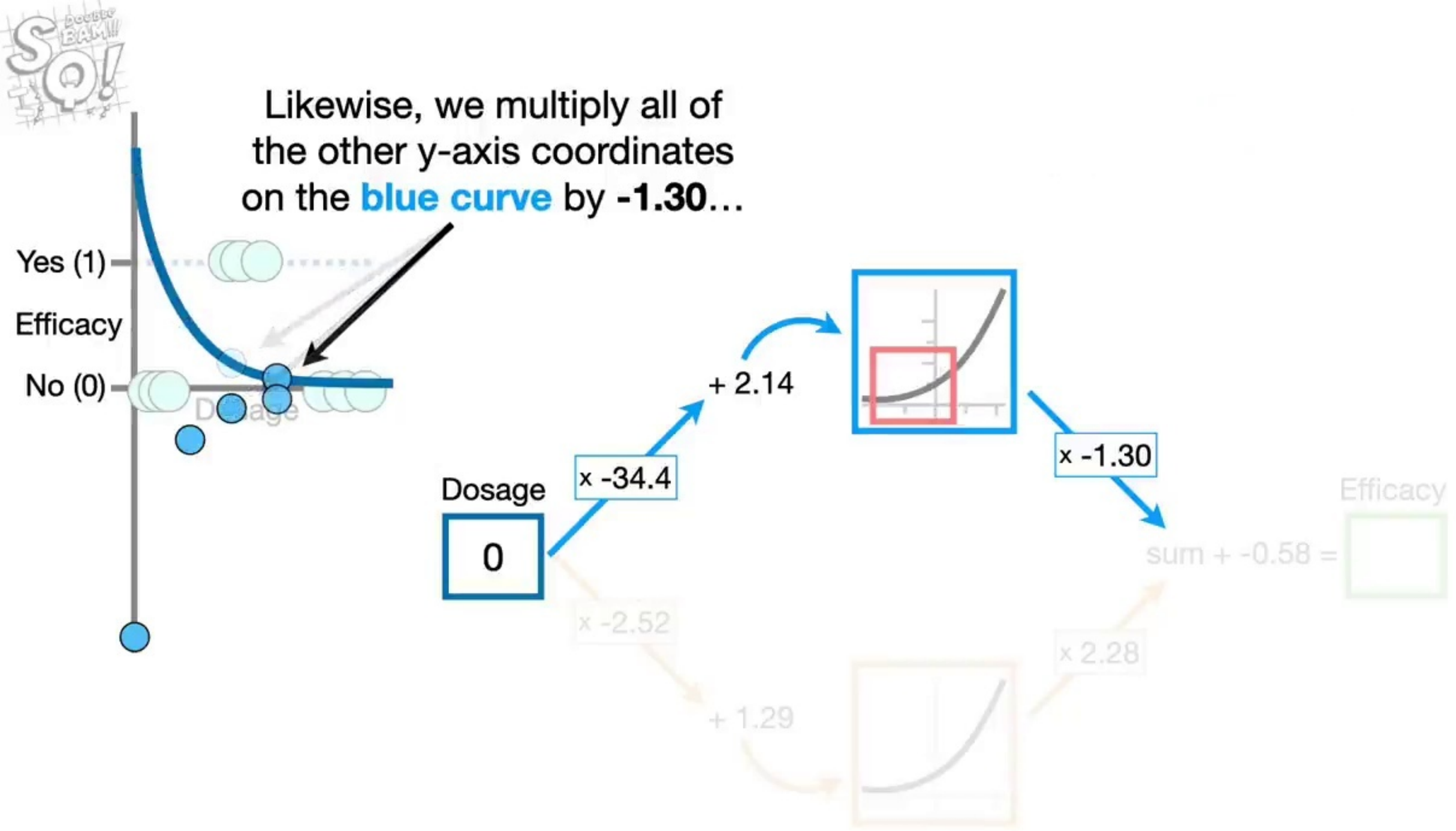

For example, when
Dosage = 0, the current
y-axis coordinate for the
blue curve is 2.25…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

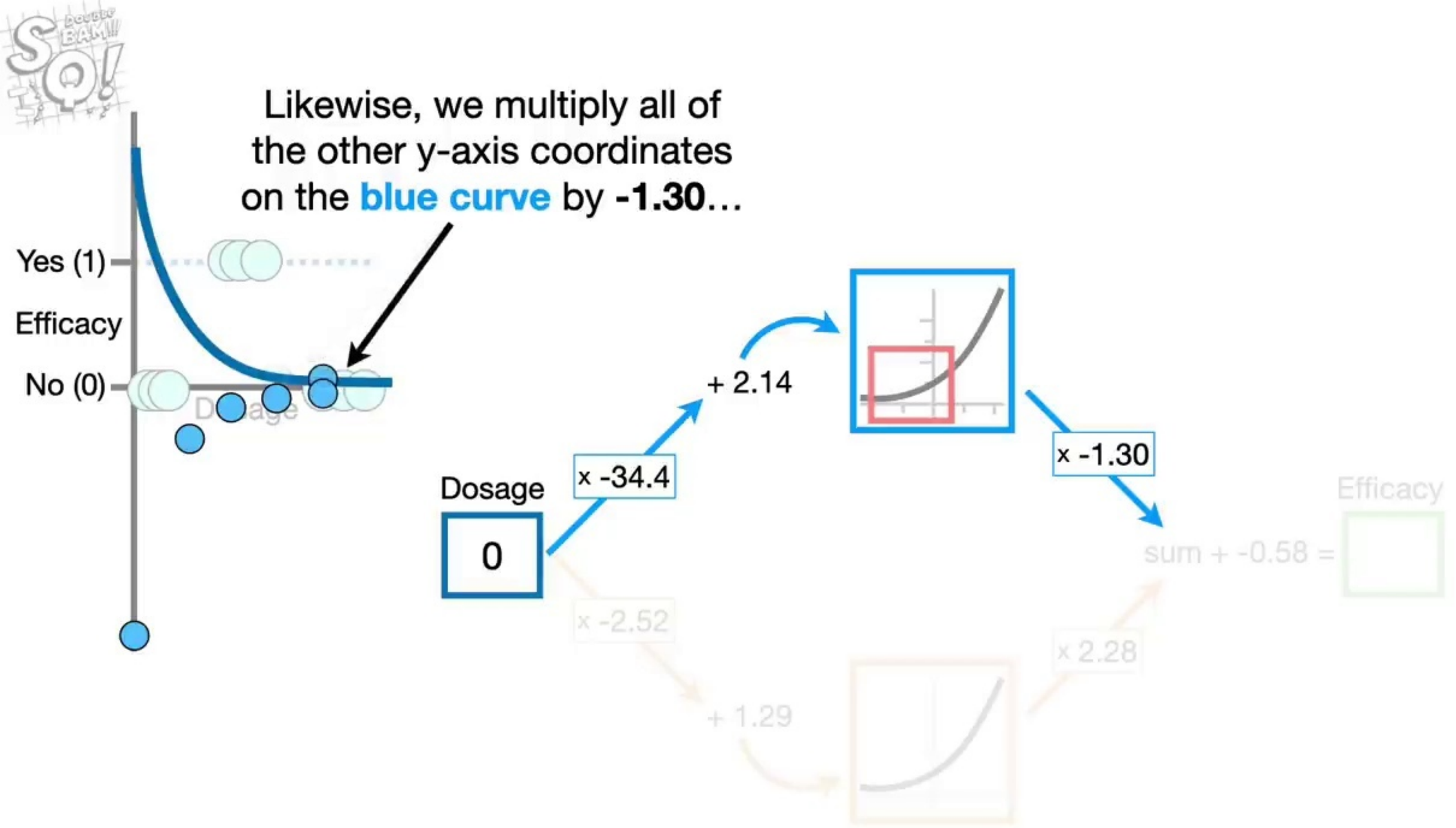

…so we multiply 2.25 by -1.30 and get -2.93…
2.25 x -1.30
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

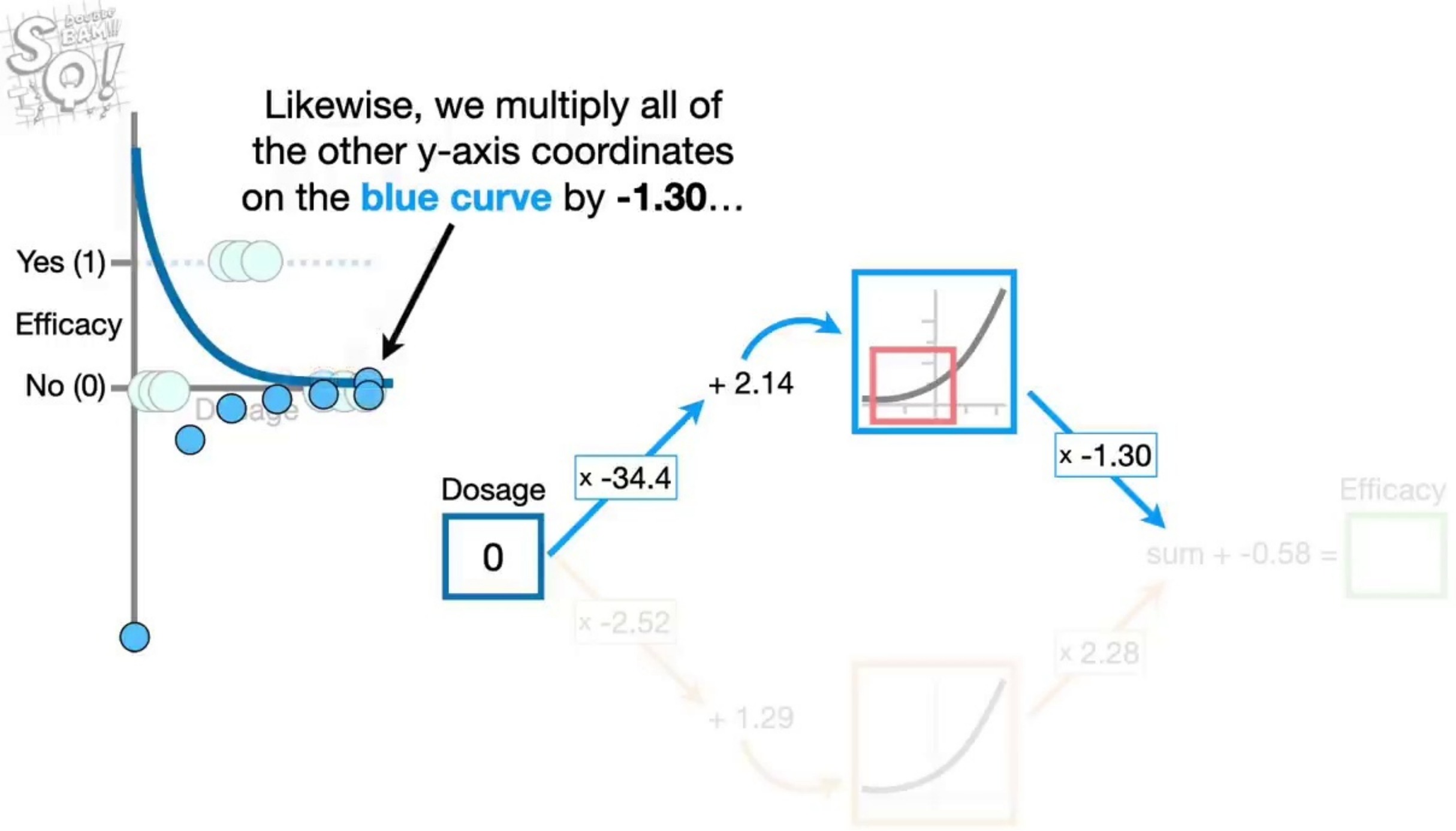

…and -2.93 corresponds to this position on the y-axis.
2.25 x -1.30 = -2.93
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

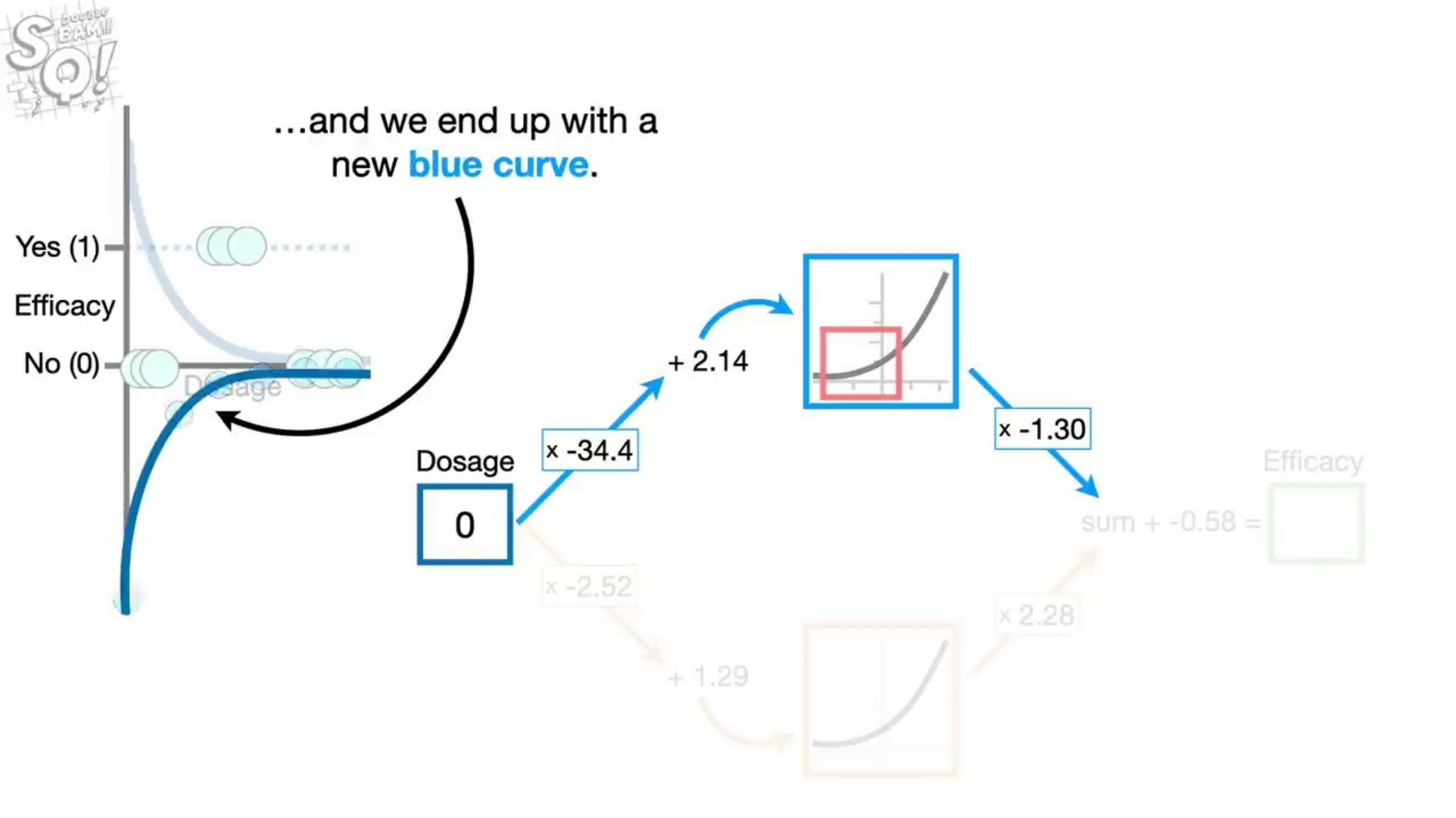

Likewise, we multiply all of the other y-axis coordinates on the blue curve by -1.30…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

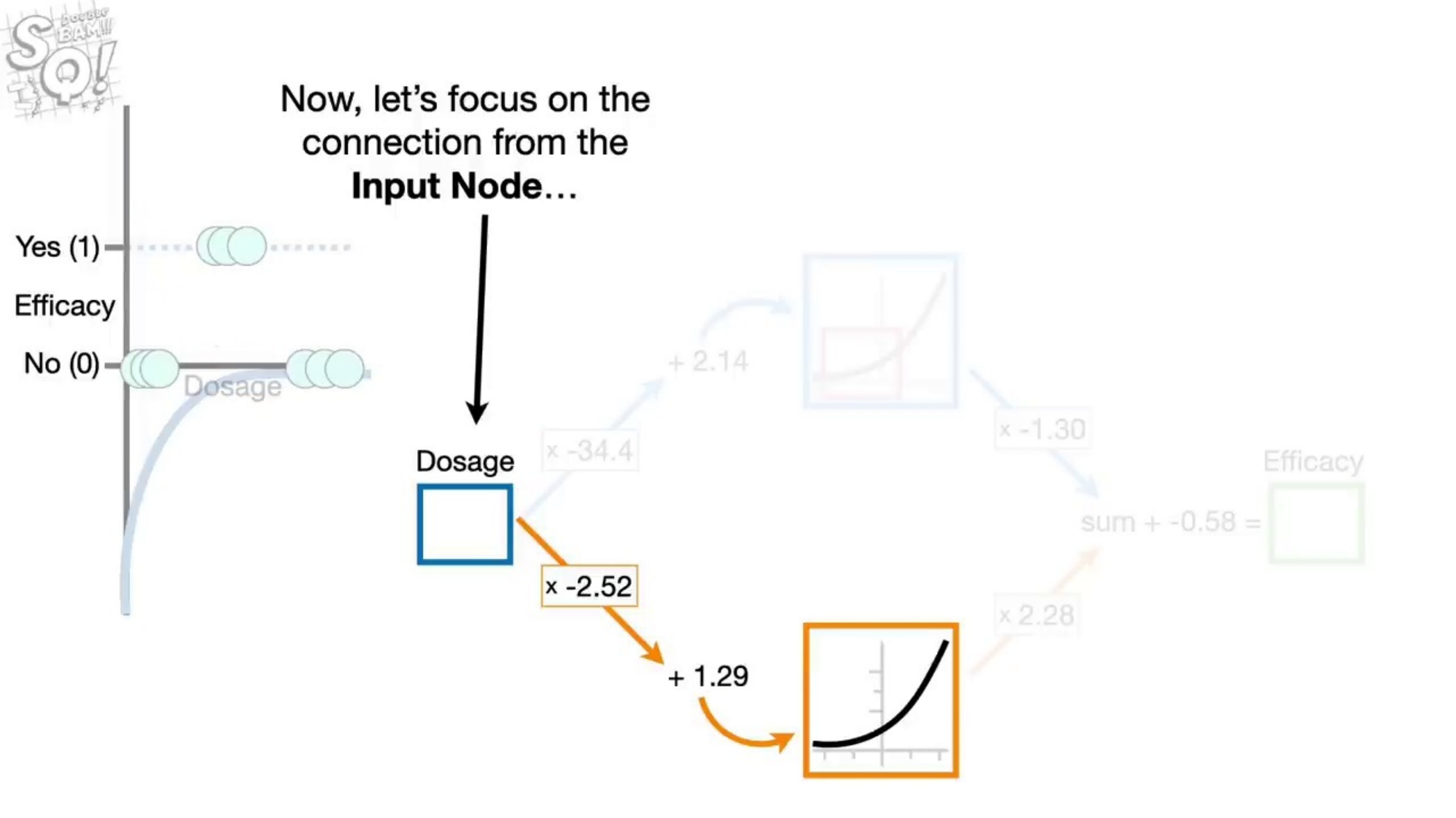

Likewise, we multiply all of the other y-axis coordinates on the blue curve by -1.30…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

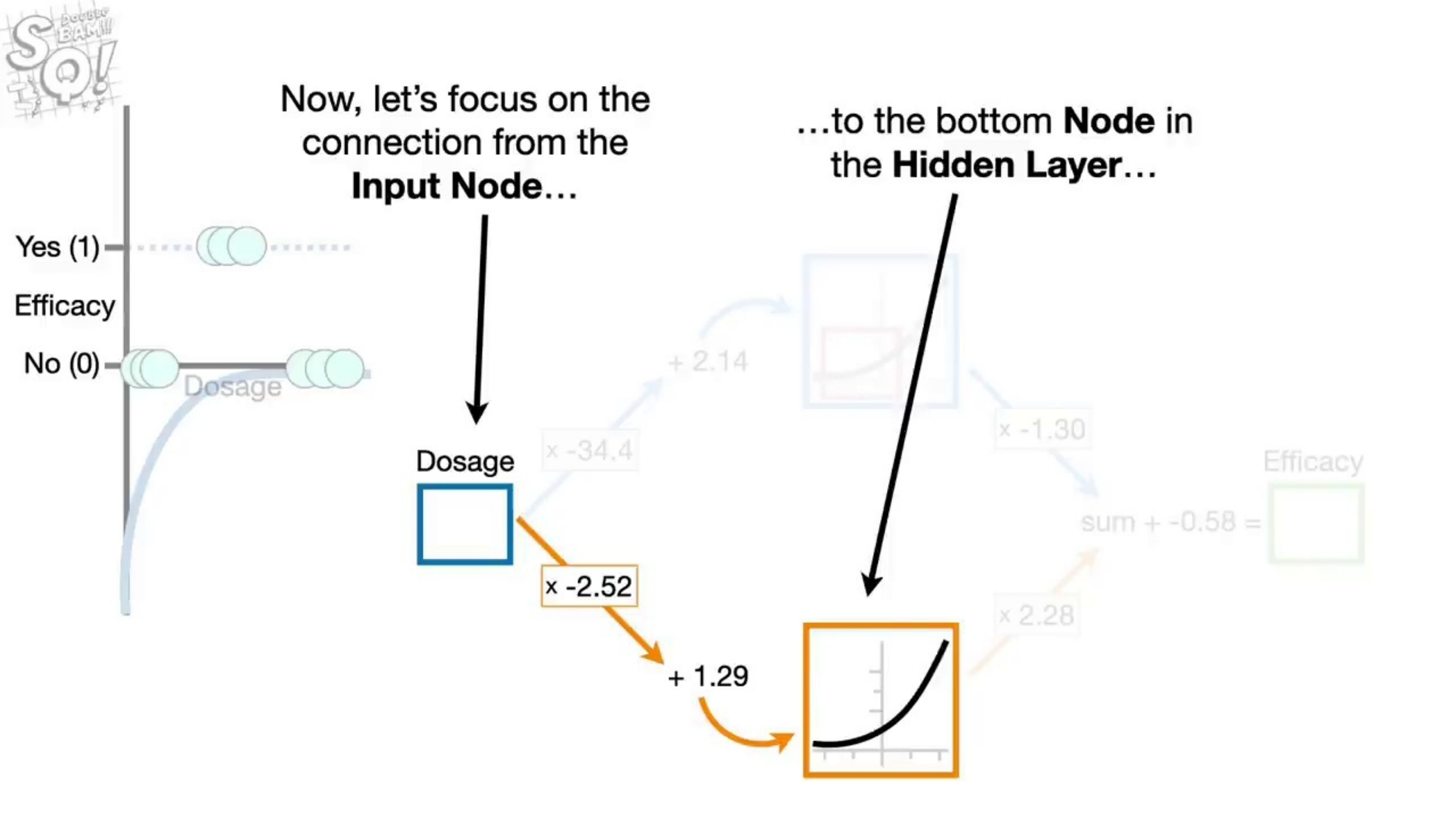

Likewise, we multiply all of the other y-axis coordinates on the blue curve by -1.30…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

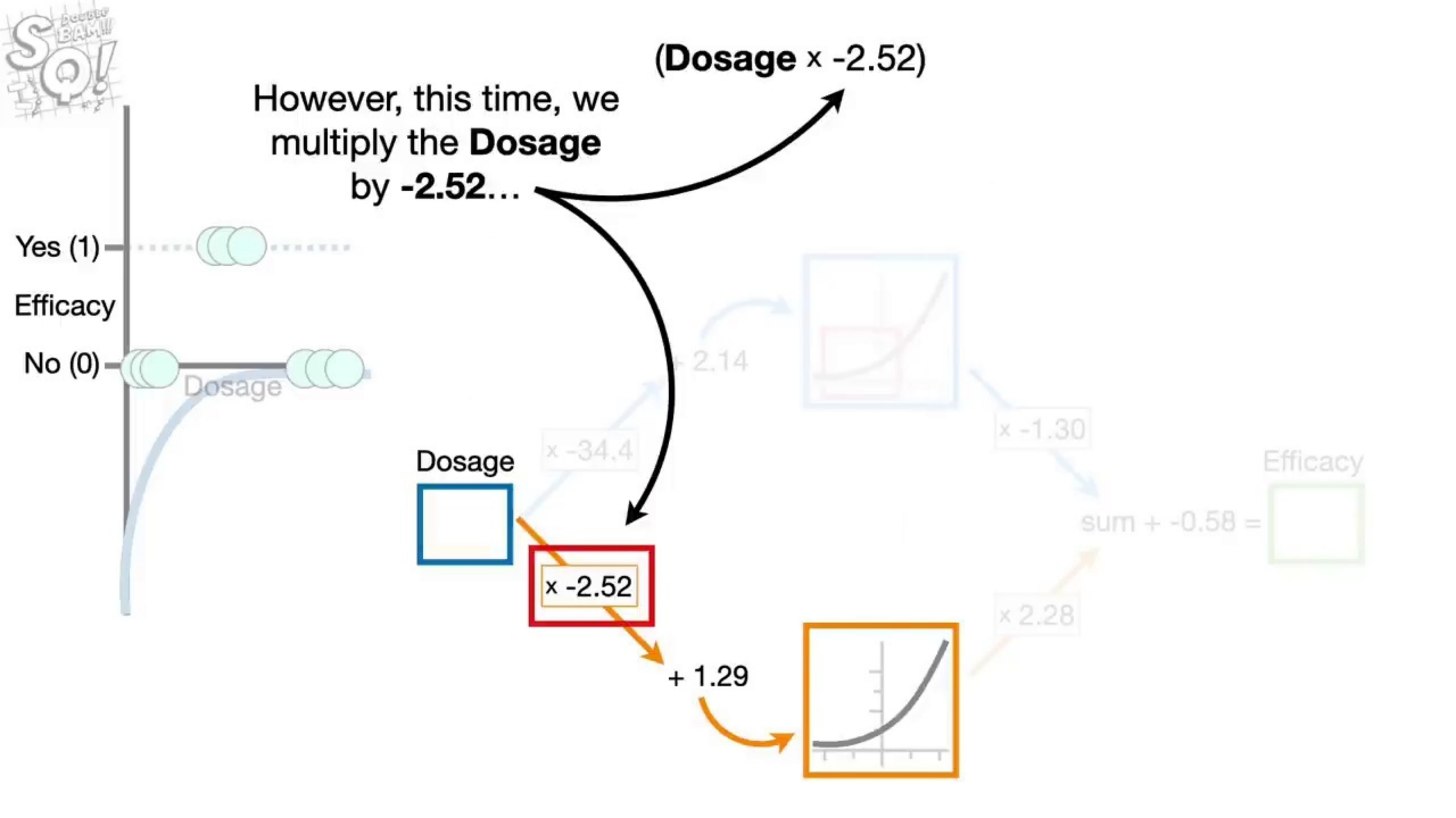

Likewise, we multiply all of the other y-axis coordinates on the blue curve by -1.30…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

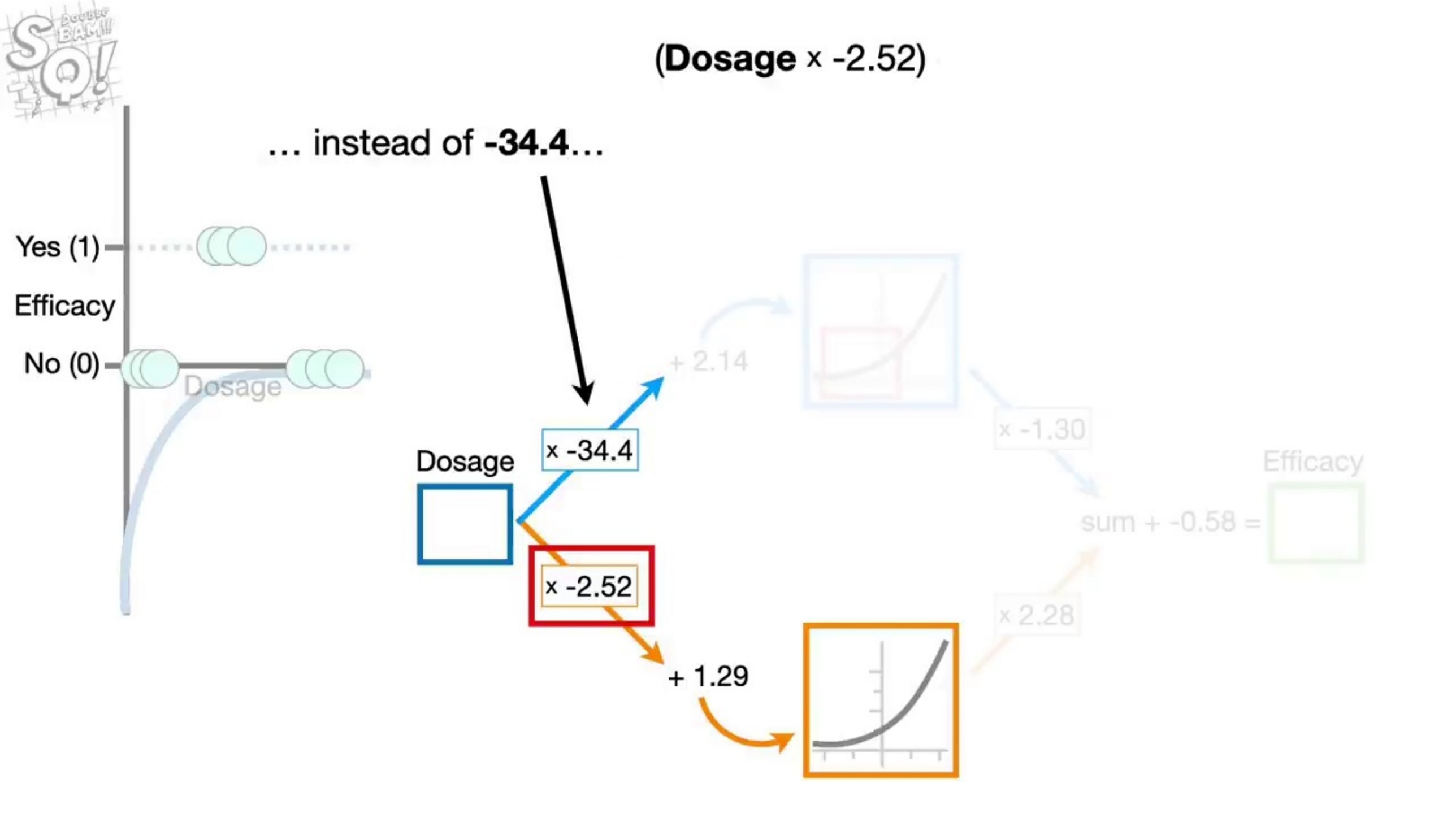

Likewise, we multiply all of the other y-axis coordinates on the blue curve by -1.30…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

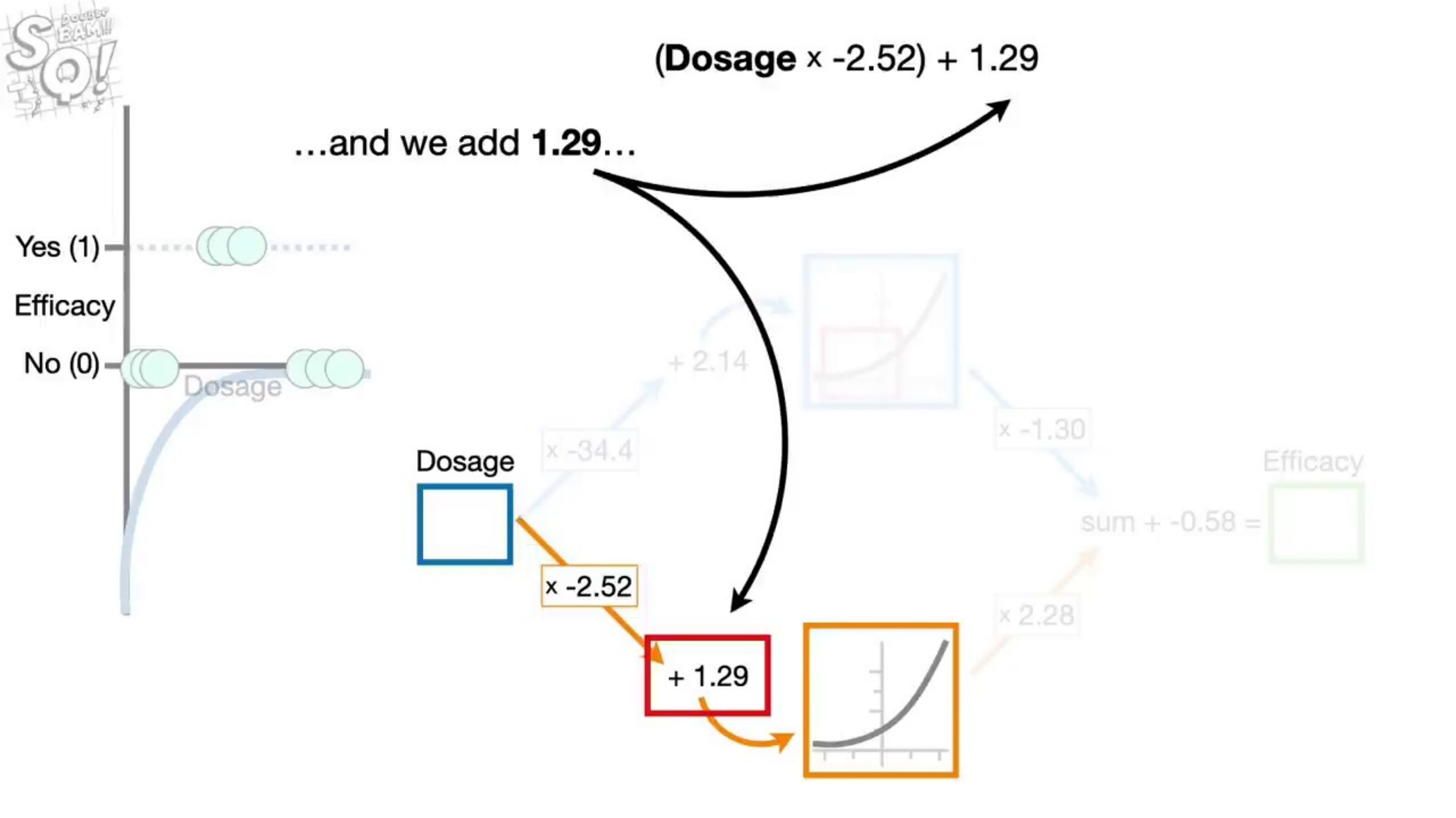

...and we end up with a new blue curve.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28


Now, let's focus on the connection from the **Input Node**...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28


Now, let's focus on the connection from the **Input Node**…
…to the bottom **Node** in the **Hidden Layer**…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy
x 2.28

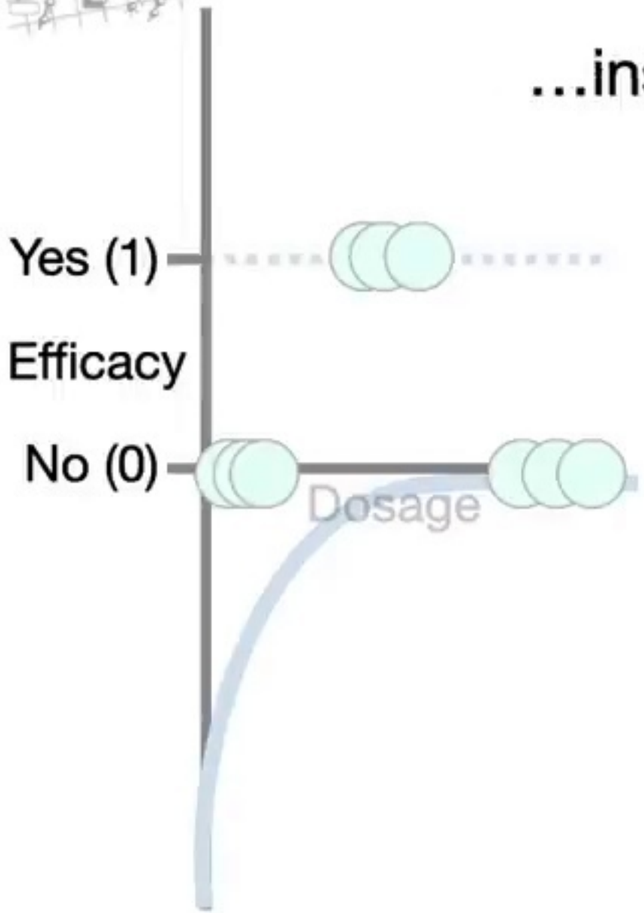

(Dosage x -2.52)
However, this time, we multiply the Dosage by -2.52…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy
x 2.28

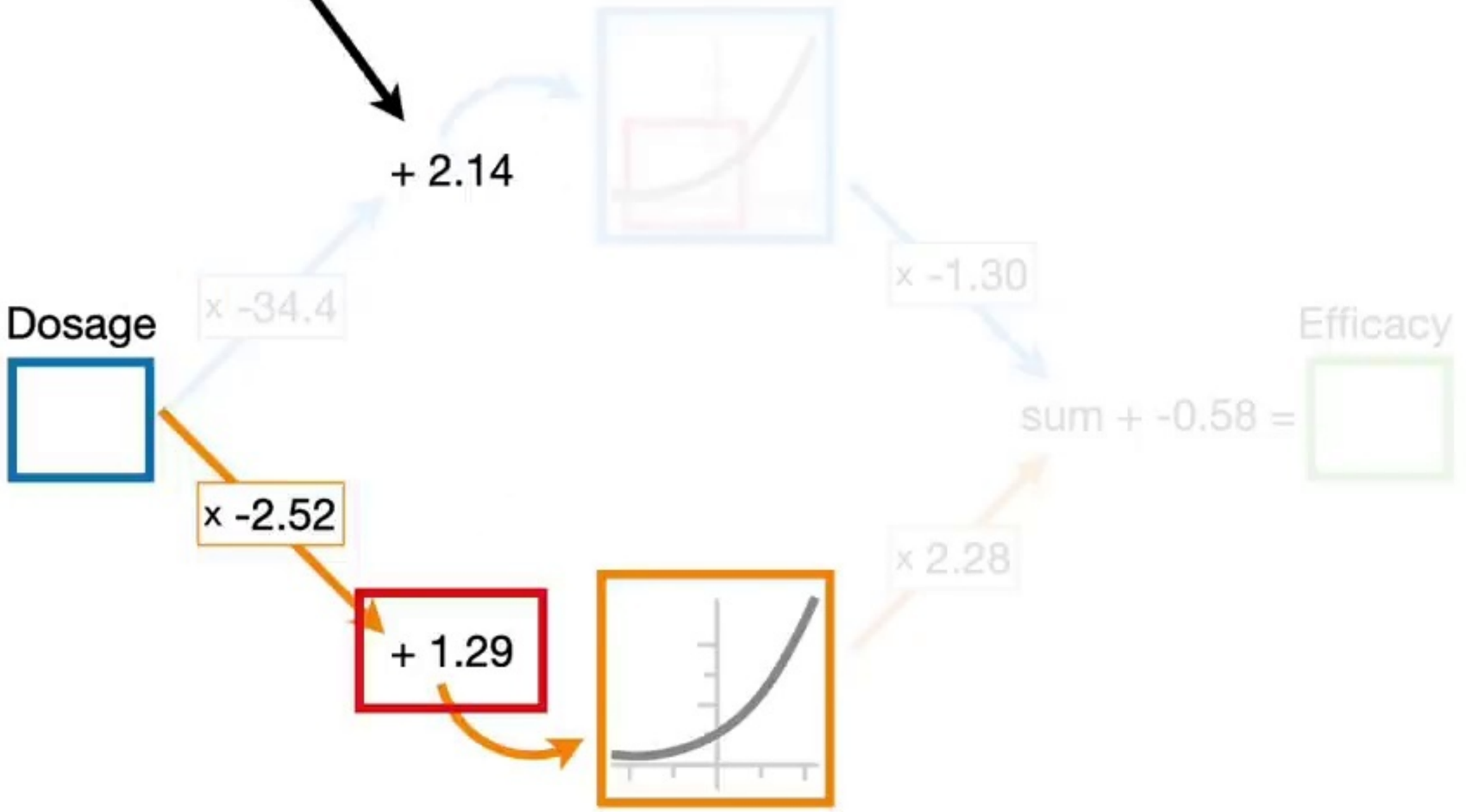

(Dosage x -2.52)
… instead of -34.4…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

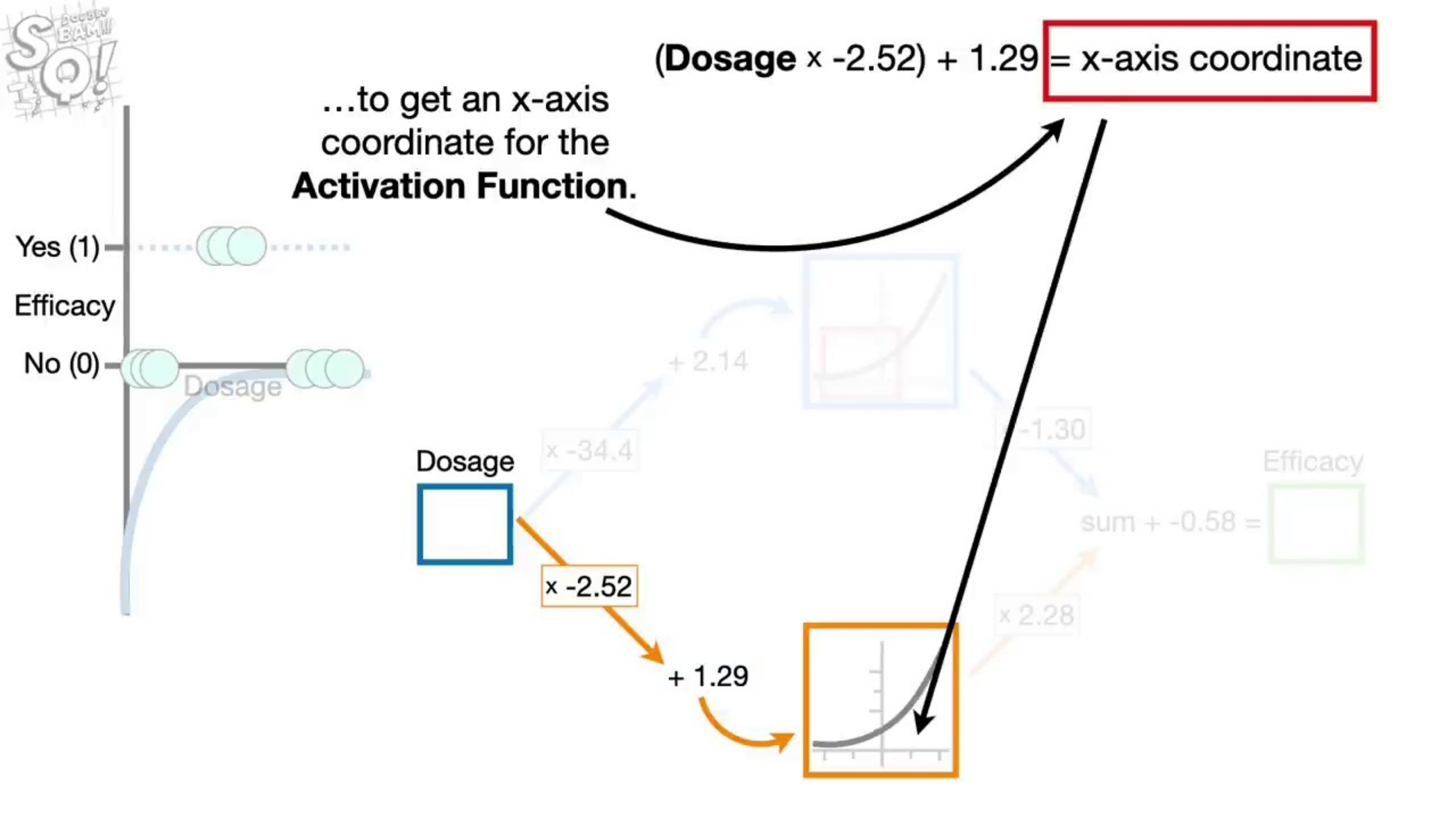

(Dosage x -2.52) + 1.29
…and we add 1.29…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy
x 2.28

