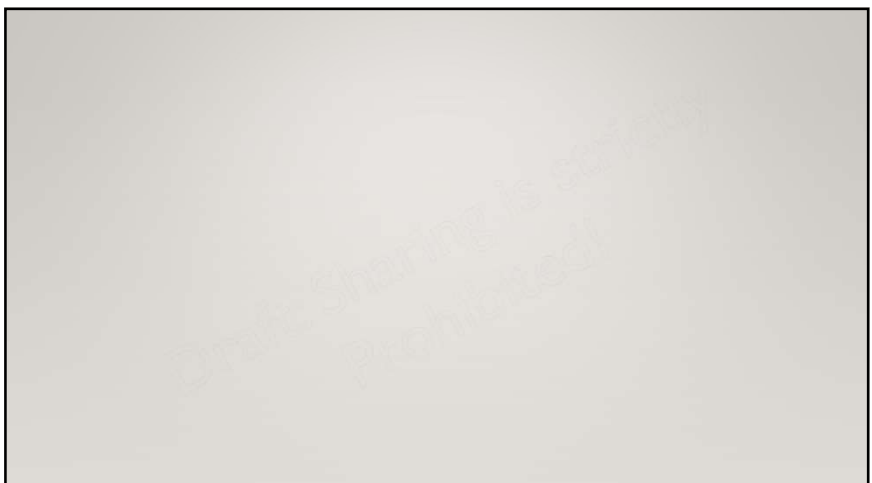
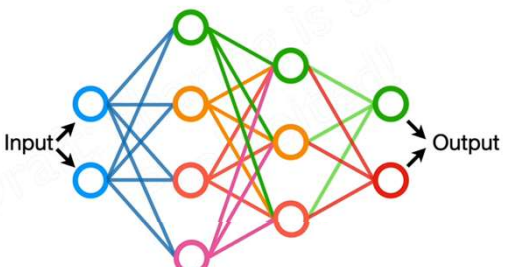
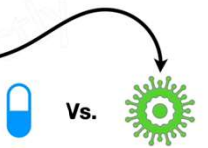


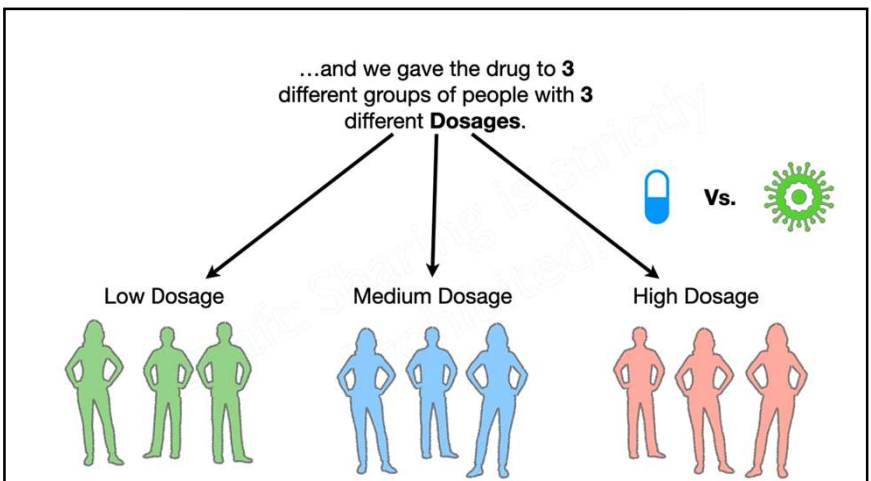
Neural Networks, one of the most popular algorithms in **Machine Learning**, cover a broad range of concepts and techniques.

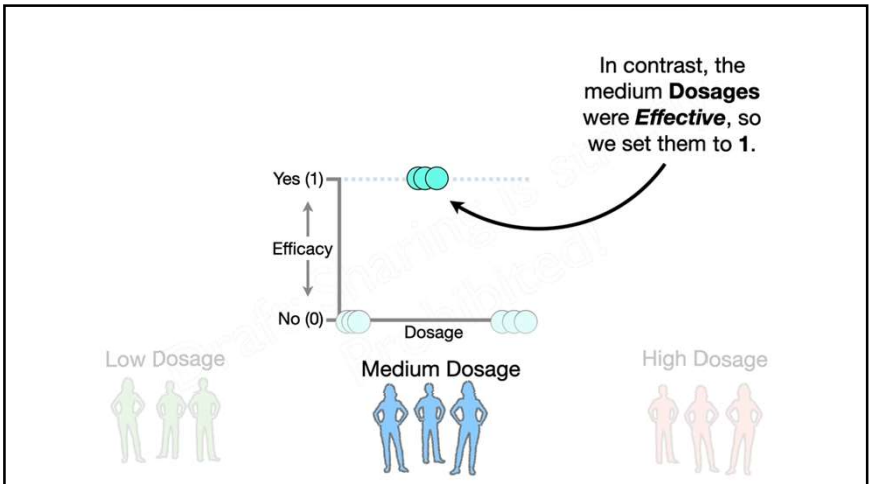


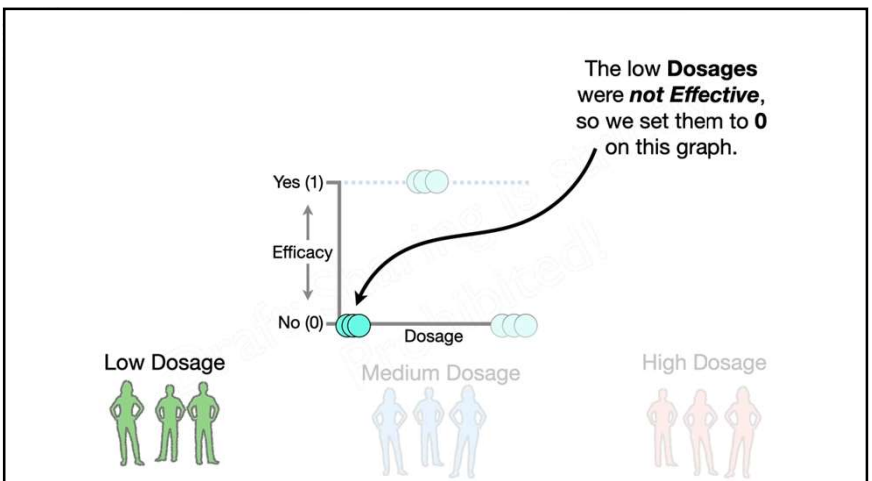
Neural Networks…

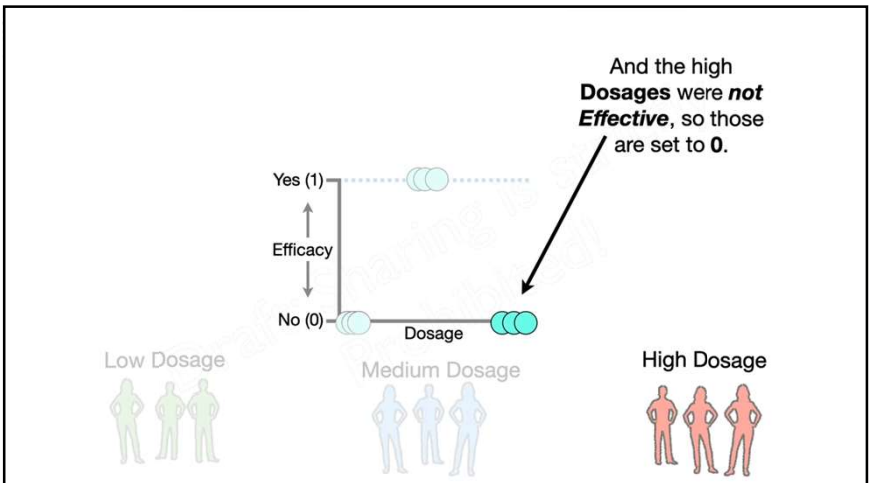
So, with that said, let's imagine we tested a drug that was designed to treat an illness…

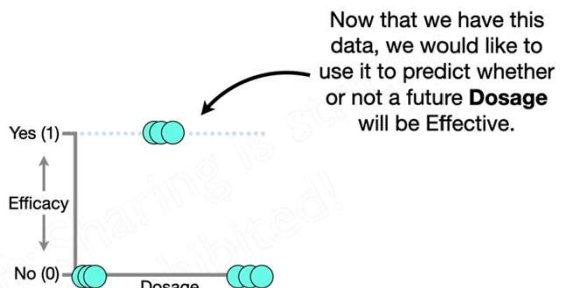


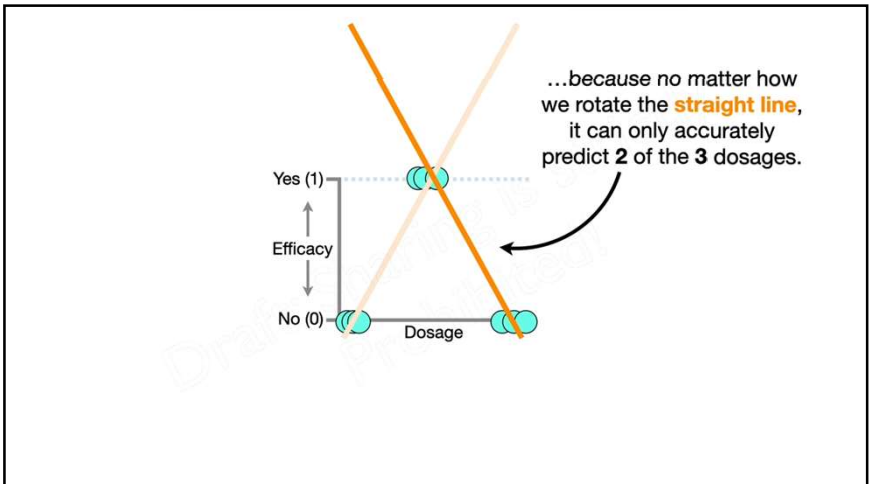

…and we gave the drug to 3 different groups of people with 3 different Dosages.
Vs.
Low Dosage
Medium Dosage
High Dosage