(**Dosage** x -2.52) + 1.29

…instead of **2.14**…

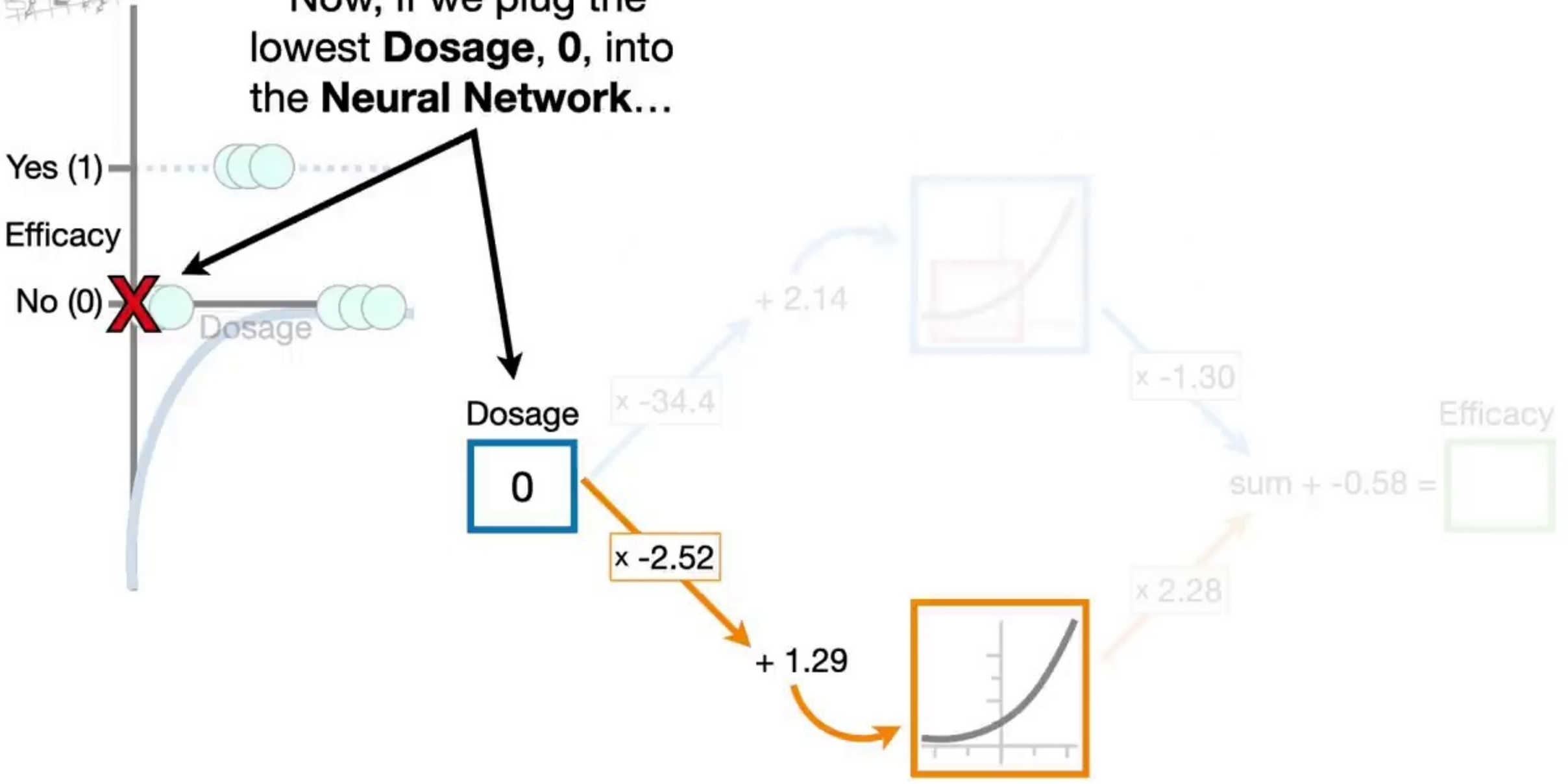


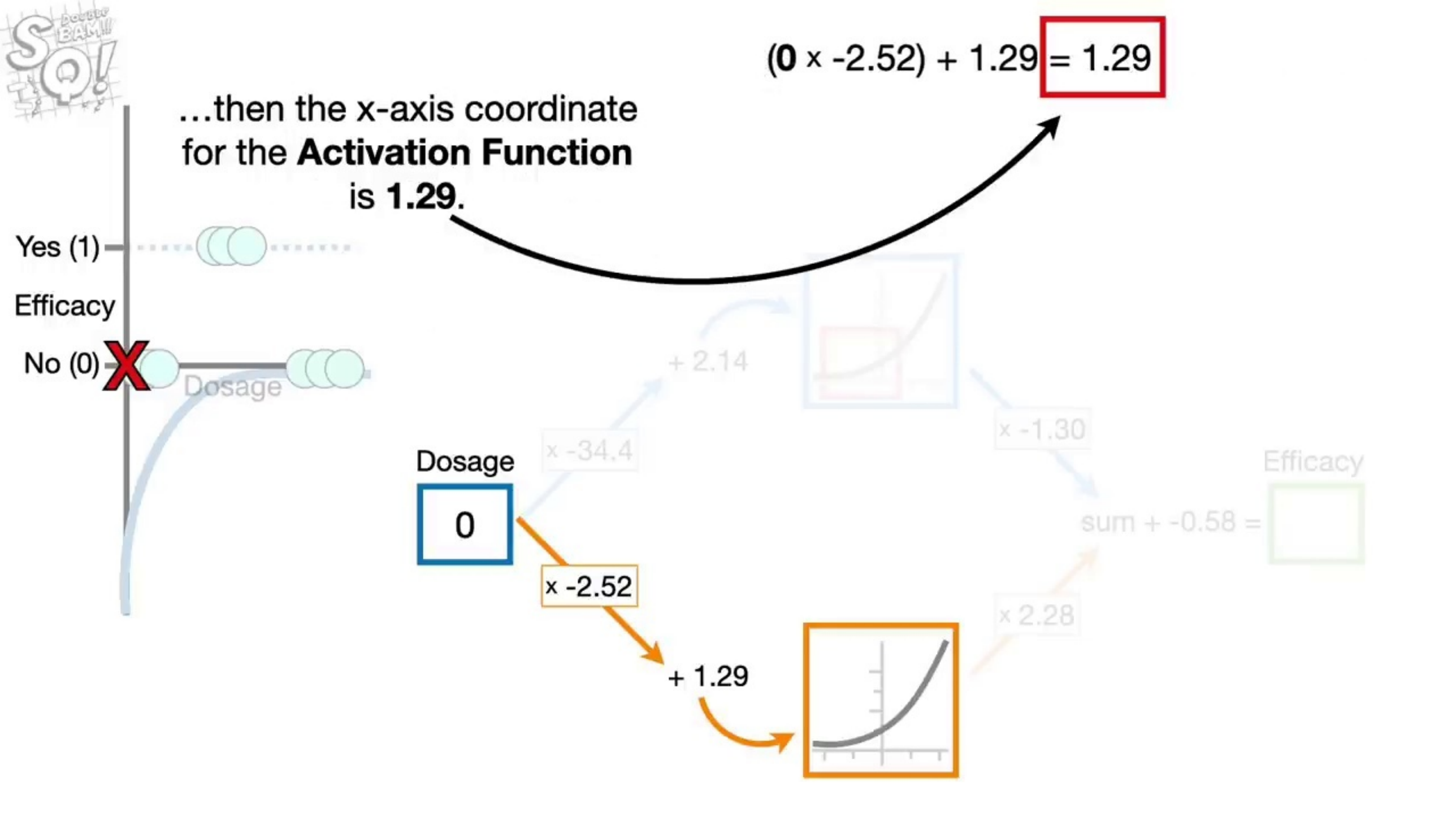


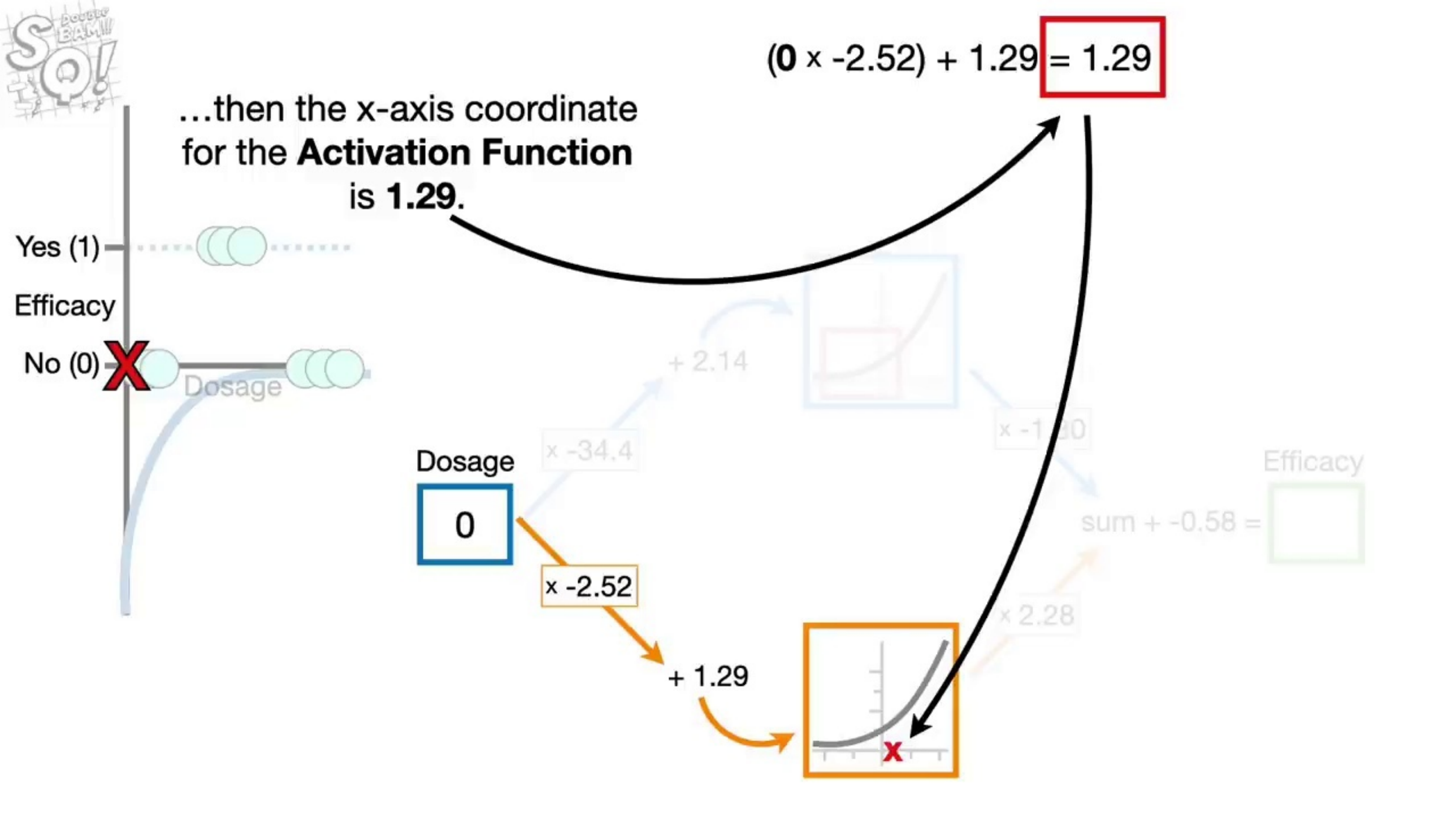

(Dosage x -2.52) + 1.29 = x-axis coordinate
…to get an x-axis coordinate for the Activation Function.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
-1.30
Efficacy
sum + -0.58 =
x 2.28

(**Dosage** x -2.52) + 1.29 = x-axis coordinate

Now, if we plug the lowest **Dosage**, **0**, into the **Neural Network**…




(0 x -2.52) + 1.29 = 1.29
…then the x-axis coordinate for the Activation Function is 1.29.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -2.52
+ 1.29
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x 2.28


(0 x -2.52) + 1.29 = 1.29
…then the x-axis coordinate for the **Activation Function** is **1.29**.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.20
sum + -0.58 =
Efficacy
x 2.28

Now we plug **1.29** into the **Activation Function** to get the corresponding y-axis value…

$(\mathbf{0} \times -2.52) + 1.29 = 1.29$

$f(x) = \log(1 + e^x)$

Yes (1)

Efficacy

No (0)

Dosage

Dosage

0

x -2.52

+ 1.29

x

x -34.4

+ 2.14

x -1.30

sum + -0.58 =

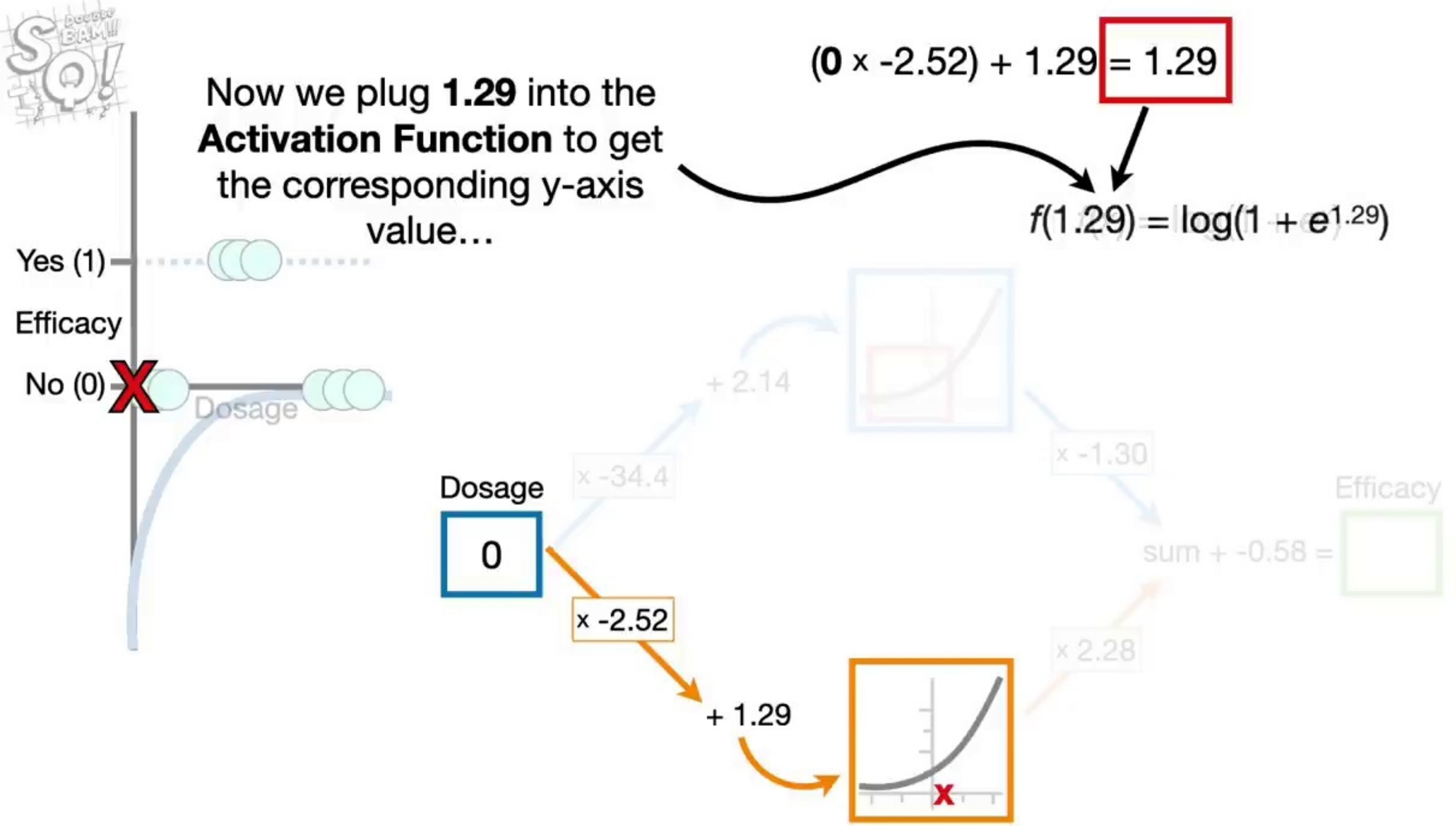
Efficacy

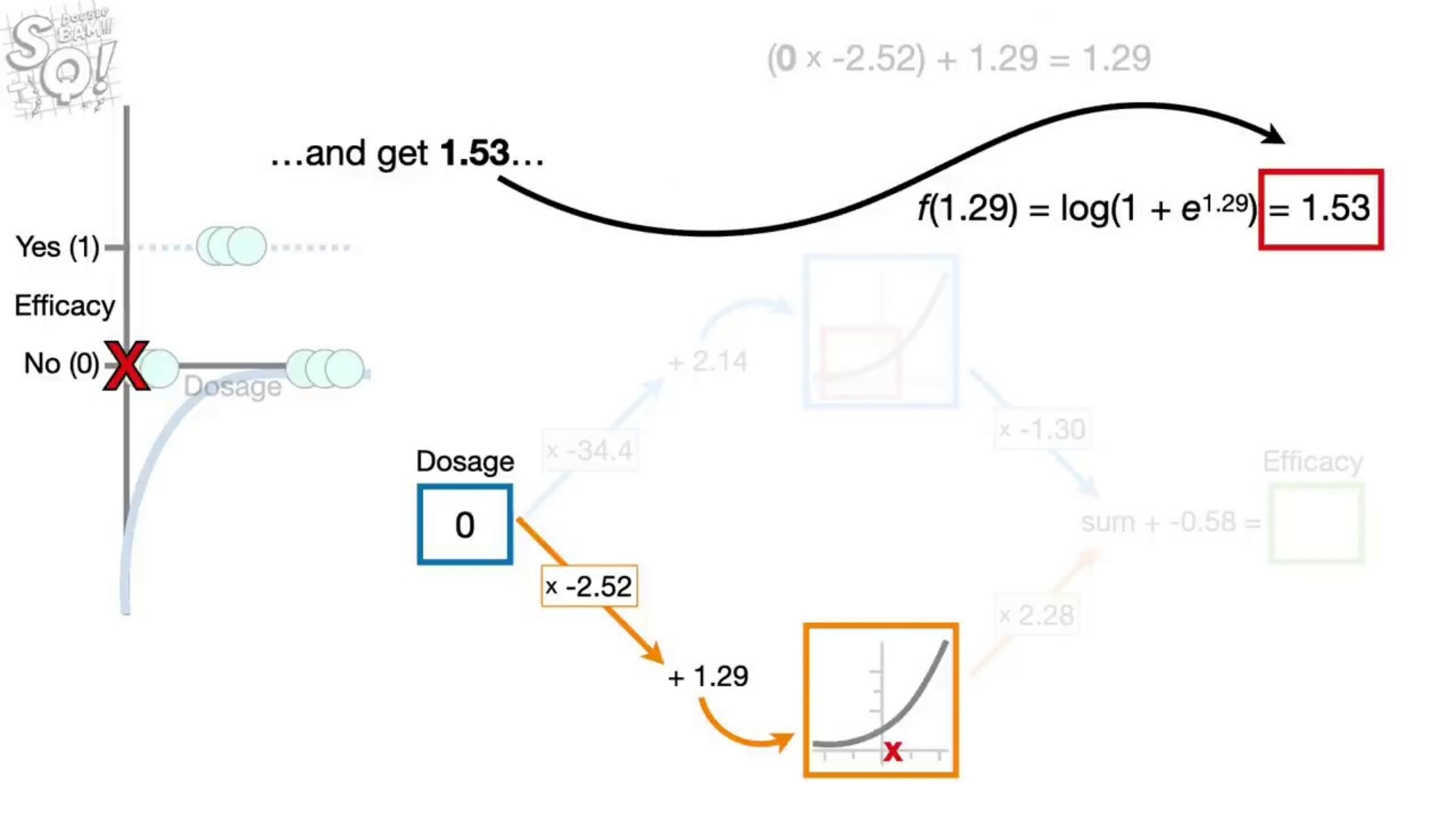
x 2.28

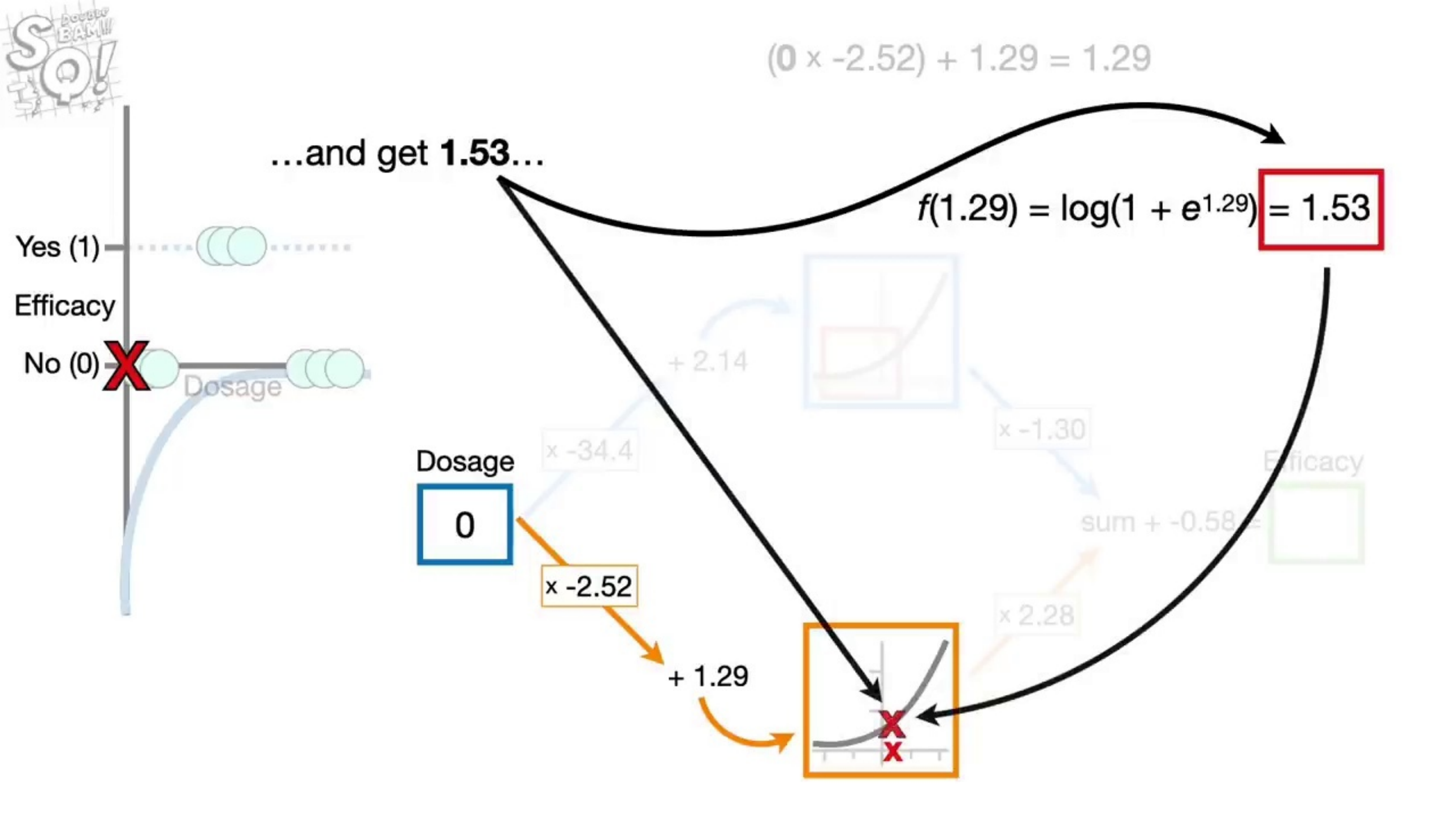
Now we plug **1.29** into the **Activation Function** to get the corresponding y-axis value…

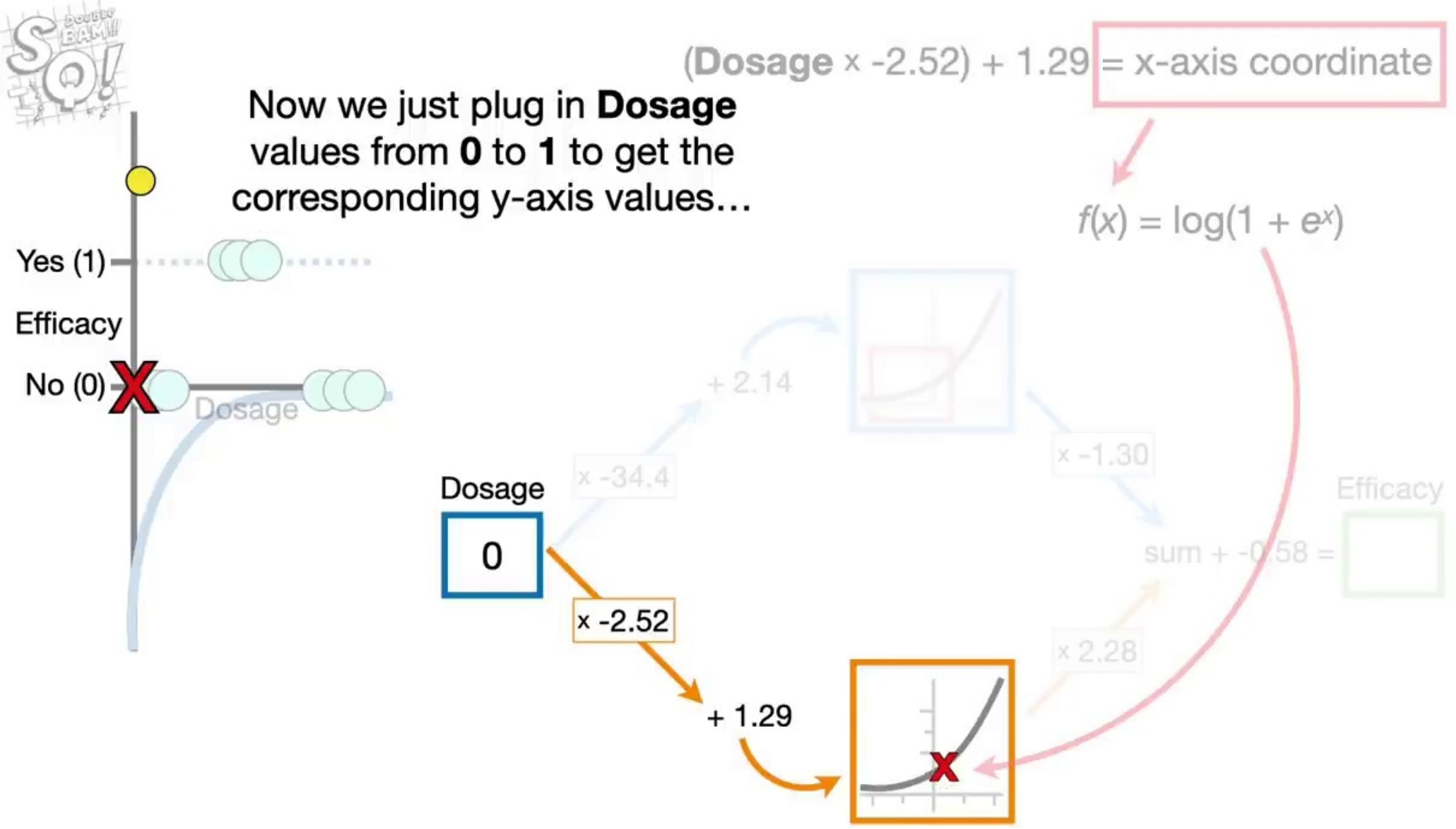
$(\mathbf{0} \times -2.52) + 1.29 = 1.29$

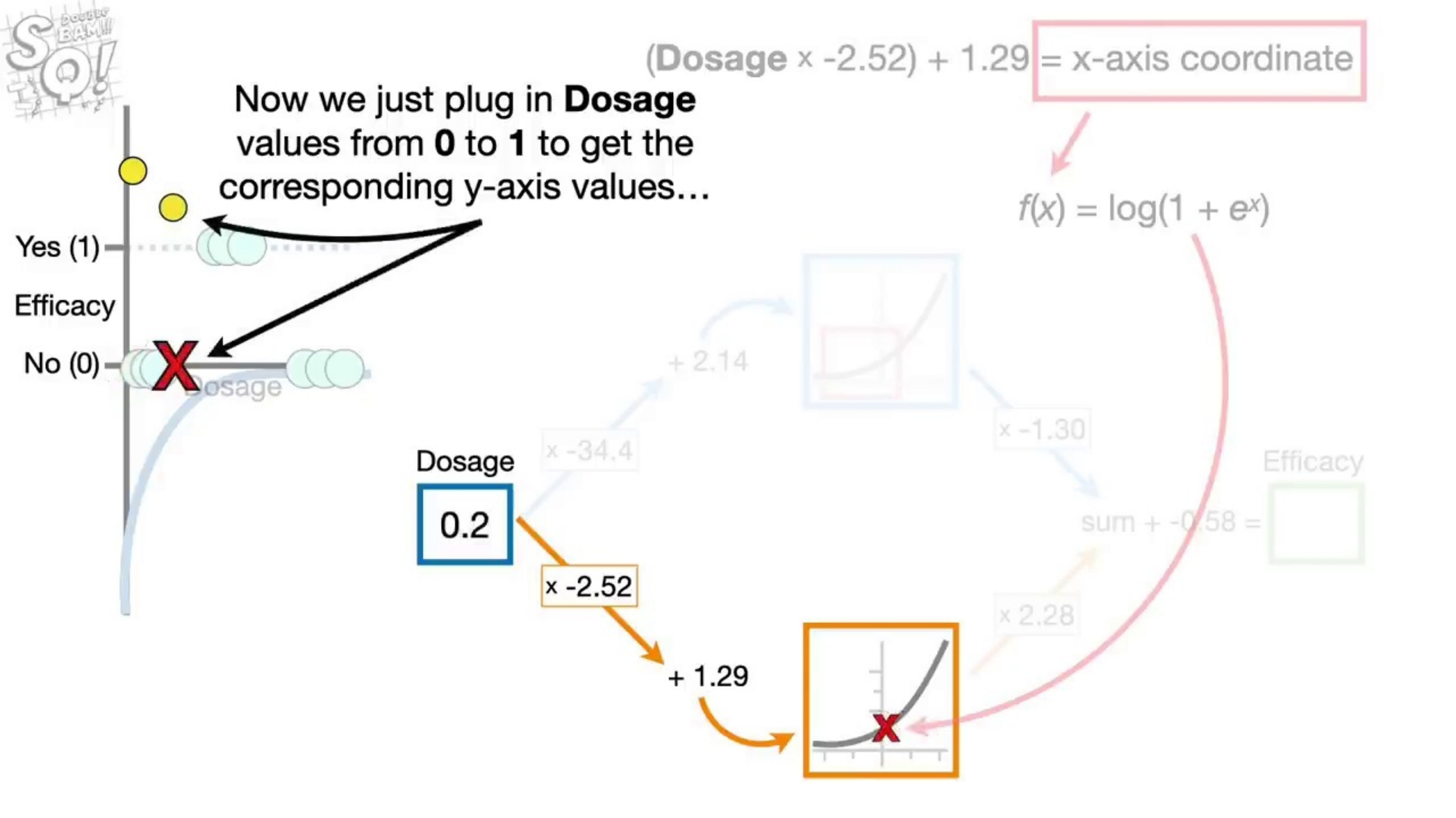
$f(1.29) = \log(1 + e^{1.29})$

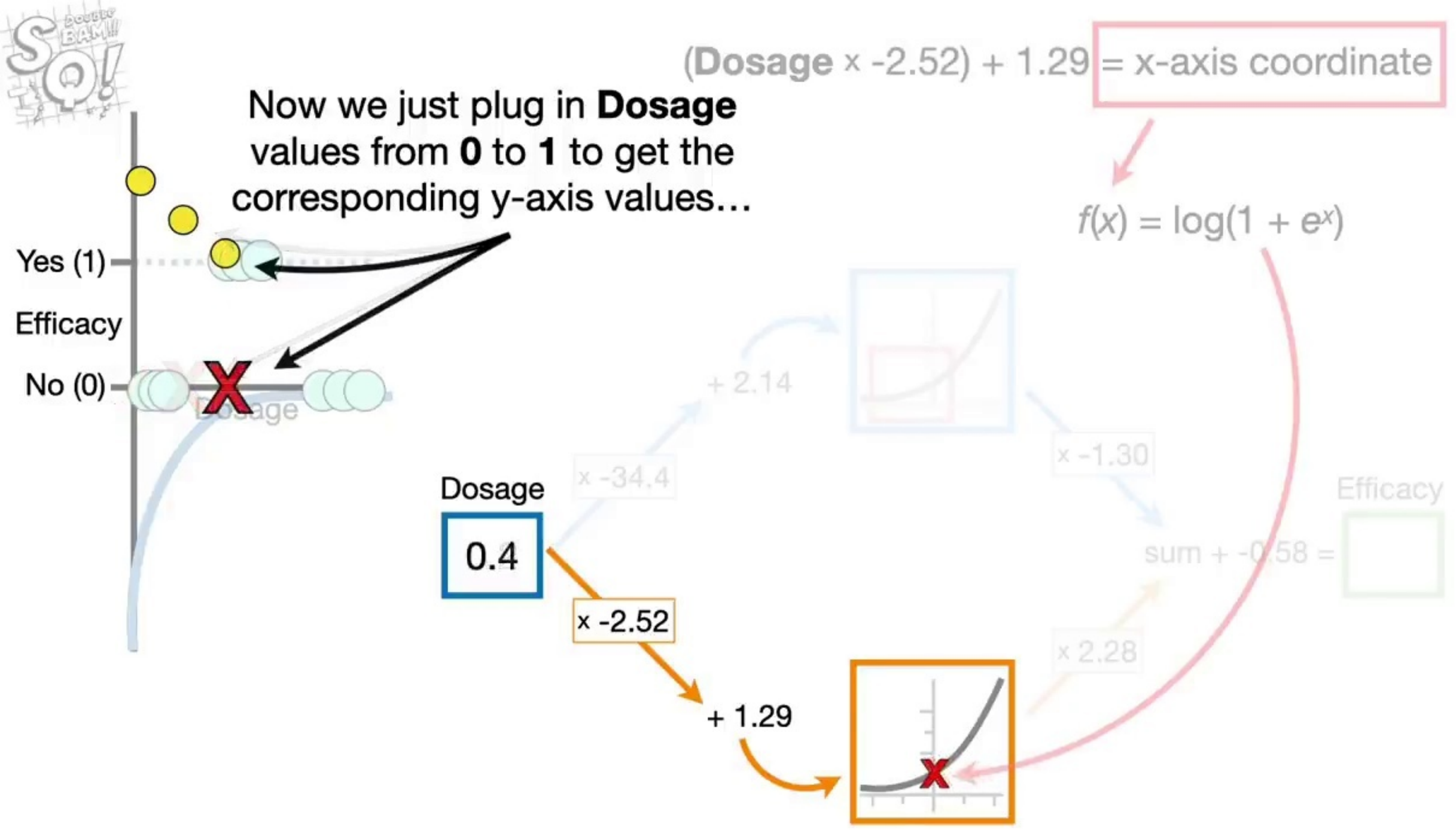


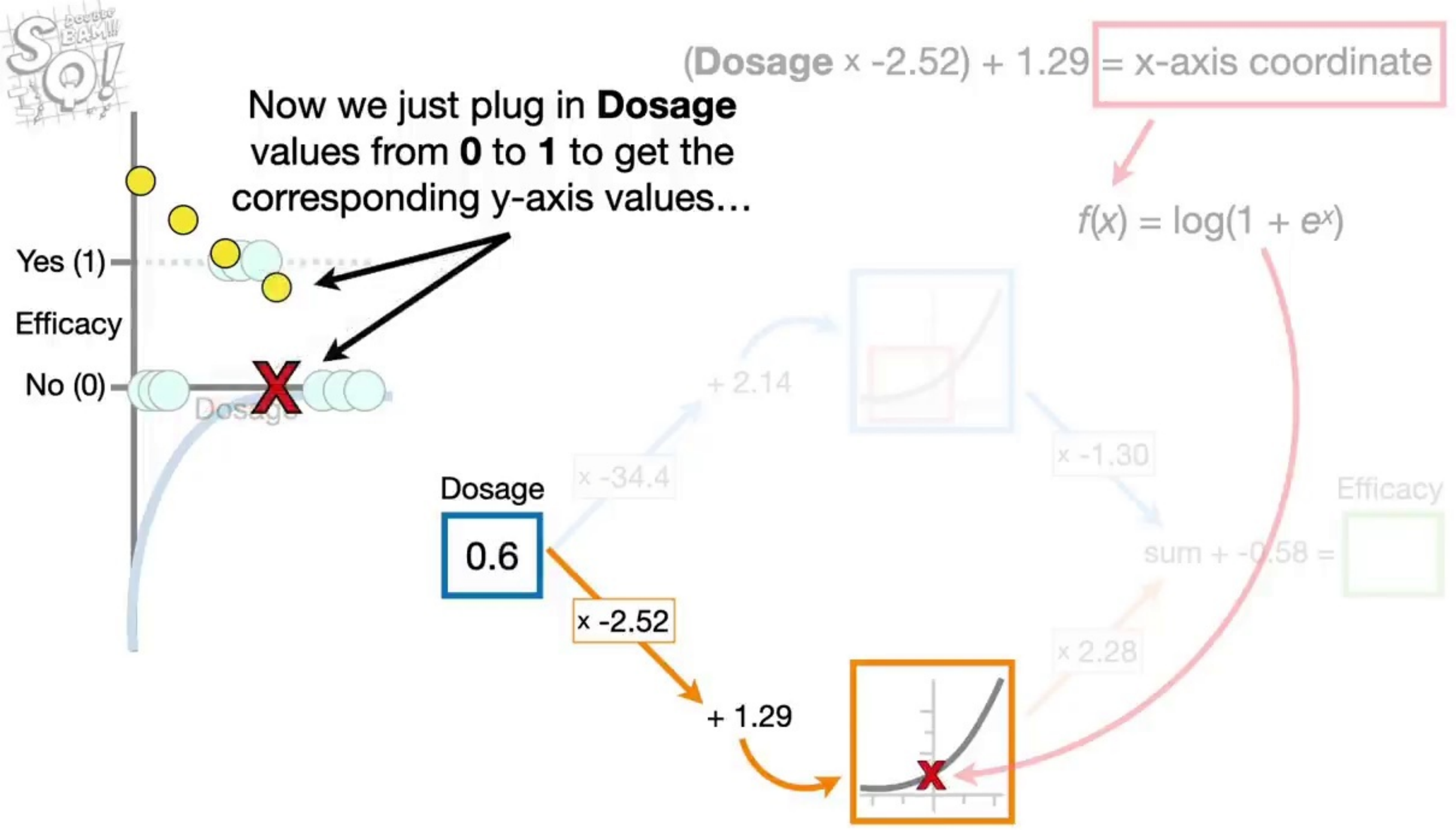

(0 x -2.52) + 1.29 = 1.29
…and get 1.53…
f(1.29) = log(1 + e^1.29) = 1.53
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x -34.4
x -1.30
Dosage
Efficacy
0
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

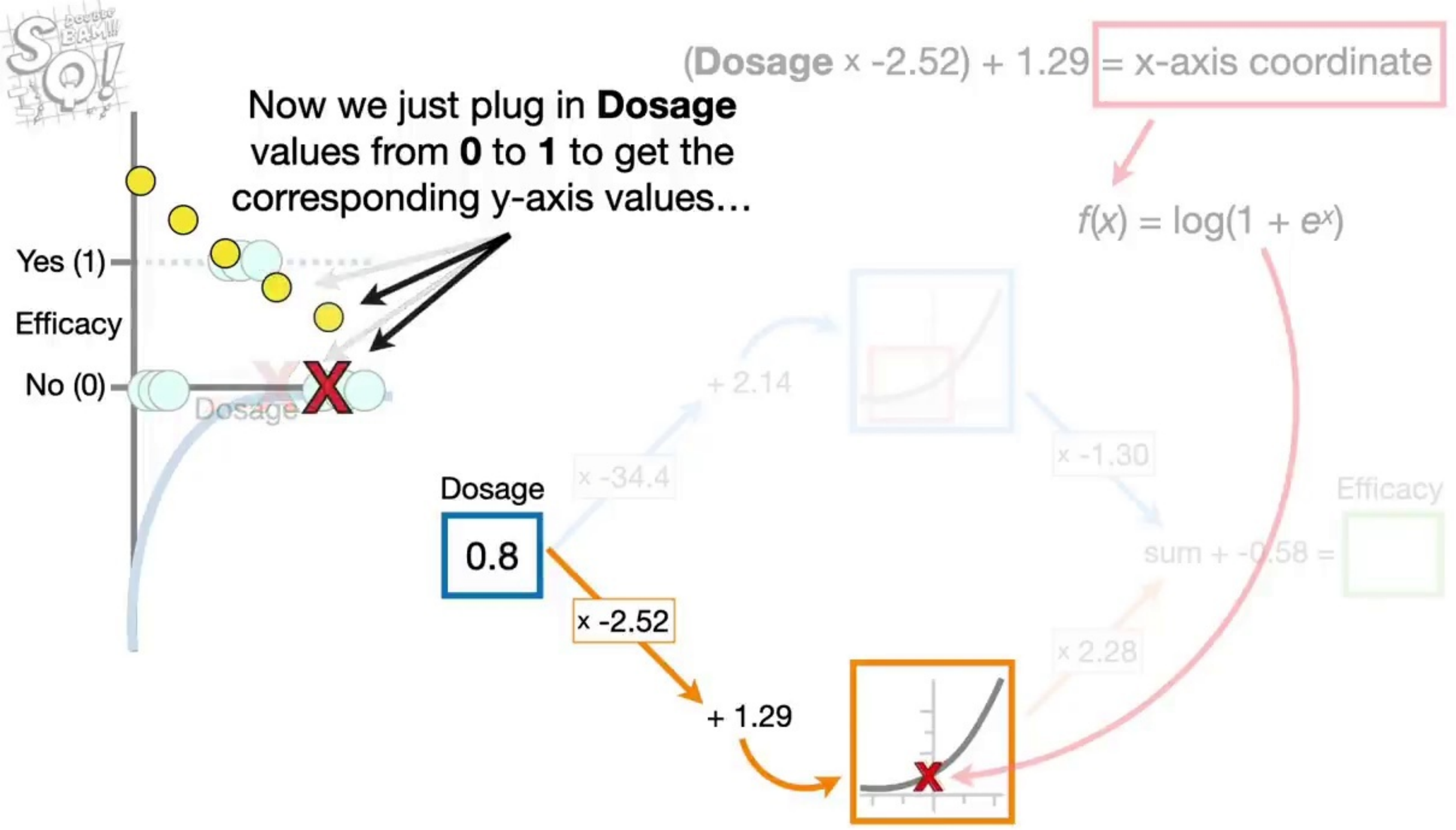

(0 × -2.52) + 1.29 = 1.29
…and get 1.53…
f(1.29) = log(1 + e^1.29) = 1.53
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28
Dosage
0
x -2.52
+ 1.29


(Dosage x -2.52) + 1.29 = x-axis coordinate
Now we just plug in Dosage values from 0 to 1 to get the corresponding y-axis values…
f(x) = log(1 + e^x)
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
Dosage
0
x -2.52
+ 1.29
x 2.28


(Dosage x -2.52) + 1.29 = x-axis coordinate
Now we just plug in Dosage values from 0 to 1 to get the corresponding y-axis values…
Yes (1)
Efficacy
No (0)
Dosage
f(x) = log(1 + e^x)
+ 2.14
x -34.4
x -1.30
Dosage
0.2
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

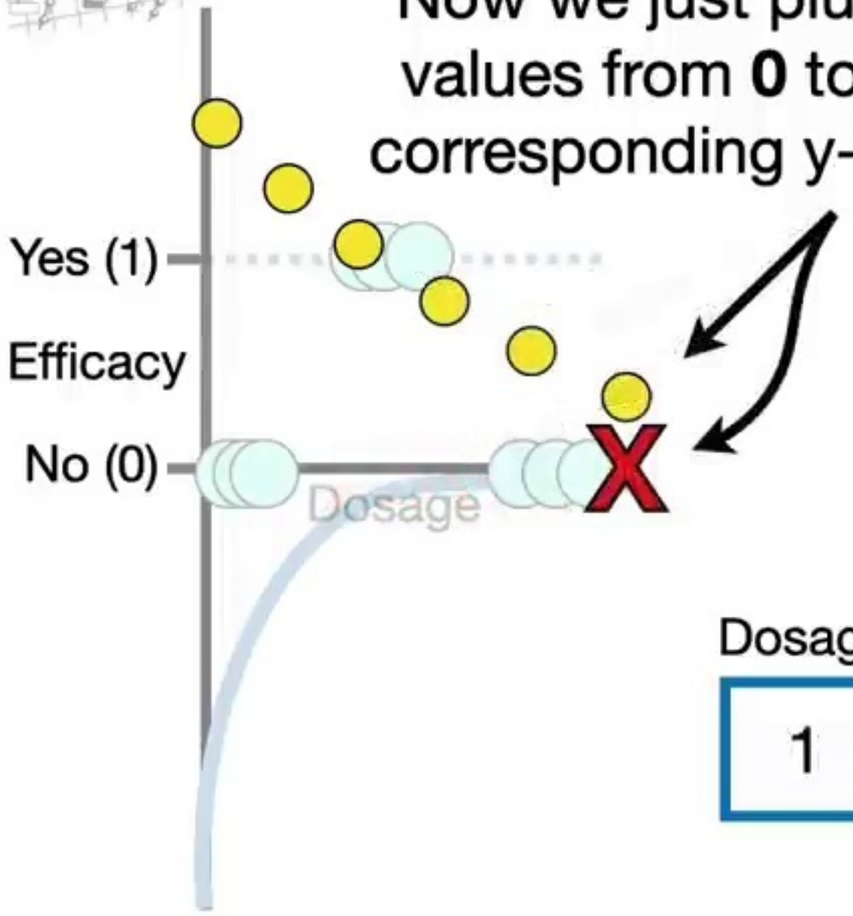

(Dosage x -2.52) + 1.29 = x-axis coordinate
Now we just plug in Dosage values from 0 to 1 to get the corresponding y-axis values…
Yes (1)
Efficacy
No (0)
Dosage
f(x) = log(1 + e^x)
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
Dosage
0.4
x -2.52
+ 1.29
x 2.28


(Dosage x -2.52) + 1.29 = x-axis coordinate
Now we just plug in Dosage values from 0 to 1 to get the corresponding y-axis values…
Yes (1)
Efficacy
No (0)
Dosage
f(x) = log(1 + e^x)
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28
Dosage
0.6
x -2.52
+ 1.29


(Dosage x -2.52) + 1.29 = x-axis coordinate
Now we just plug in Dosage values from 0 to 1 to get the corresponding y-axis values…
Yes (1)
Efficacy
No (0)
Dosage
f(x) = log(1 + e^x)
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
Dosage
0.8
x -2.52
+ 1.29
x 2.28

(**Dosage** x -2.52) + 1.29 = x-axis coordinate

Now we just plug in **Dosage** values from **0** to **1** to get the corresponding y-axis values…



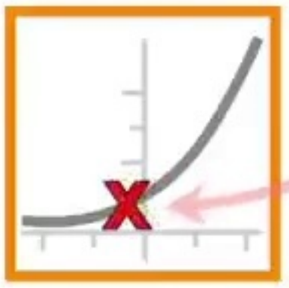
$f(x) = \log(1 + e^x)$

Dosage

1

x -2.52

+ 1.29



x 2.28

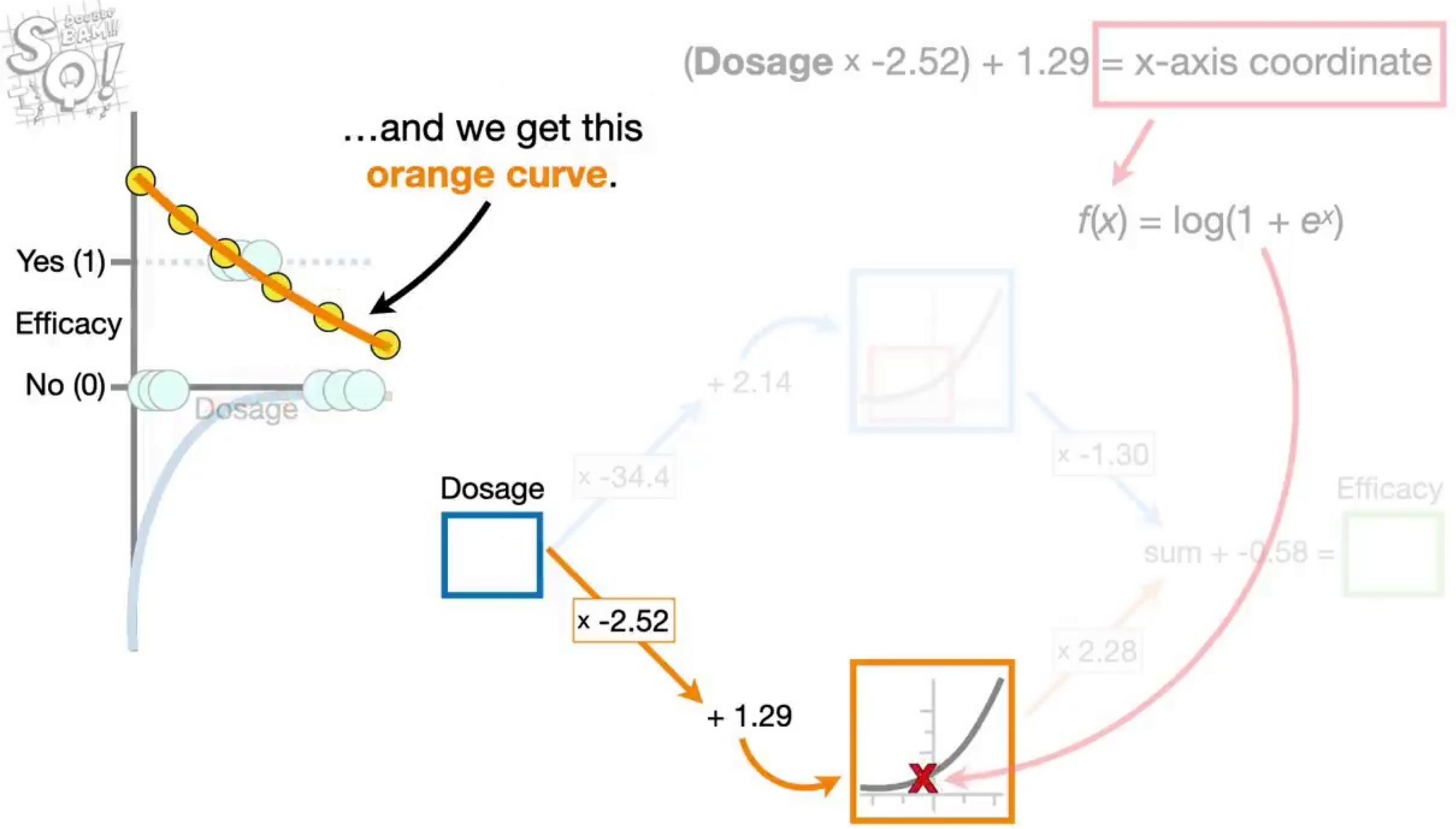
sum + -0.58 =

Efficacy

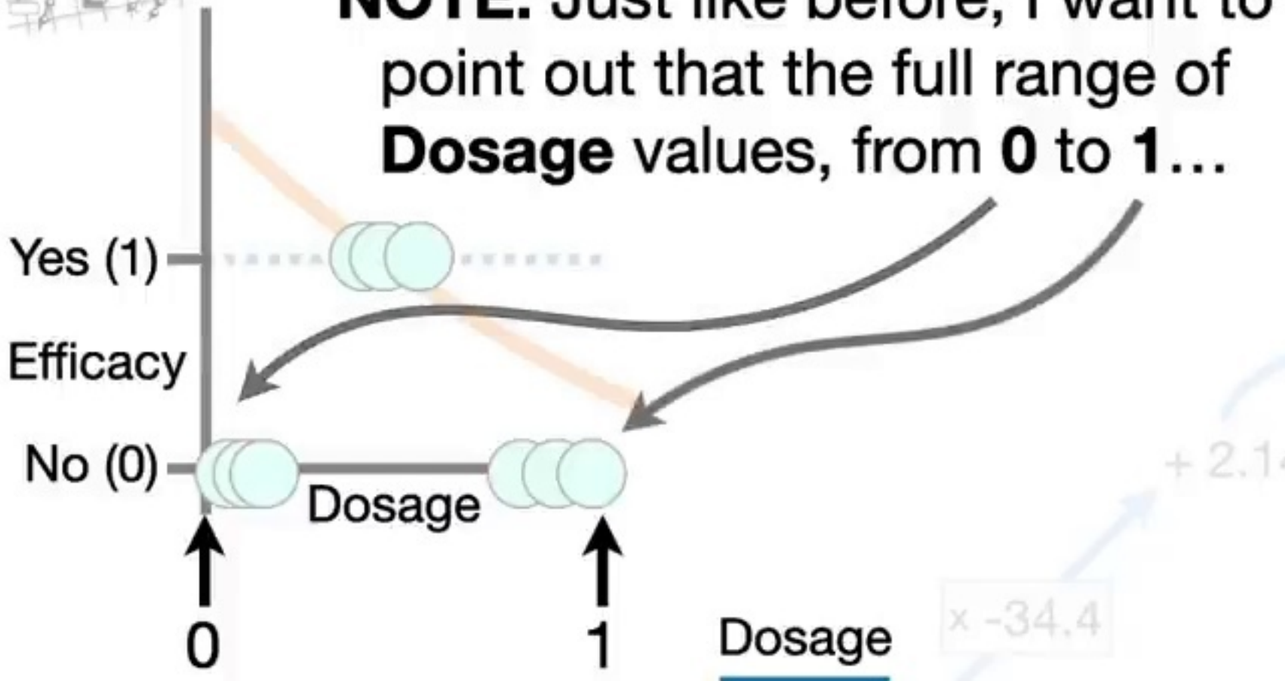
x -1.30

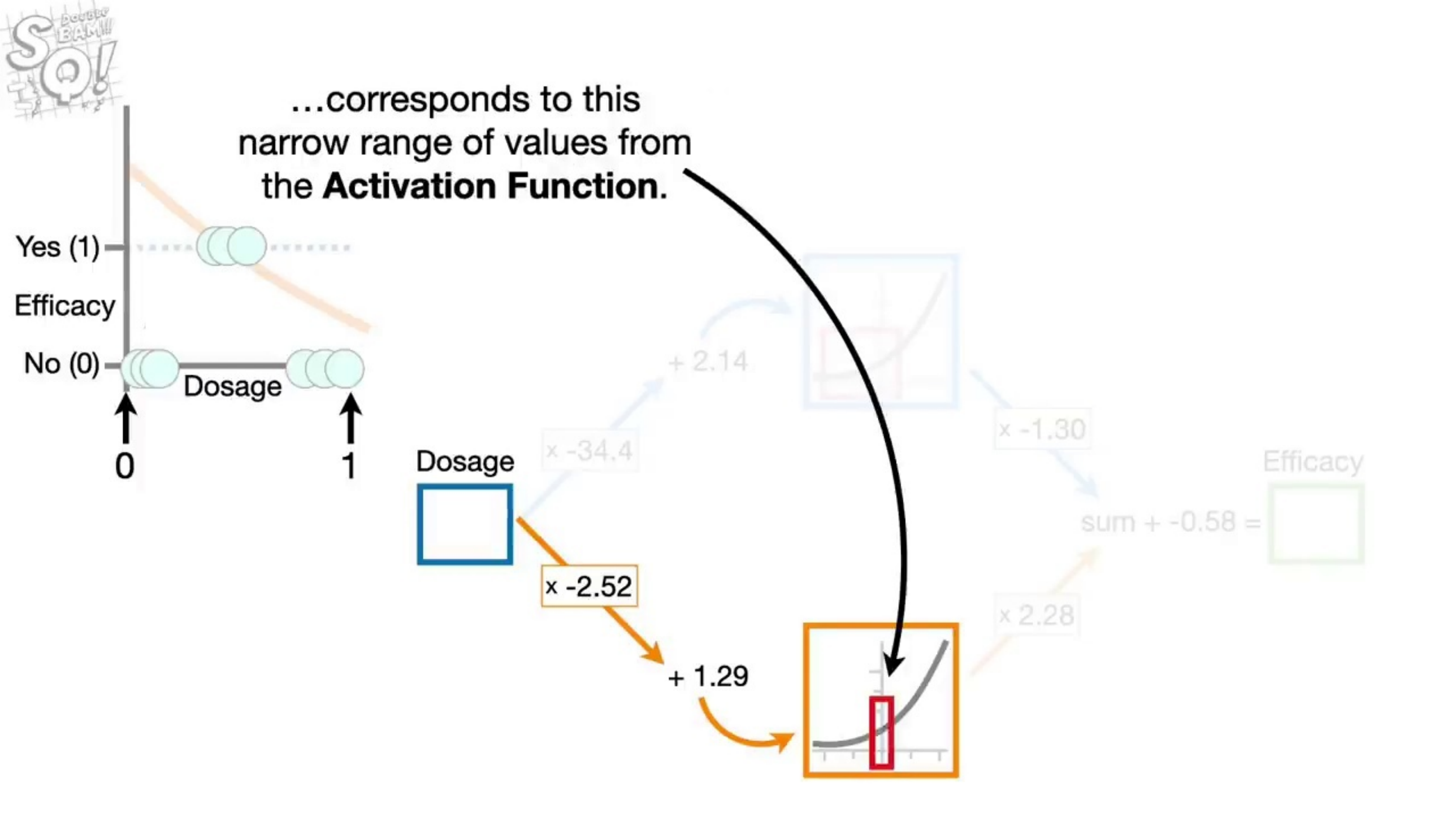
+ 2.14

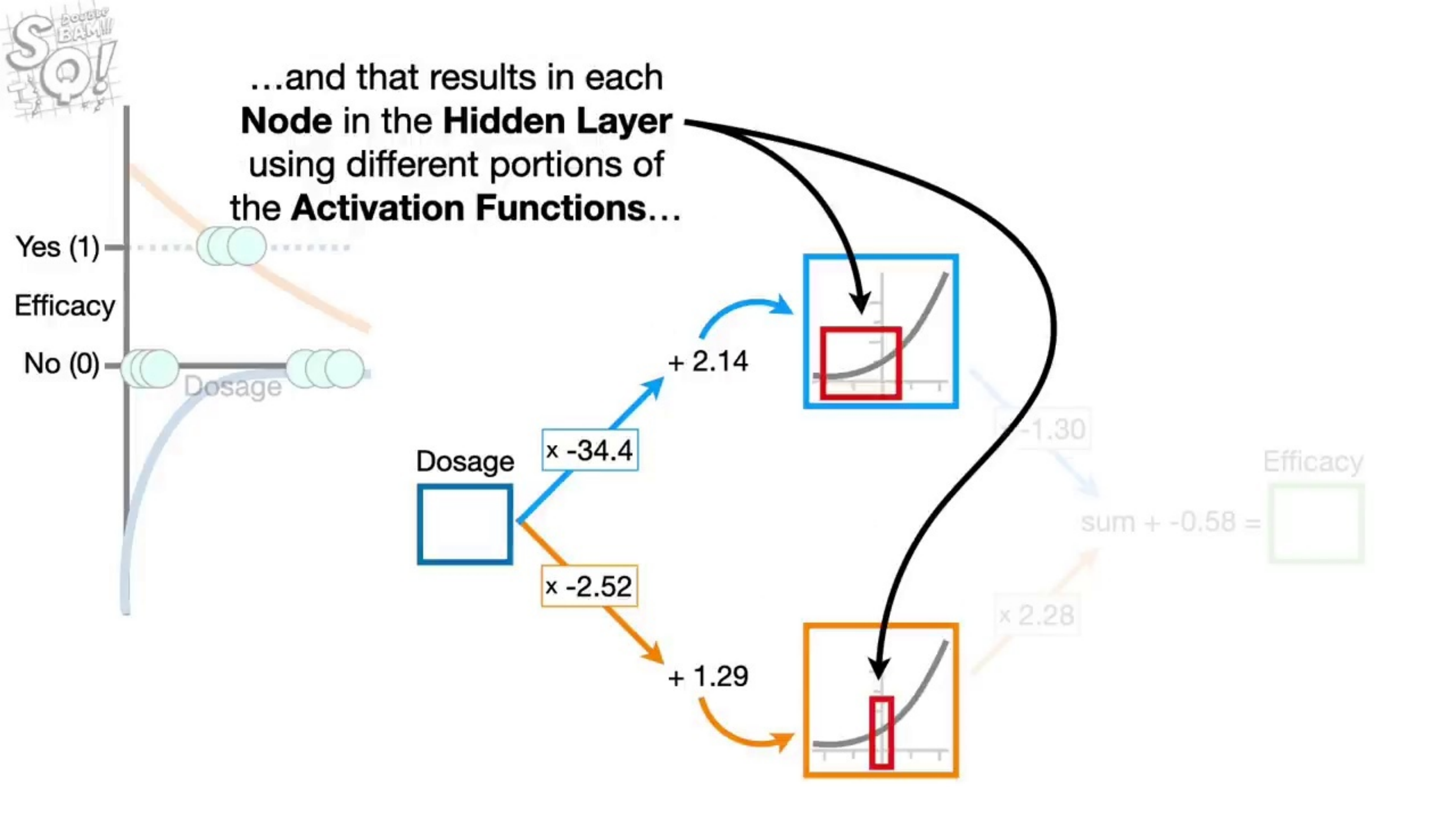
x -34.4


(Dosage x -2.52) + 1.29 = x-axis coordinate
f(x) = log(1 + e^x)
...and we get this orange curve.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy
x 2.28

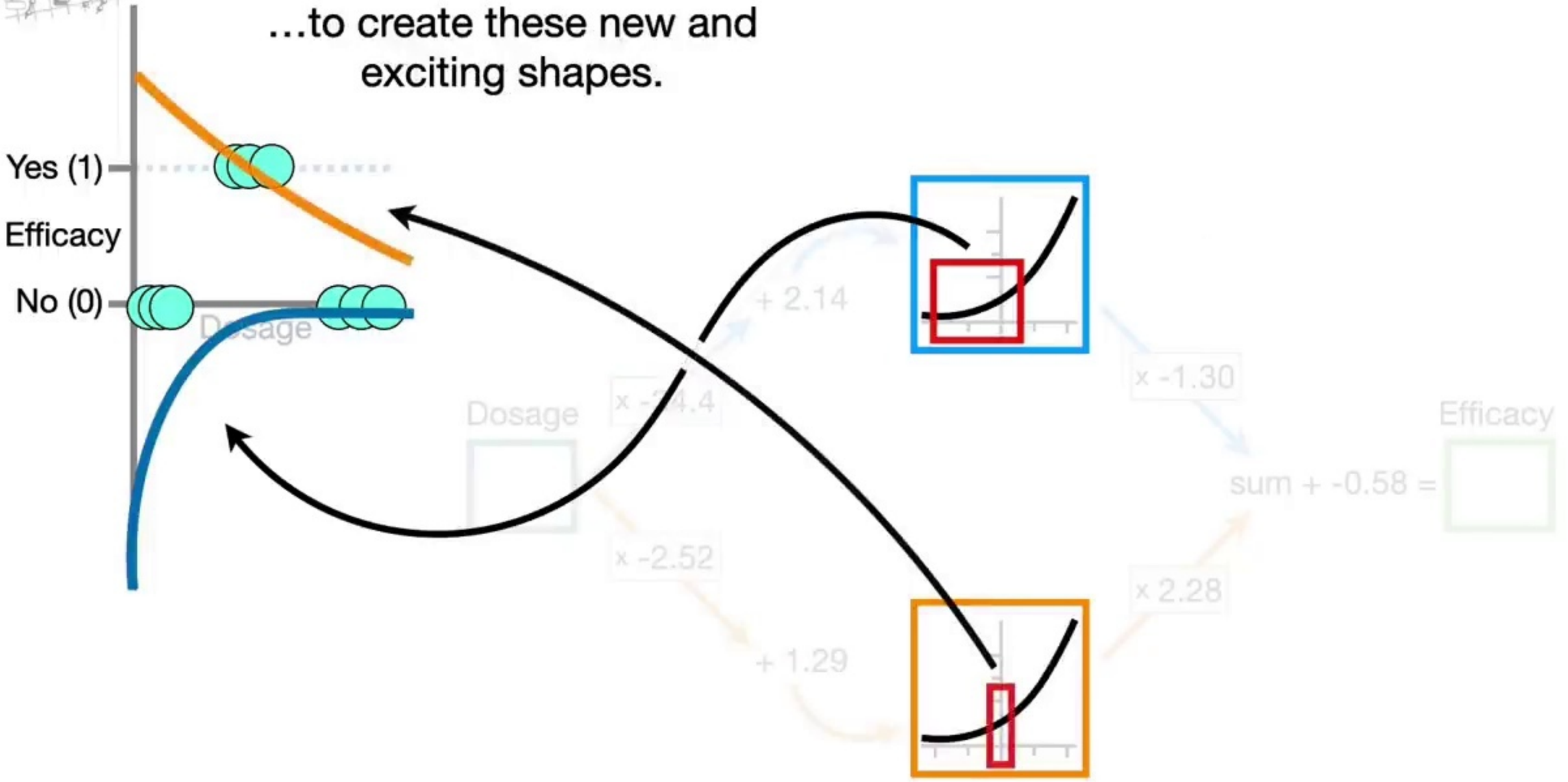
NOTE: Just like before, I want to point out that the full range of **Dosage** values, from **0** to **1**...

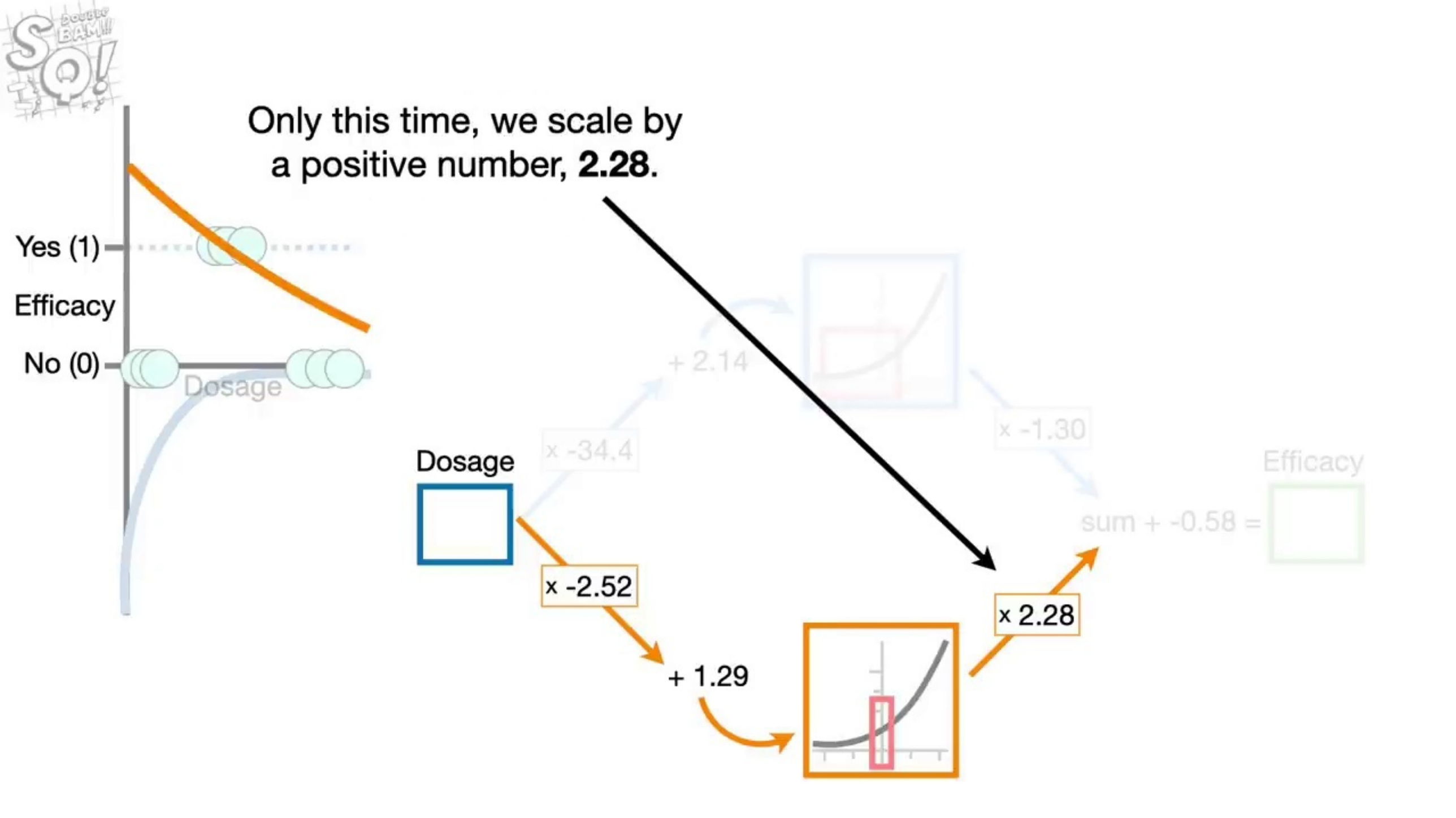


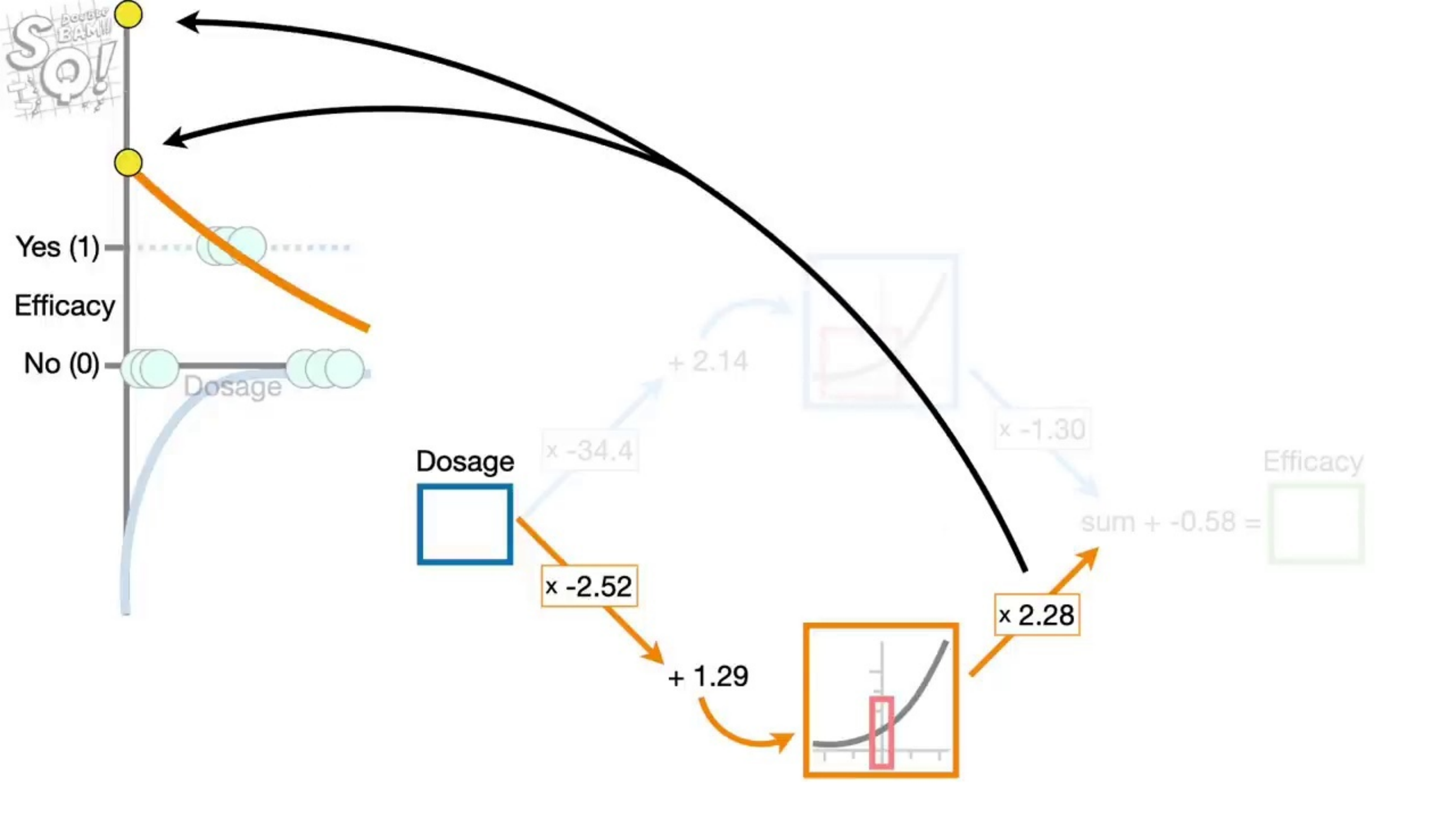

…corresponds to this narrow range of values from the **Activation Function**.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -2.52
+ 1.29
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x 2.28

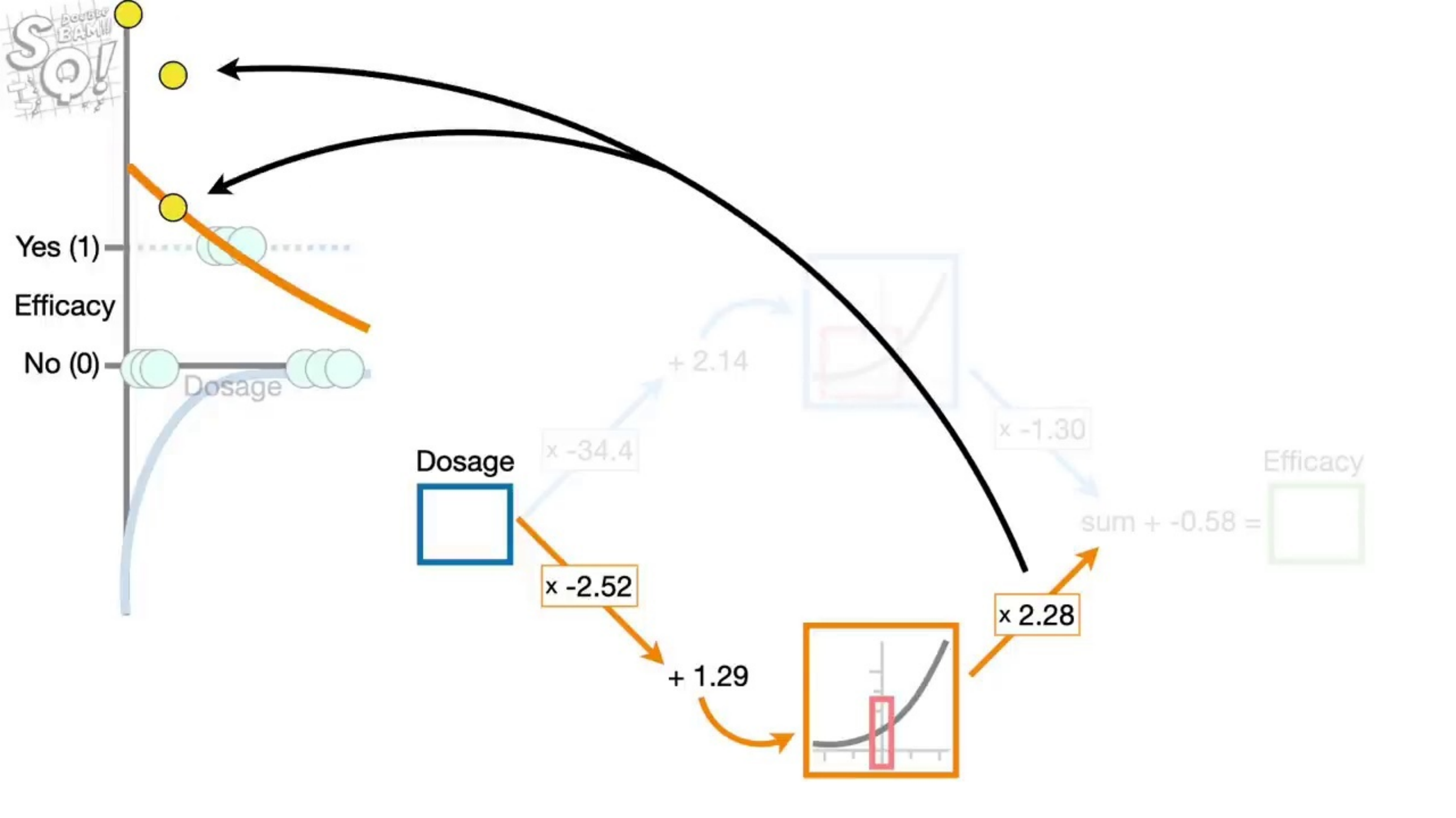

…and that results in each **Node** in the **Hidden Layer** using different portions of the **Activation Functions**…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
-1.30
sum + -0.58 =
Efficacy
x 2.28

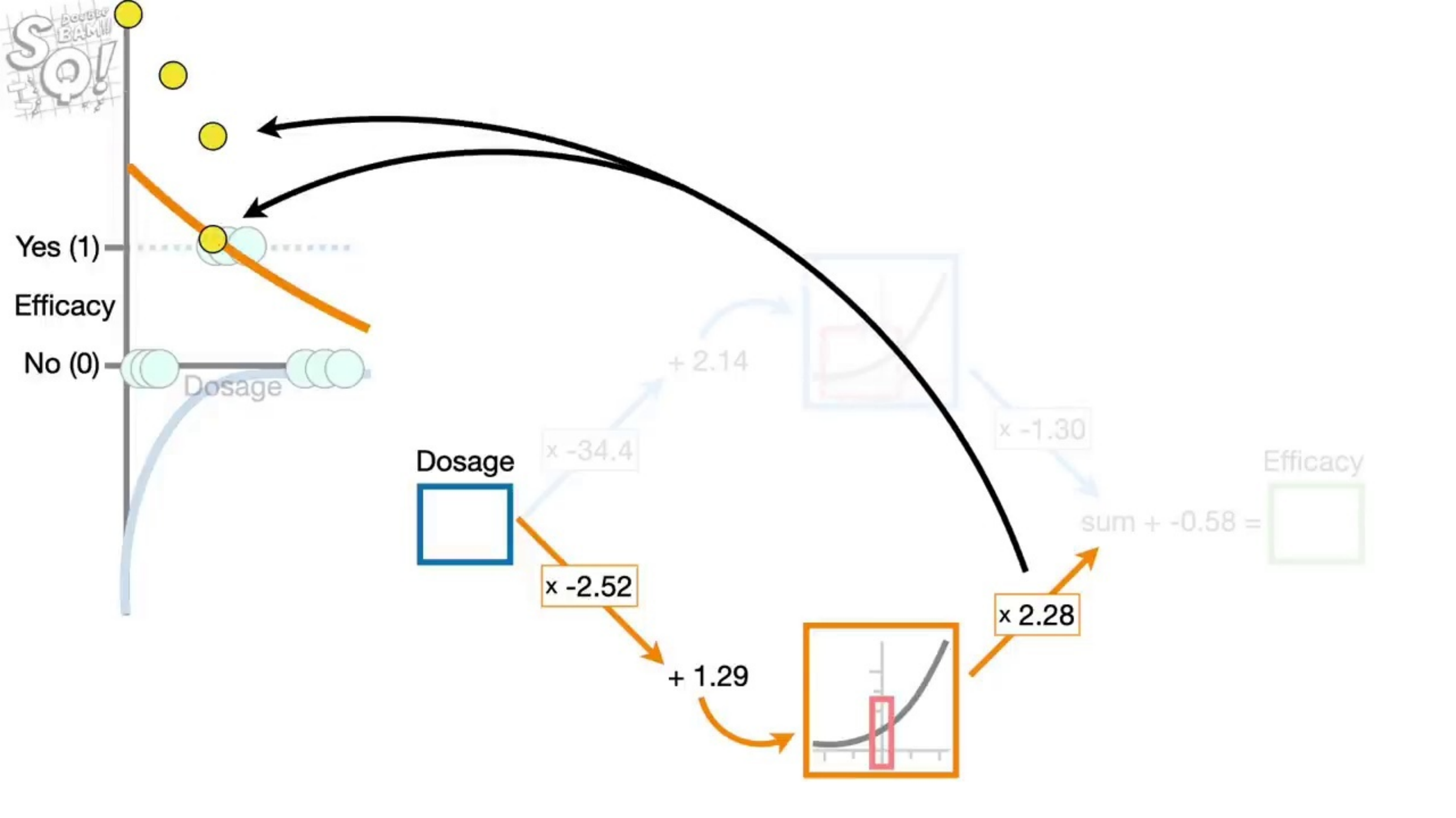
…to create these new and exciting shapes.

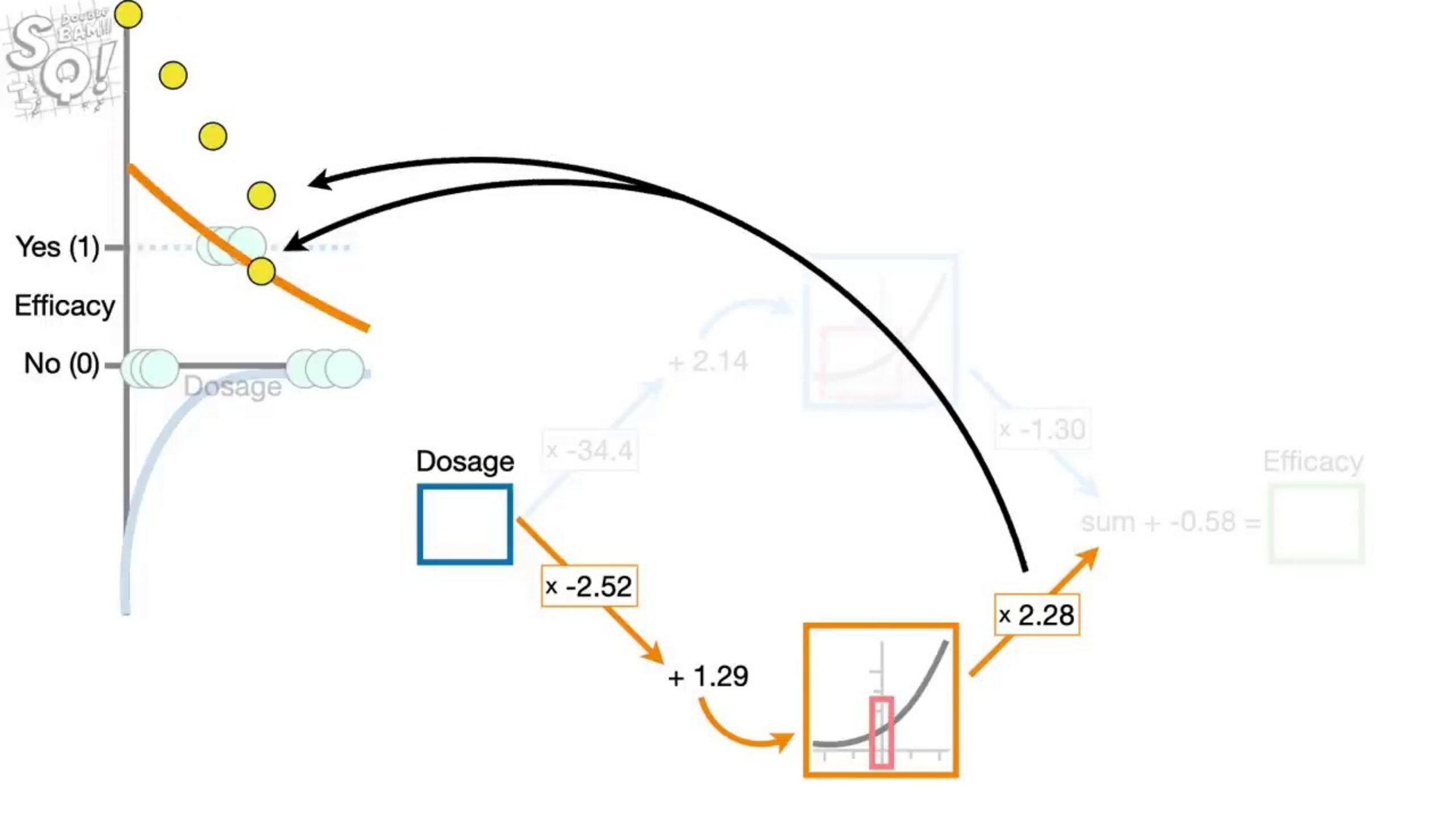


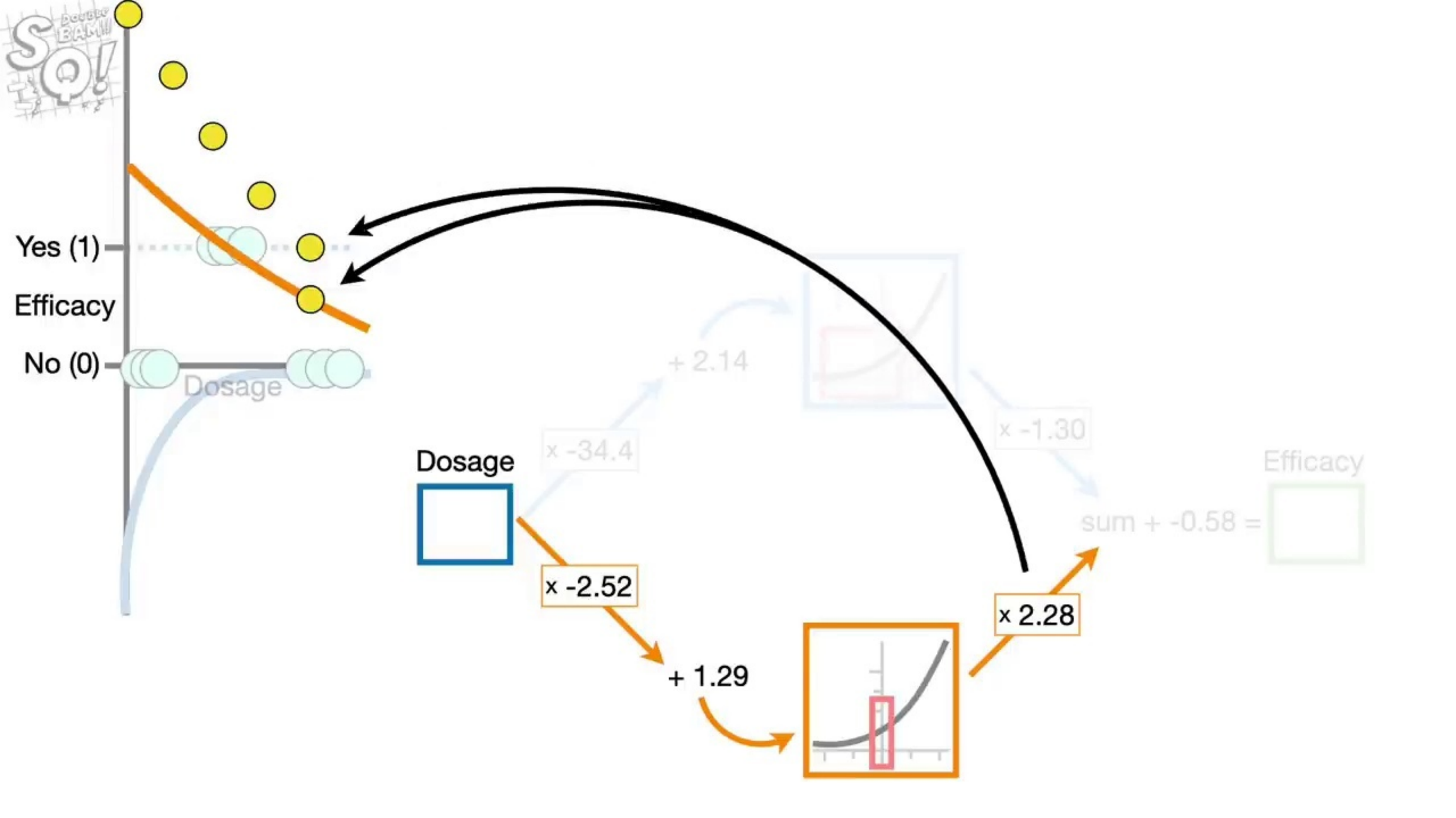

Only this time, we scale by a positive number, 2.28.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