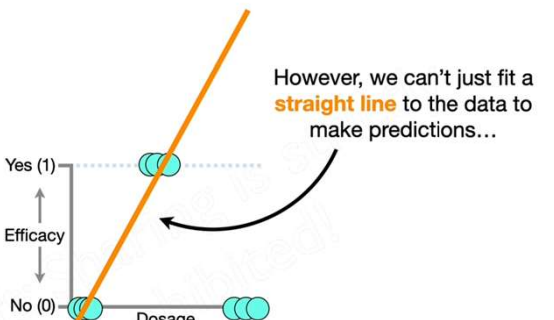

In contrast, the medium **Dosages** were ***Effective***, so we set them to **1**.
Yes (1)
Efficacy
No (0)
Dosage
Low Dosage
Medium Dosage
High Dosage

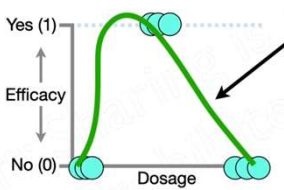

The low **Dosages** were ***not Effective***, so we set them to **0** on this graph.
Yes (1)
Efficacy
No (0)
Dosage
Low Dosage
Medium Dosage
High Dosage


And the high
Dosages were *not*
Effective, so those
are set to 0.
Yes (1)
Efficacy
No (0)
Dosage
Low Dosage
Medium Dosage
High Dosage

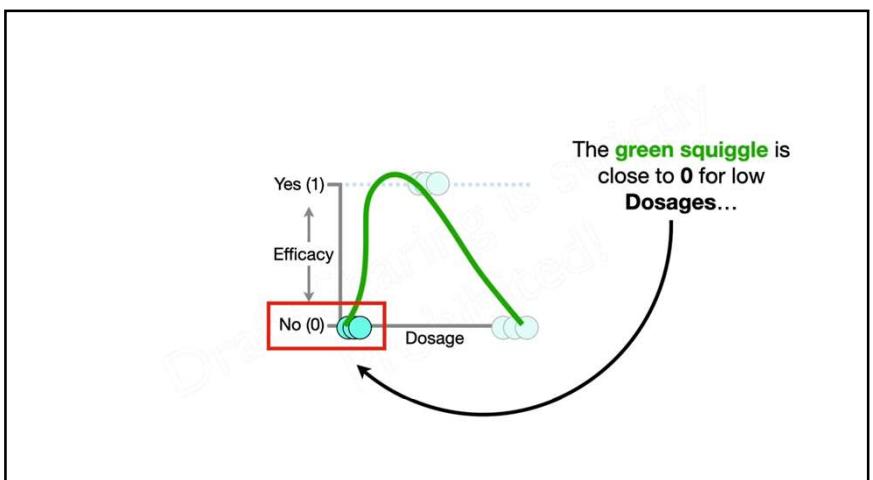

Now that we have this data, we would like to use it to predict whether or not a future **Dosage** will be Effective.
Yes (1)
Efficacy
No (0)
Dosage

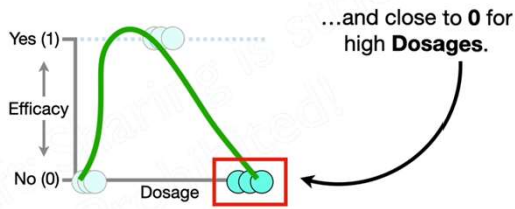

…because no matter how we rotate the straight line, it can only accurately predict 2 of the 3 dosages.
Yes (1)
Efficacy
No (0)
Dosage

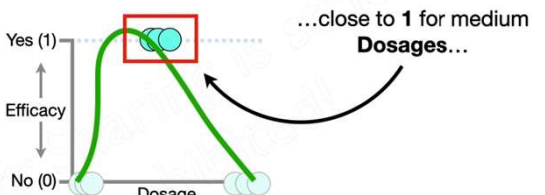

However, we can't just fit a straight line to the data to make predictions...
Yes (1)
Efficacy
No (0)
Dosage

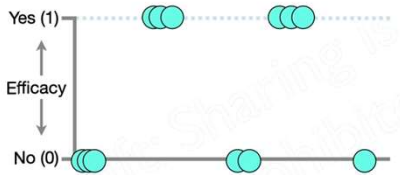


The good news is that a **Neural Network** can fit a **squiggle** to the data.

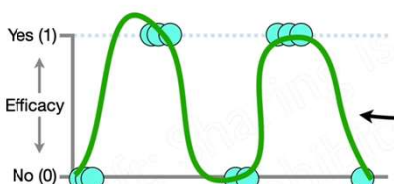

Yes (1)
Efficacy
No (0)
Dosage
The green squiggle is close to 0 for low Dosages…


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

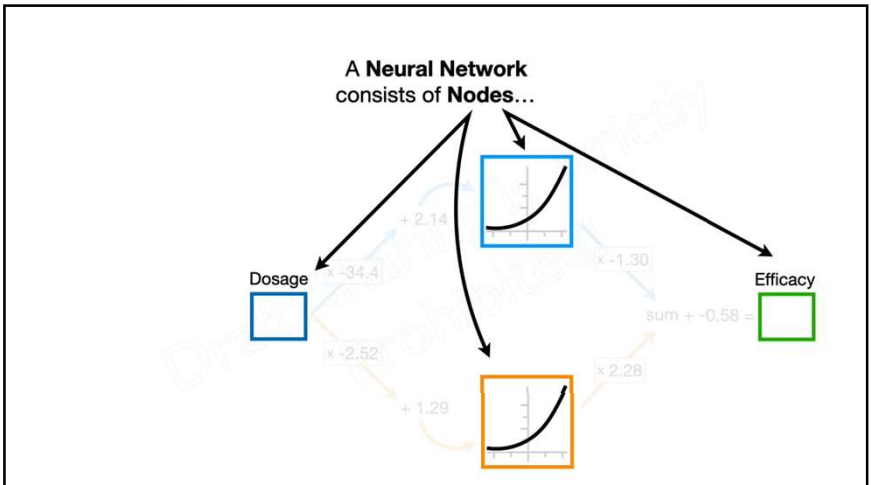

Yes (1)
Efficacy
No (0)
Dosage
…close to **1** for medium
Dosages…



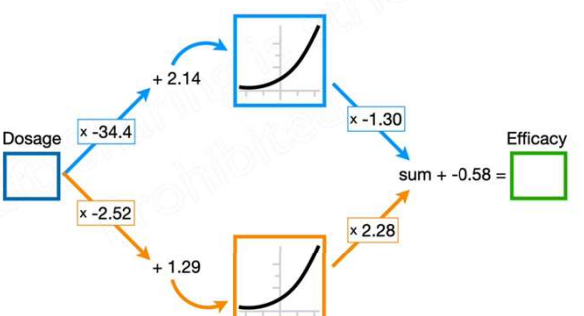
And even if we a have really complicated dataset like this…

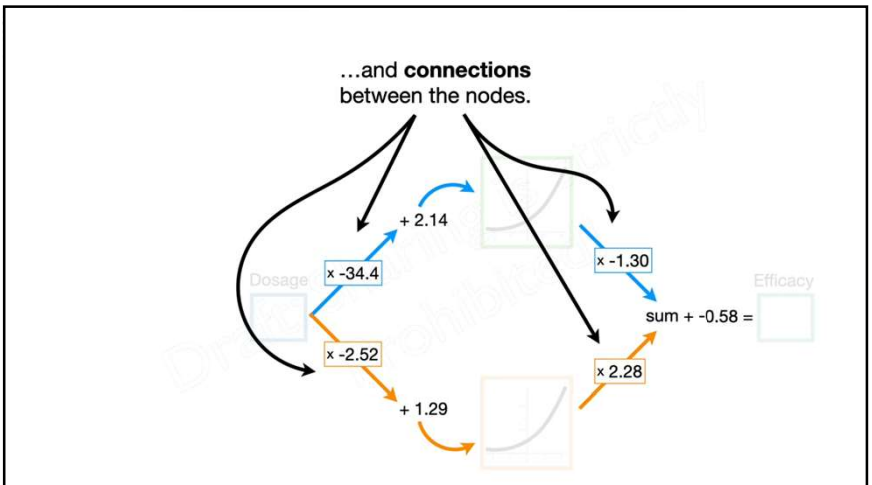


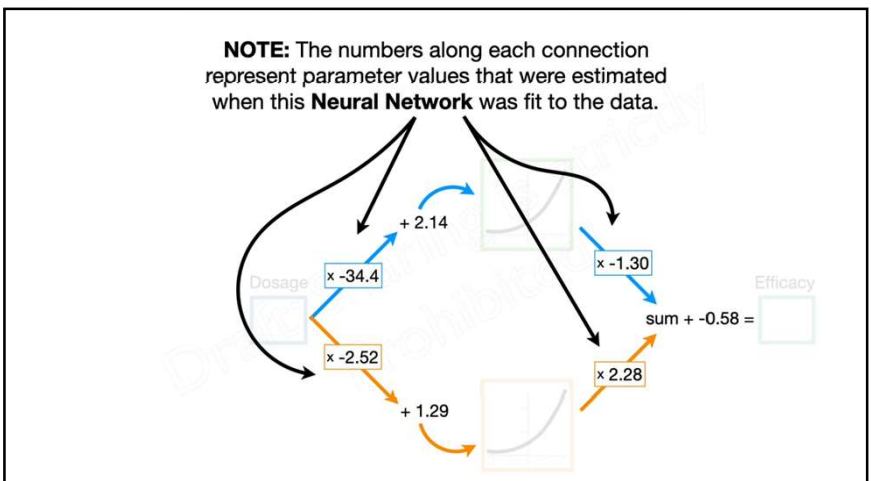
…a **Neural Network** can fit a **squiggle** to it.