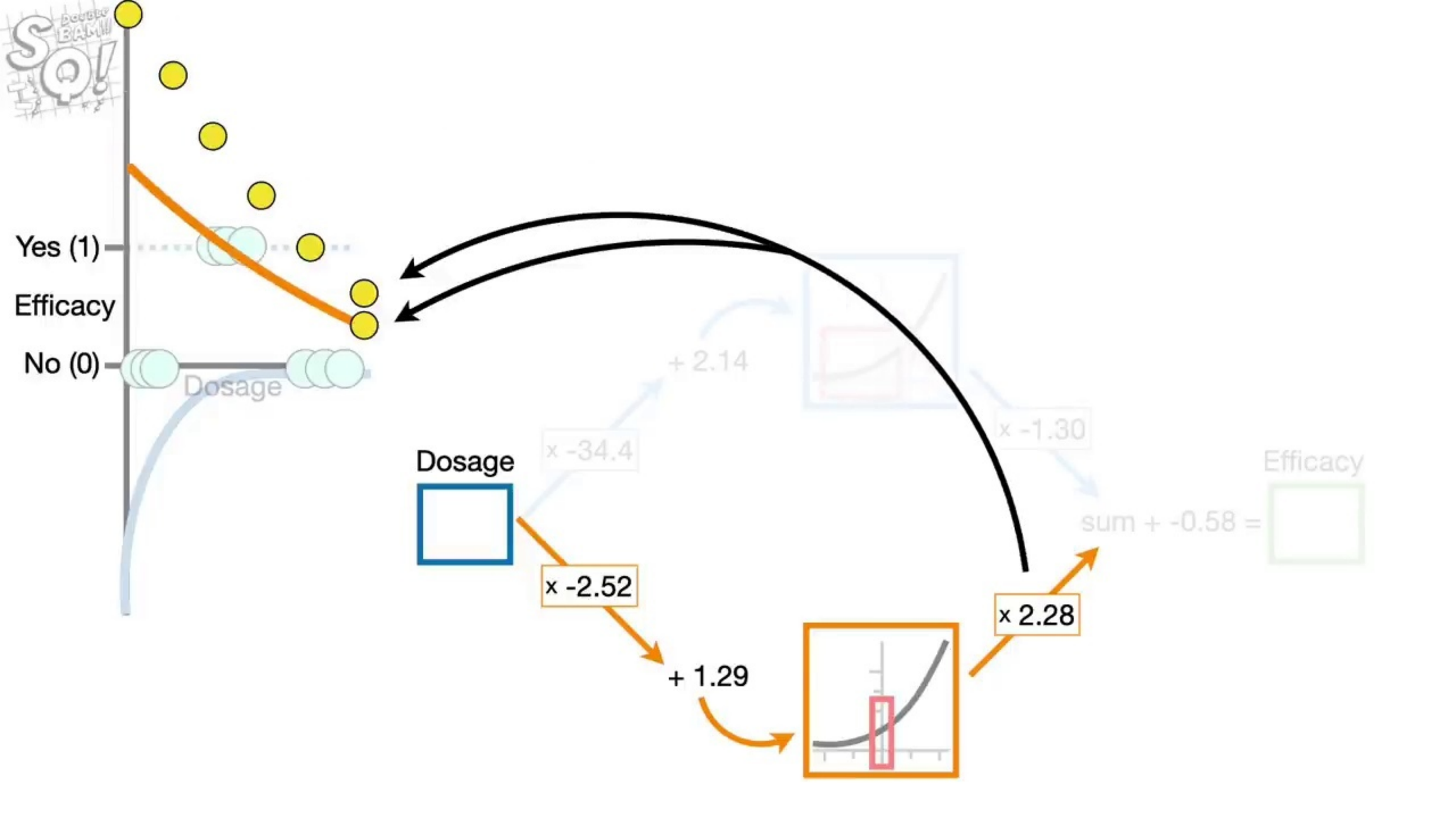

Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

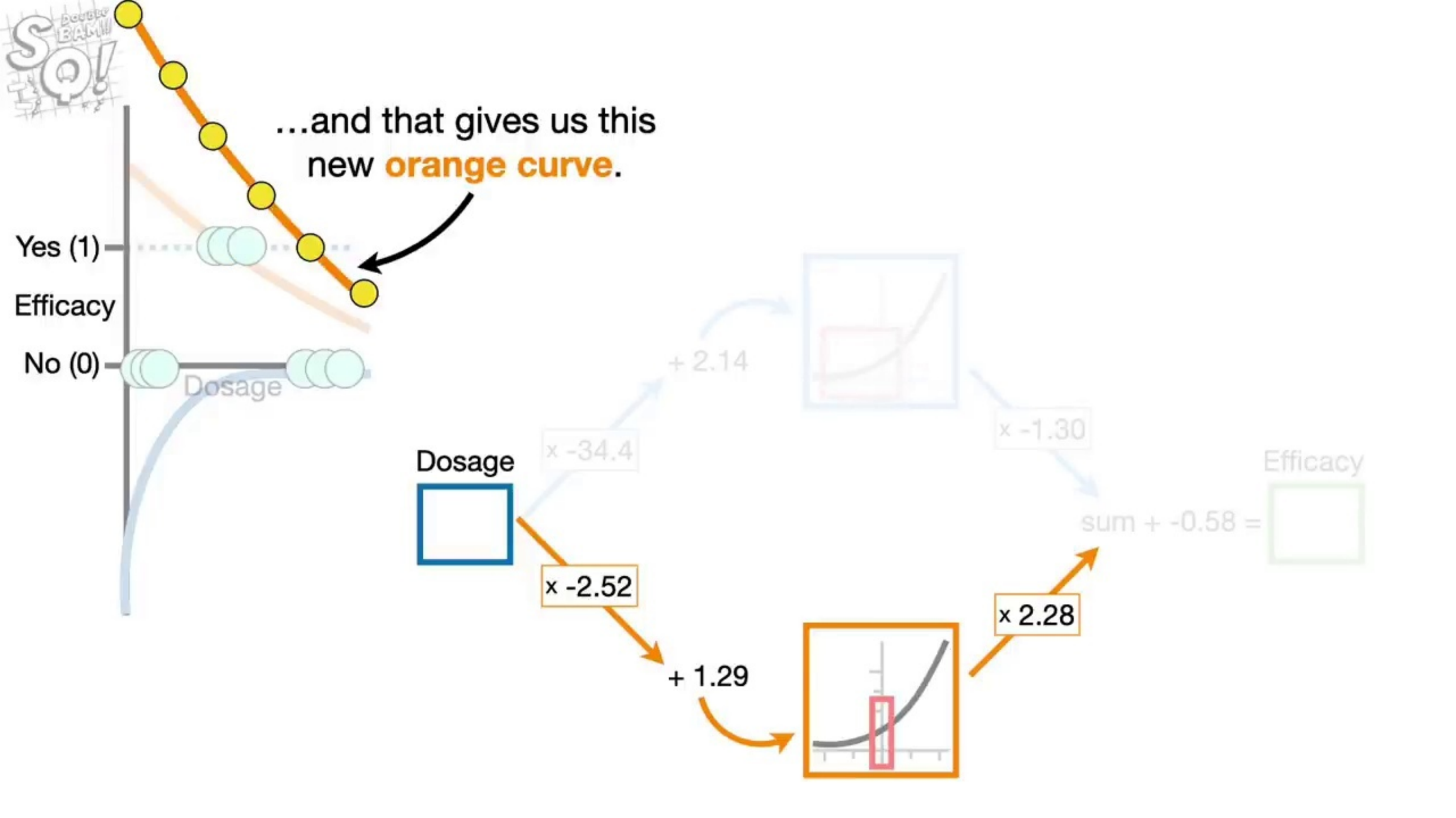

Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

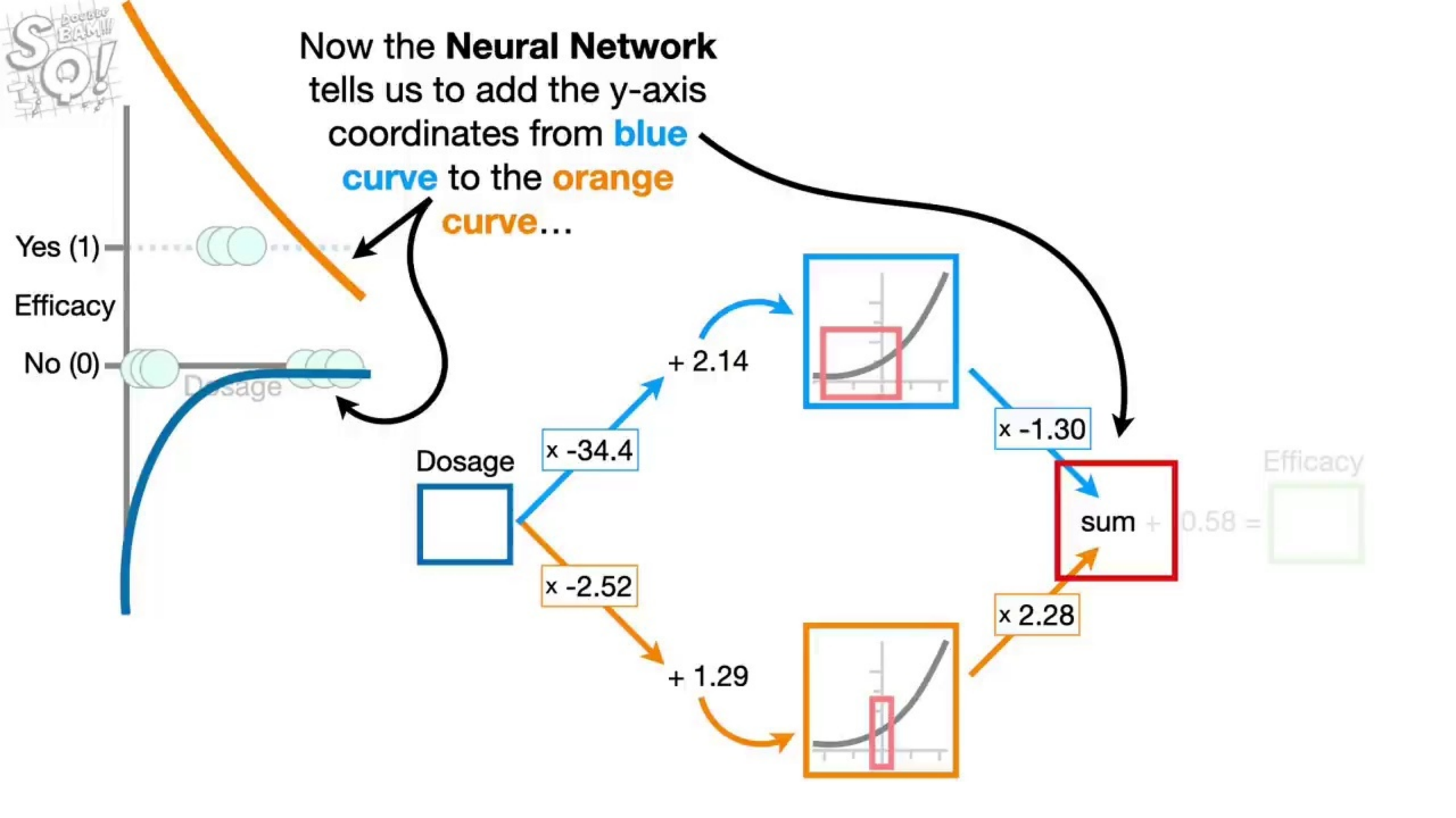

Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

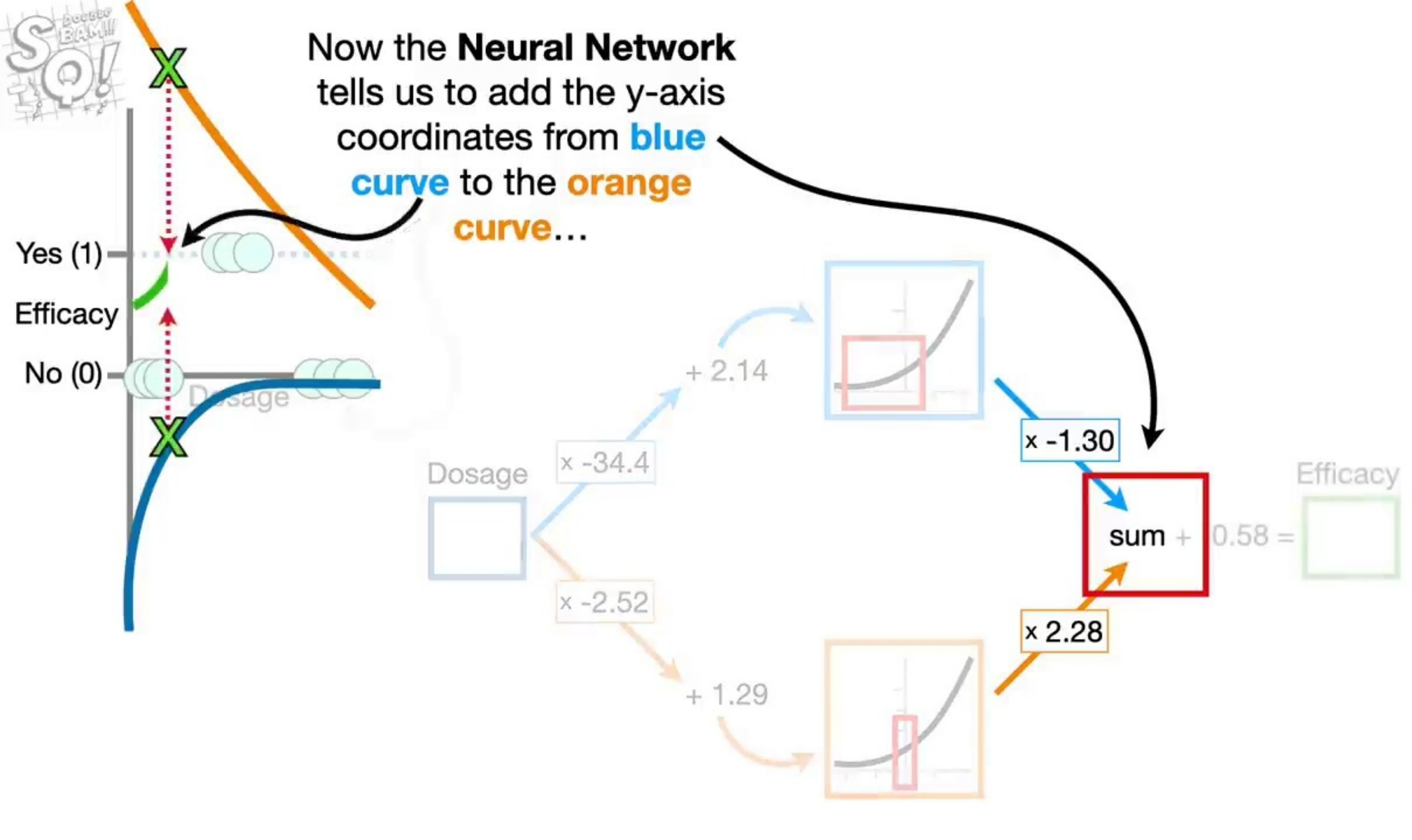

Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

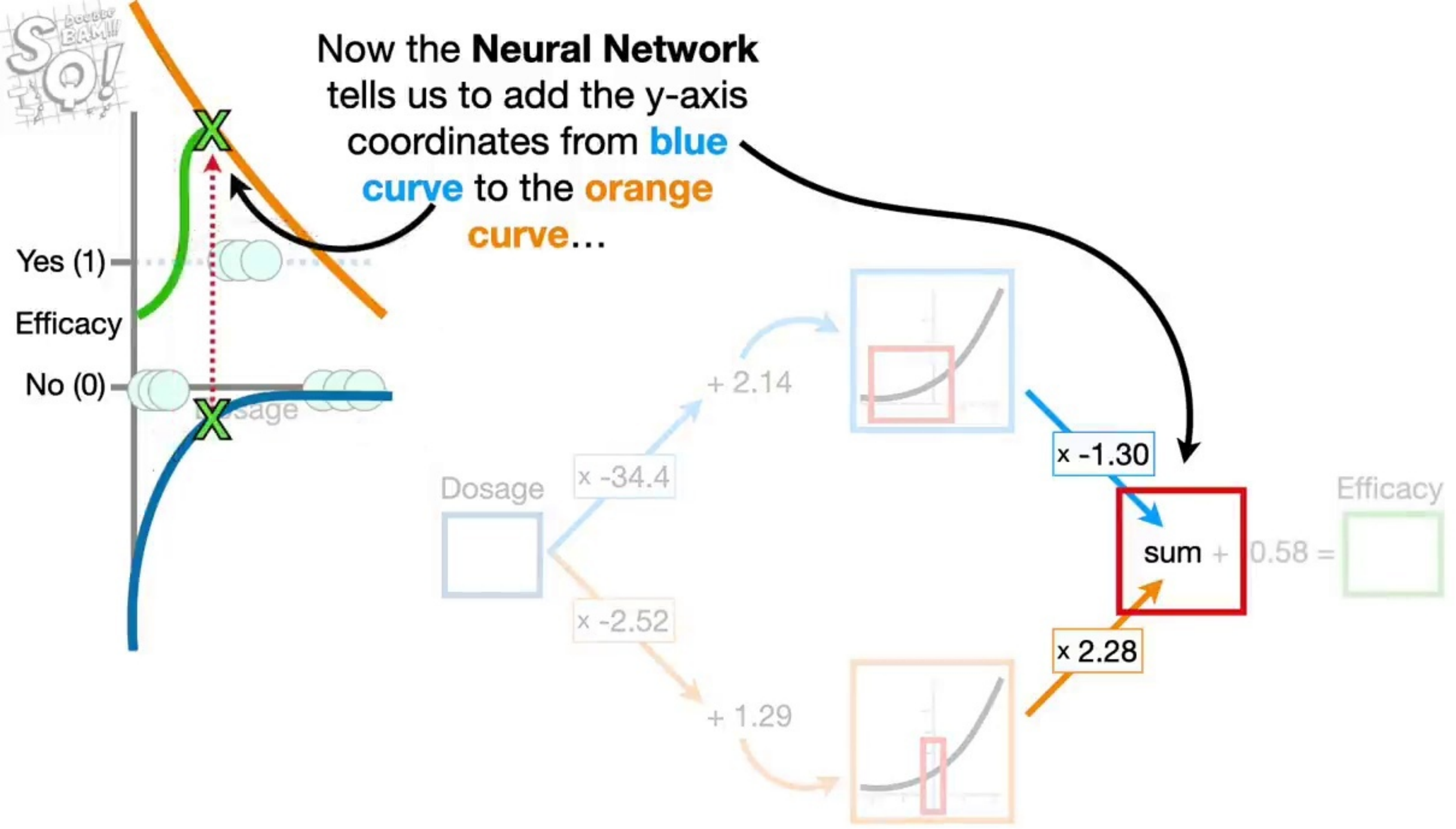

Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

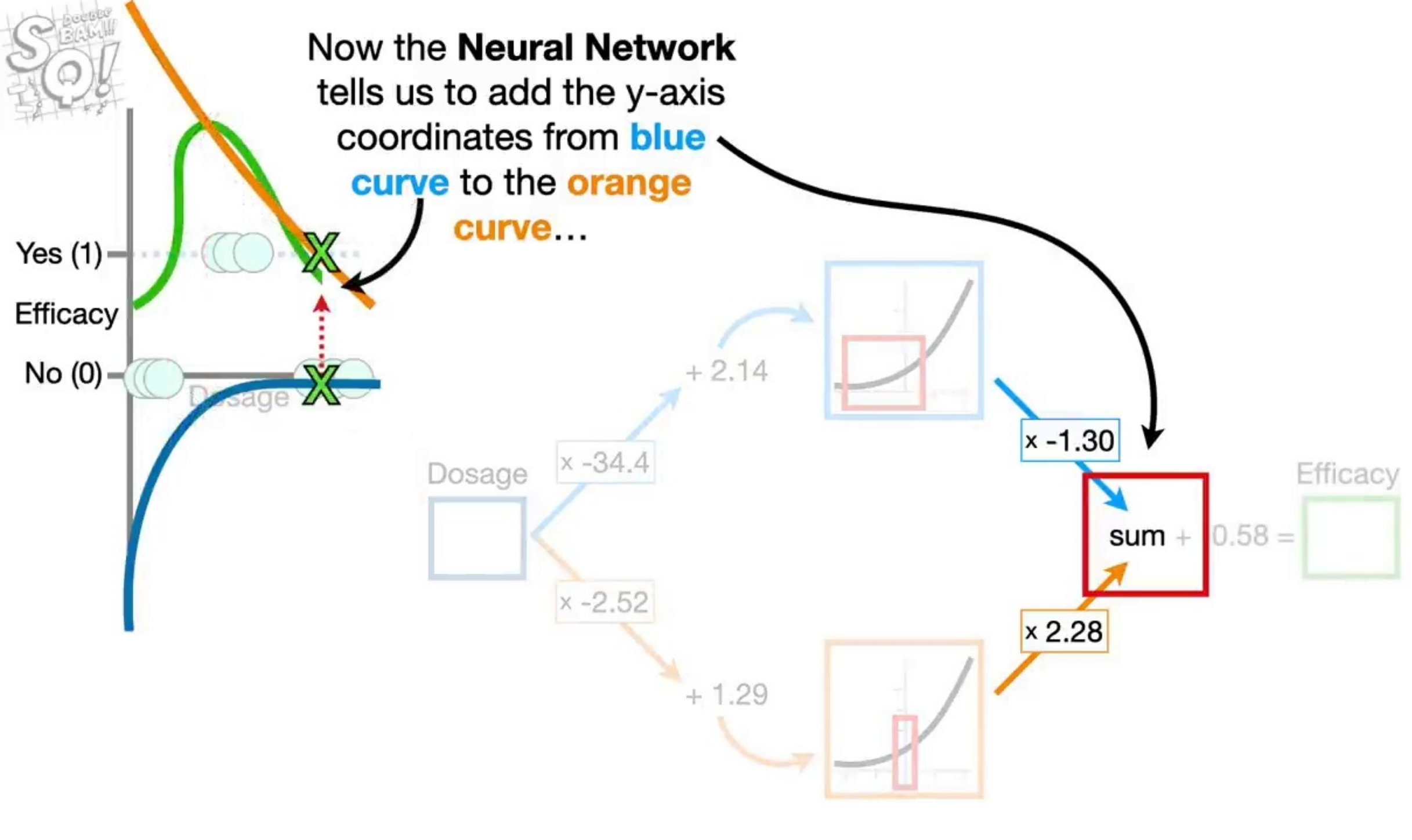

Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

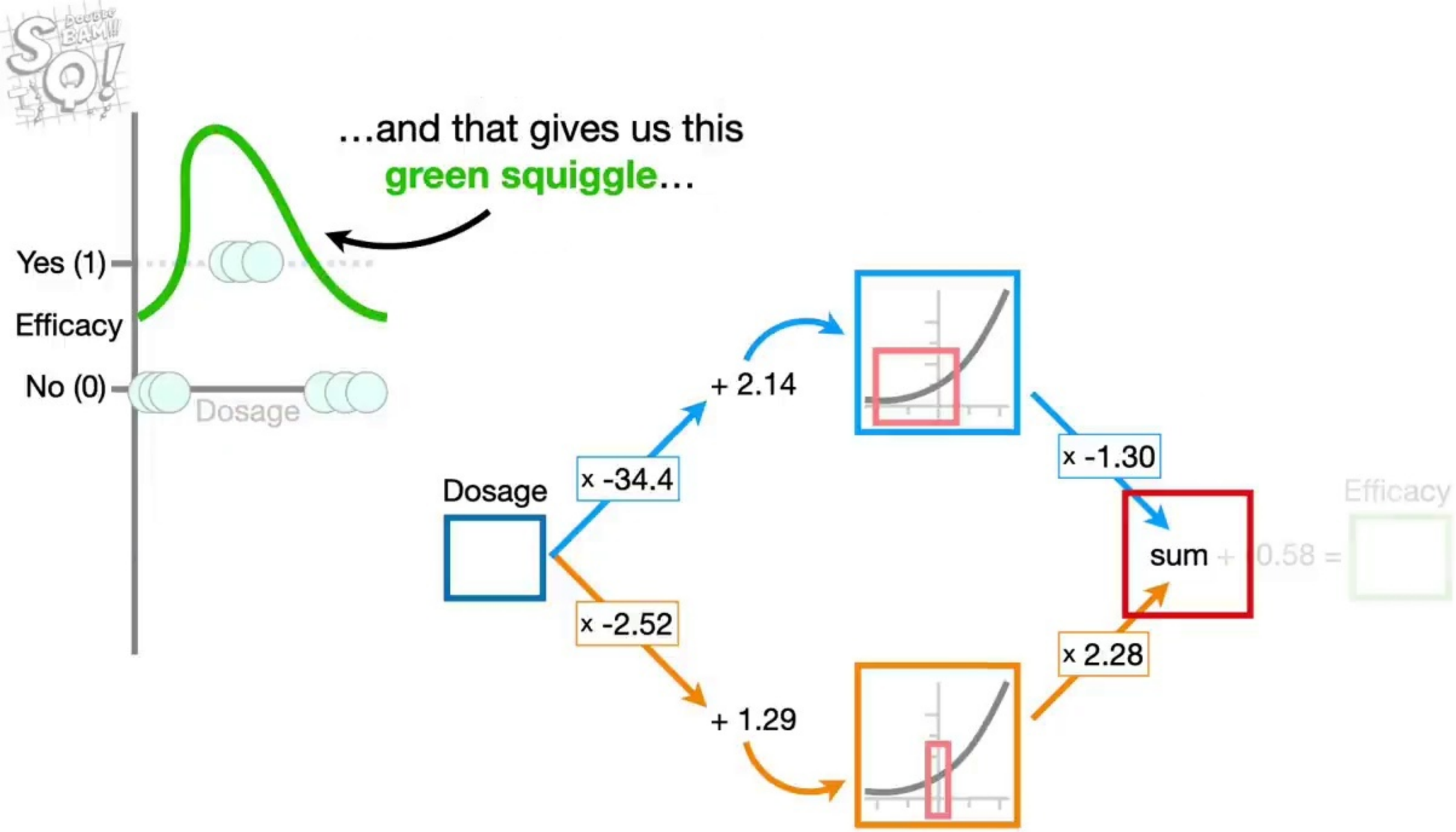

…and that gives us this new orange curve.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy

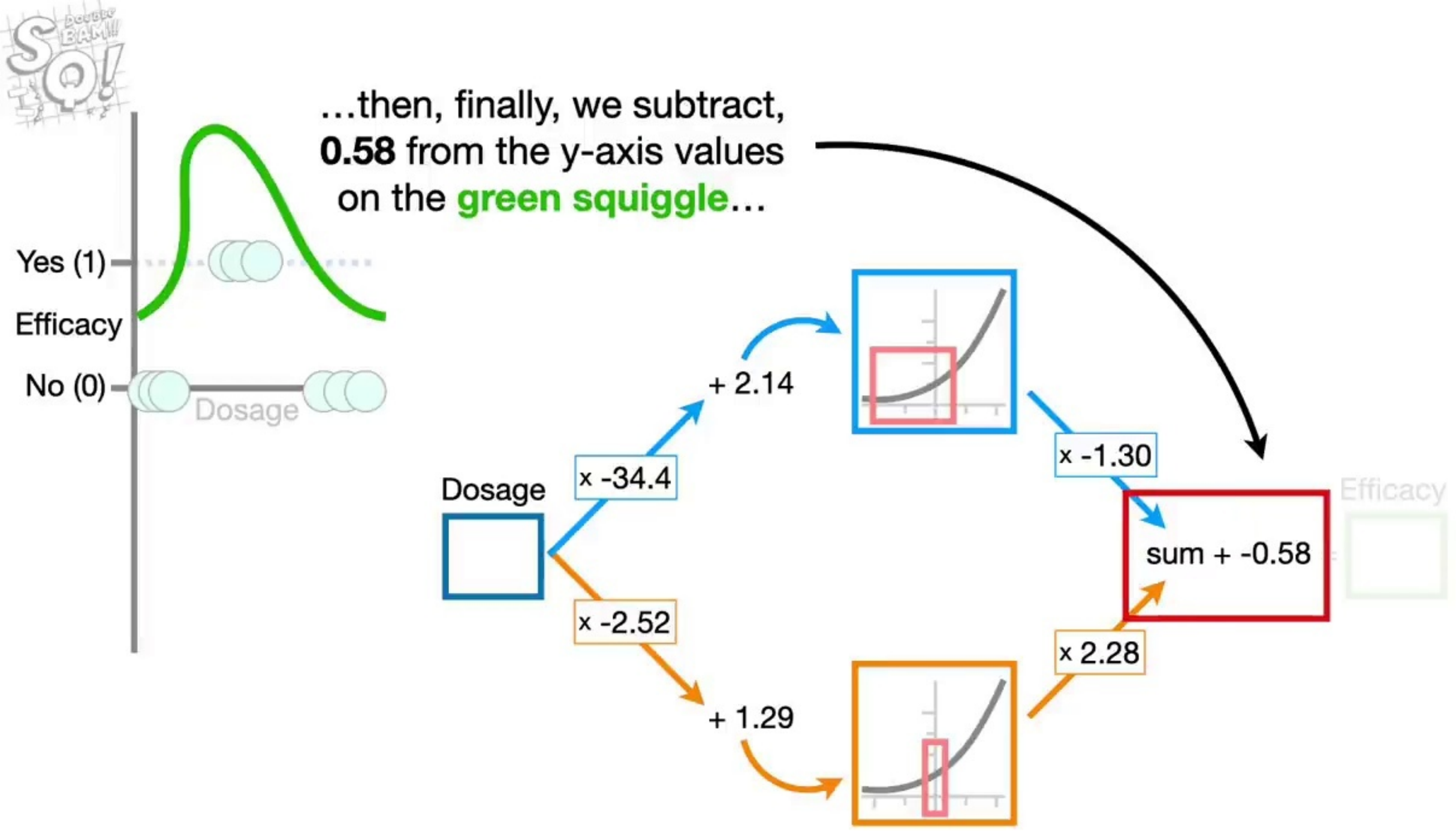

Now the Neural Network tells us to add the y-axis coordinates from blue curve to the orange curve…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy


So!
Double BAM!!!
Now the Neural Network tells us to add the y-axis coordinates from blue curve to the orange curve…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy

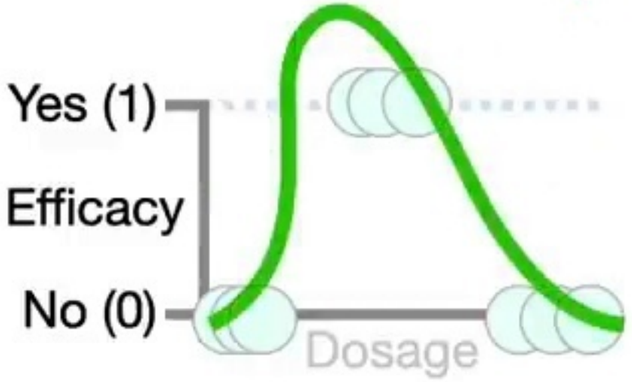

Now the Neural Network tells us to add the y-axis coordinates from blue curve to the orange curve…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy

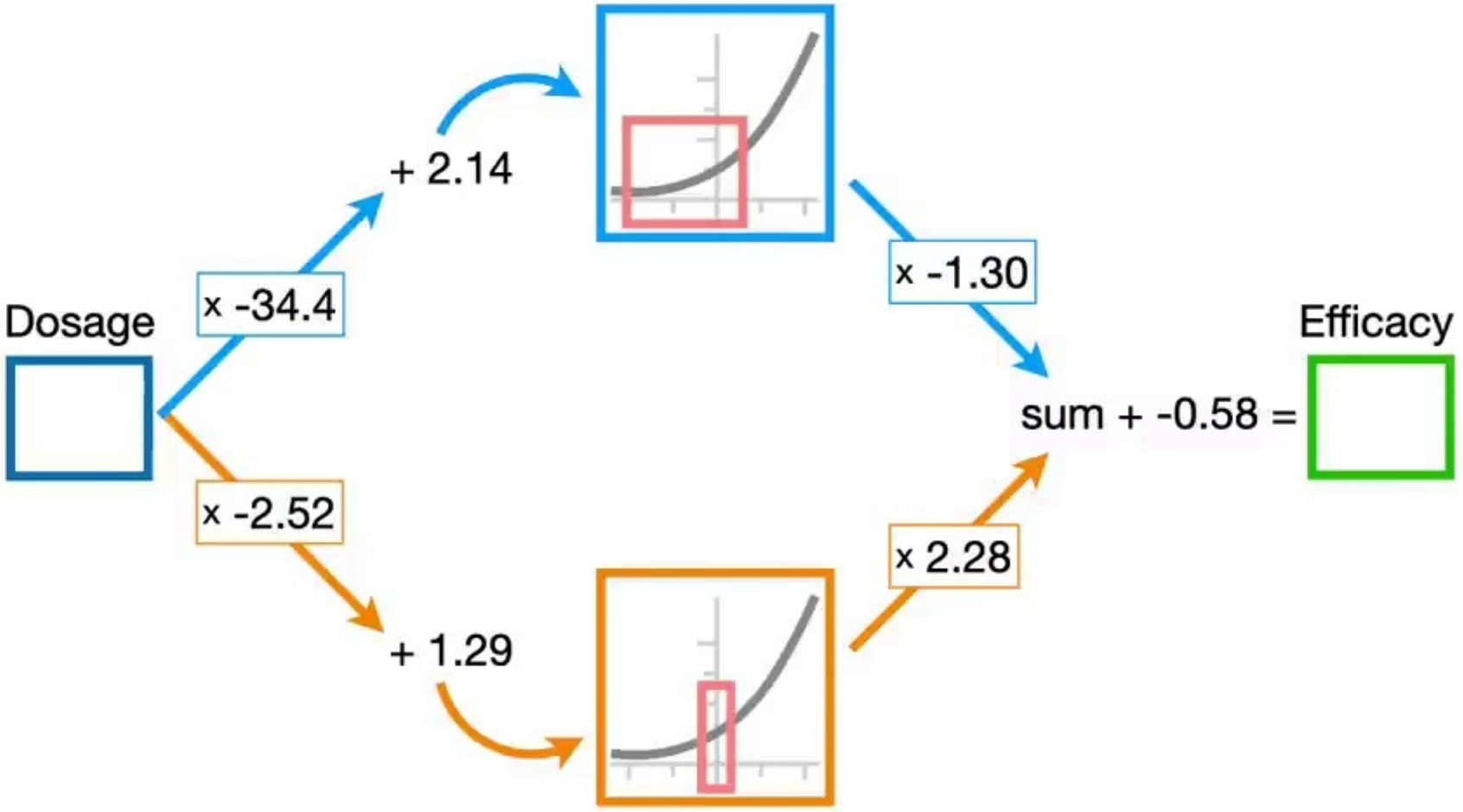

Now the Neural Network tells us to add the y-axis coordinates from blue curve to the orange curve…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy


…and that gives us this
green squiggle…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + 0.58 =
Efficacy

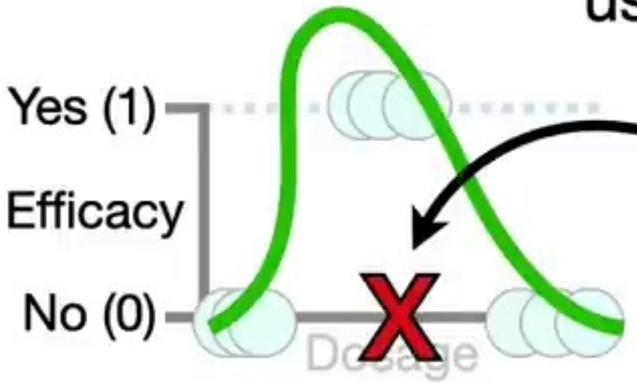

…then, finally, we subtract,
0.58 from the y-axis values
on the green squiggle…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58
Efficacy

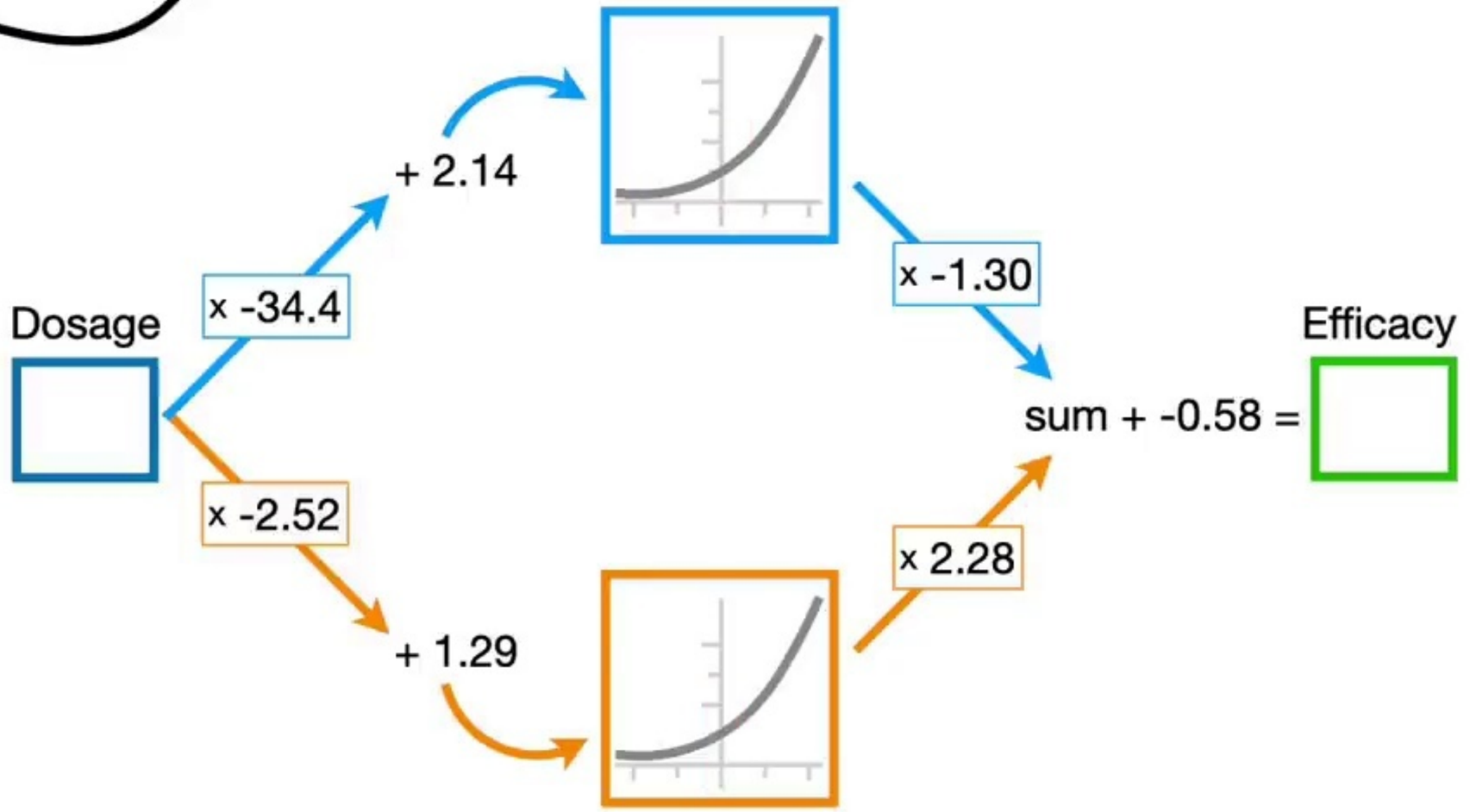
…and we have a **green squiggle** that fits the data.



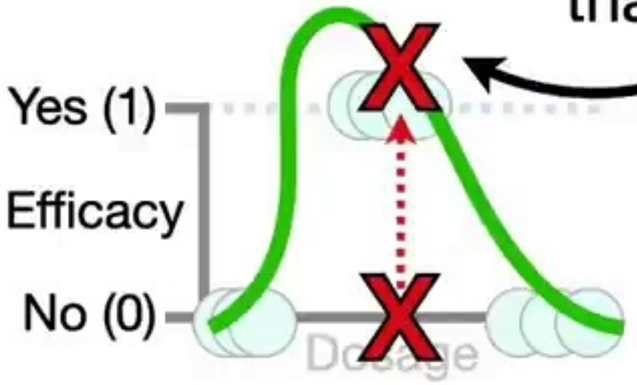


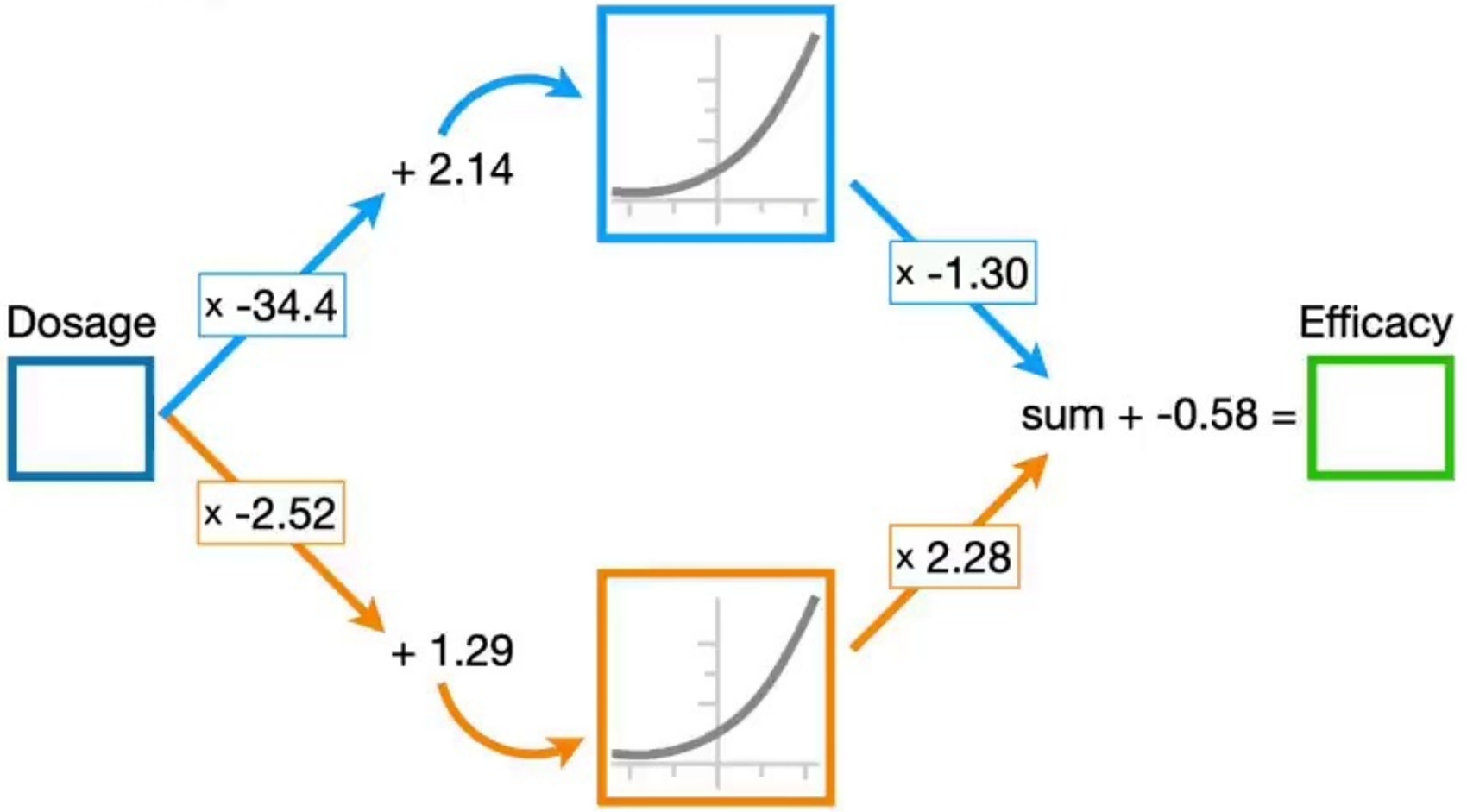
Now, if someone comes along and says that the are using **Dosage = 0.5**…



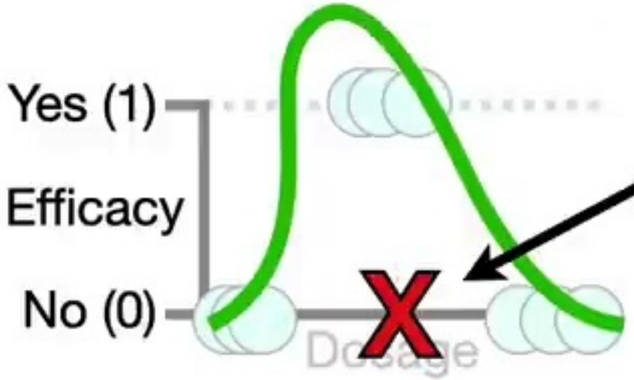


…we can look at the corresponding y-axis coordinate on the **green squiggle** and see that the **Dosage** will be effective.





Or we can solve for the y-axis coordinate by plugging **Dosage = 0.5** into the **Neural Network**…