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

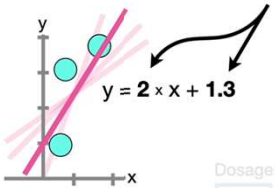
But first let's just talk about
what a **Neural Network** is.

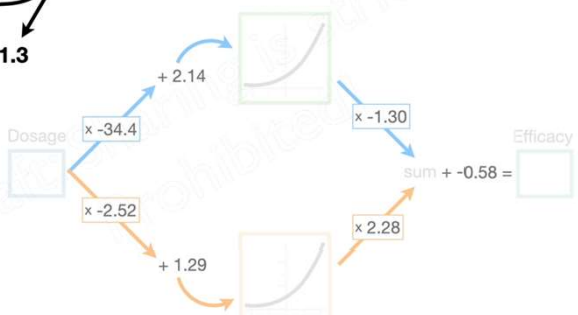



…and **connections**
between the nodes.
+ 2.14
x -34.4
Dosage
x -2.52
+ 1.29
x -1.30
sum + -0.58 =
Efficacy
x 2.28

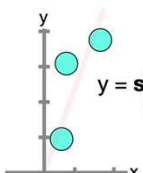

NOTE: The numbers along each connection represent parameter values that were estimated when this **Neural Network** was fit to the data.
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

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.



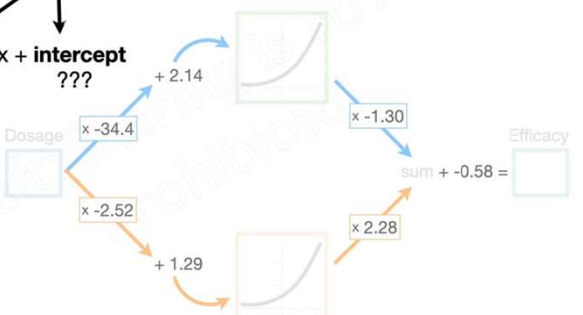


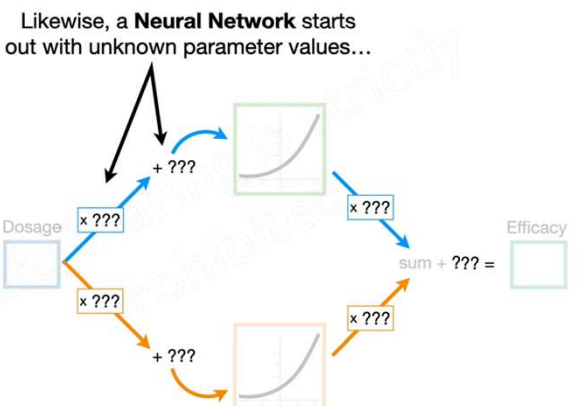
For now, just know that these parameter estimates are analogous to the **slope** and **intercept** values that we solve for when we fit a **straight line** to data.



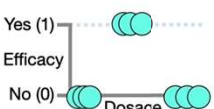
y = **slope** x x + **intercept**

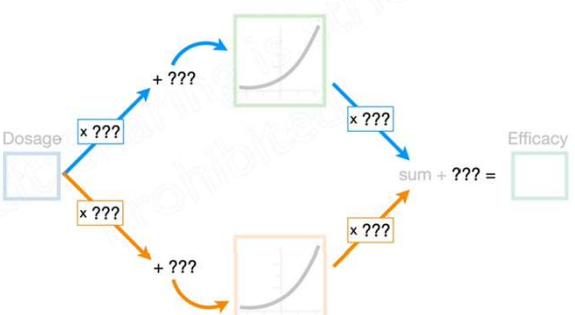
??? ???

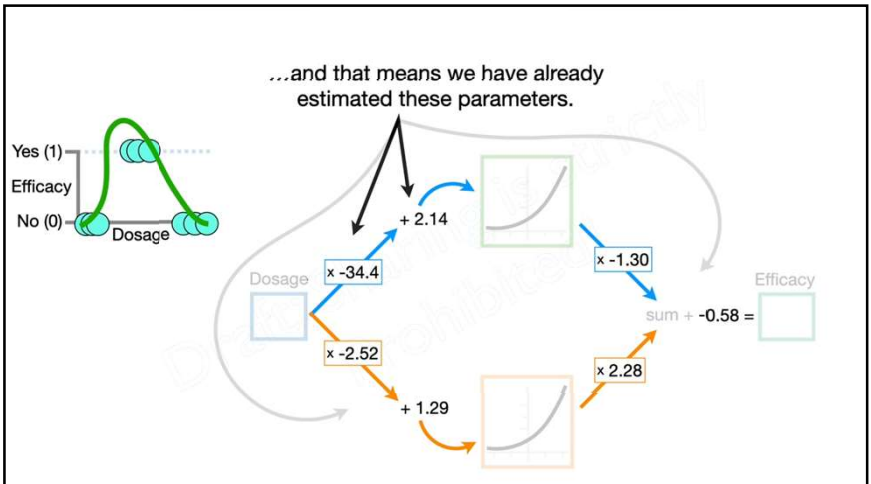


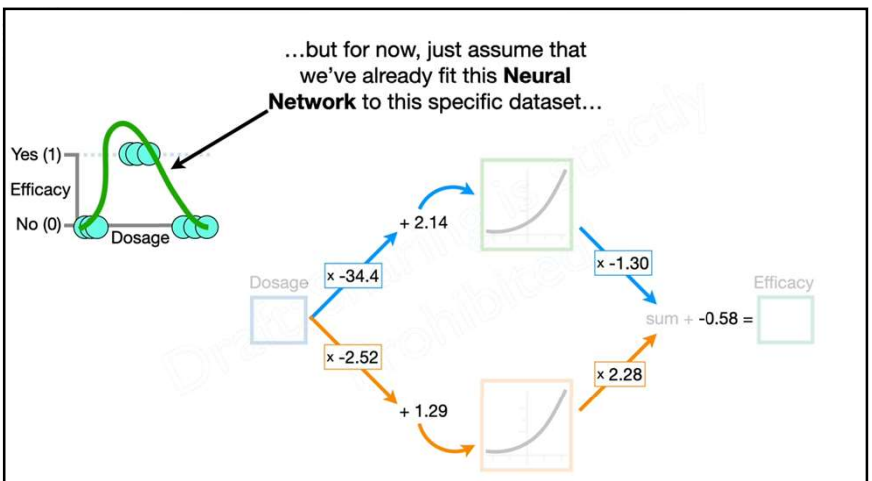

Likewise, a **Neural Network** starts out with unknown parameter values…
+ ???
x ???
Dosage
x ???
x ???
+ ???
x ???
x ???
sum + ??? =
Efficacy

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

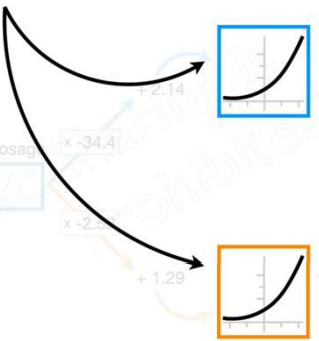


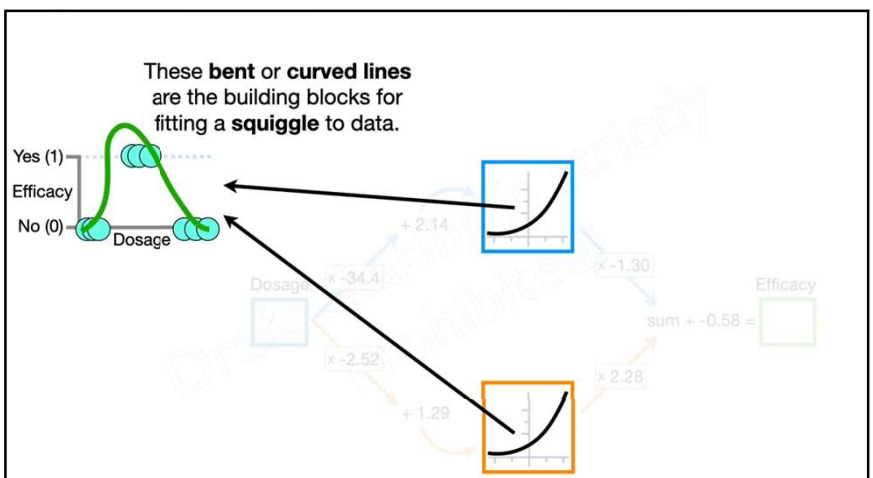


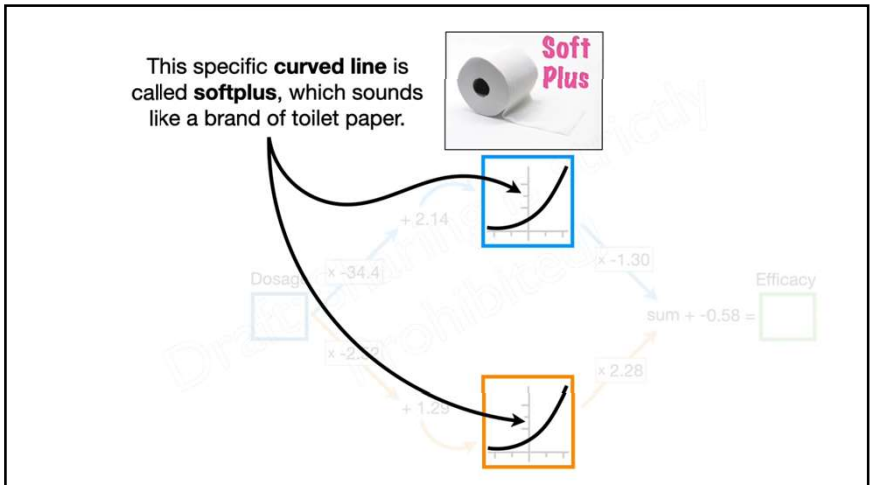

...and that means we have already
estimated these parameters.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28


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

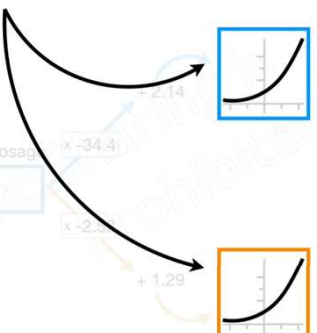
Also, you may have noticed that some of the **Nodes** have **curved lines** inside of them.



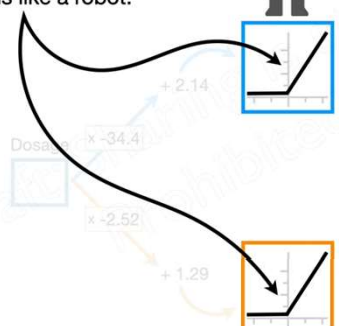

These **bent** or **curved lines** are the building blocks for fitting a **squiggle** to data.
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x -1.30
Dosage
x -34.4
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29


This specific **curved line** is called **softplus**, which sounds like a brand of toilet paper.
Soft Plus
+ 2.14
x -1.30
Dosage
x -34.4
Efficacy
sum + -0.58 =
x 2.28
+ 1.25

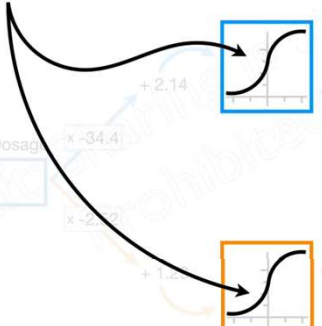
NOTE: There are many common **bent** or **curved lines** that we can choose for a **Neural Network**.



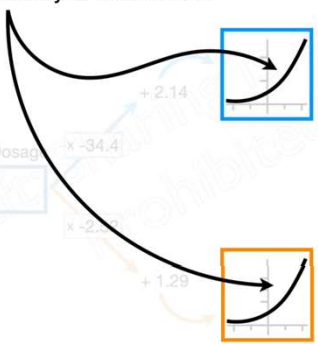
Alternatively, we could use this **bent line**, called, **ReLU**, which is short for **Rectified Linear Unit** and sounds like a robot.



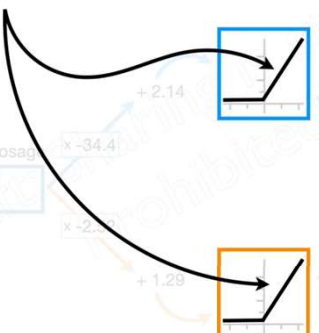
Or we could use a **sigmoid** shape or any other **bent** or **curved line**.



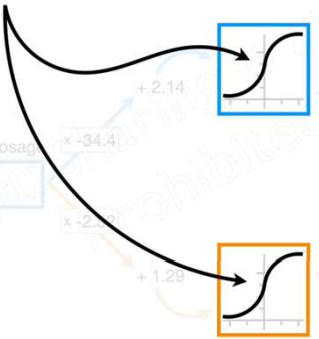
When you build a **Neural Network**, you have to decide which **Activation Function** or **Functions** you want to use.



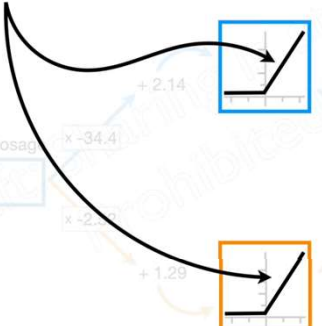
The **curved** or **bent lines** are called **Activation Functions**.

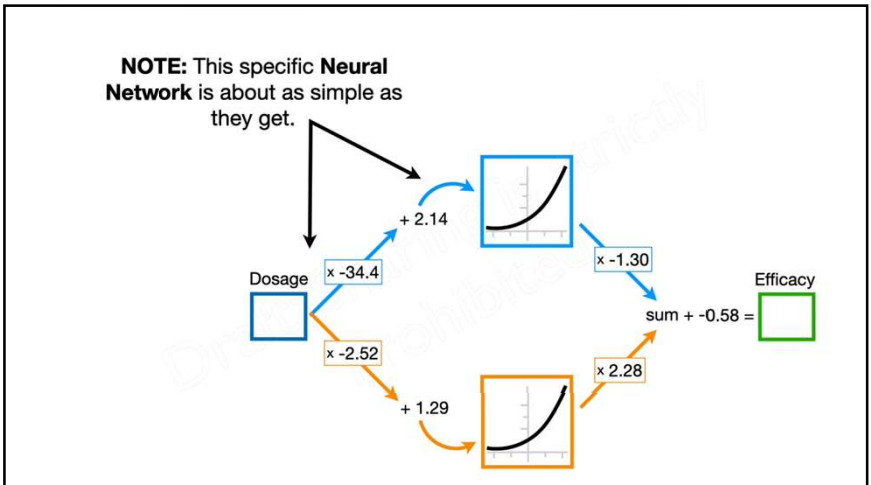


When most people *teach* **Neural Networks**, they use the **sigmoid Activation Function**.

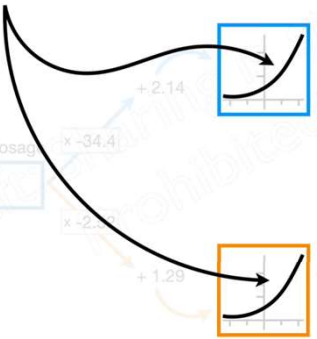


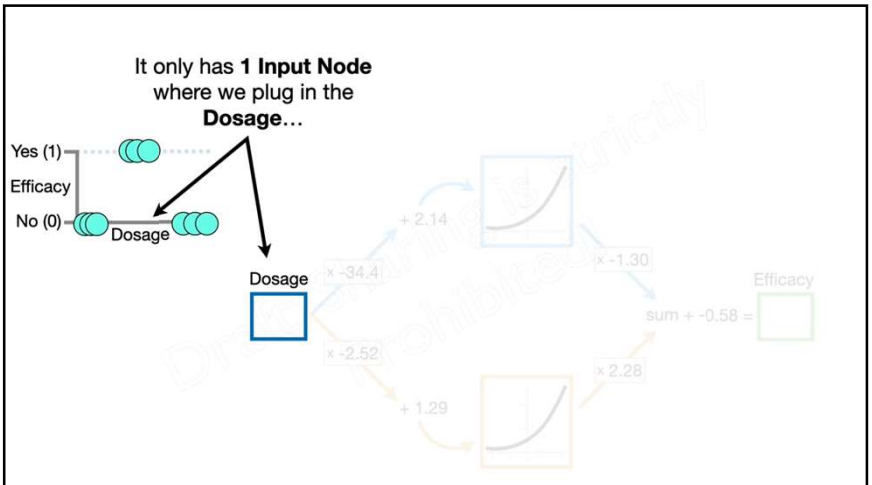
However, in *practice*, it is much more common to use the **ReLU Activation Function**…

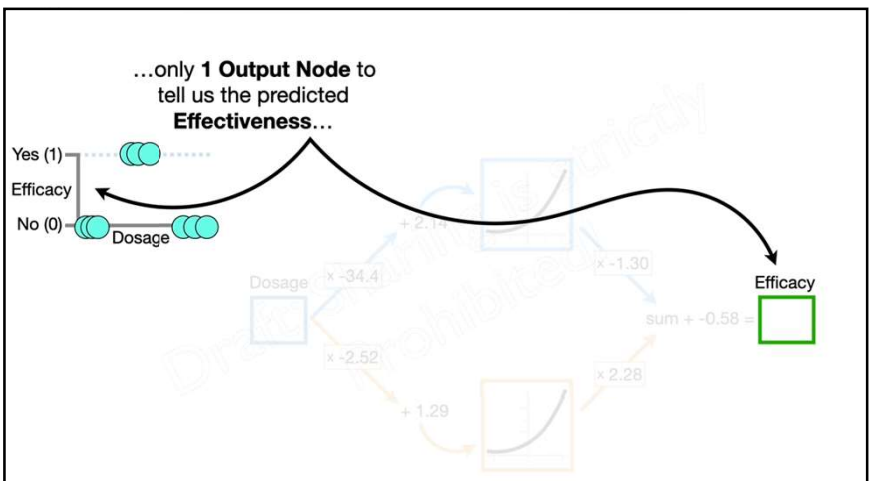



NOTE: This specific Neural Network is about as simple as they get.
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

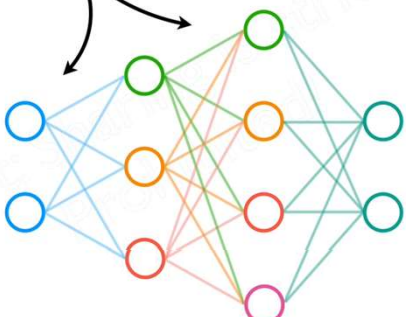
…or the **softplus Activation Function**.