Dosage

0.5

x -34.4

+ 2.14

x -1.30

x -2.52

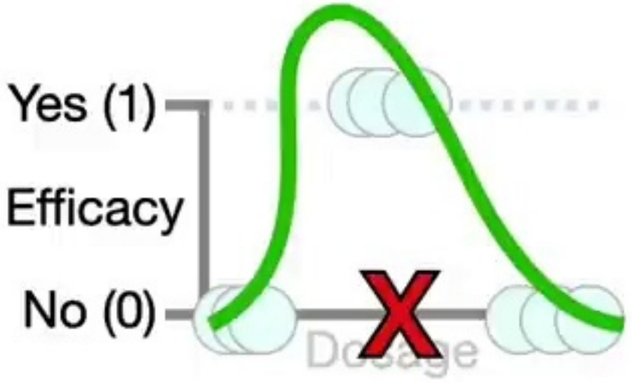
+ 1.29

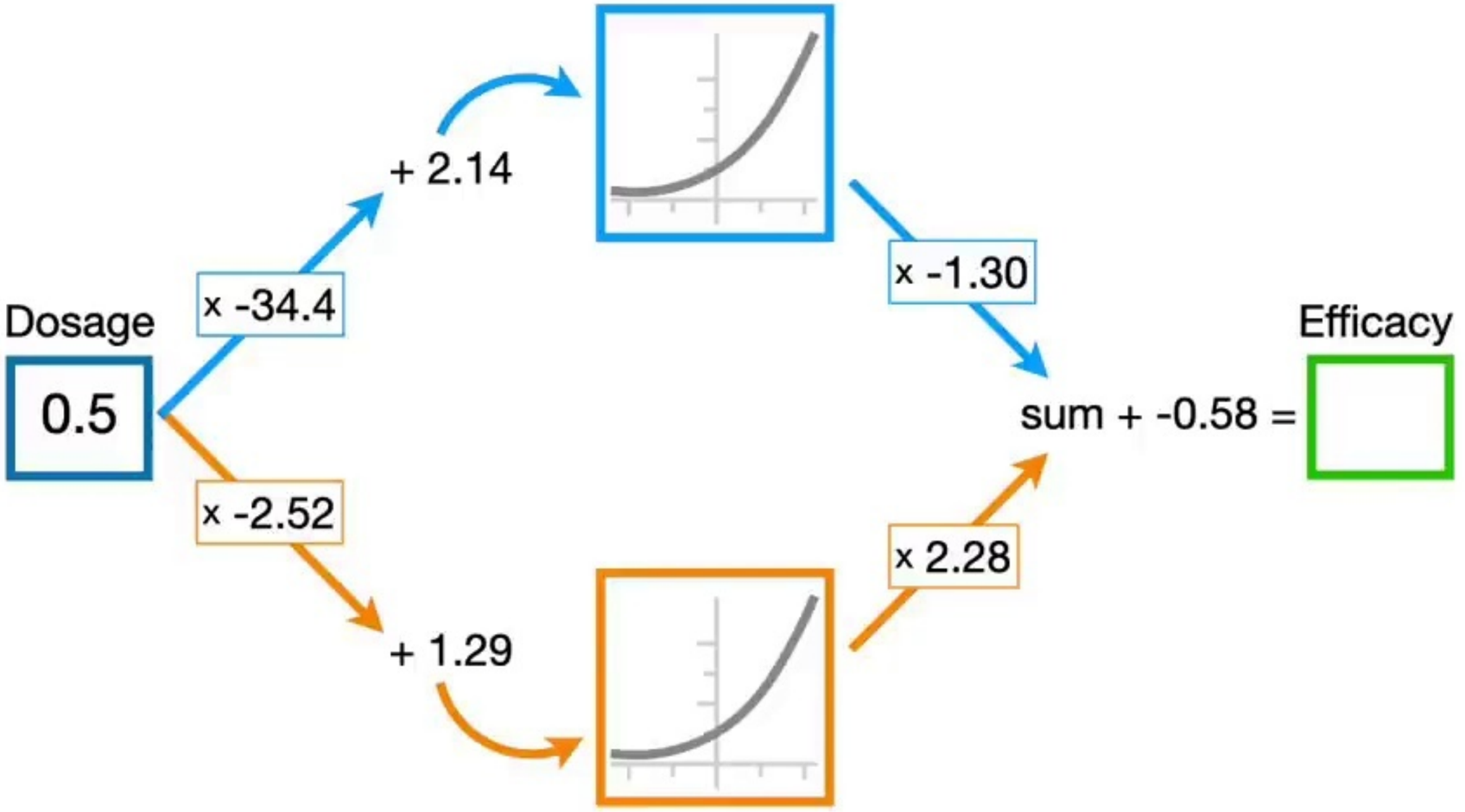
x 2.28

sum + -0.58 =

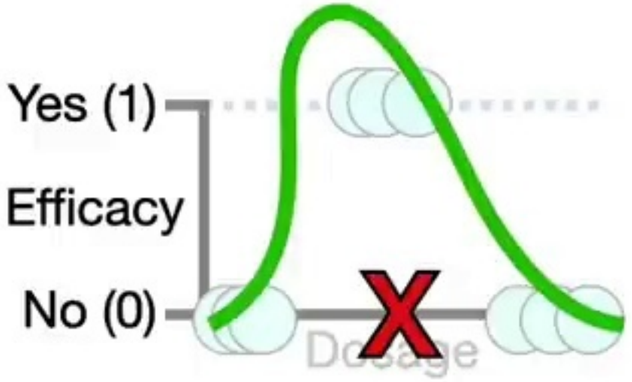
Efficacy

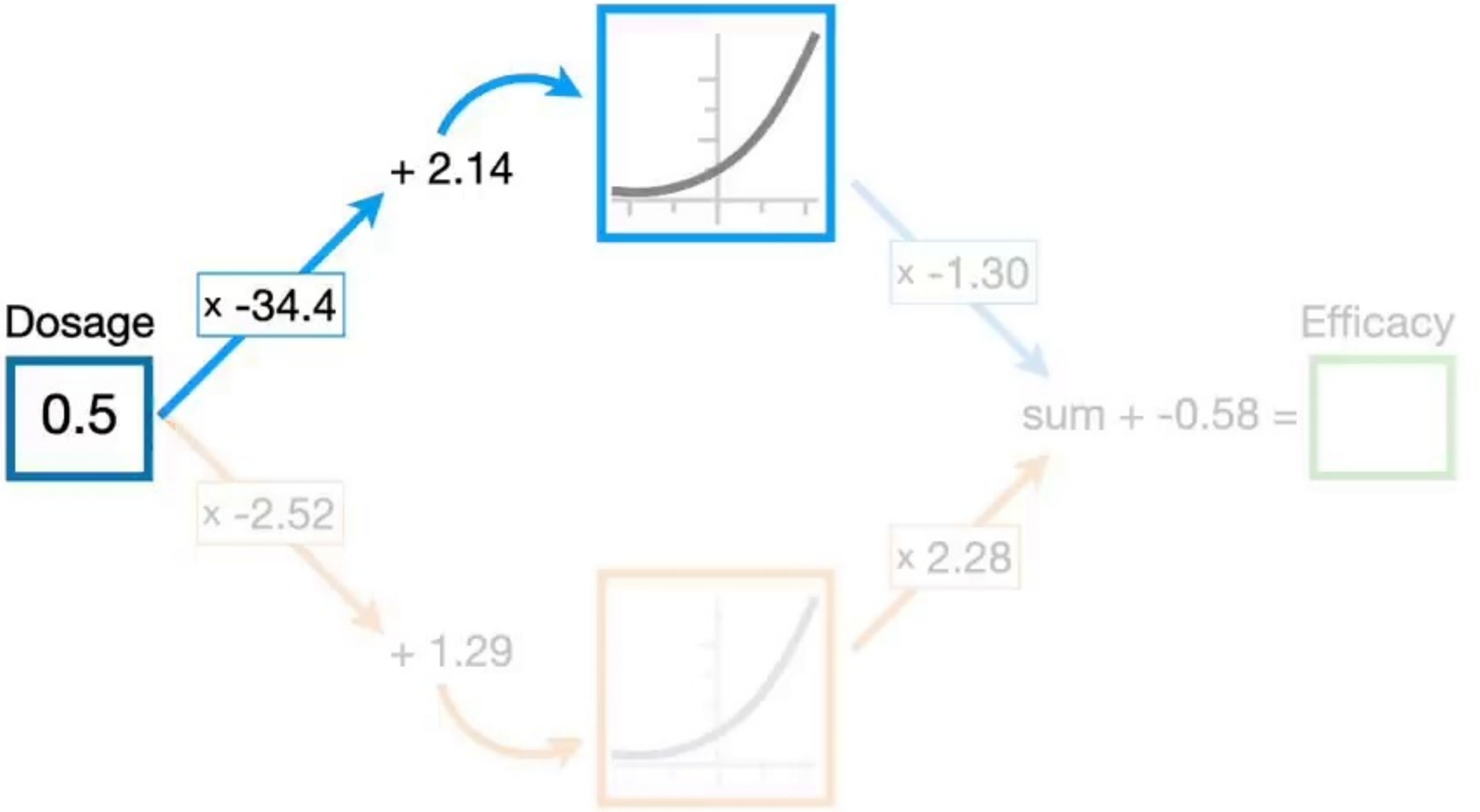
…and do the math…



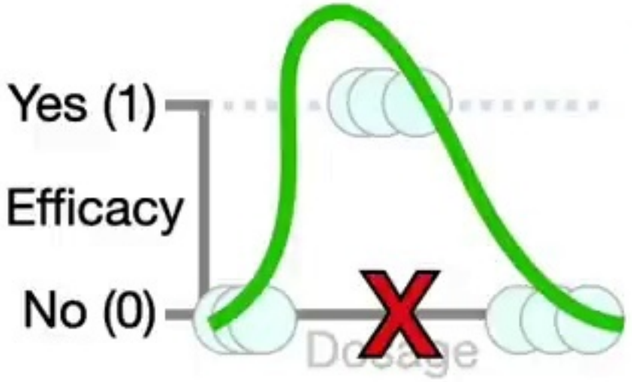


…and do the math…





(**Dosage** x -34.4) + 2.14 = x-axis coordinate



Dosage

0.5

x -34.4

+ 2.14

x -1.30

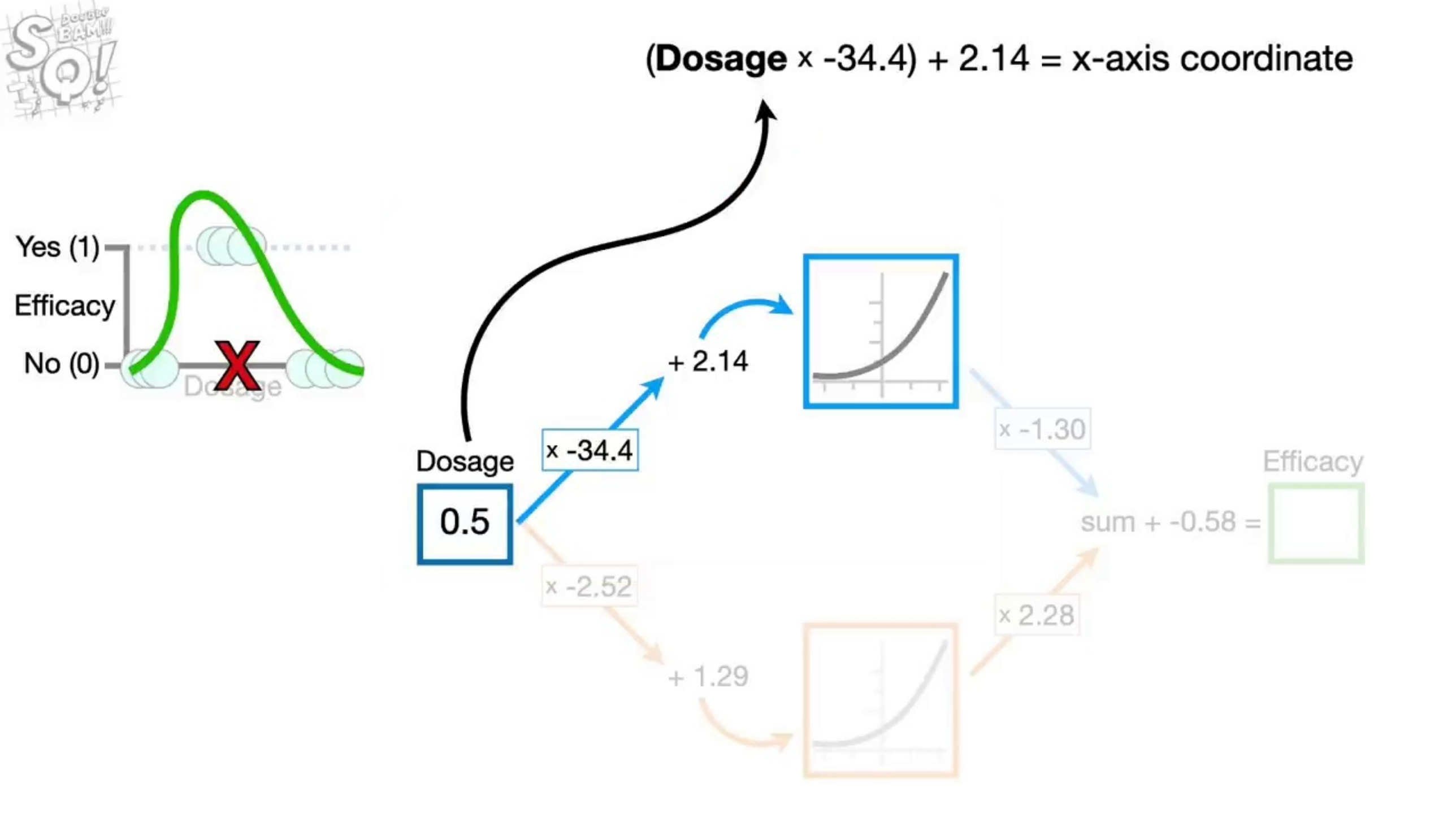
Efficacy

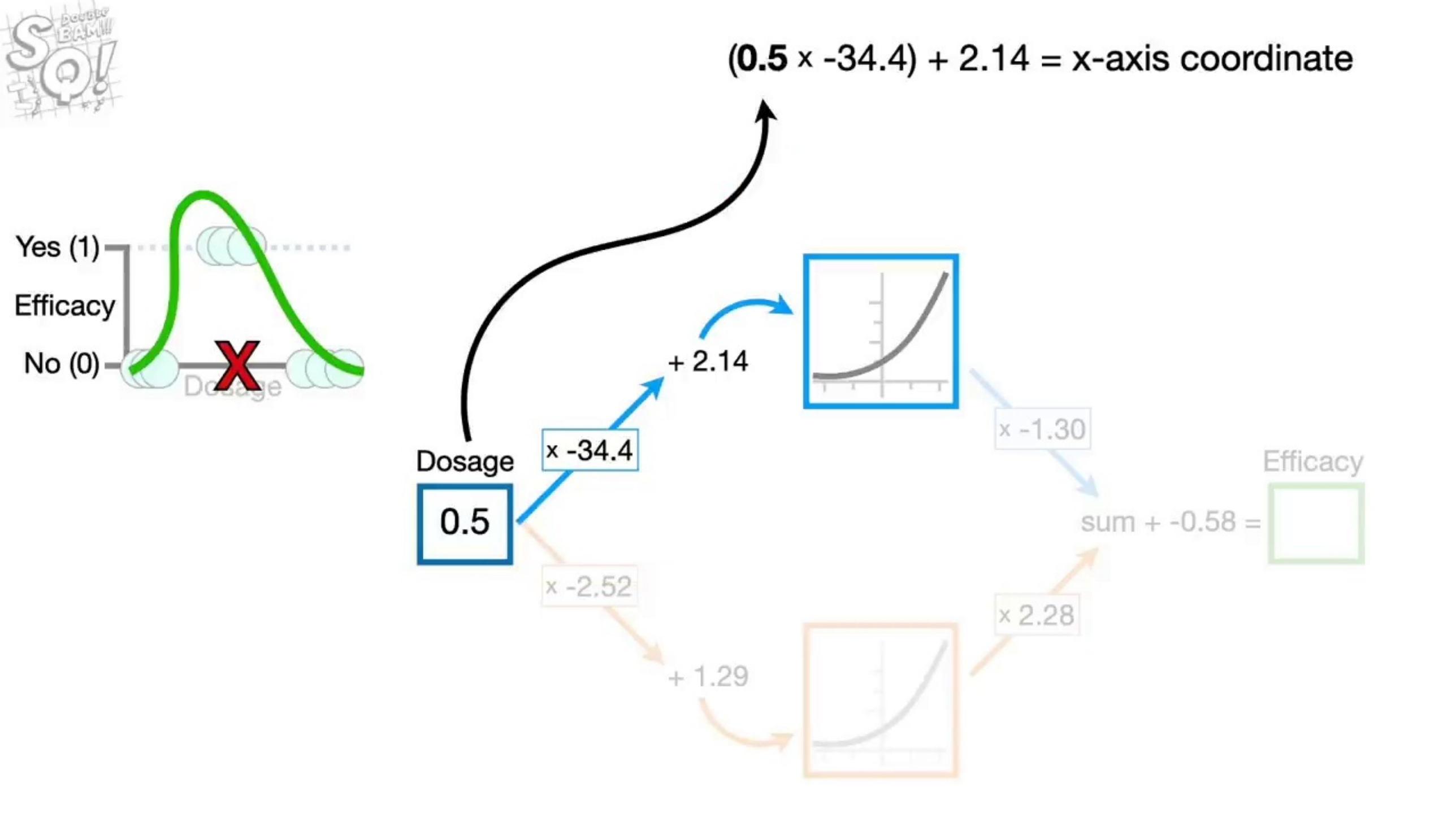
sum + -0.58 =

x -2.52

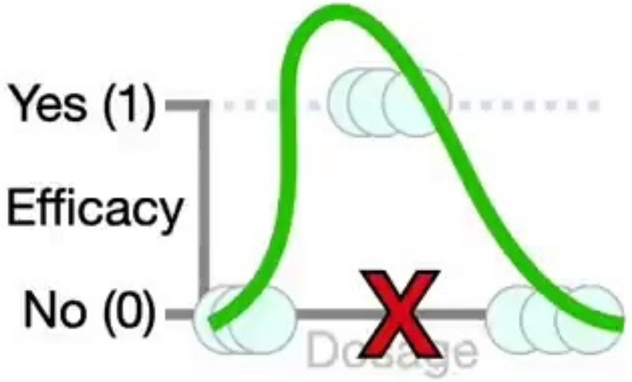
+ 1.29

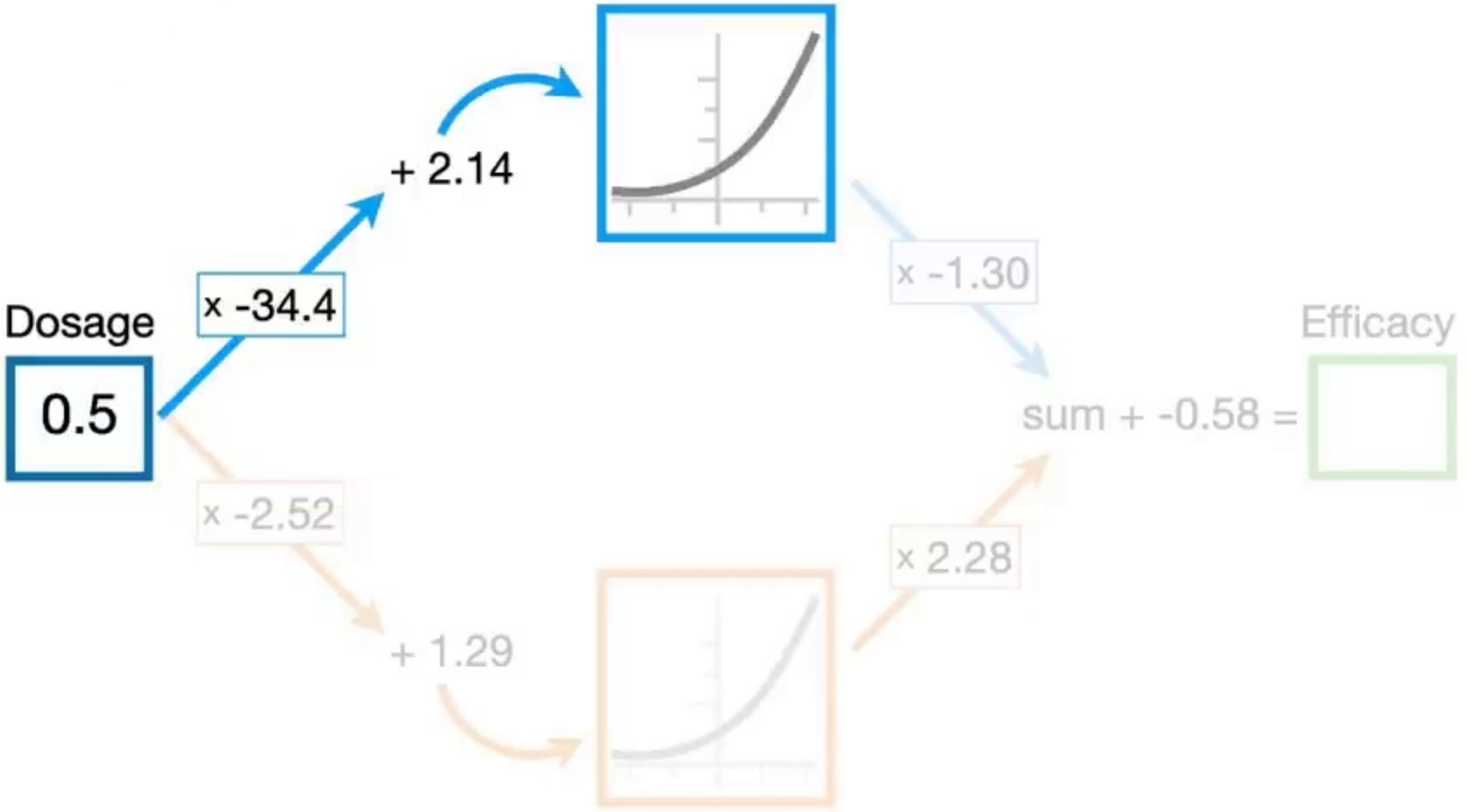
x 2.28

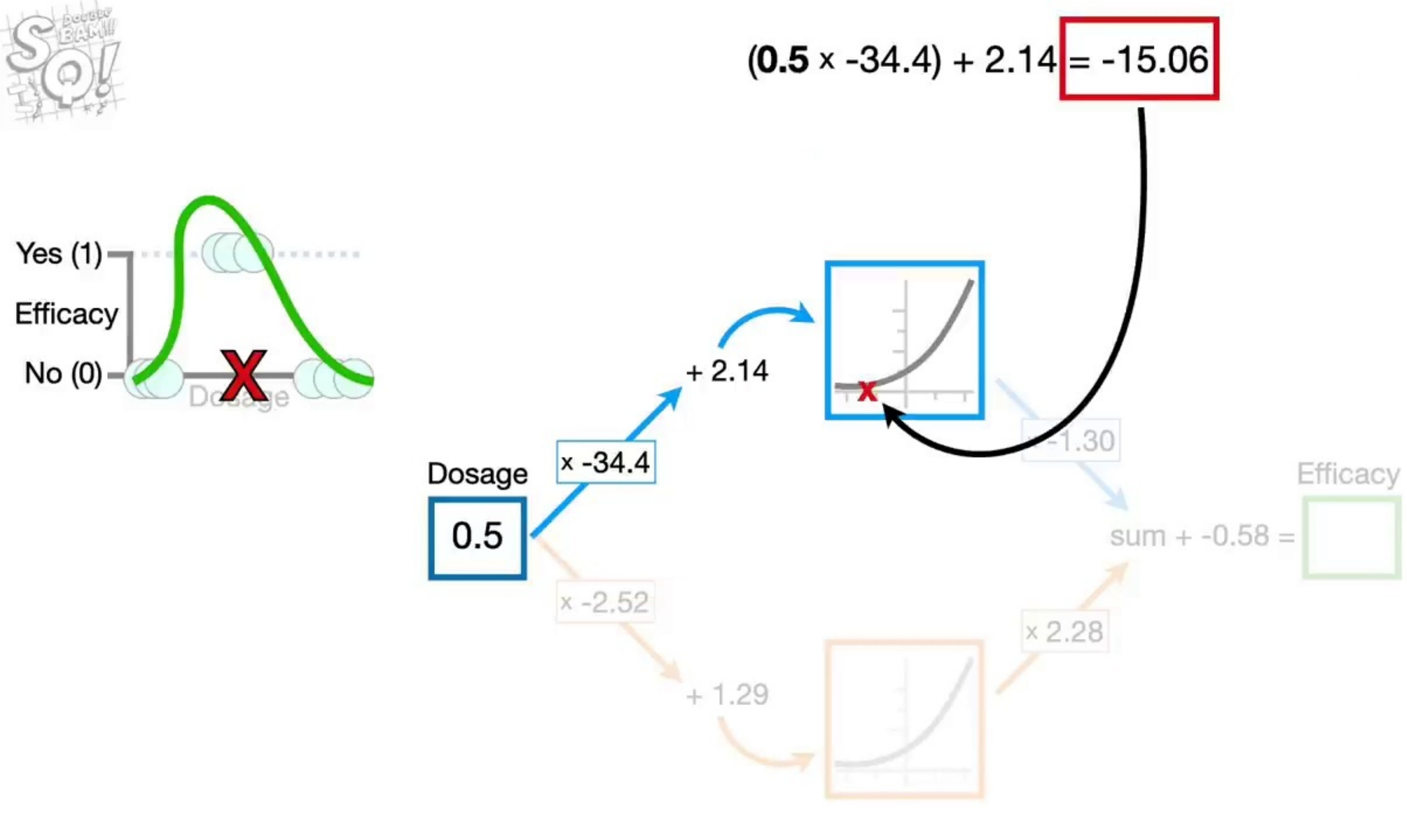

(Dosage x -34.4) + 2.14 = x-axis coordinate
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy


(0.5 x -34.4) + 2.14 = x-axis coordinate
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

$$(\mathbf{0.5} \times -34.4) + 2.14 = -15.06$$

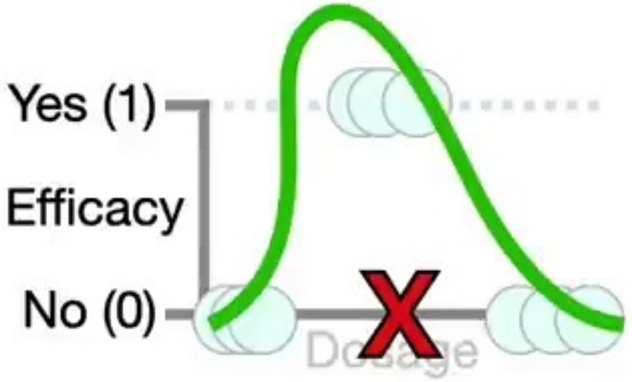


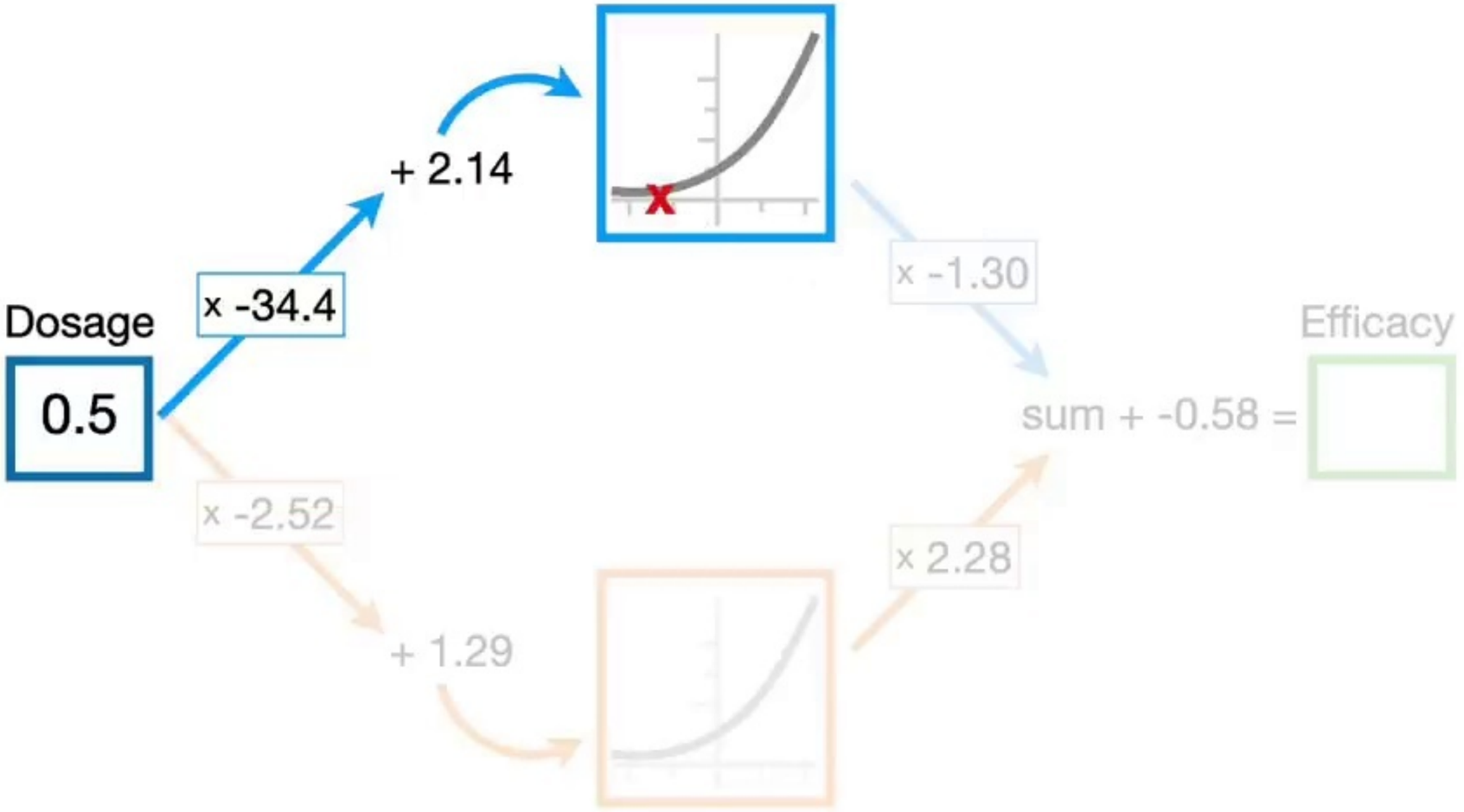


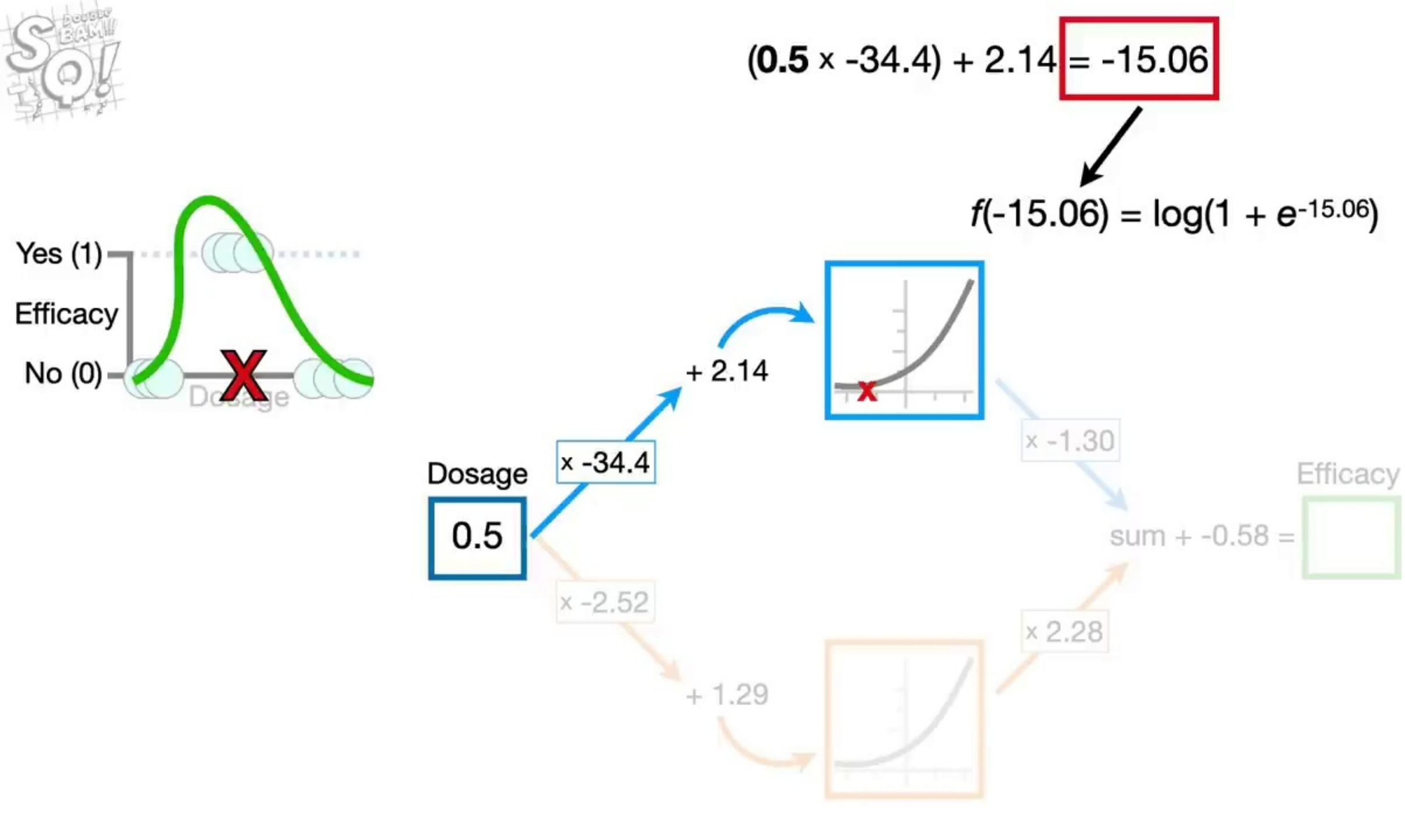

(0.5 x -34.4) + 2.14 = -15.06
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
0.5
x -34.4
x -2.52
+ 1.29
x 2.28
-1.30
sum + -0.58 =
Efficacy

$$(\mathbf{0.5} \times -34.4) + 2.14 = -15.06$$

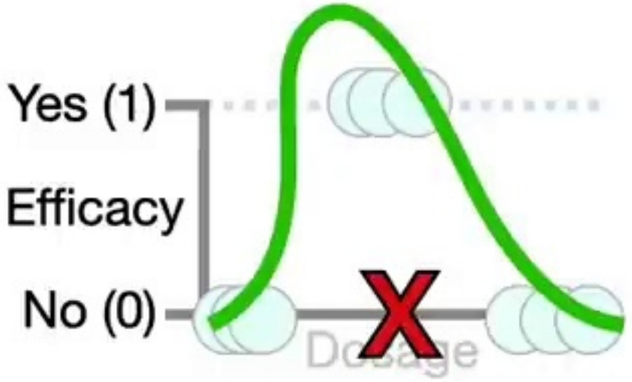
$$f(x) = \log(1 + e^x)$$





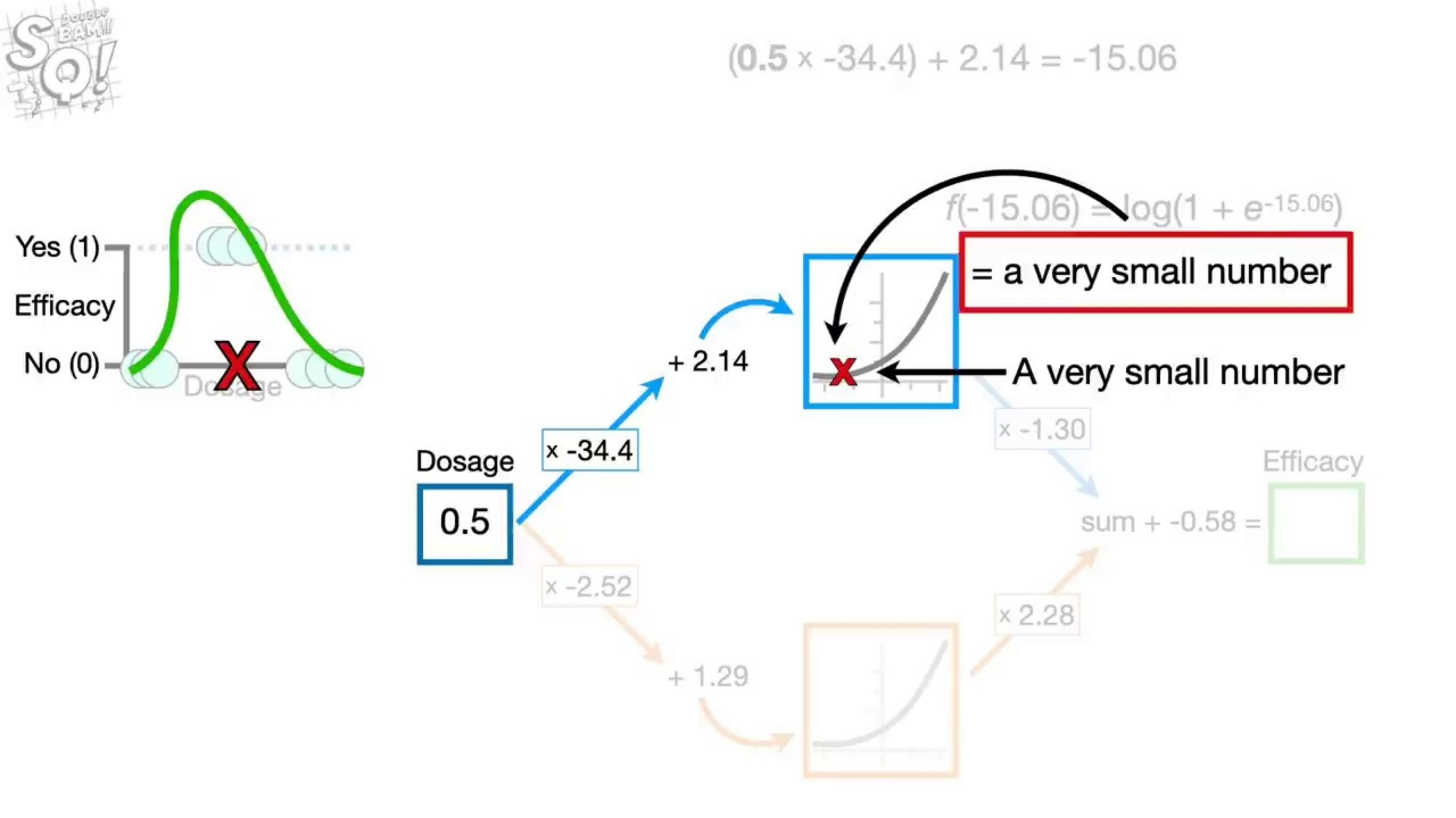

(0.5 x -34.4) + 2.14 = -15.06
f(-15.06) = log(1 + e^-15.06)
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

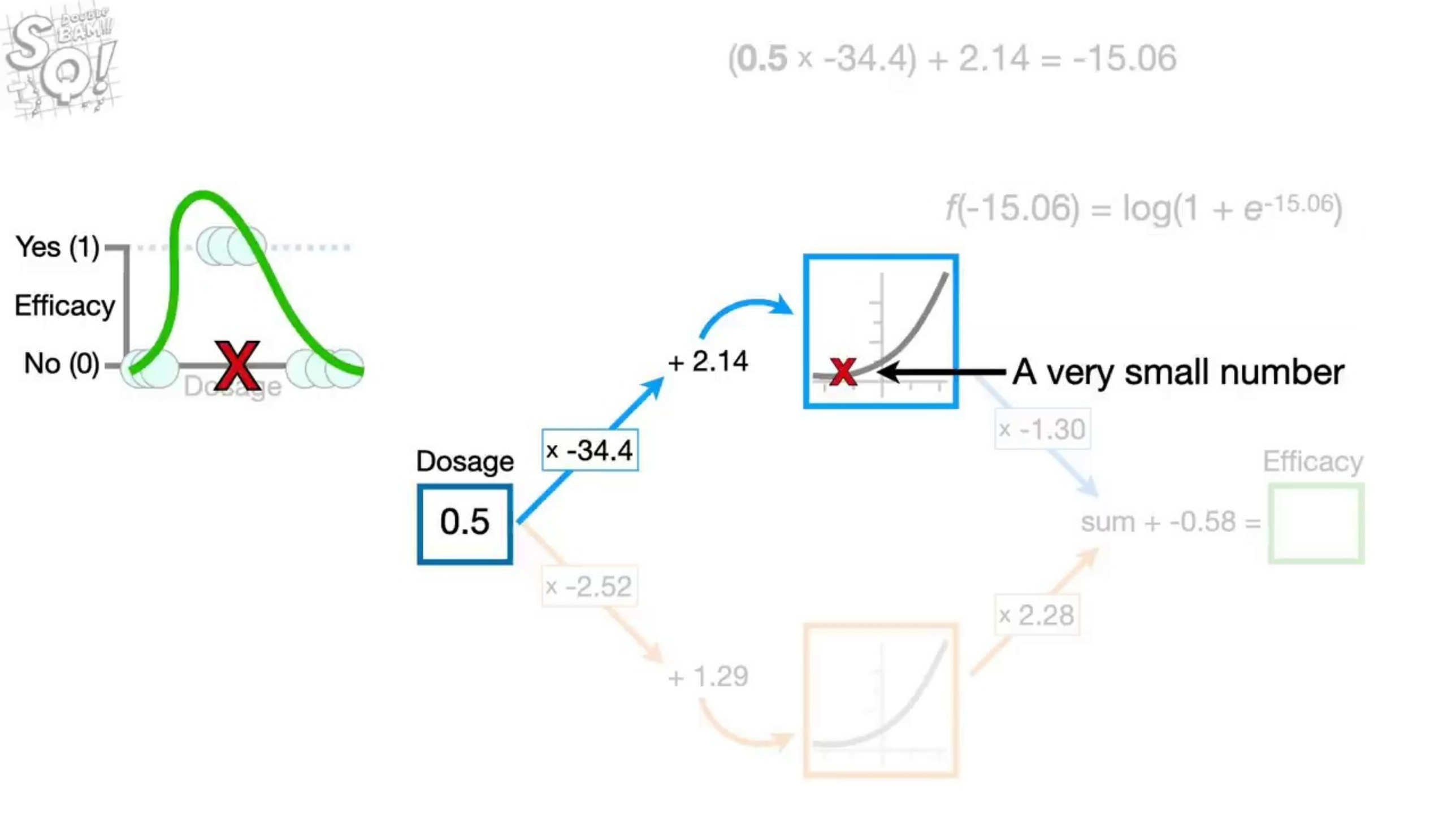
(**0.5** x -34.4) + 2.14 = -15.06

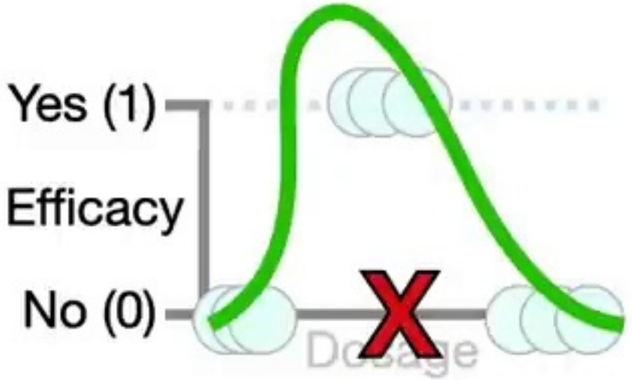


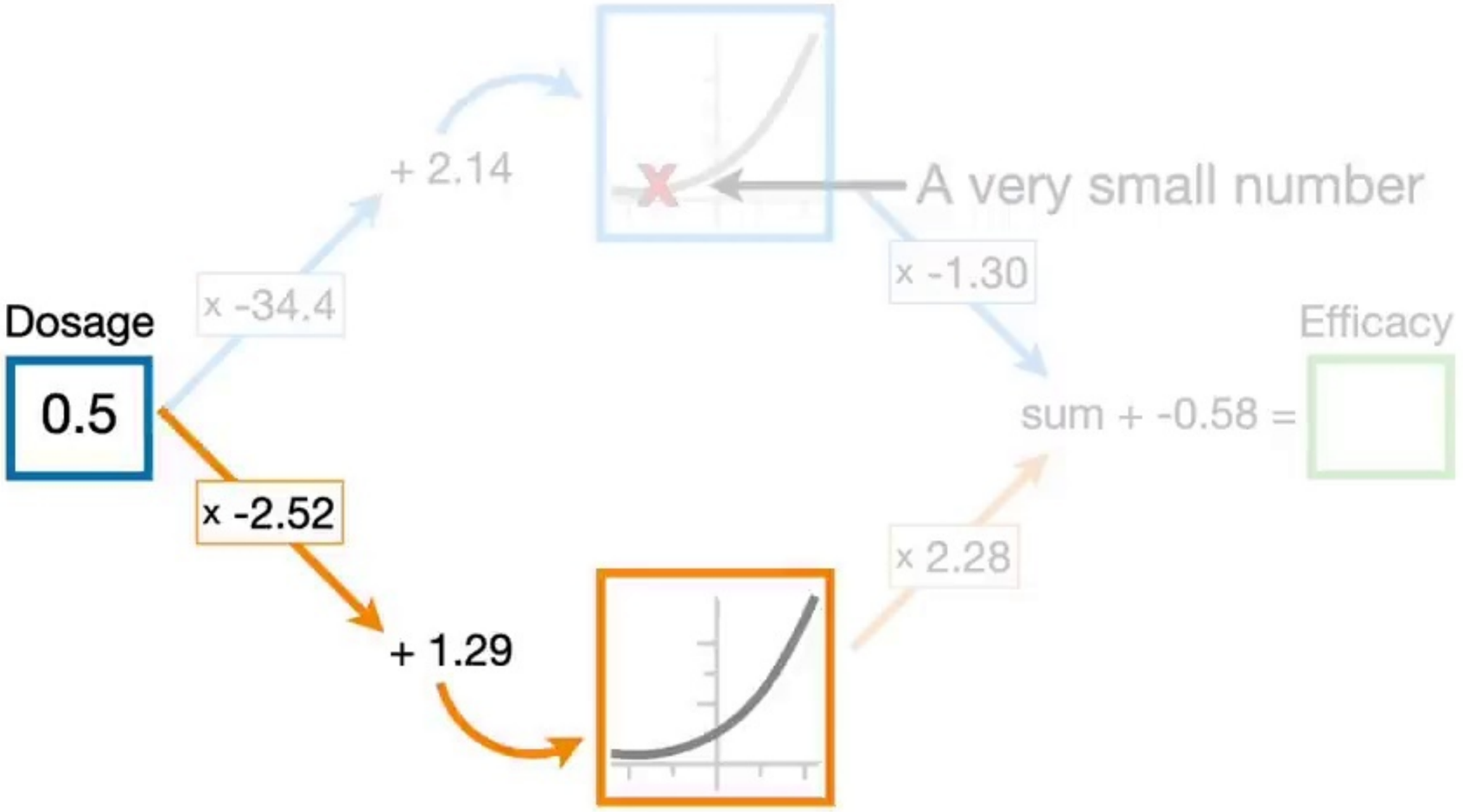
$f(-15.06) = \log(1 + e^{-15.06})$

= a very small number

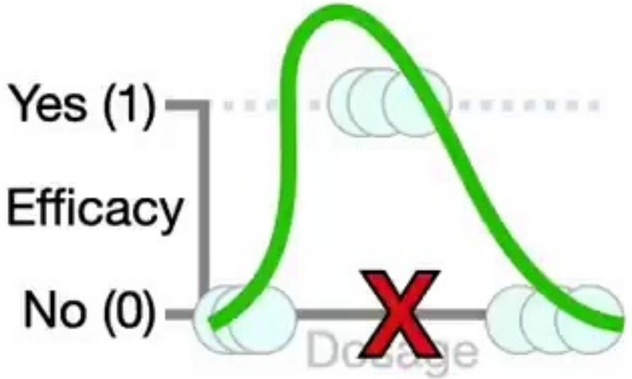

(0.5 x -34.4) + 2.14 = -15.06
Yes (1)
Efficacy
No (0)
Dosage
f(-15.06) = log(1 + e^-15.06)
= a very small number
A very small number
+ 2.14
Dosage
0.5
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28


(0.5 x -34.4) + 2.14 = -15.06
f(-15.06) = log(1 + e^-15.06)
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28