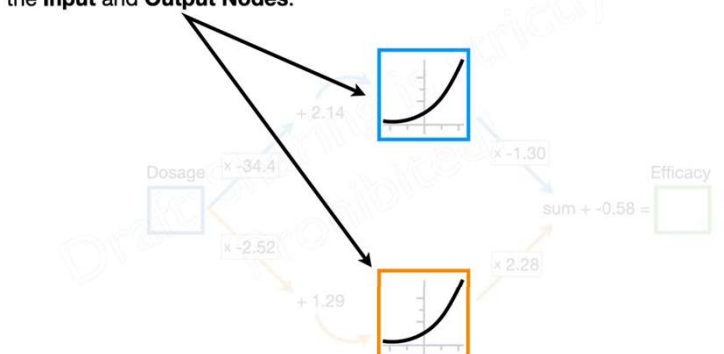

It only has **1 Input Node** where we plug in the **Dosage**...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

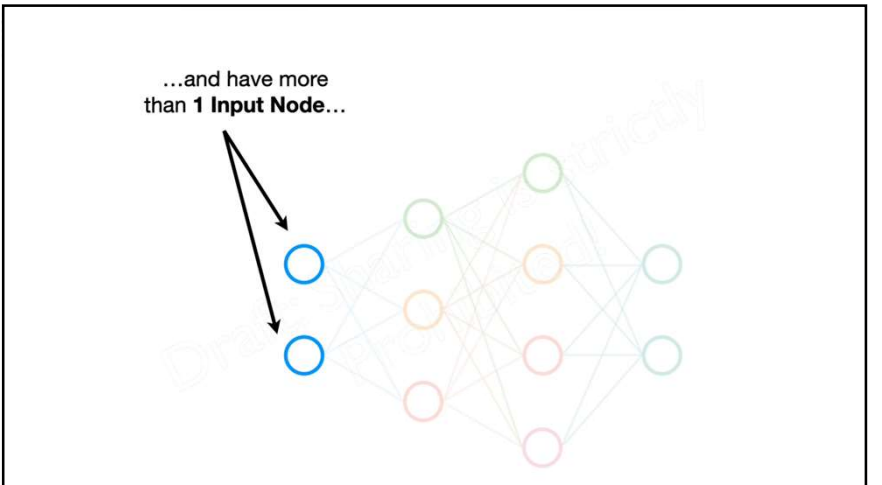

...only **1 Output Node** to tell us the predicted **Effectiveness**...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

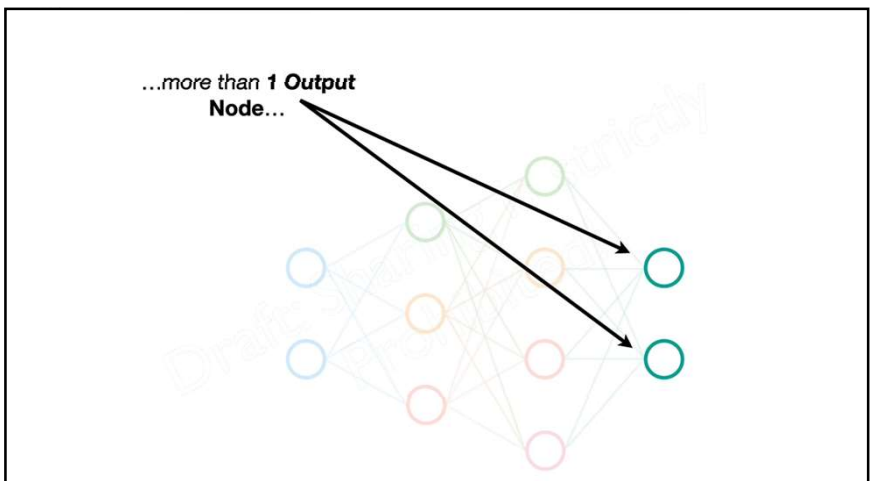
However, in practice, **Neural Networks** are usually much fancier…

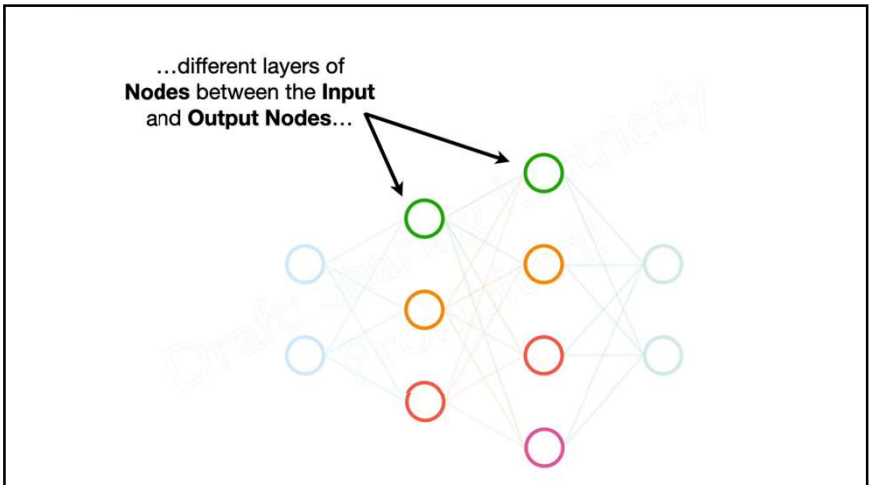


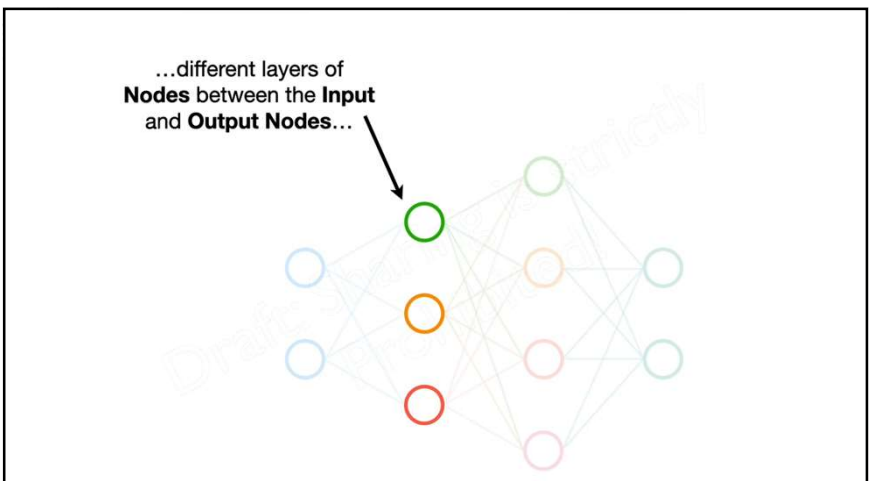
…and only **2 Nodes** between the **Input** and **Output Nodes**.

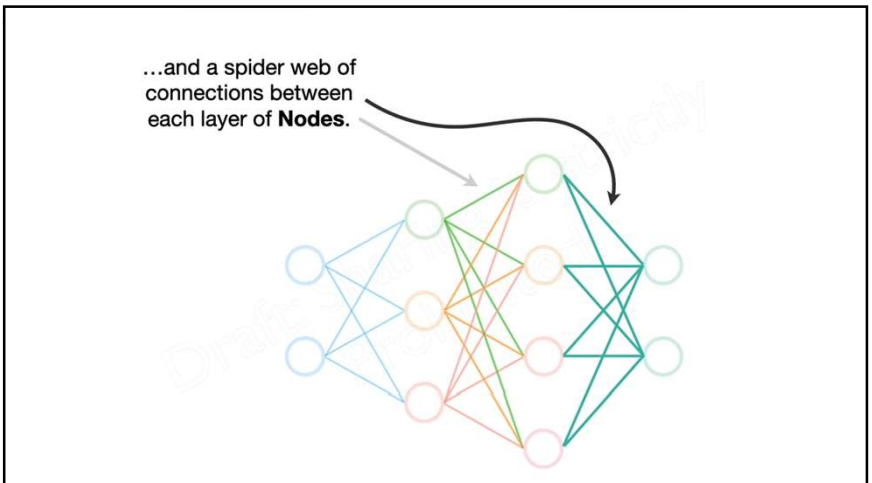



…and have more
than **1 Input Node**…

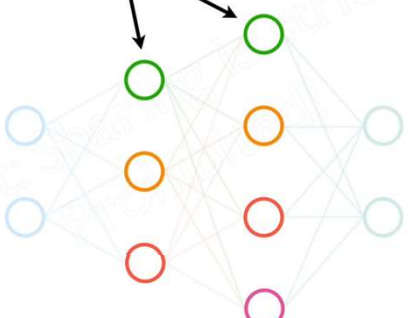

...more than 1 Output
Node...


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

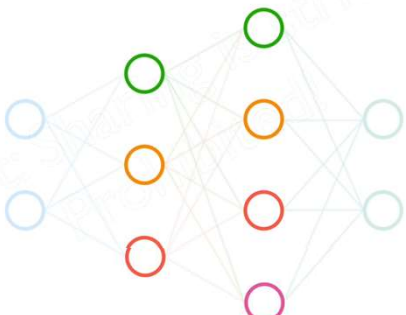

...different layers of
Nodes between the **Input**
and **Output Nodes**...


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

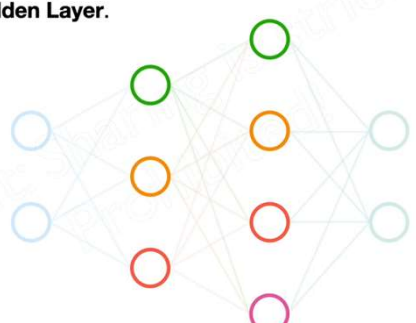
The layers of **Nodes** between the **Input** and **Output Nodes** are called **Hidden Layers**.



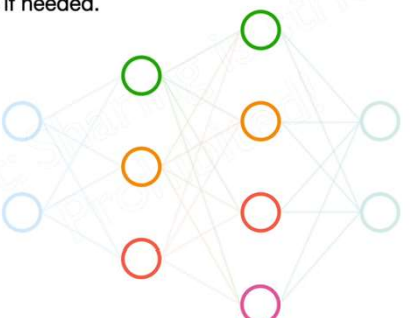
Although there are rules of thumb for making decisions about the **Hidden Layers**...



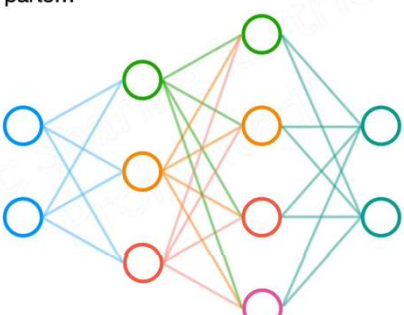
When you build a **Neural Network**, one of the first things you do is decide how many **Hidden Layers** you want, and how many **Nodes** go into each **Hidden Layer**.

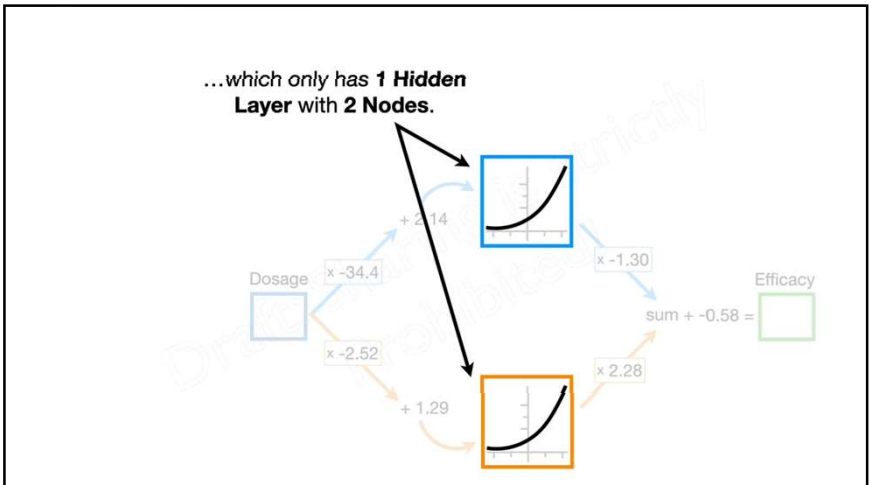


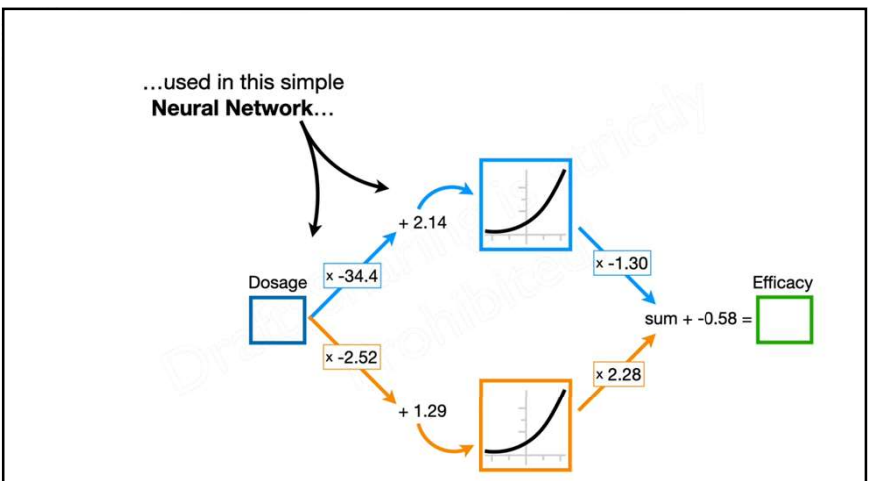
…you essentially make a guess and see how well the **Neural Network** performs, adding more layers and nodes if needed.



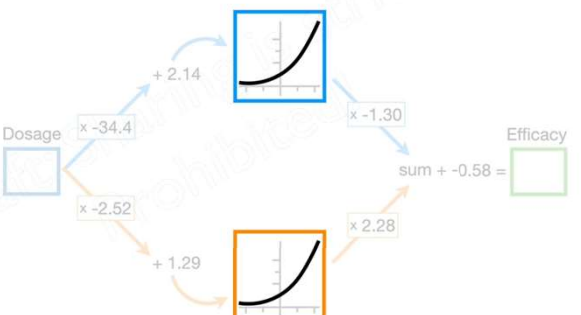
Now, even though this **Neural Network** looks fancy, it is still made from the same parts…

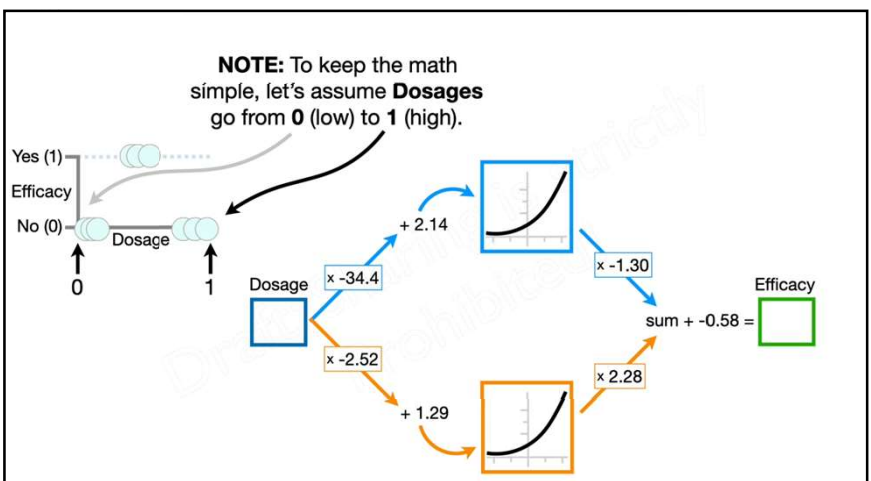


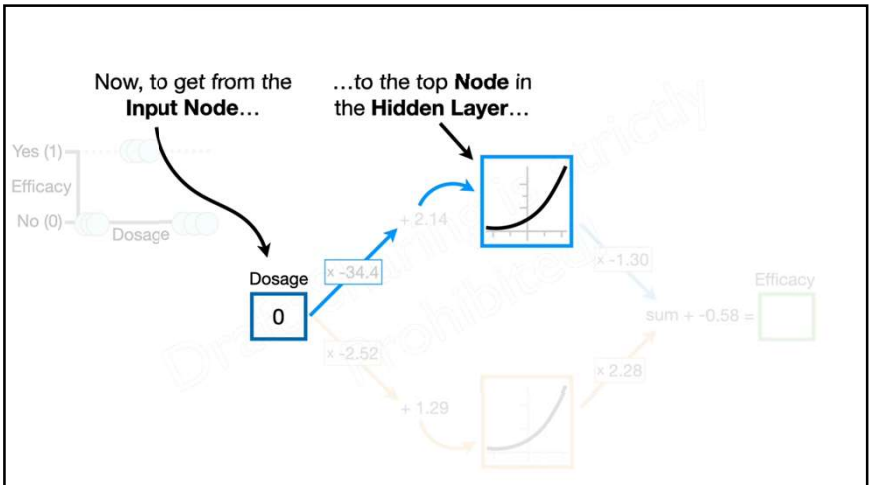

...which only has 1 Hidden Layer with 2 Nodes.
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

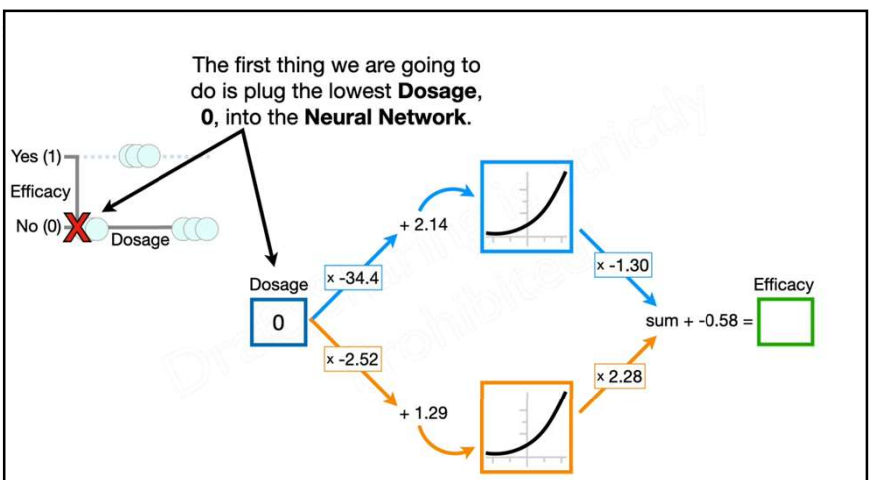

...used in this simple
Neural Network...
Dosage
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