Yes (1)
Efficacy
No (0)
Dosage


Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

(**Dosage** x -2.52) + 1.29 = x-axis coordinate



Dosage

0.5

x -2.52

+ 1.29

x -34.4

+ 2.14

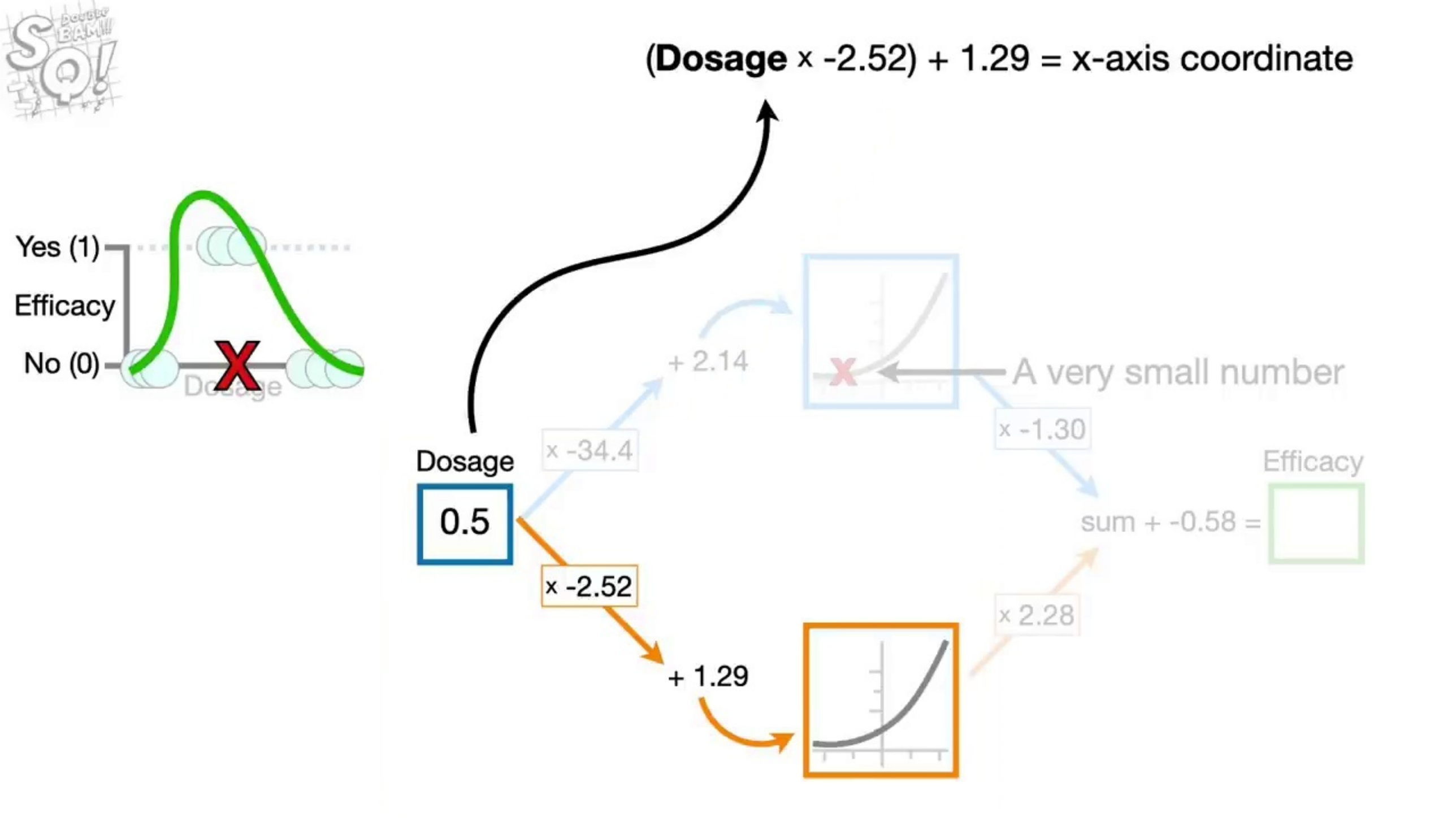
A very small number

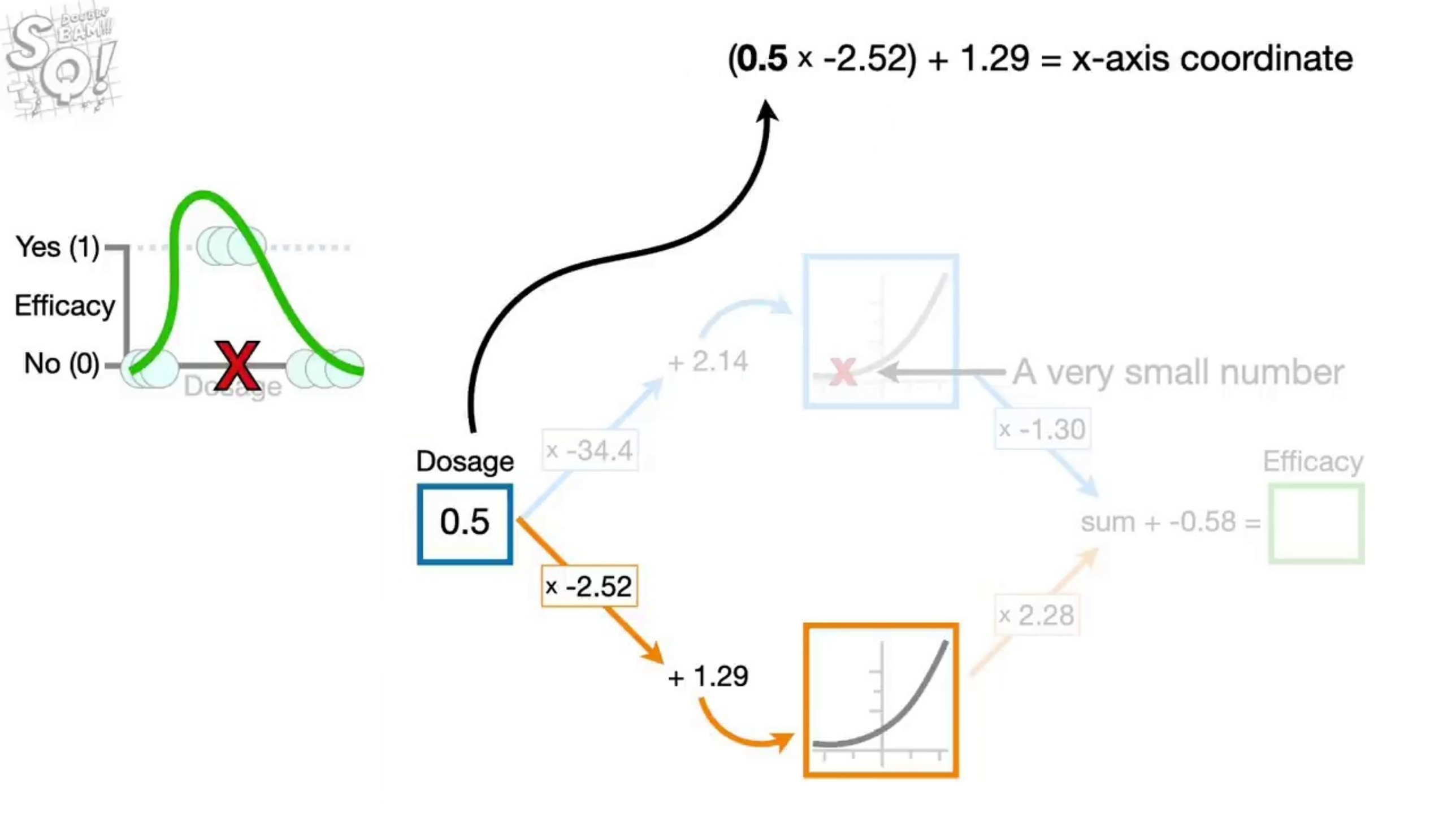
x -1.30

sum + -0.58 =

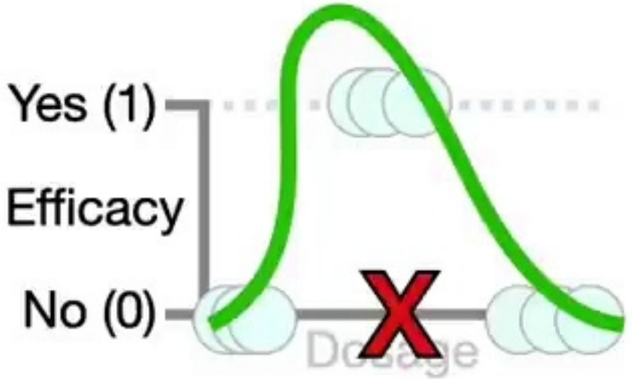
Efficacy

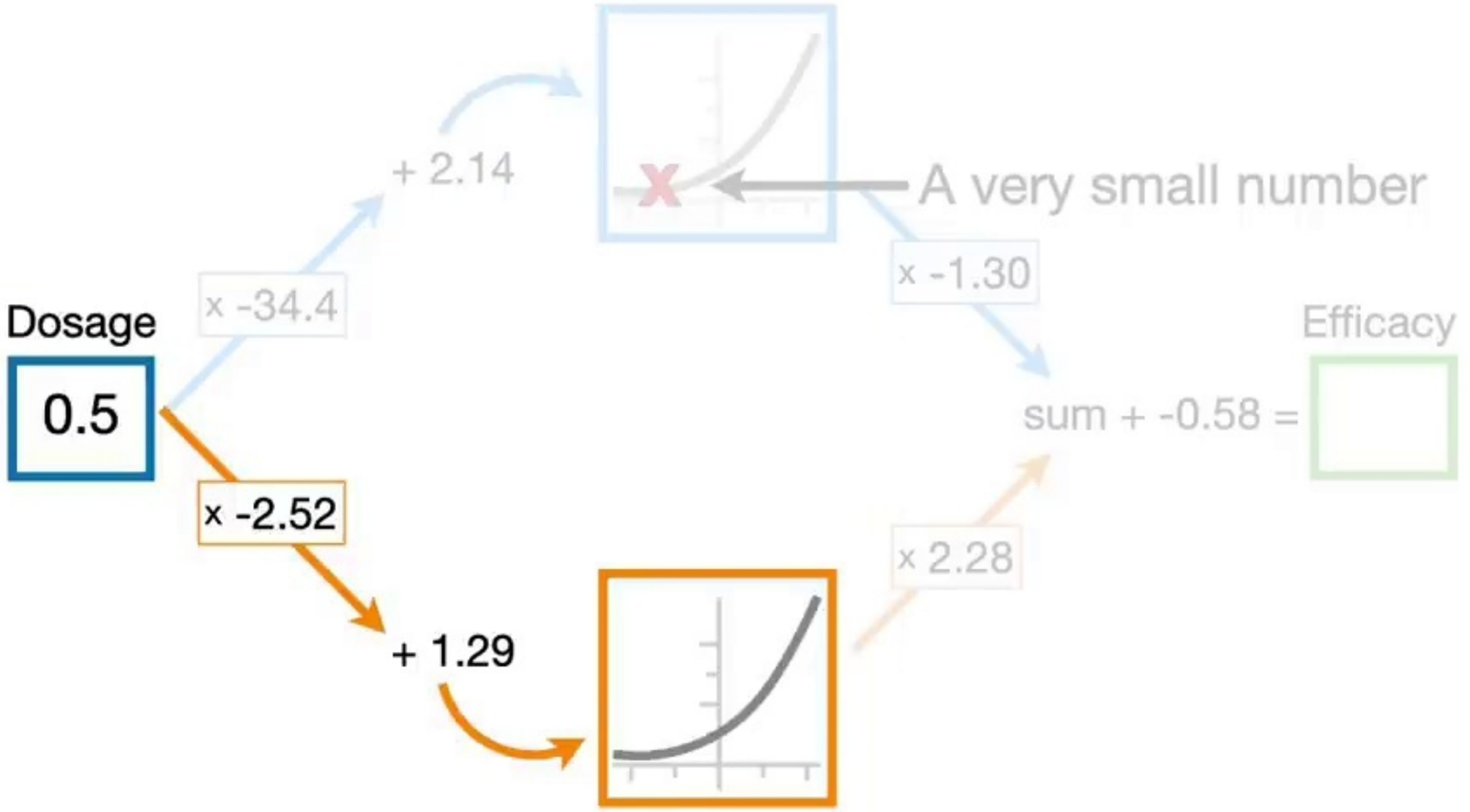
x 2.28

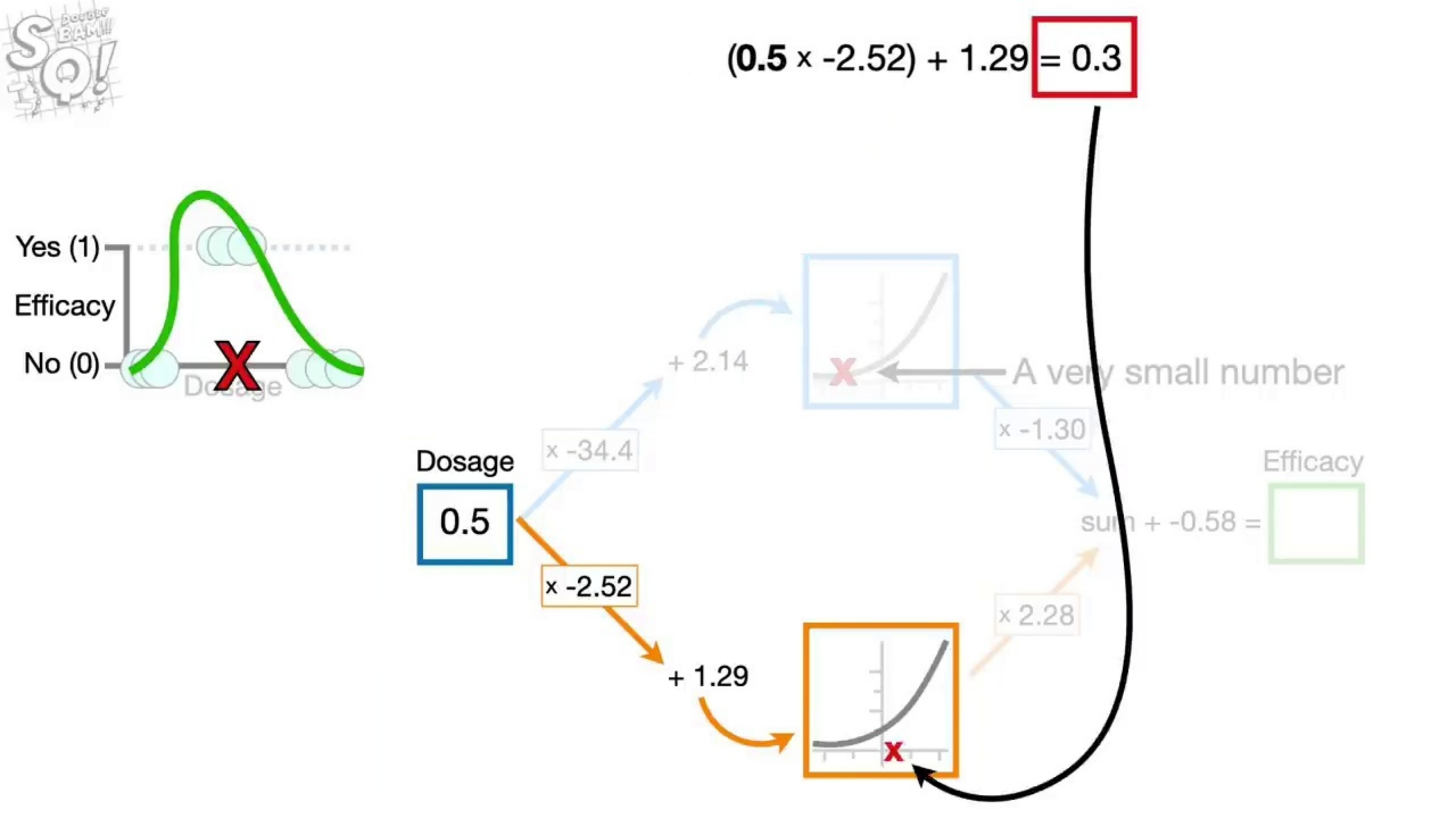

(Dosage x -2.52) + 1.29 = x-axis coordinate
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28


(0.5 x -2.52) + 1.29 = x-axis coordinate
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

$$(\mathbf{0.5} \times -2.52) + 1.29 = 0.3$$

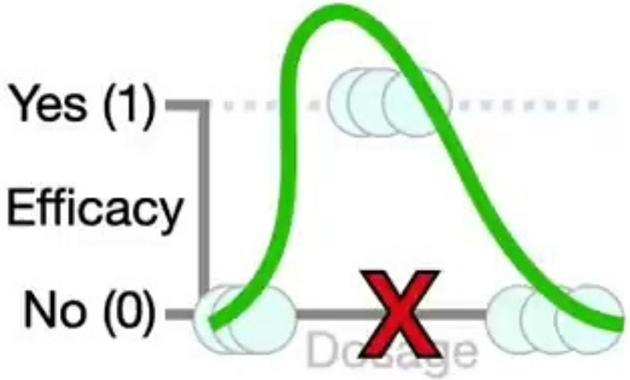


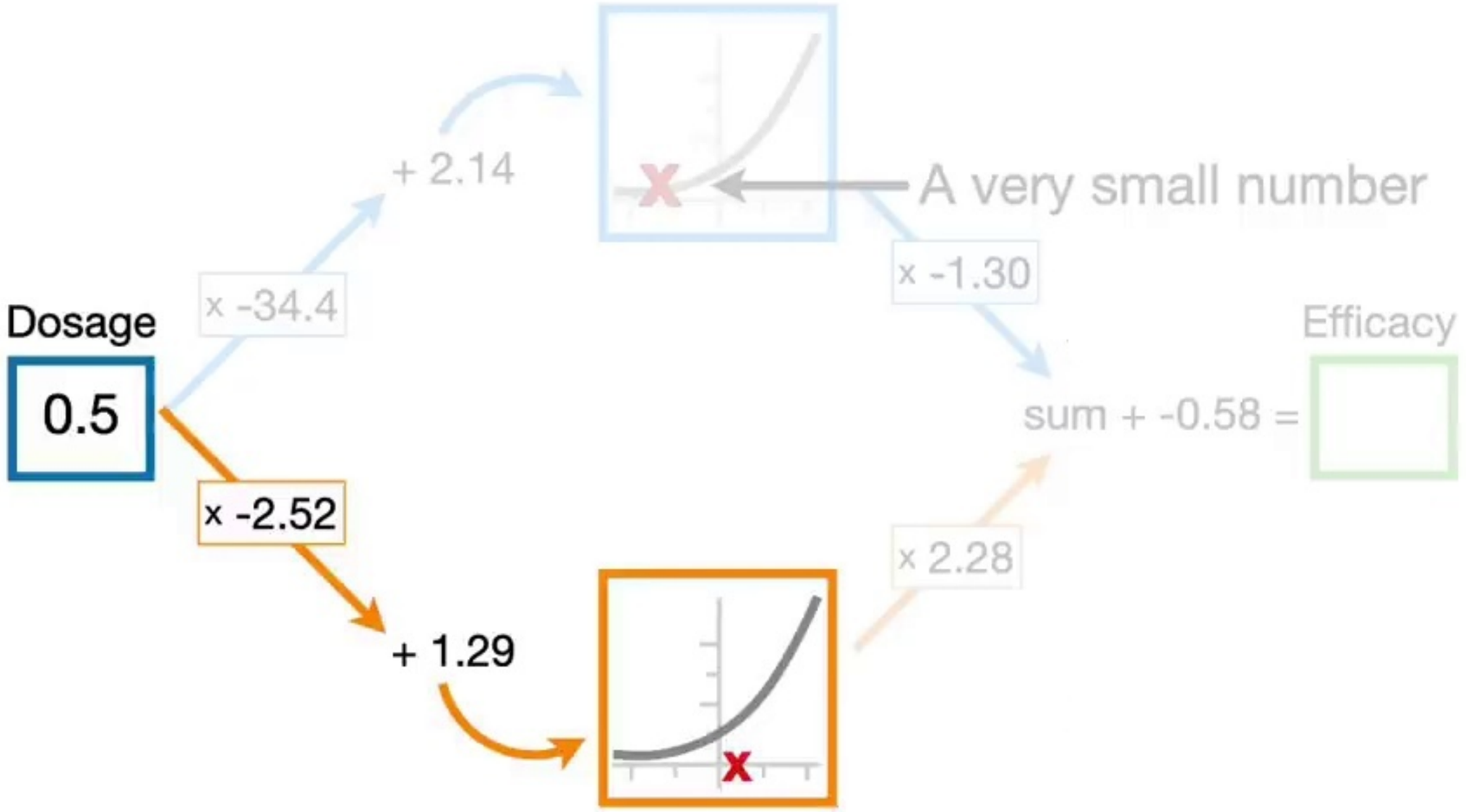



(0.5 x -2.52) + 1.29 = 0.3
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
A very small number
x -34.4
x -1.30
Dosage
0.5
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

$$(\mathbf{0.5} \times -2.52) + 1.29 = 0.3$$

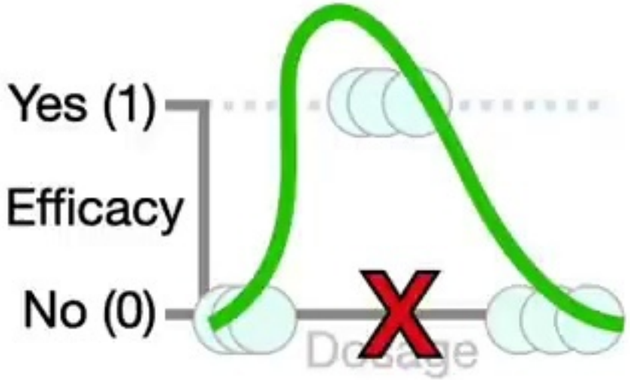
$$f(x) = \log(1 + e^x)$$

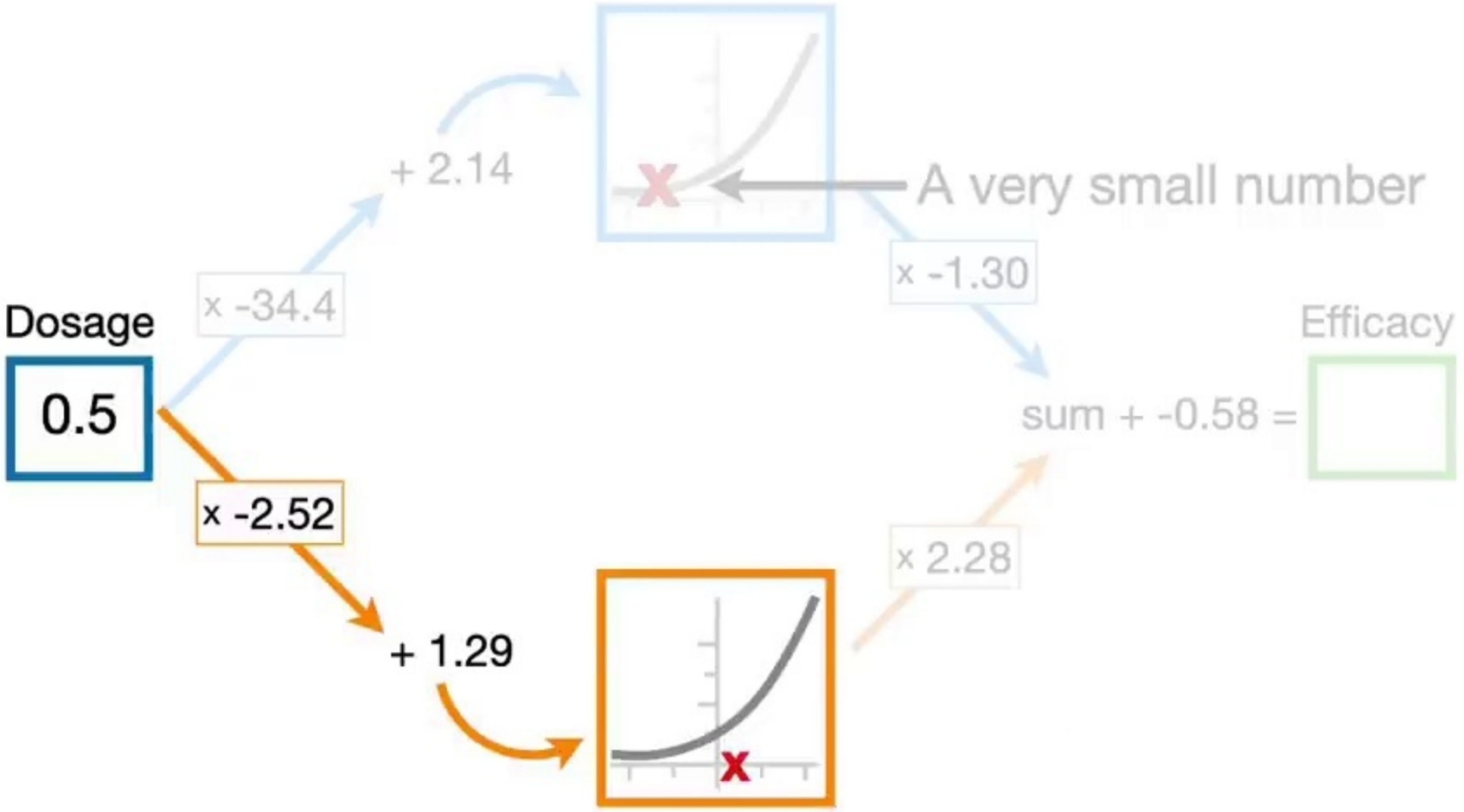




$$(\mathbf{0.5} \times -2.52) + 1.29 = 0.3$$

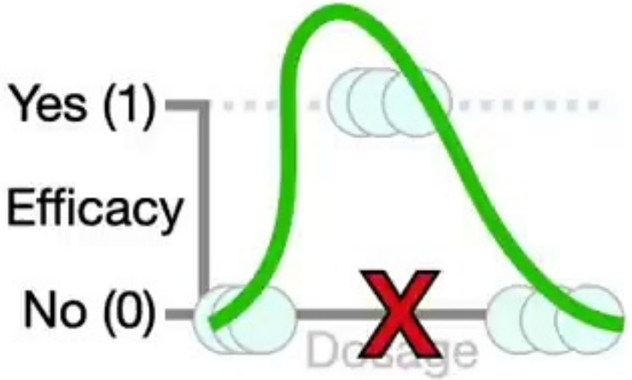
$$f(0.3) = \log(1 + e^{0.3})$$

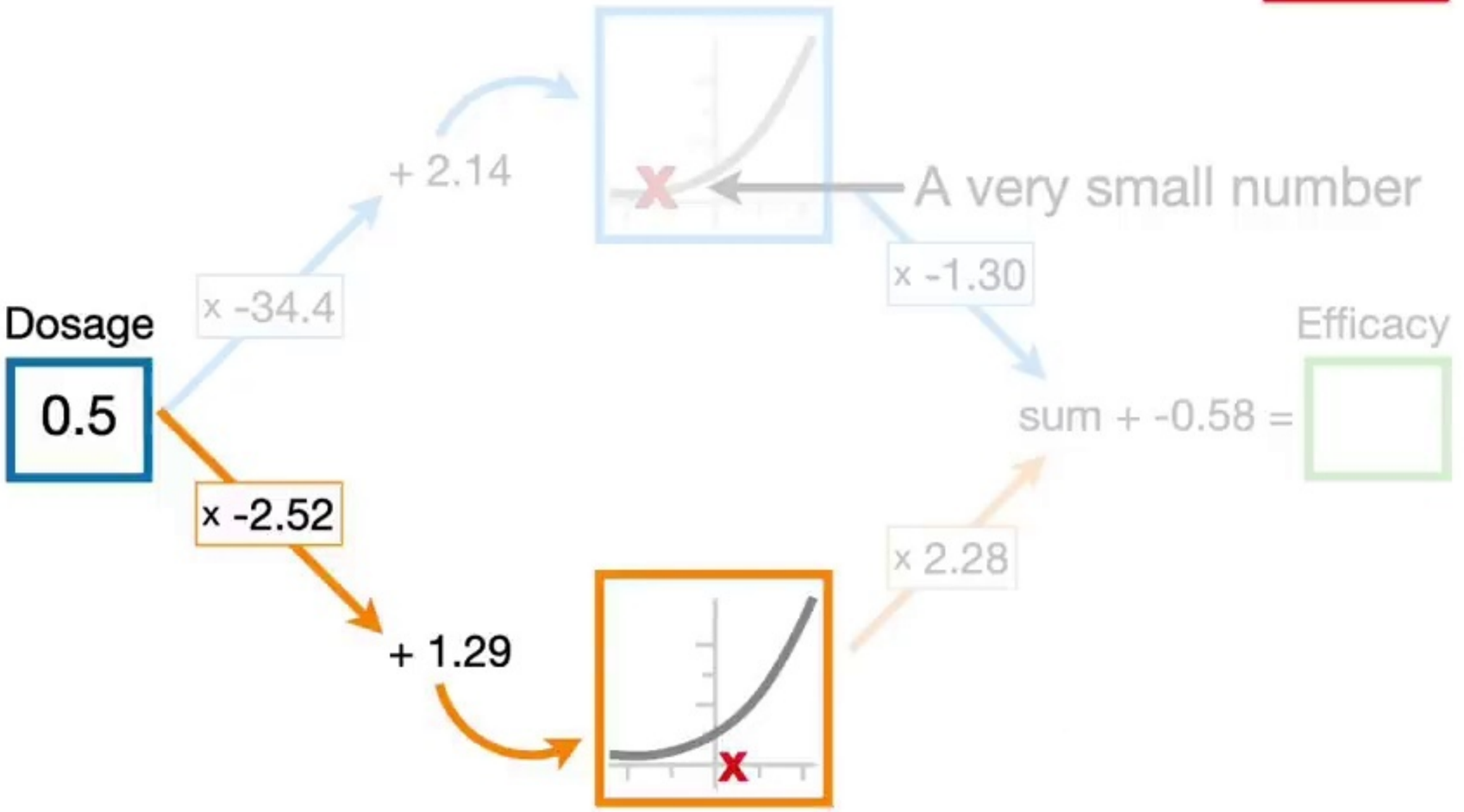


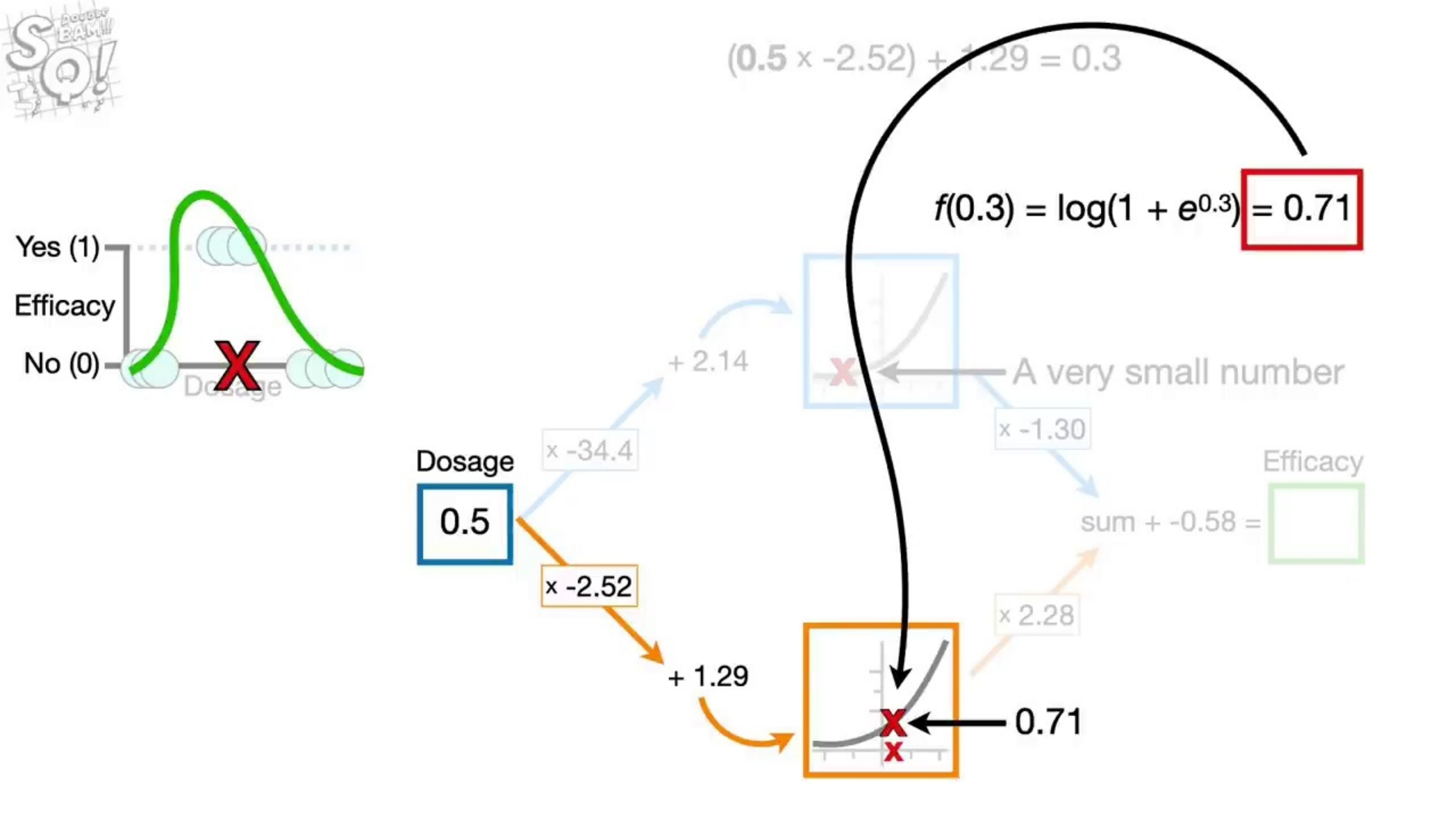


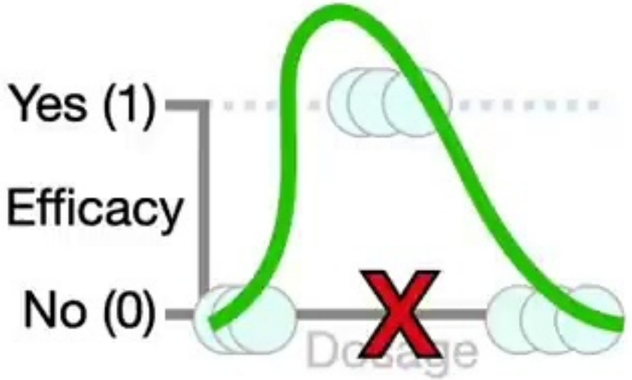
$$(0.5 \times -2.52) + 1.29 = 0.3$$

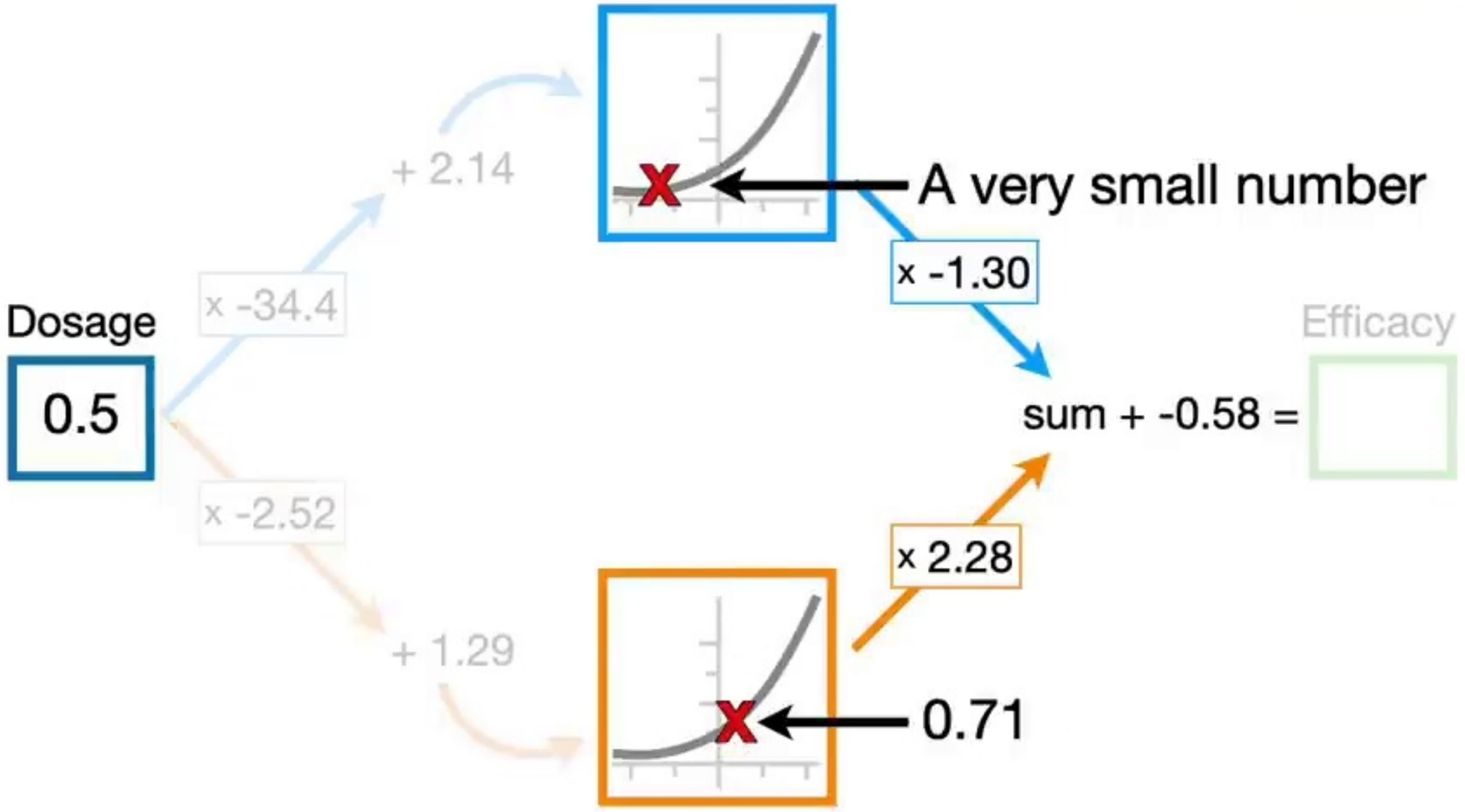
$$f(0.3) = \log(1 + e^{0.3}) = 0.71$$

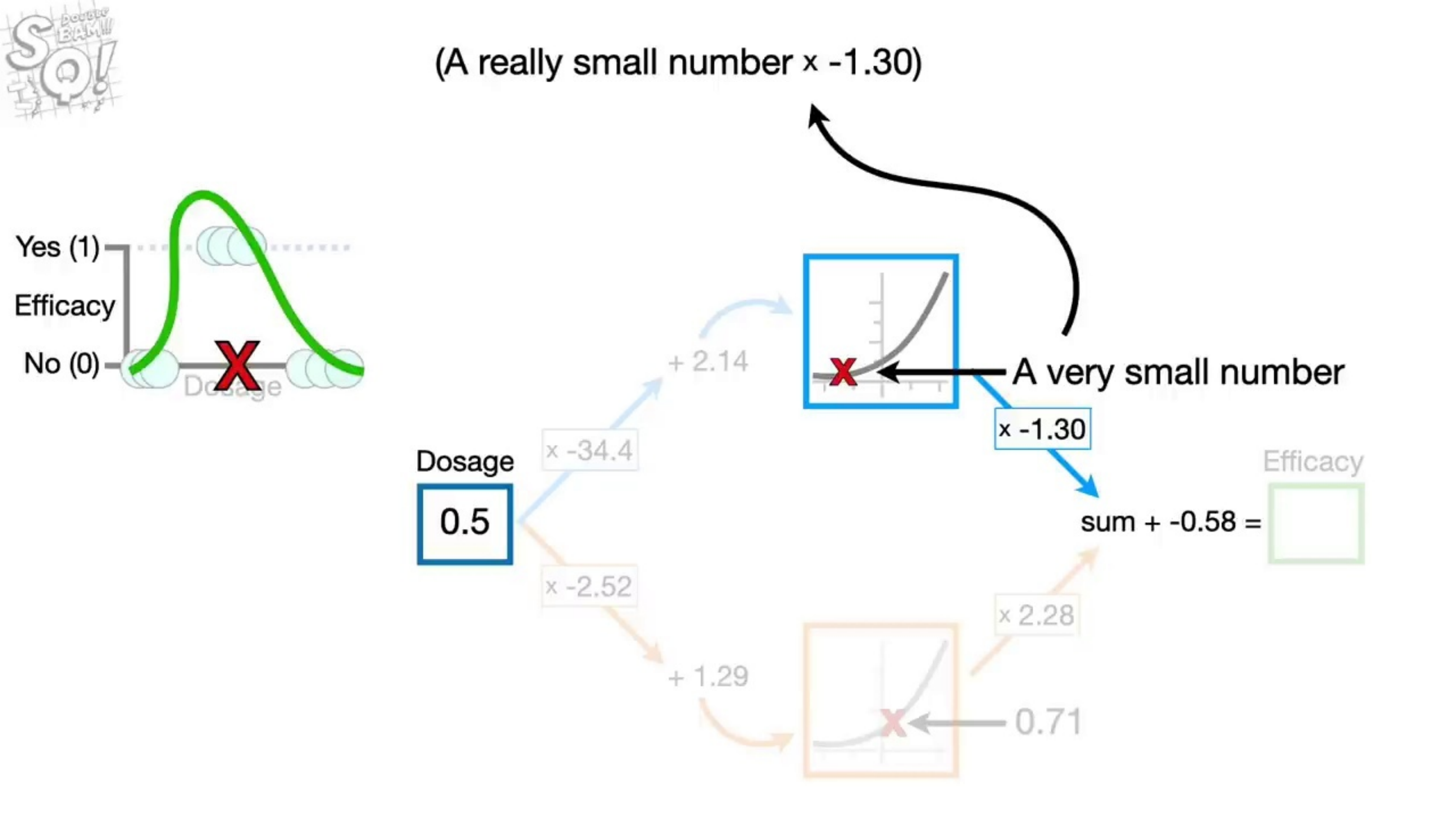





(0.5 x -2.52) + 1.29 = 0.3
f(0.3) = log(1 + e^0.3) = 0.71
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
A very small number
x -34.4
x -1.30
Dosage
Efficacy
0.5
sum + -0.58 =
x -2.52
x 2.28
+ 1.29
0.71

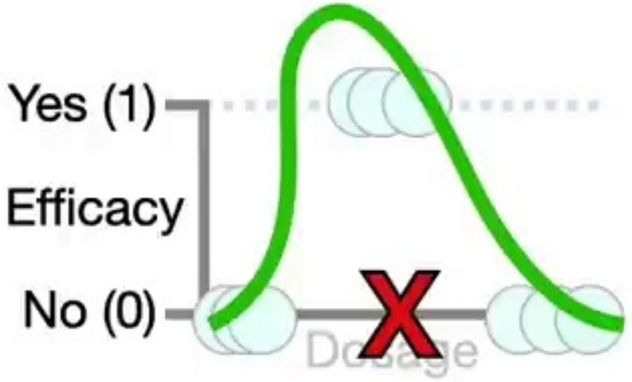

Yes (1)
Efficacy
No (0)
Dosage

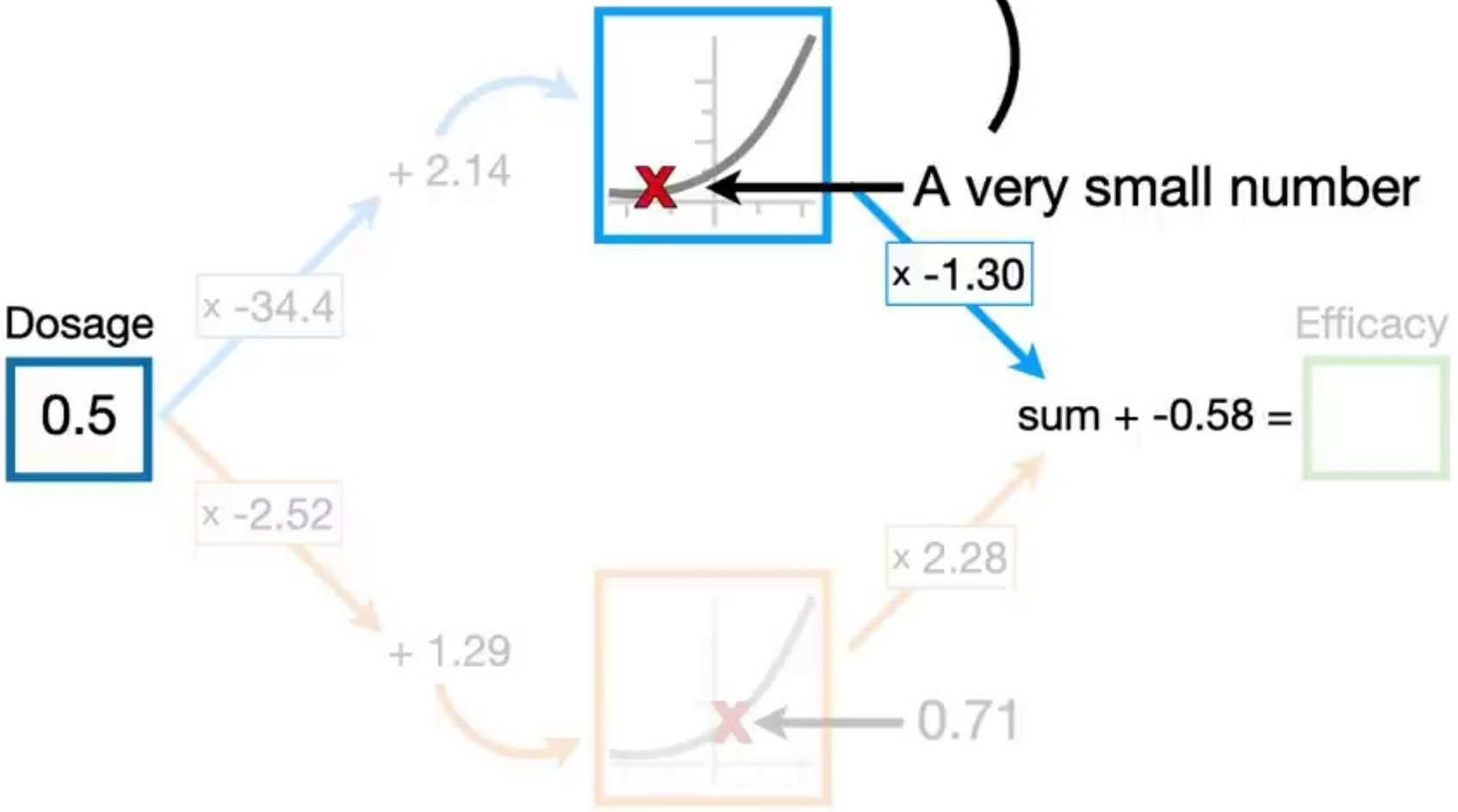

Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28
0.71


(A really small number x -1.30)
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
A very small number
x -1.30
Dosage
0.5
x -34.4
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29
0.71

(A really small number x -1.30)

Approximately Zero!

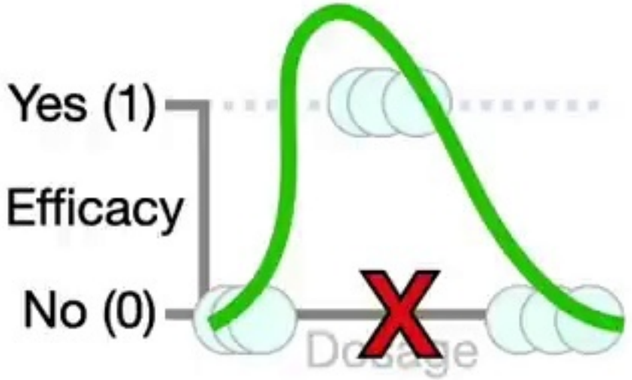




(A really small number x -1.30)

Approximately Zero!

(0.71 x 2.28)



Dosage

0.5

x -34.4

+ 2.14

x -2.52

+ 1.29

A very small number

x -1.30

sum + -0.58 =

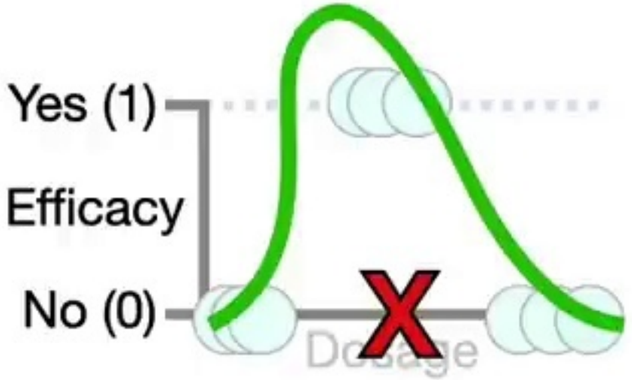
Efficacy

x 2.28

0.71

(A really small number x -1.30) + (0.71 x 2.28) - 0.58

Approximately Zero!



Dosage

0.5

x -34.4

+ 2.14

x -2.52

+ 1.29

A very small number

x -1.30

x 2.28

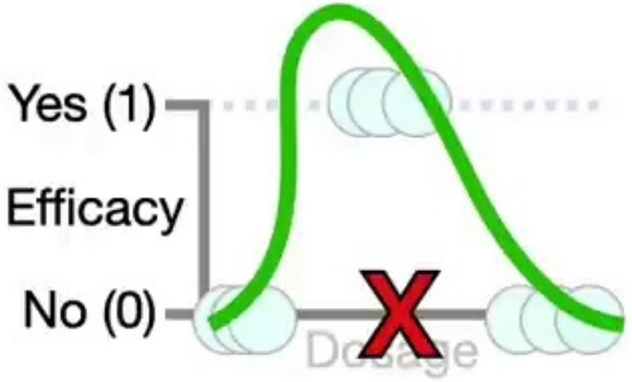
0.71

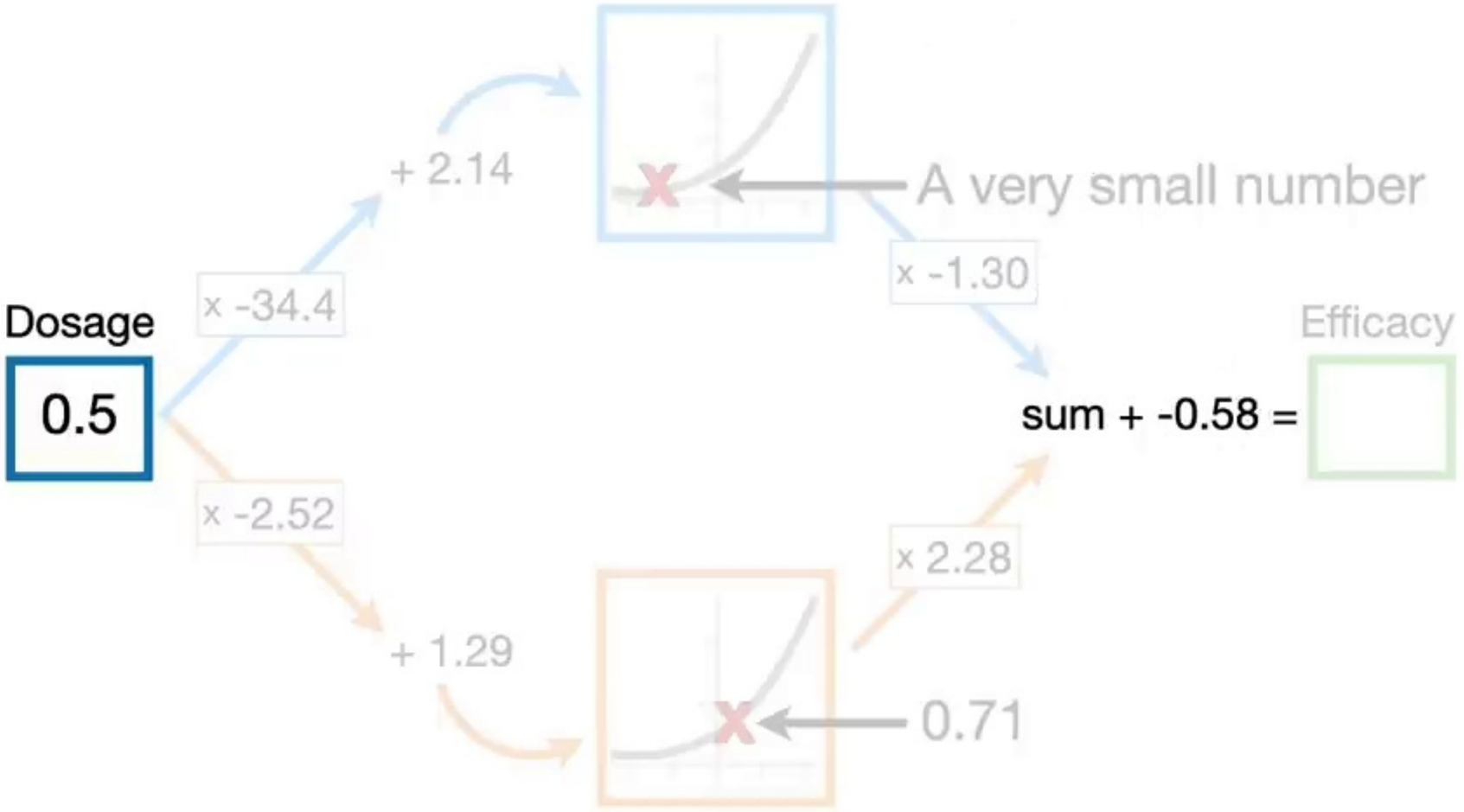
sum + -0.58 =

Efficacy

(A really small number x -1.30) + (0.71 x 2.28) - 0.58 = 1.03

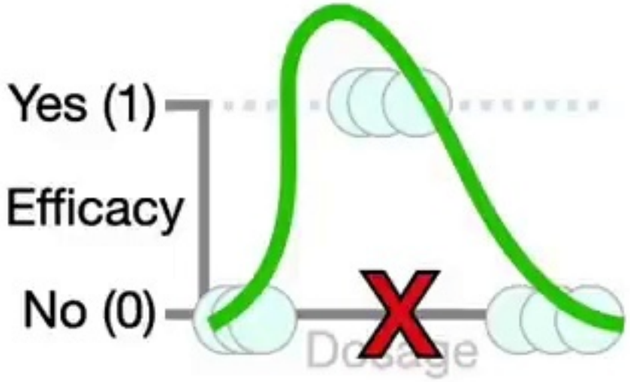
Approximately Zero!