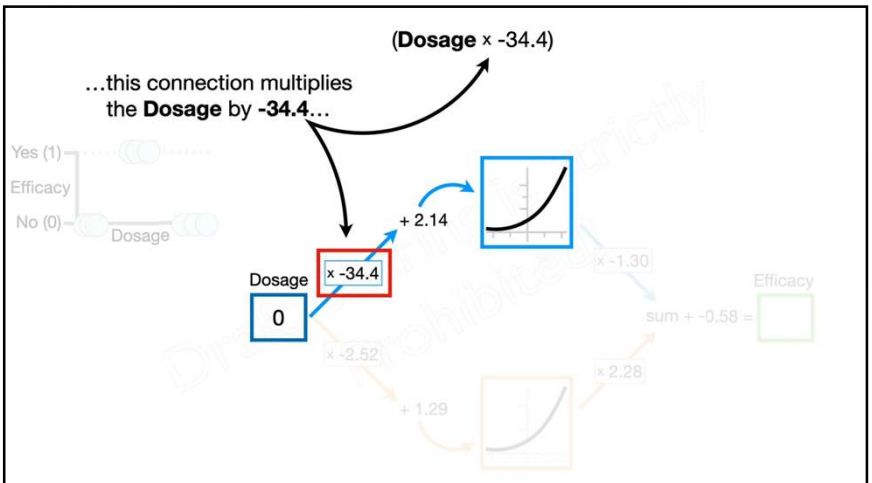
So let's learn how this **Neural Network** creates new shapes from the **curved** or **bent lines** in the **Hidden Layer**…

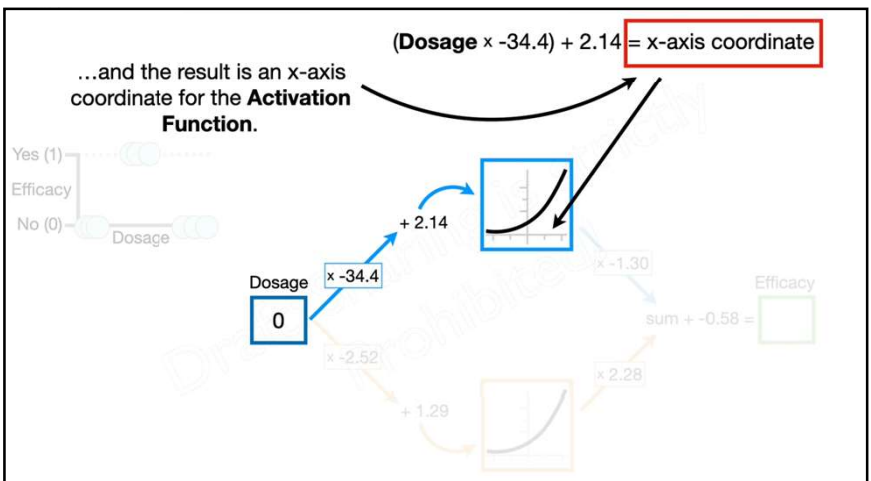


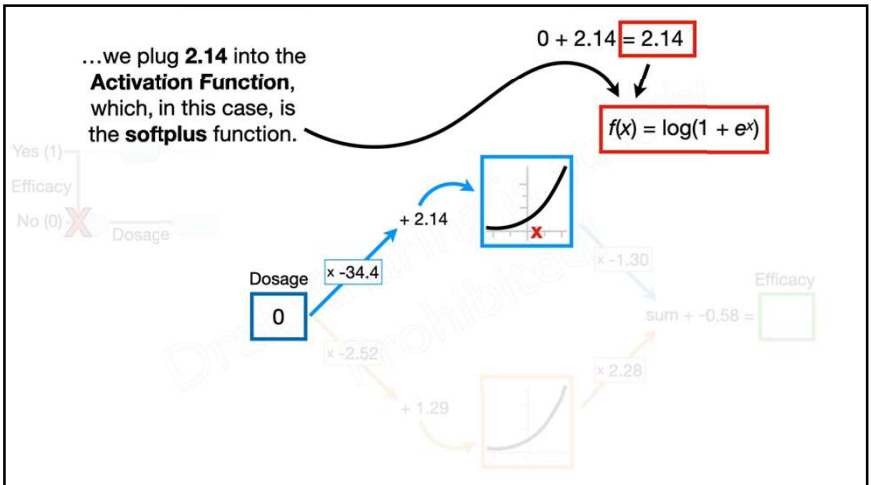

NOTE: To keep the math simple, let's assume Dosages go from 0 (low) to 1 (high).
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

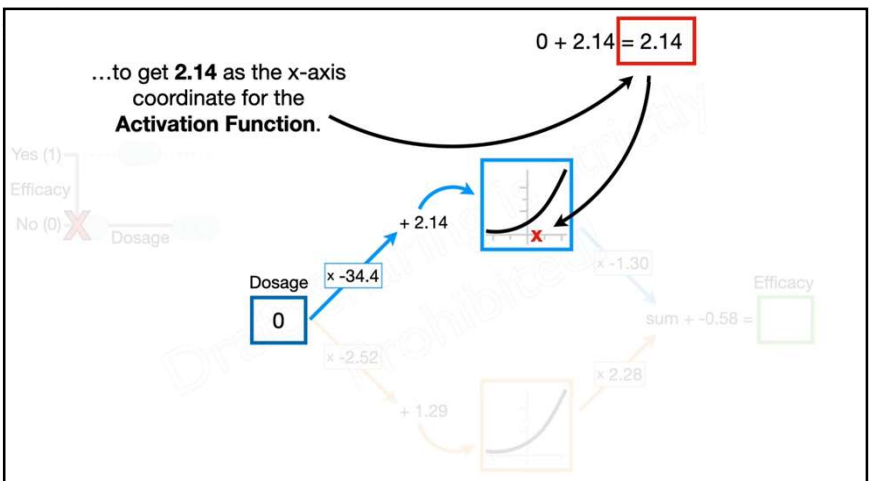

Now, to get from the Input Node…
…to the top Node in the Hidden Layer…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

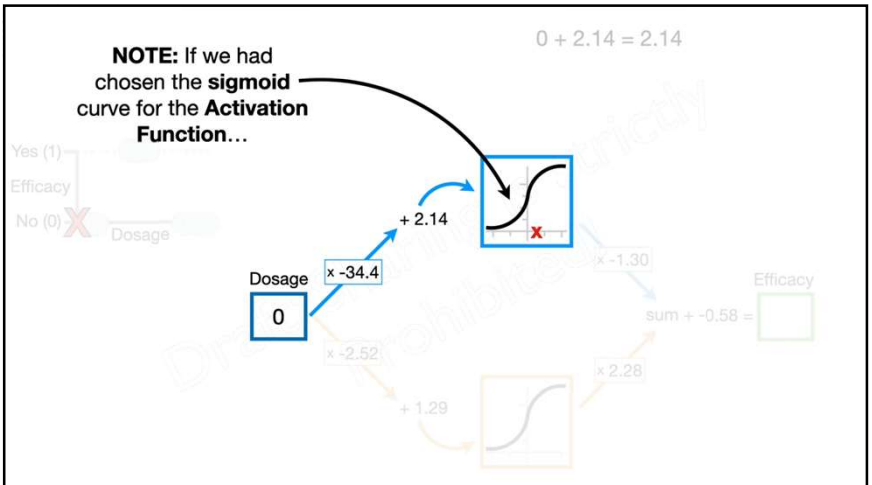

The first thing we are going to do is plug the lowest **Dosage**, **0**, into the **Neural Network**.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

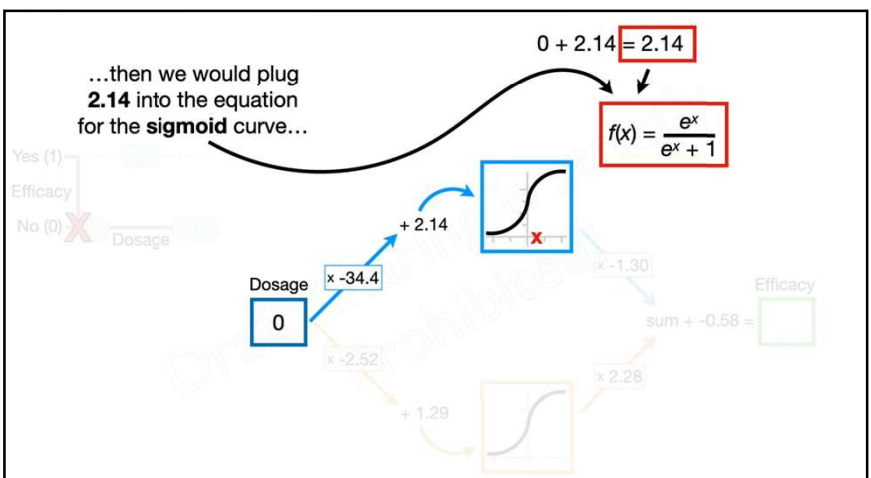

(Dosage x -34.4)
...this connection multiplies the Dosage by -34.4...
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

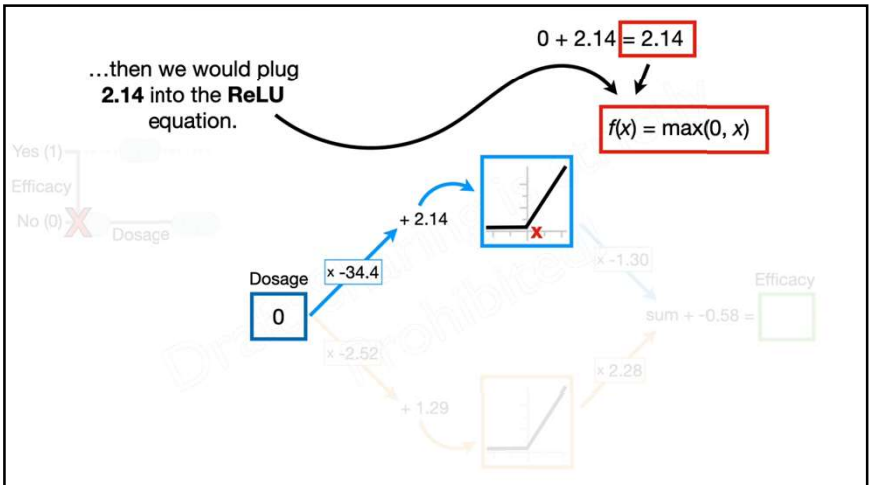

(Dosage x -34.4) + 2.14 = x-axis coordinate
...and the result is an x-axis coordinate for the Activation Function.
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