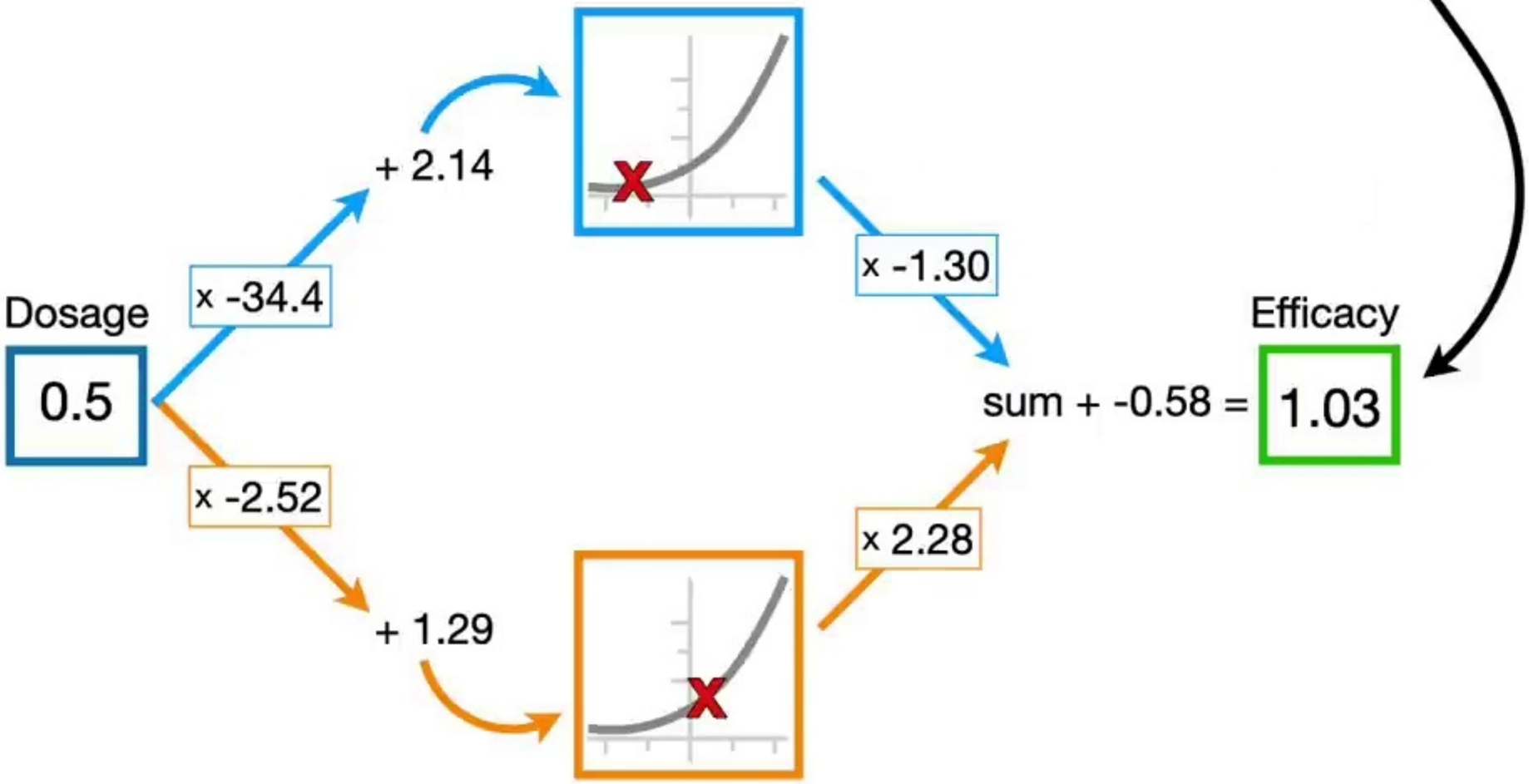


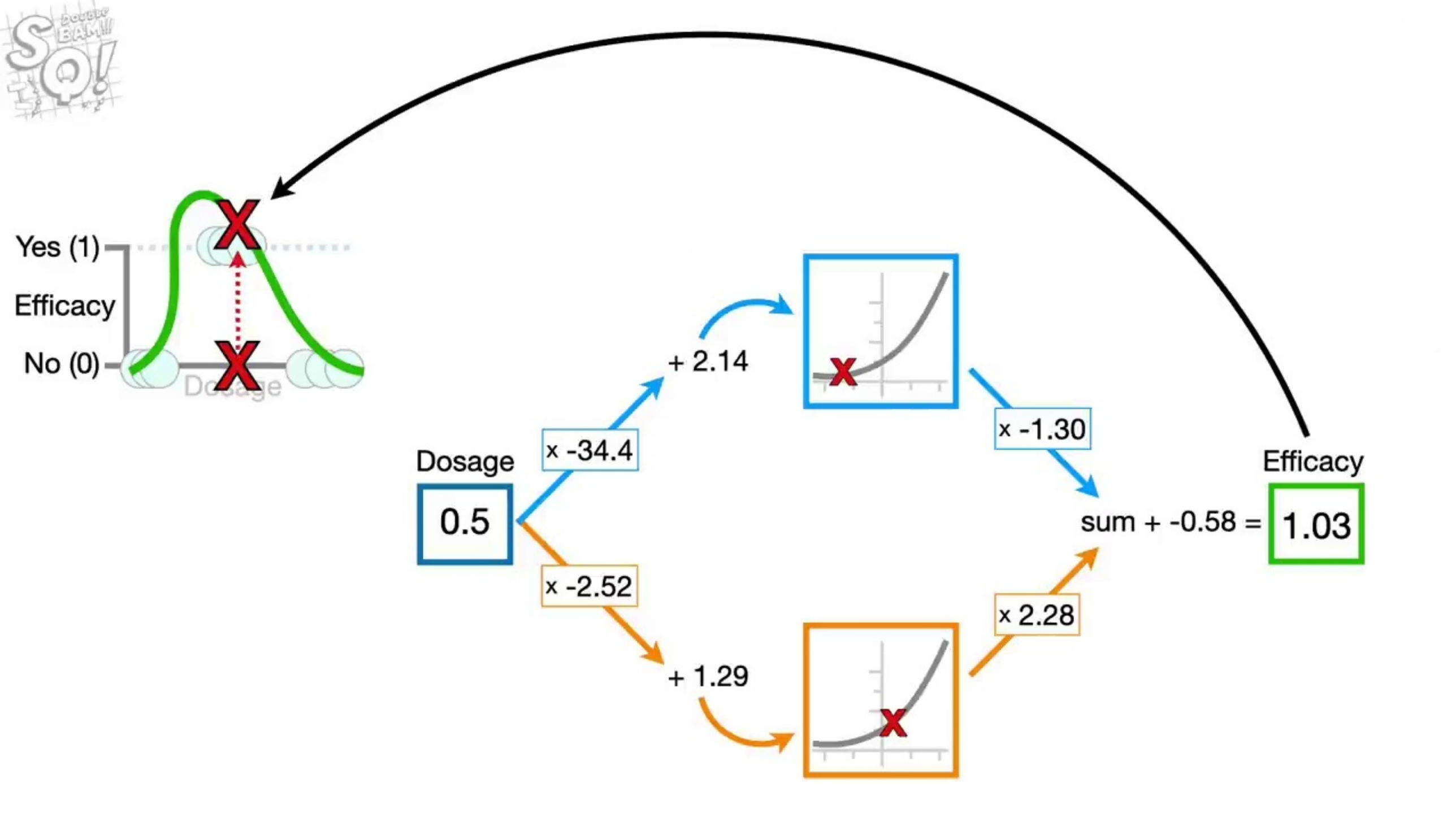


(A really small number x -1.30) + (0.71 x 2.28) - 0.58 = 1.03

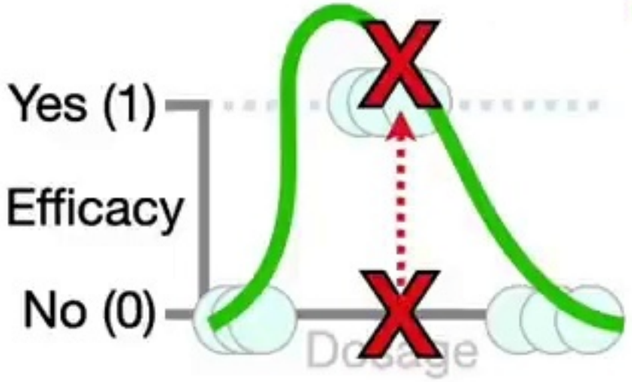
Approximately Zero!

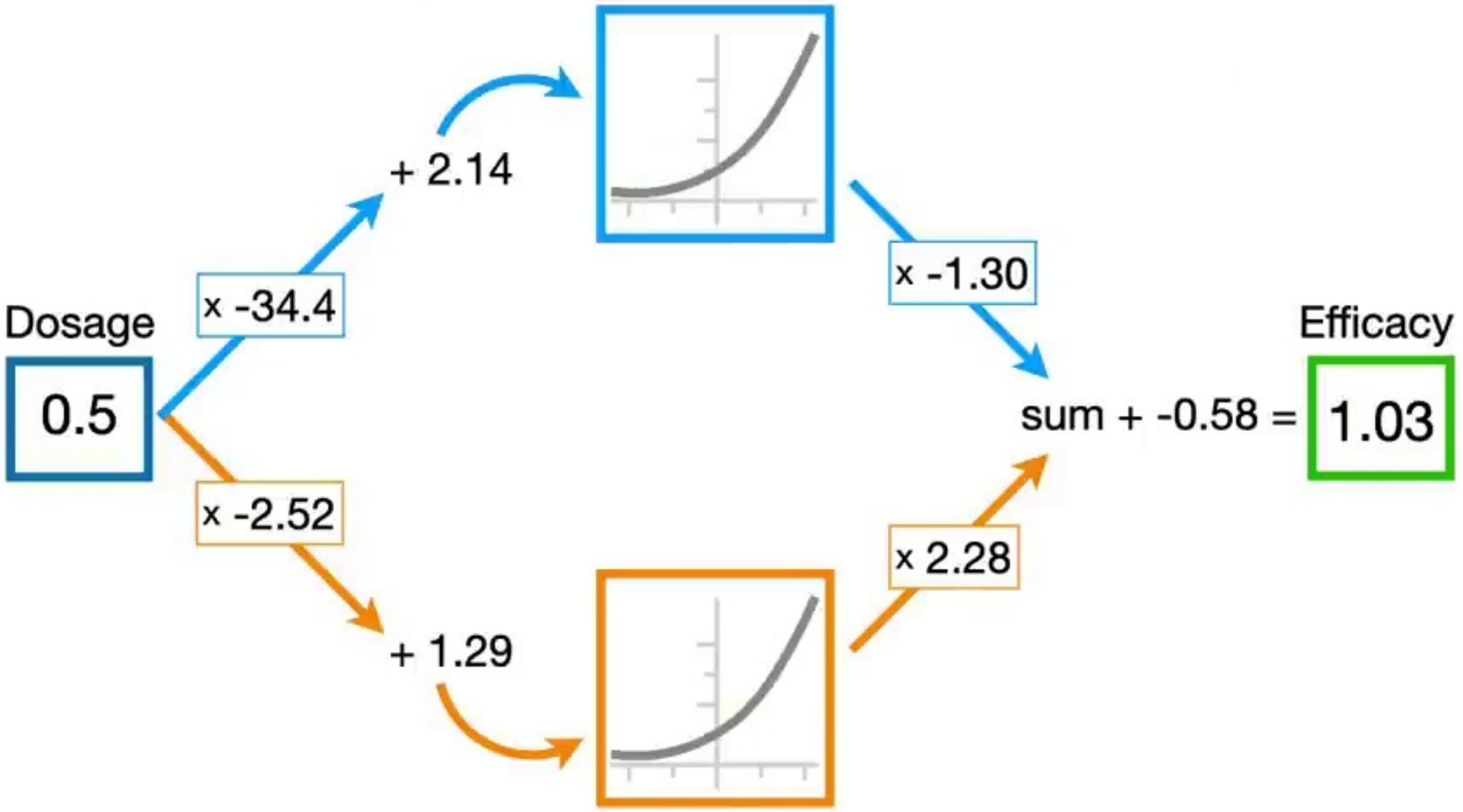




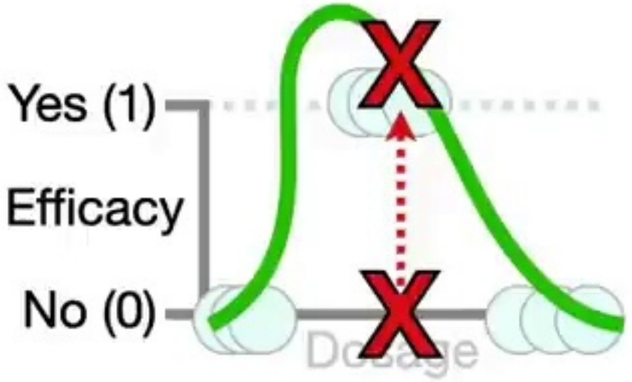

Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy
1.03

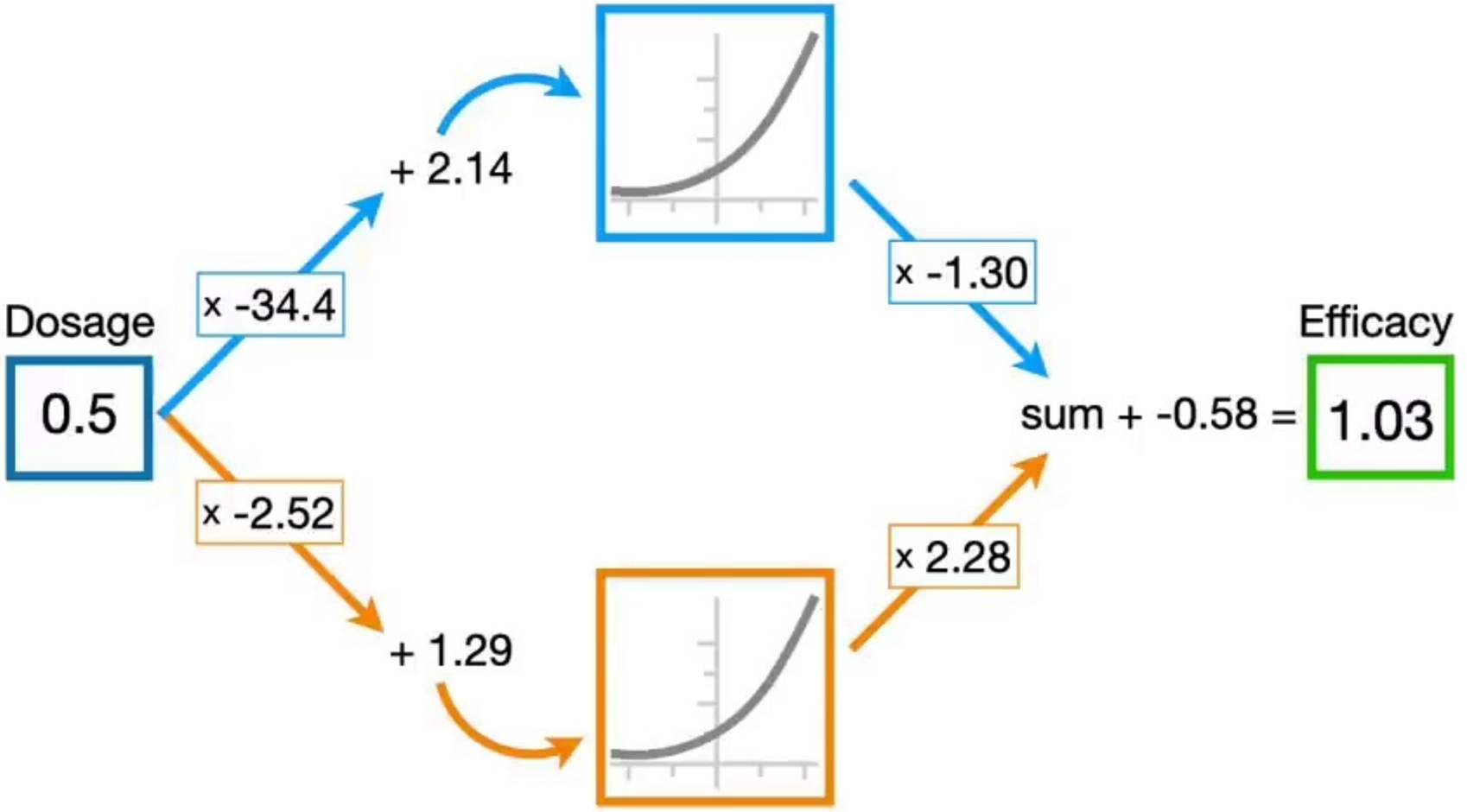
…and we see that the y-axis coordinate on the **green squiggle** is **1.03**…

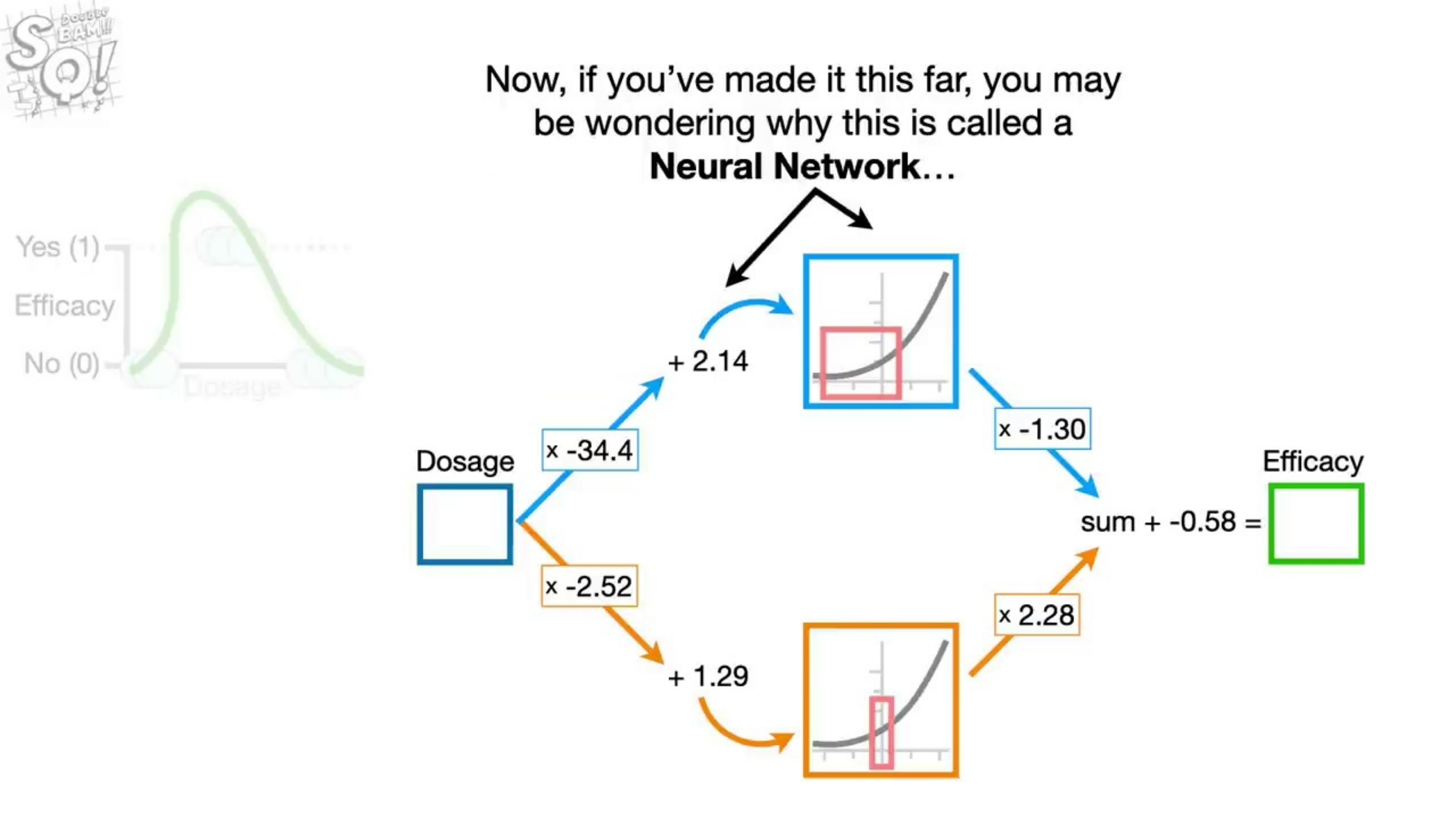




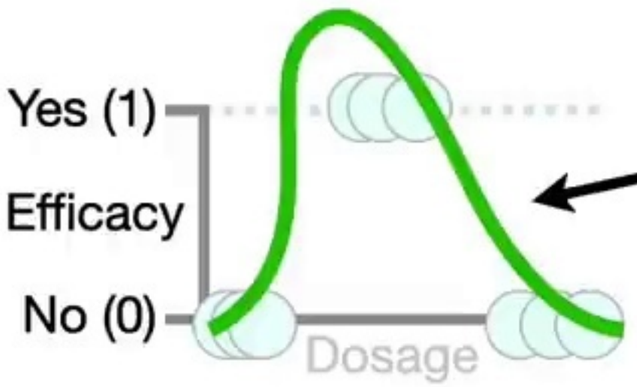
…and since **1.03** is closer to **1** than **0**, we will conclude that a **Dosage = 0.5** is effective.

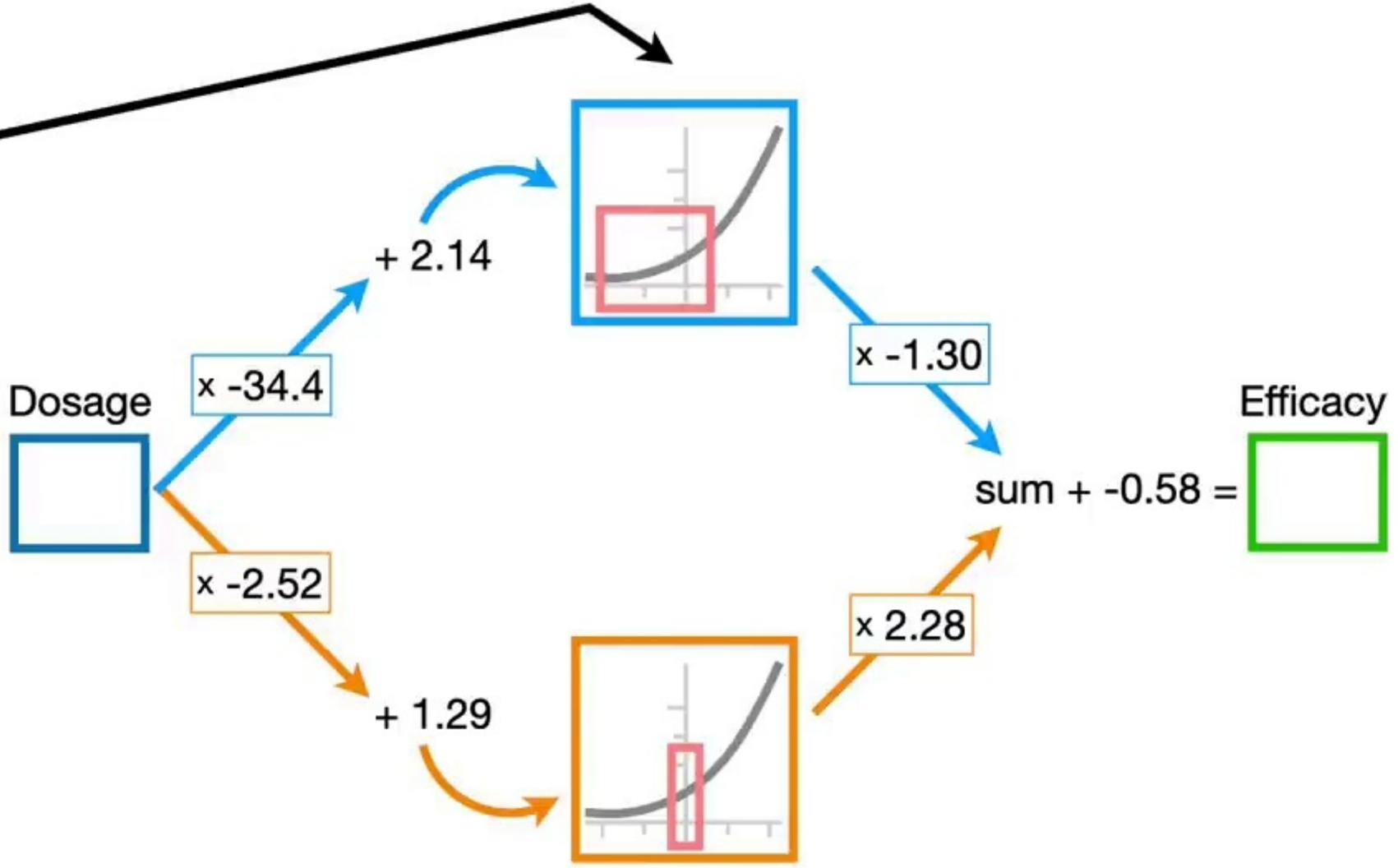




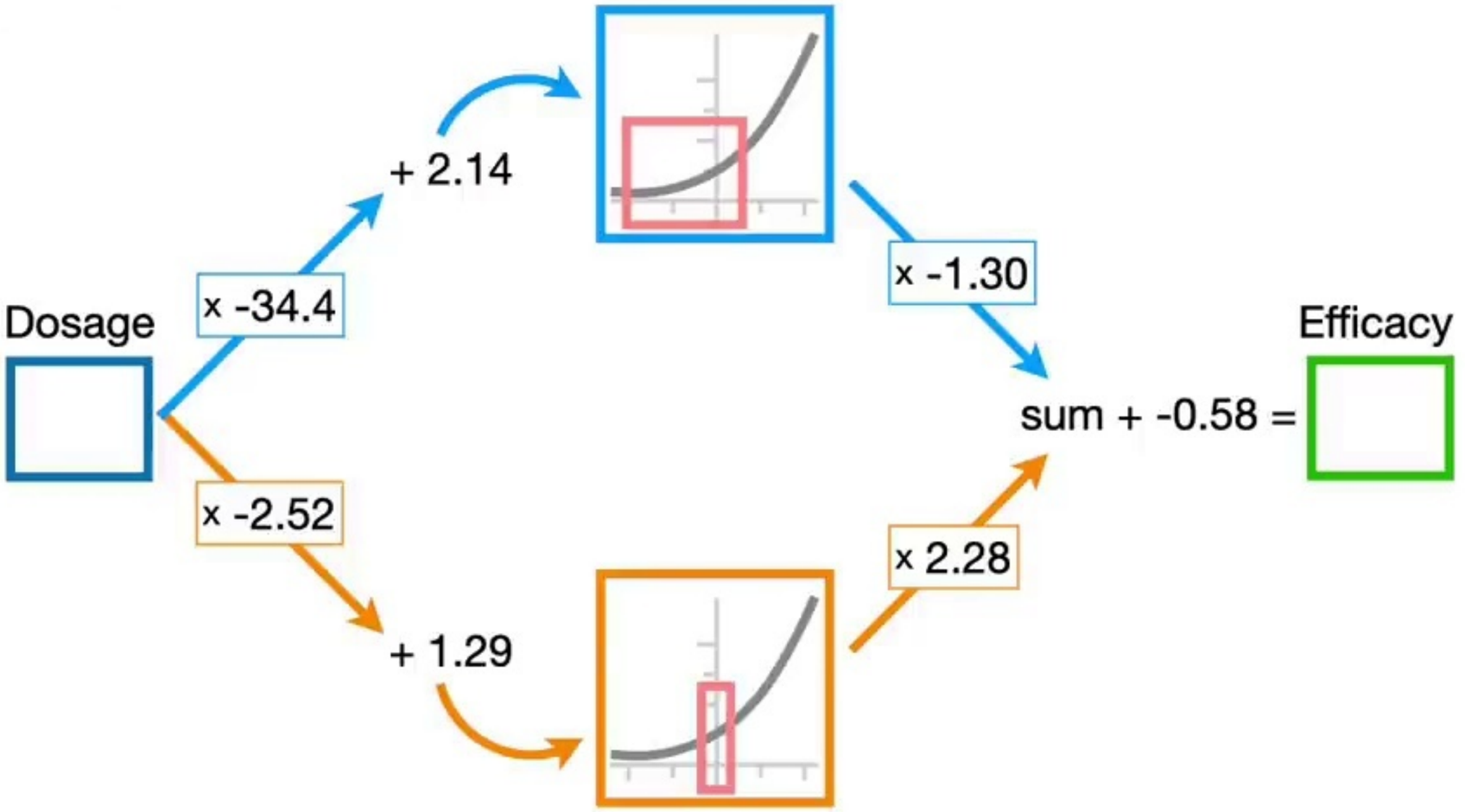

Now, if you've made it this far, you may be wondering why this is called a **Neural Network**…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

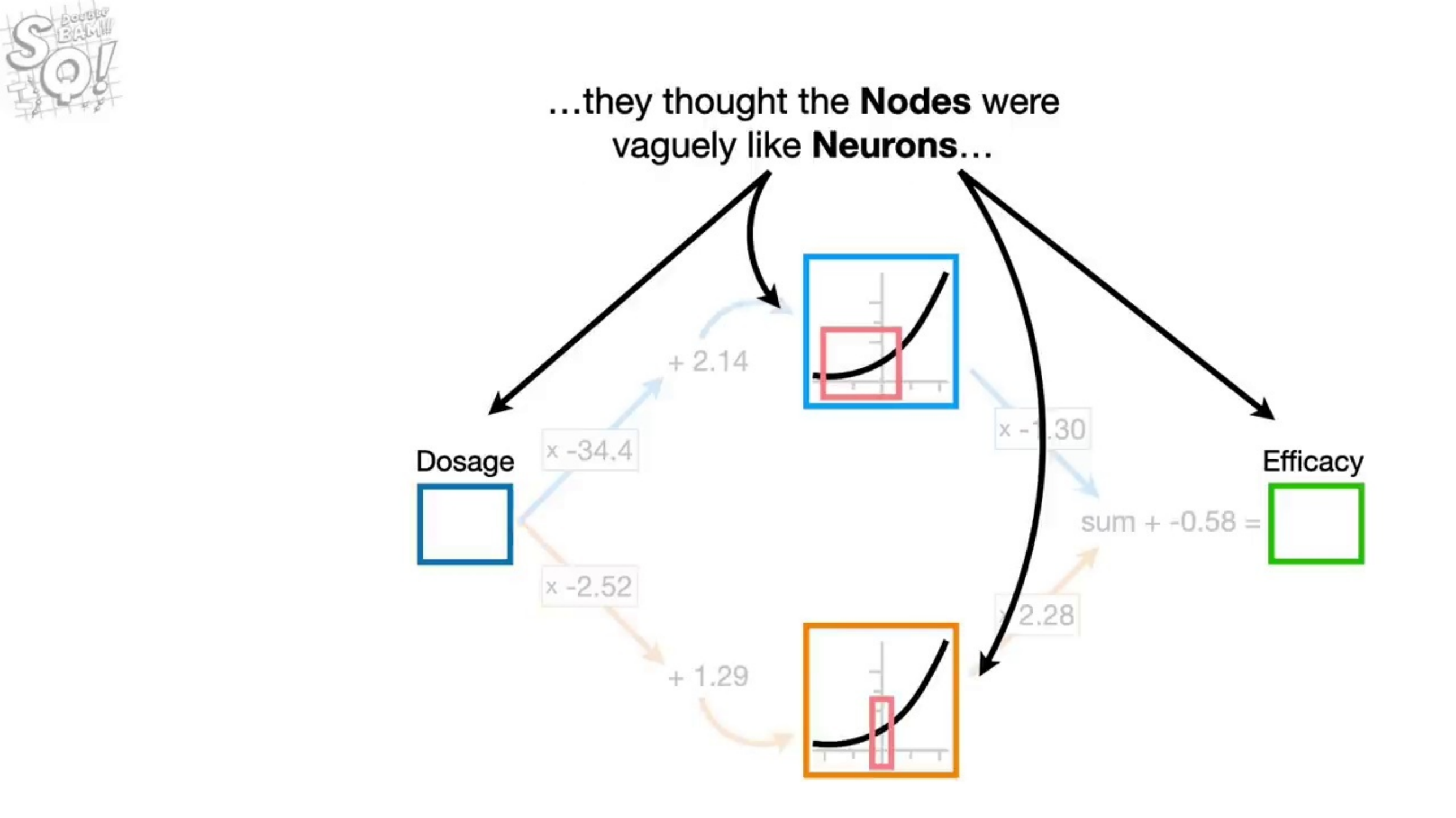
…instead of a **Big Fancy Squiggle Fitting Machine.**



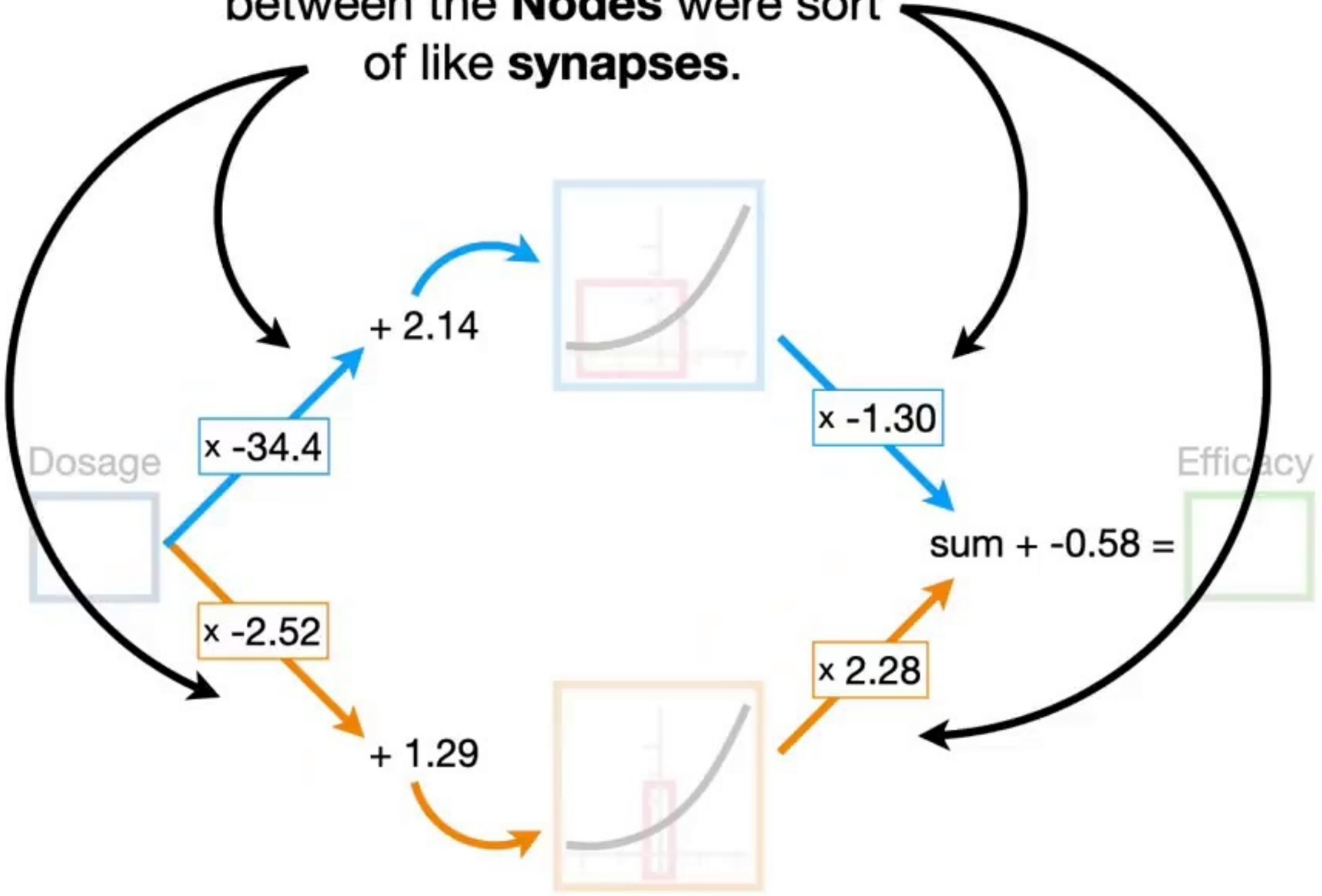


The reason is that way back in the **1940s** and **50s** when **Neural Networks** were invented…

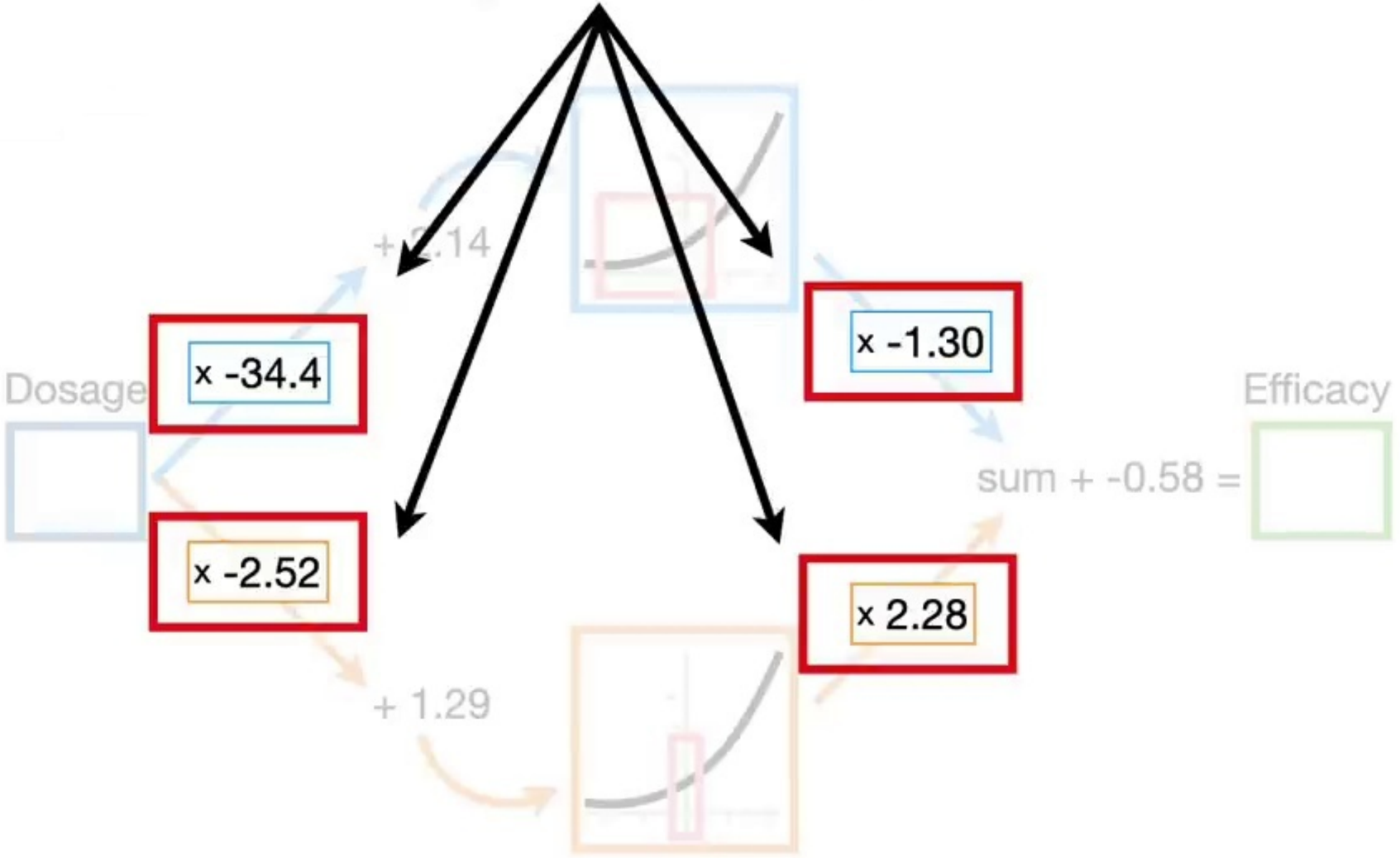


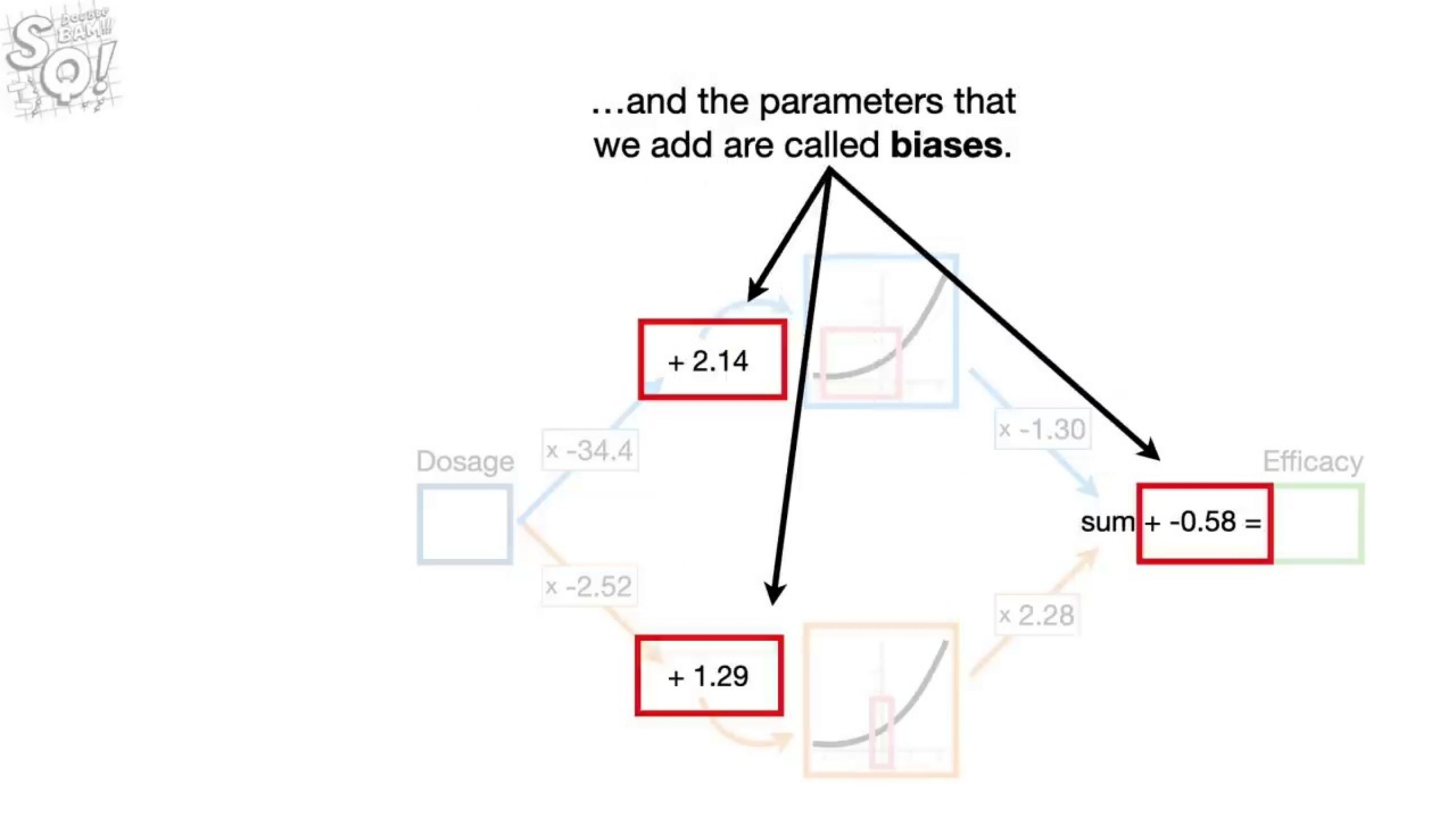

…they thought the **Nodes** were vaguely like **Neurons**…
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

…and the **connections** between the **Nodes** were sort of like **synapses**.

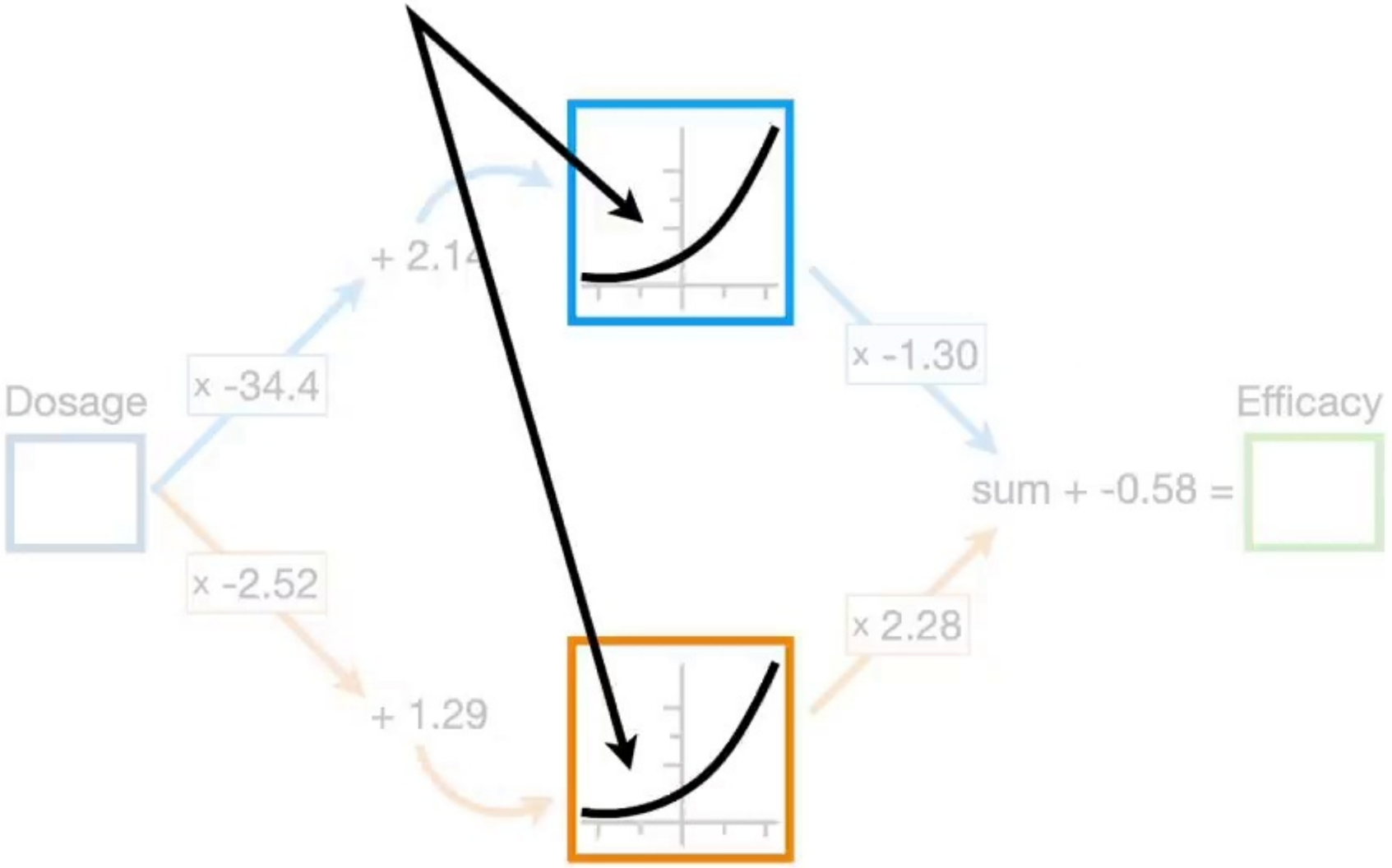


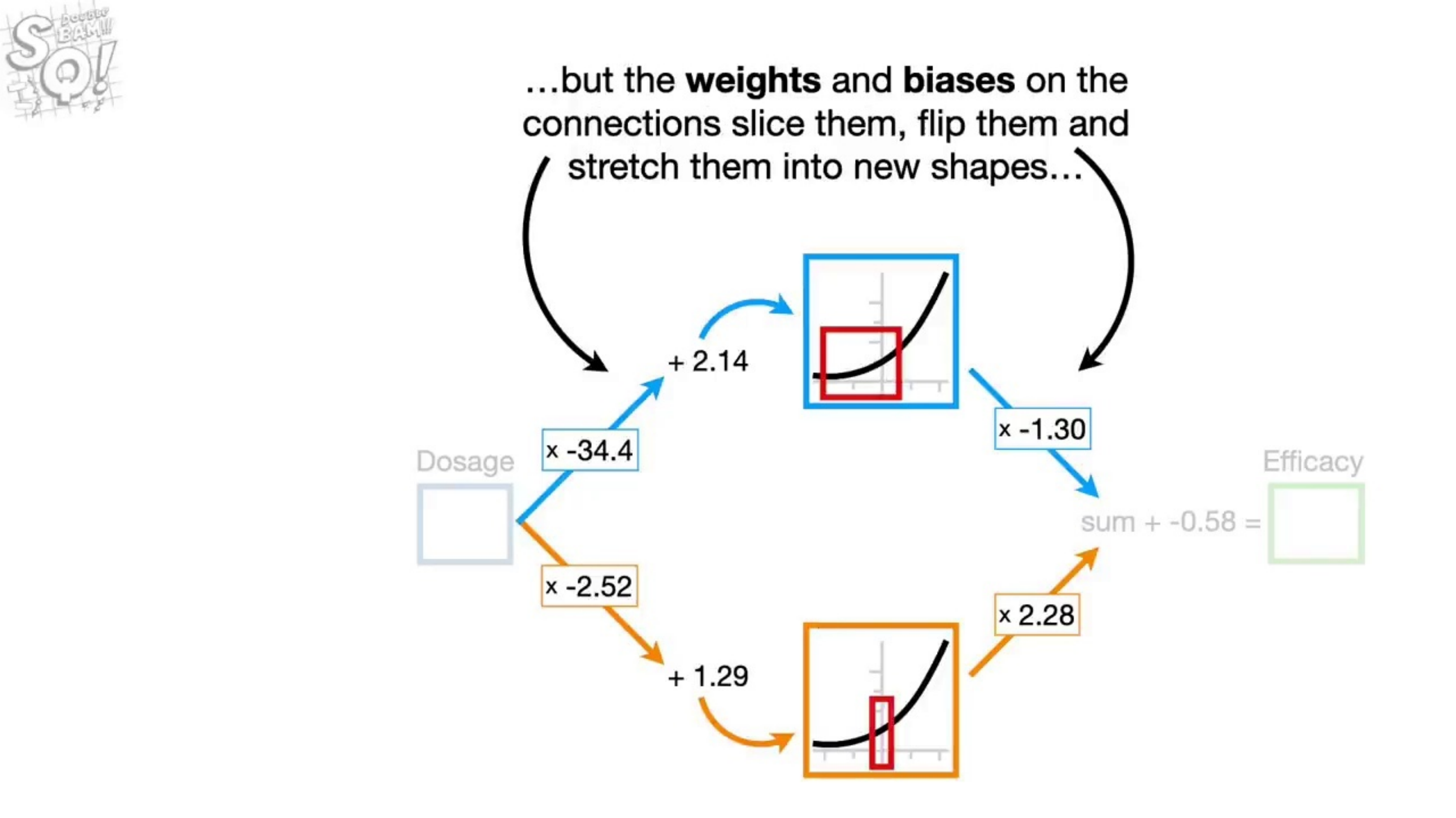
NOTE: Whether or not you call it a **Squiggle Fitting Machine**, the parameters that we multiply are called **weights**…



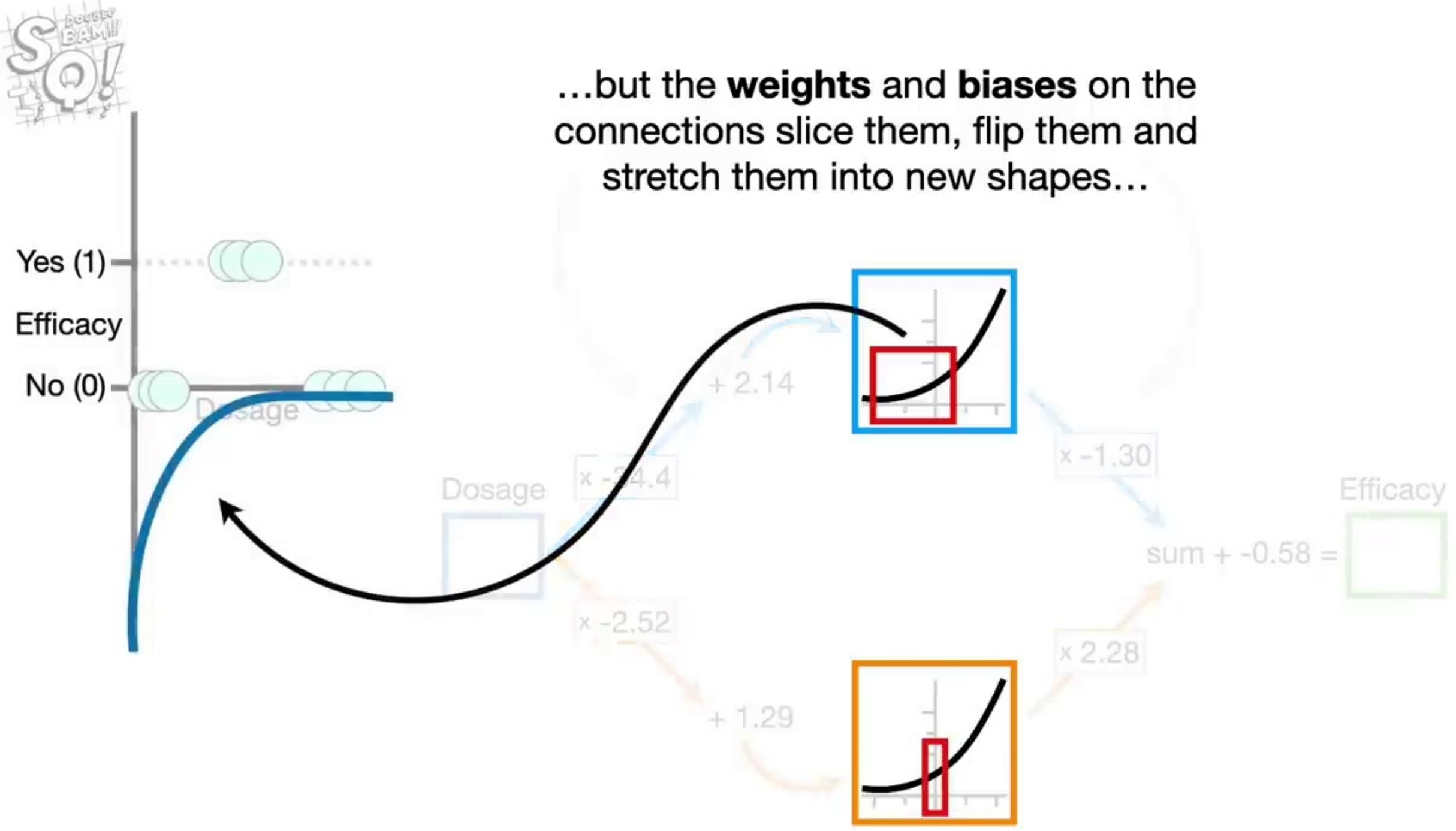

…and the parameters that we add are called **biases**.
+ 2.14
Dosage
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

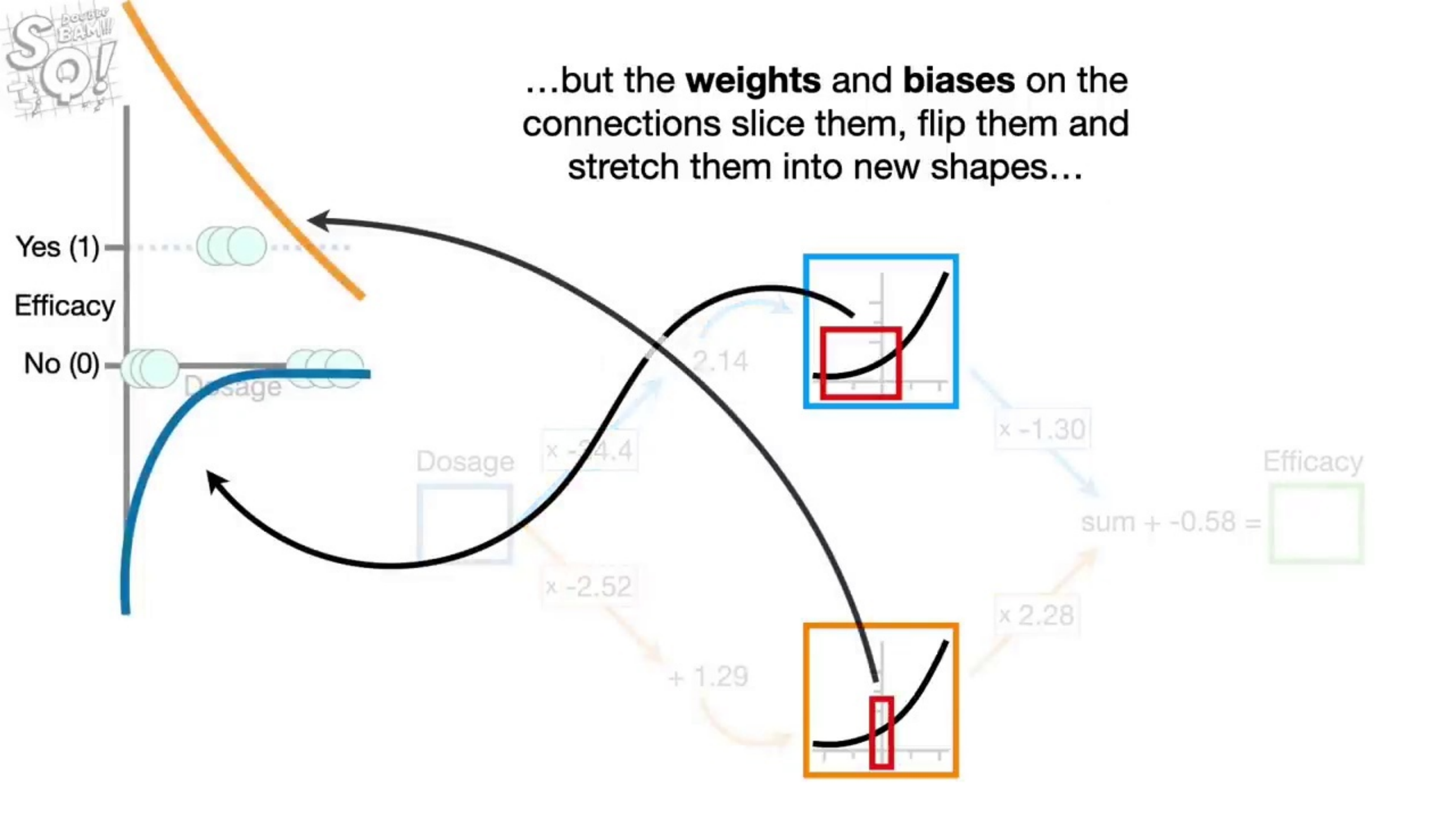
NOTE: This **Neural Network** starts with two identical **Activation Functions**…

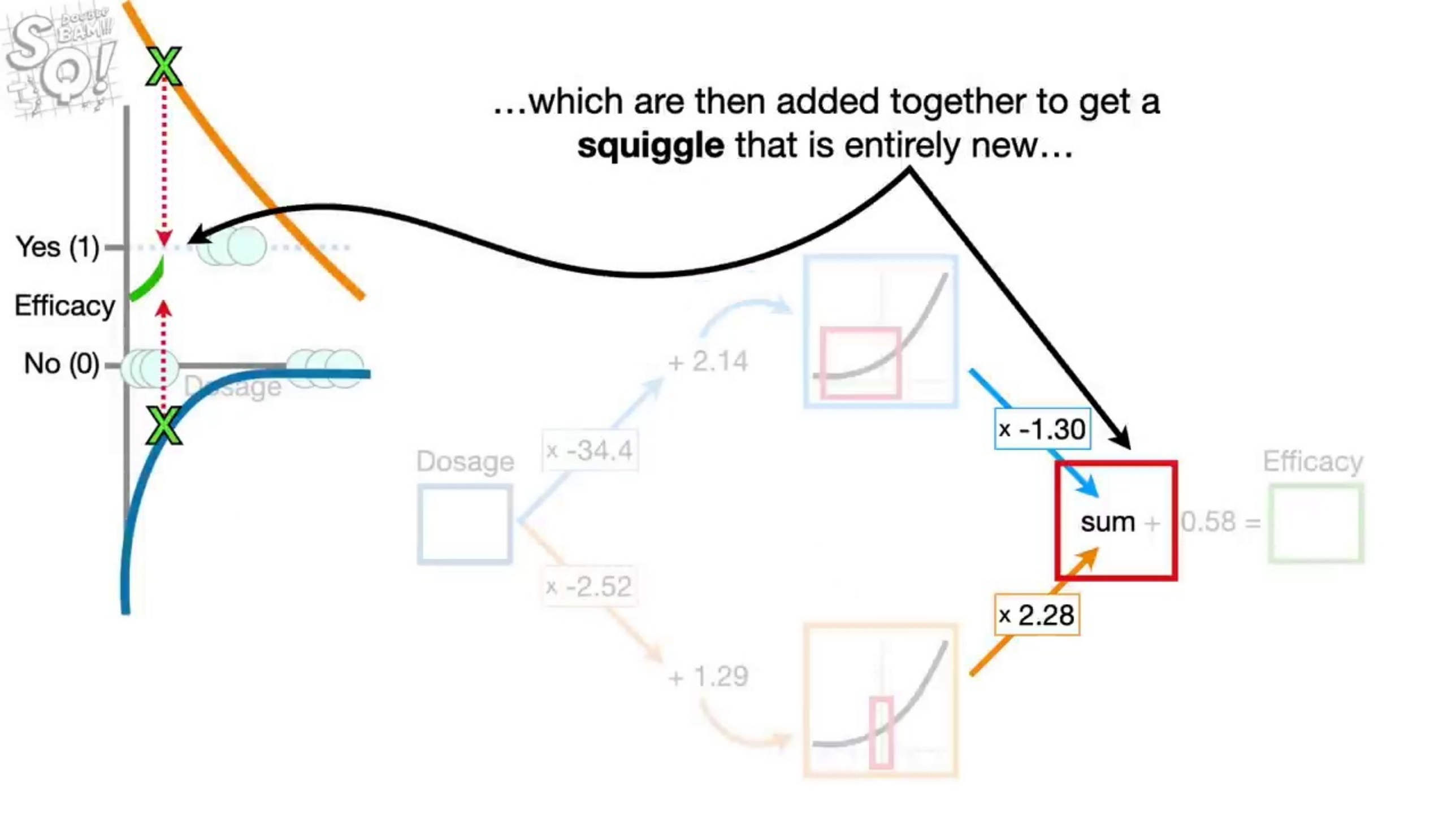


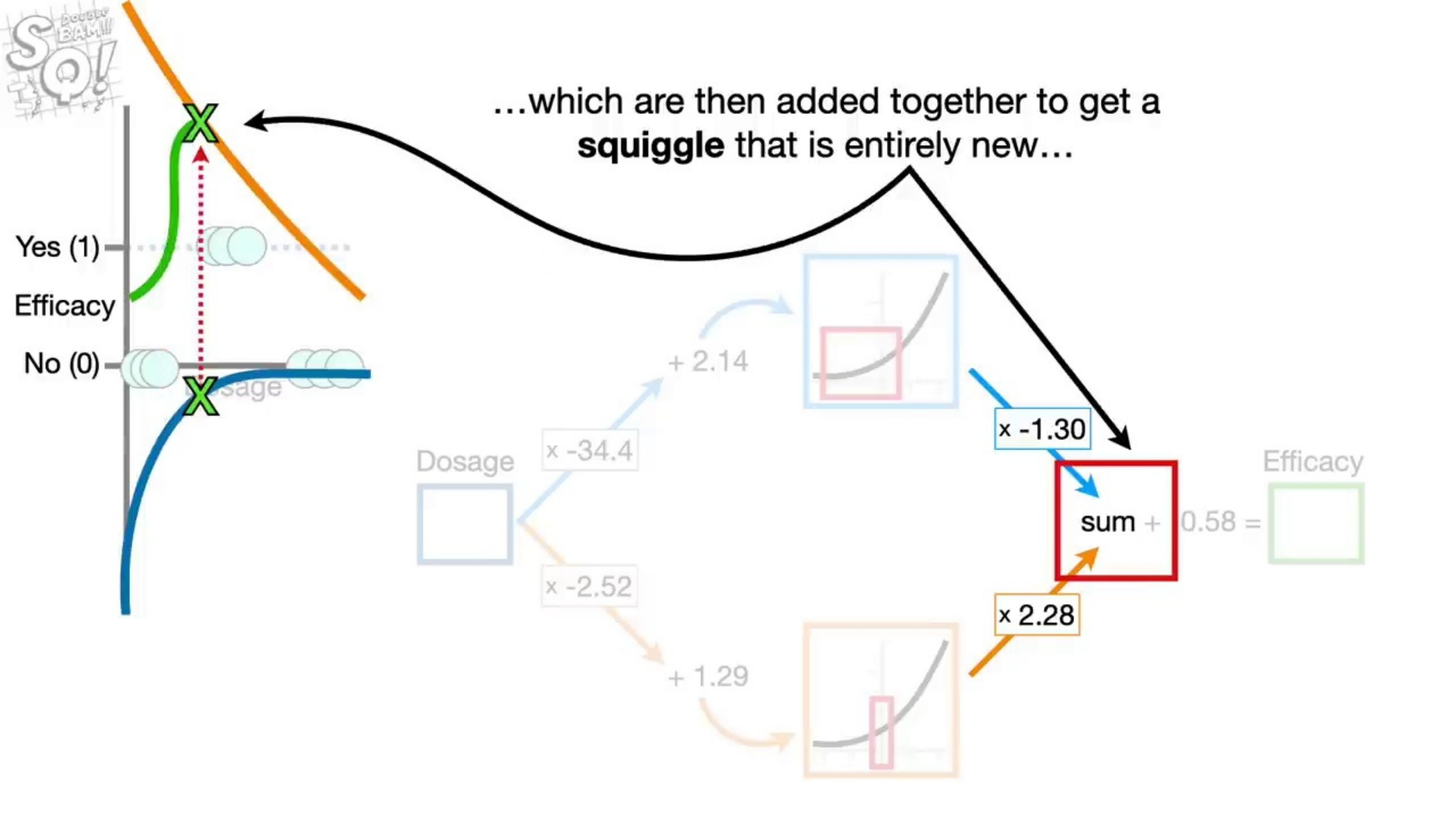

…but the **weights** and **biases** on the connections slice them, flip them and stretch them into new shapes…
Dosage
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

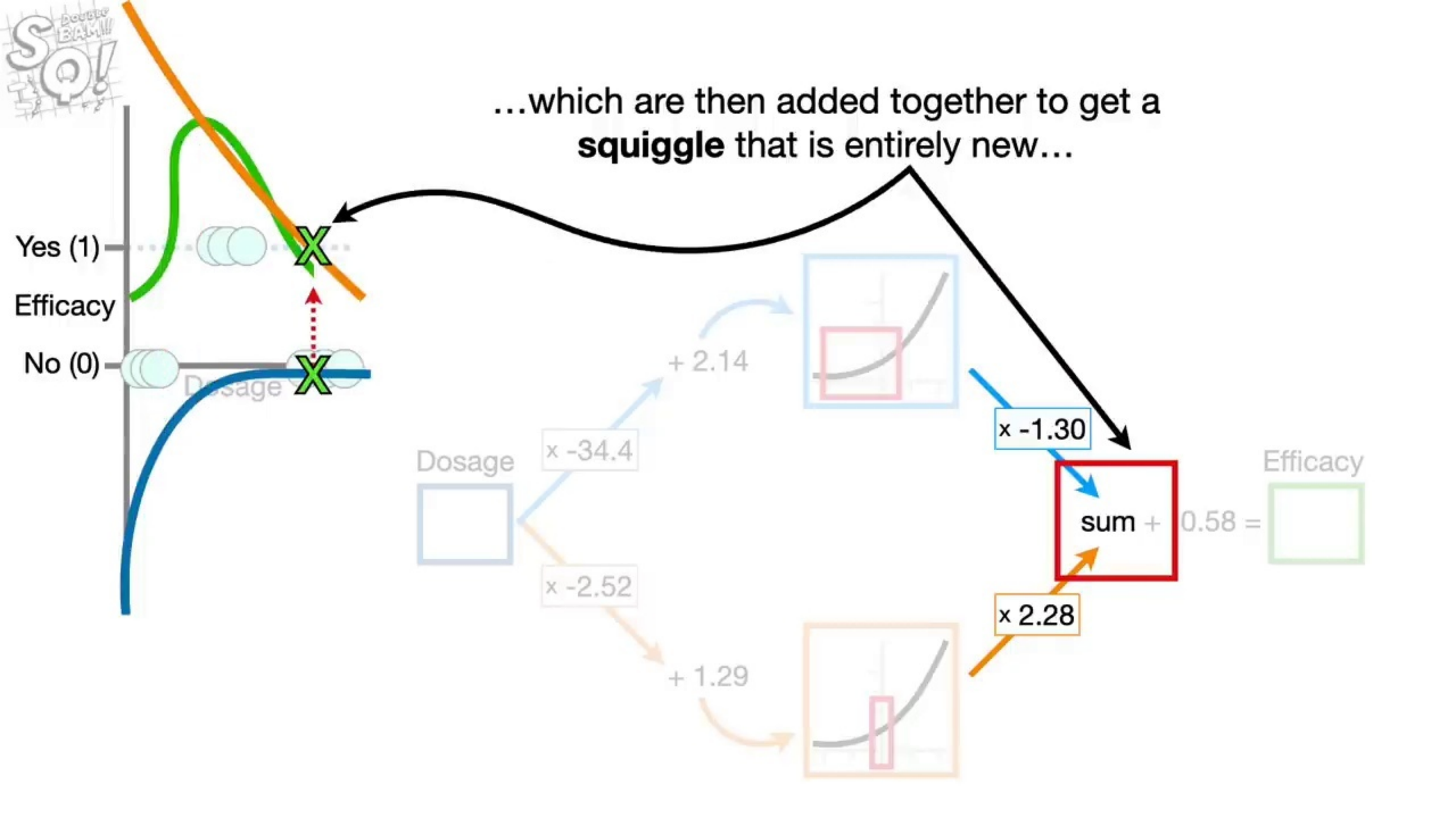
…but the **weights** and **biases** on the connections slice them, flip them and stretch them into new shapes…

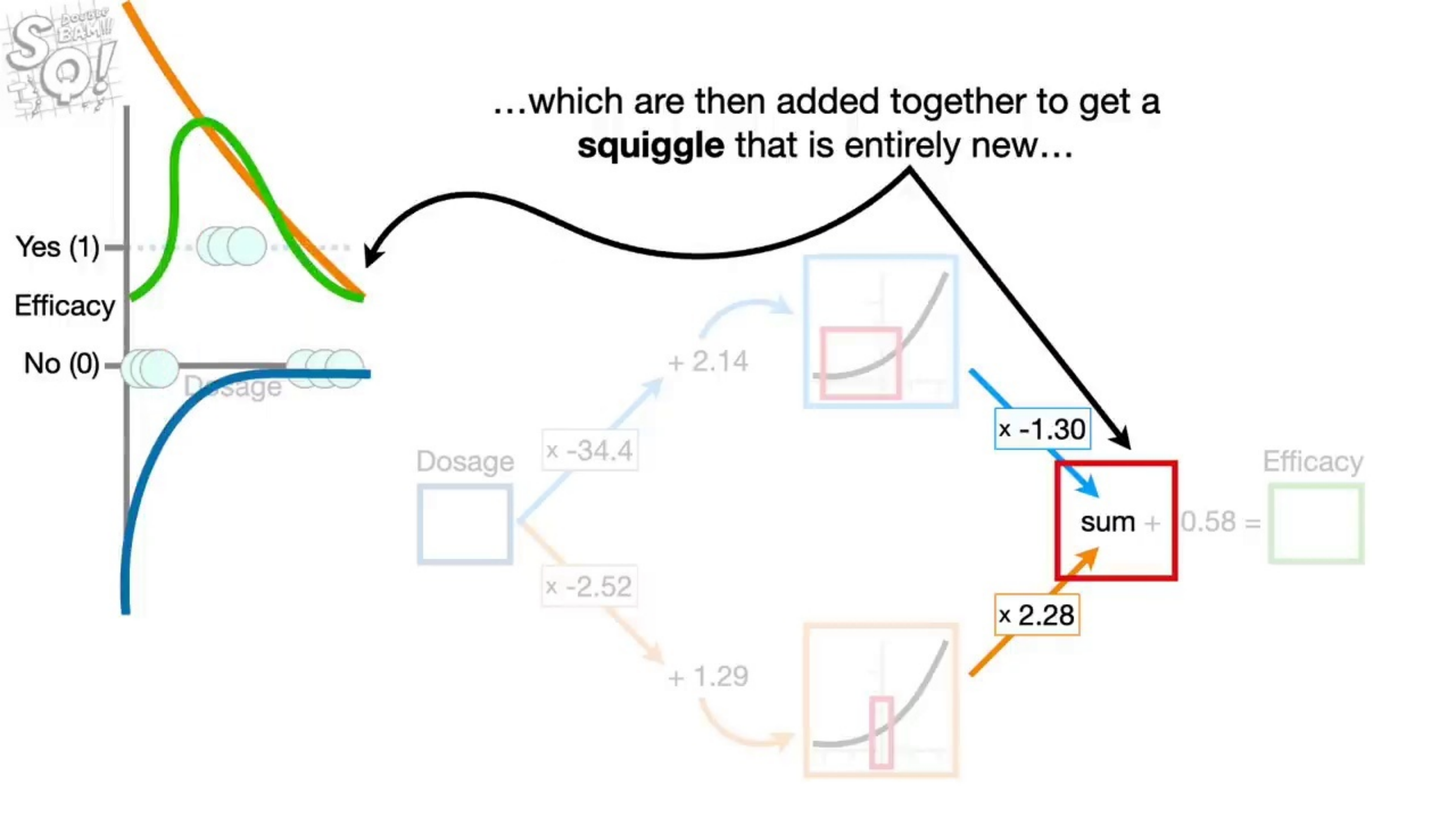


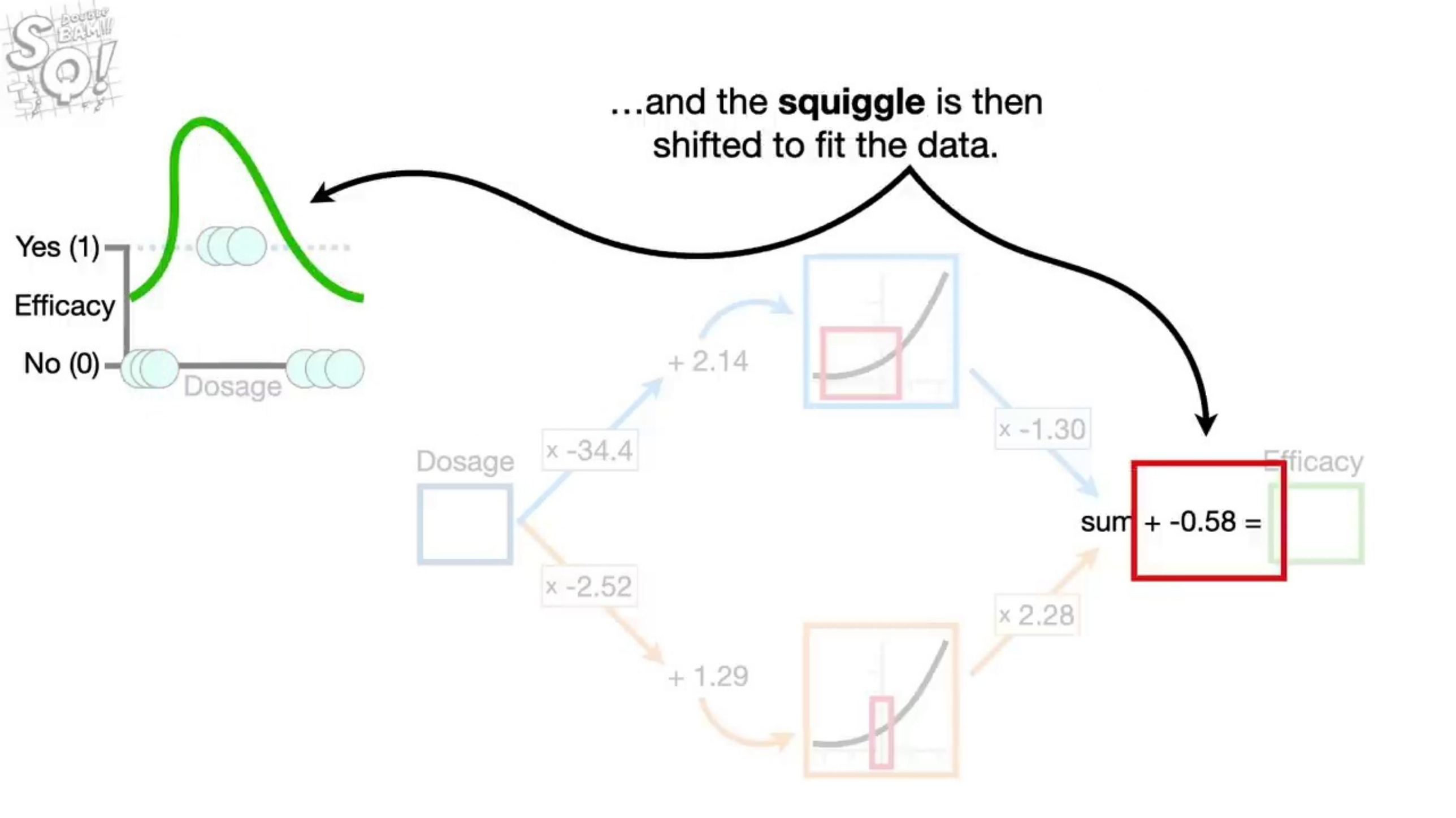

…but the **weights** and **biases** on the connections slice them, flip them and stretch them into new shapes…
Yes (1)
Efficacy
No (0)
Dosage
2.14
x -34.4
Dosage
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29


…which are then added together to get a
squiggle that is entirely new…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy

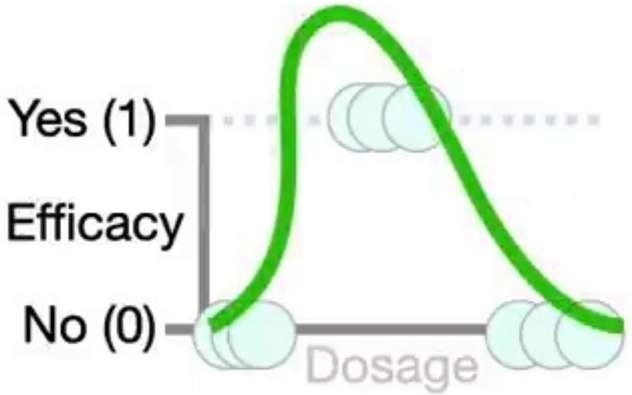

…which are then added together to get a
squiggle that is entirely new…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy

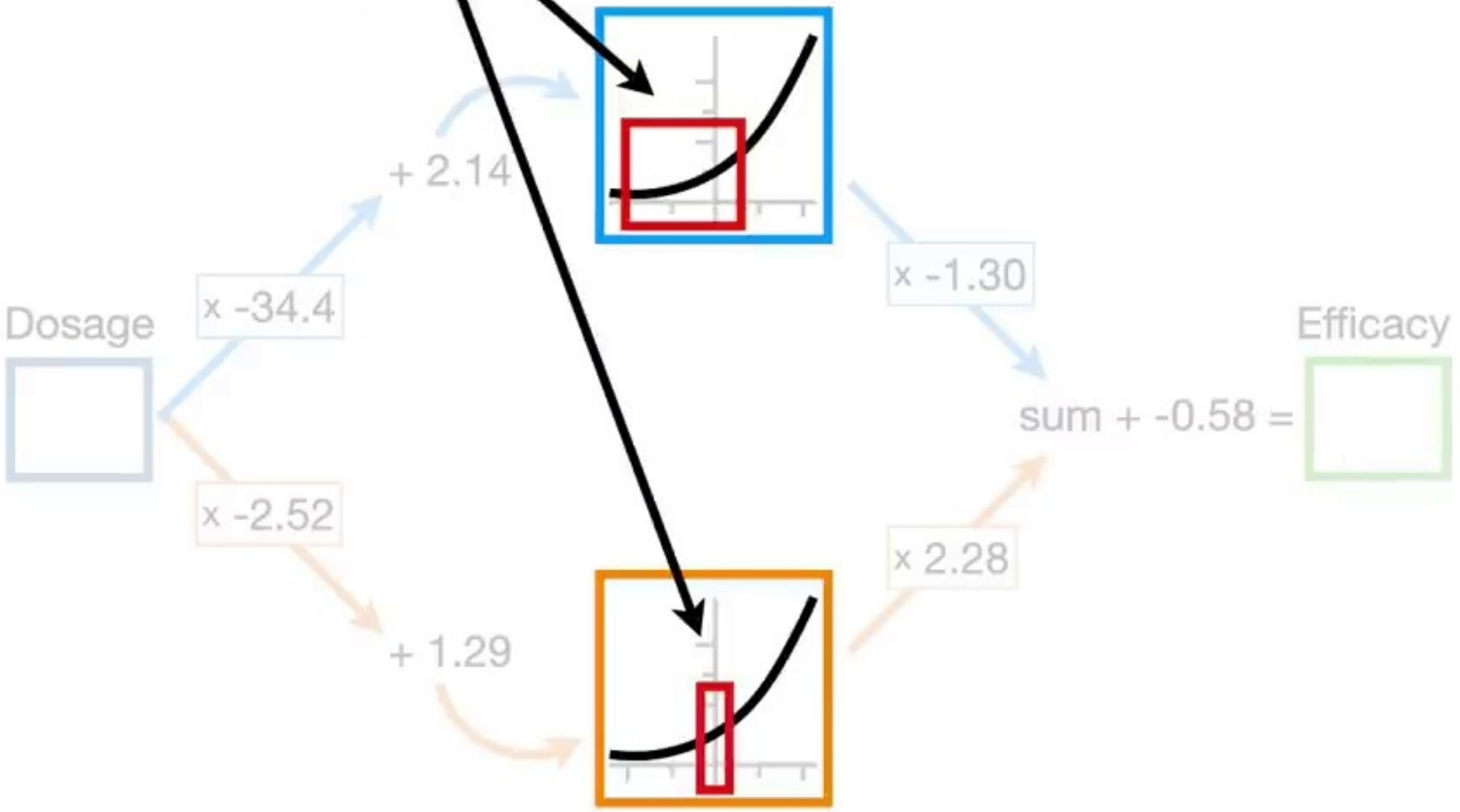

…which are then added together to get a
squiggle that is entirely new…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy


…which are then added together to get a
squiggle that is entirely new…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy

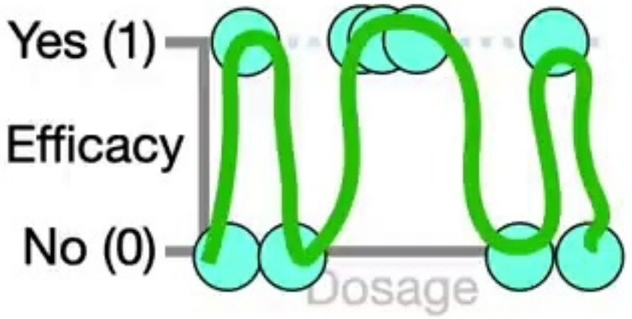

…and the squiggle is then shifted to fit the data.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum
+ -0.58 =
Efficacy

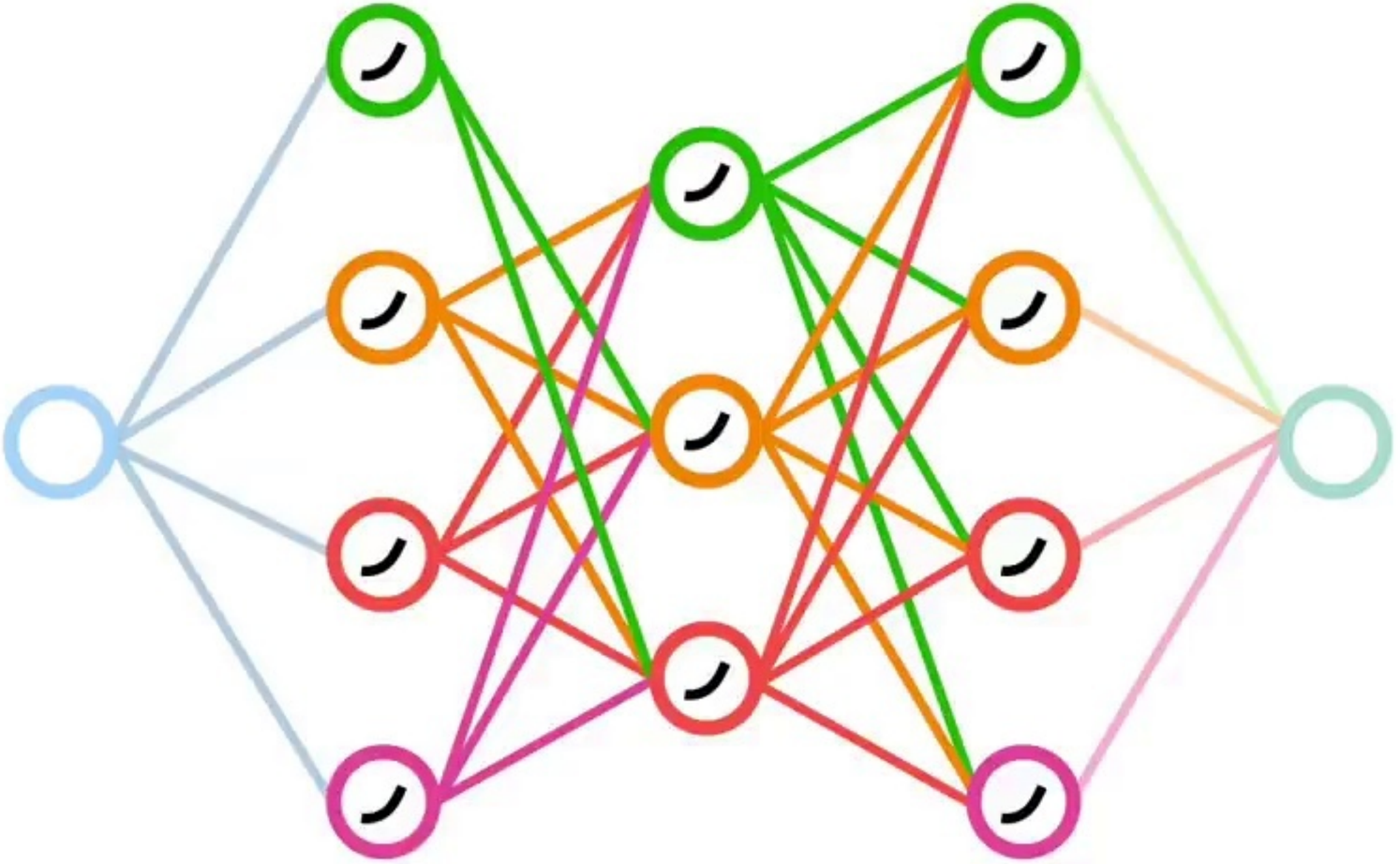
Now, if we can create this **green squiggle** with just two **Nodes** in a single **Hidden Layer**…



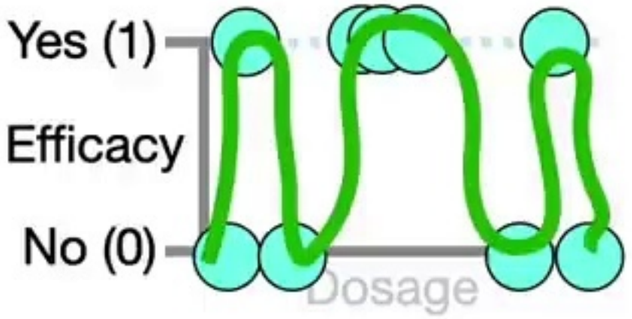


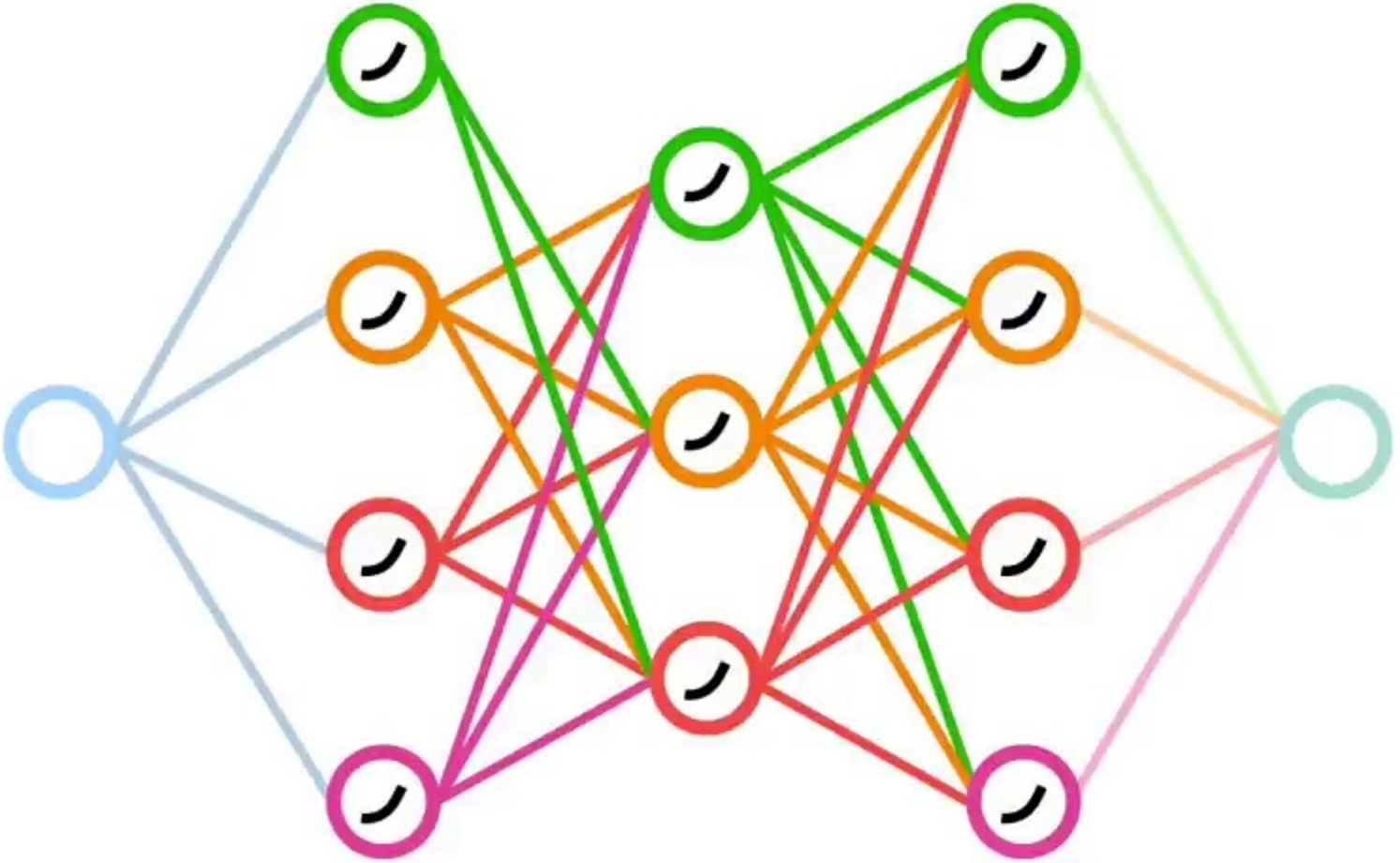
…just imagine what types of **green squiggles** we could fit with more **Hidden Layers** and more **Nodes** in each **Hidden Layer**.





In theory, **Neural Networks** can fit a **green squiggle** to just about any dataset, no matter how complicated!





And I think that's pretty cool!