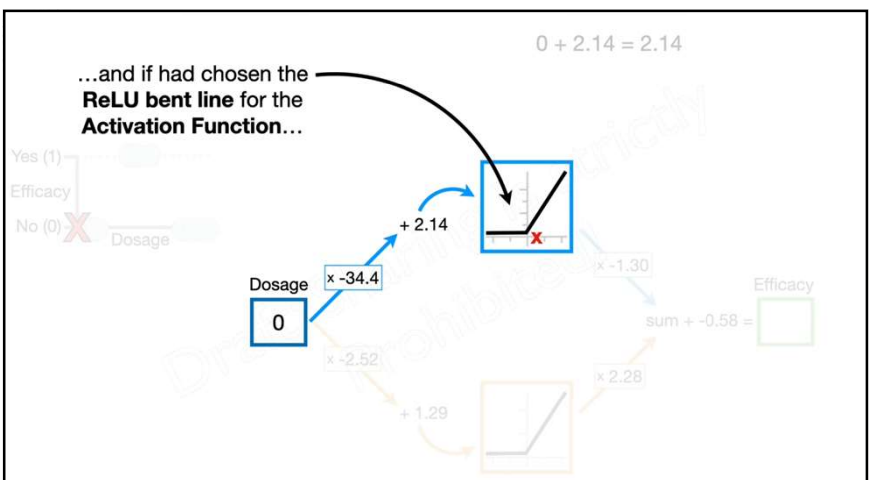

...we plug **2.14** into the **Activation Function**, which, in this case, is the **softplus** function.
0 + 2.14 = 2.14
$f(x) = \log(1 + e^x)$
Dosage
0
x -34.4
+ 2.14
x
Yes (1)
Efficacy
No (0)
Dosage
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

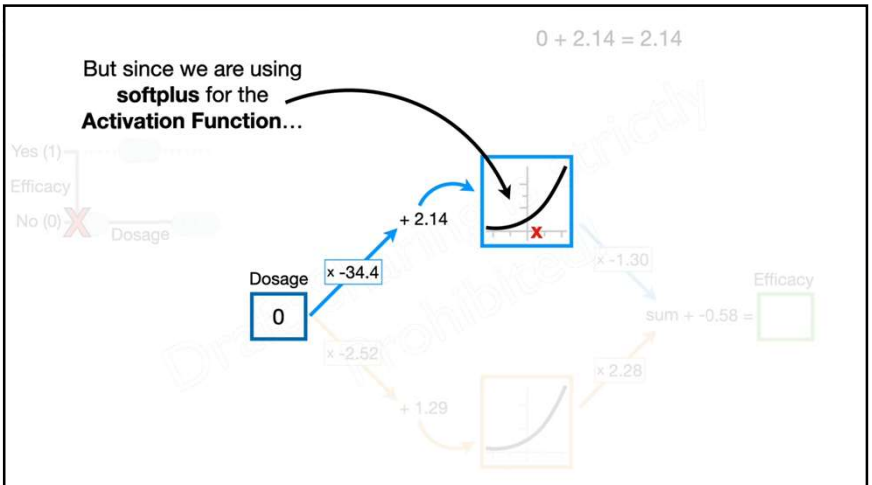

0 + 2.14 = 2.14
...to get **2.14** as the x-axis coordinate for the **Activation Function**.
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

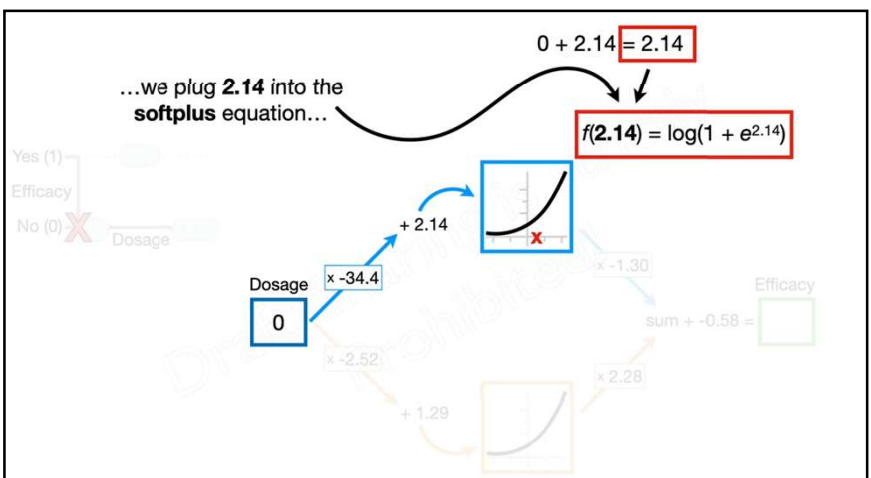

NOTE: If we had chosen the sigmoid curve for the Activation Function…
0 + 2.14 = 2.14
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x
Dosage
0
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

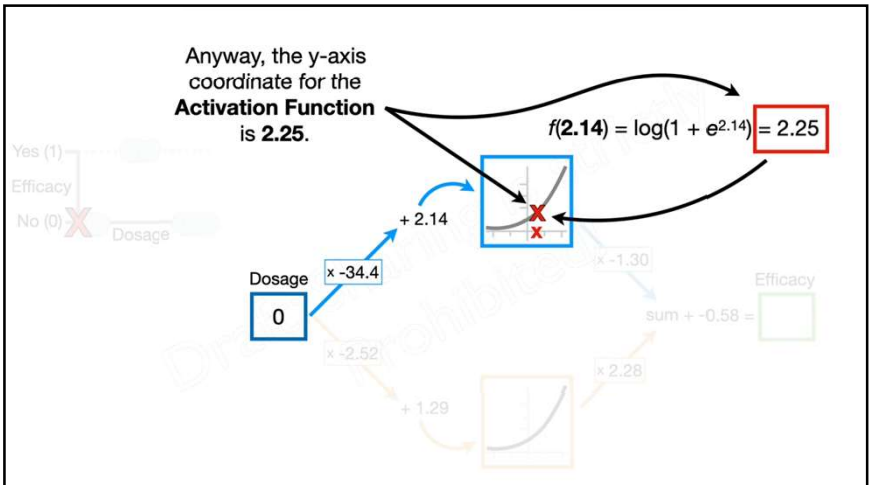

0 + 2.14 = 2.14
…then we would plug
2.14 into the equation
for the **sigmoid** curve…
$f(x) = \frac{e^x}{e^x + 1}$
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
x
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

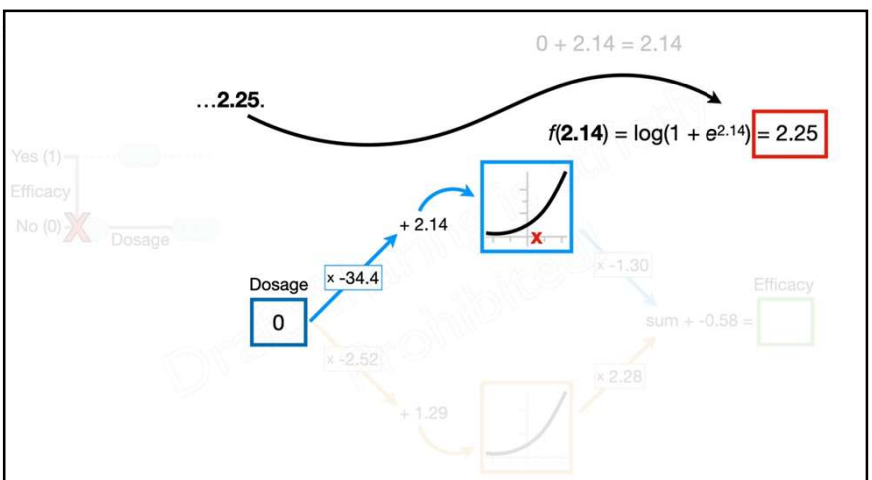

0 + 2.14 = 2.14
…then we would plug **2.14** into the **ReLU** equation.
f(x) = max(0, x)
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

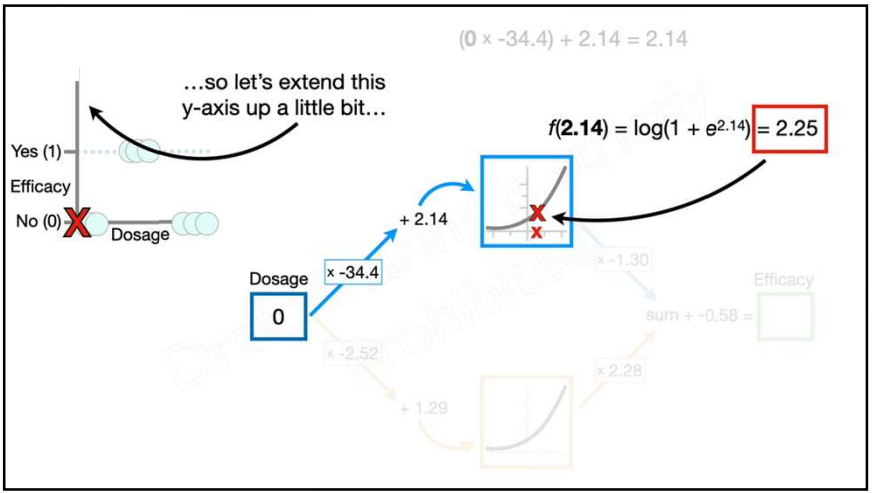

0 + 2.14 = 2.14
...and if had chosen the
ReLU bent line for the
Activation Function...
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

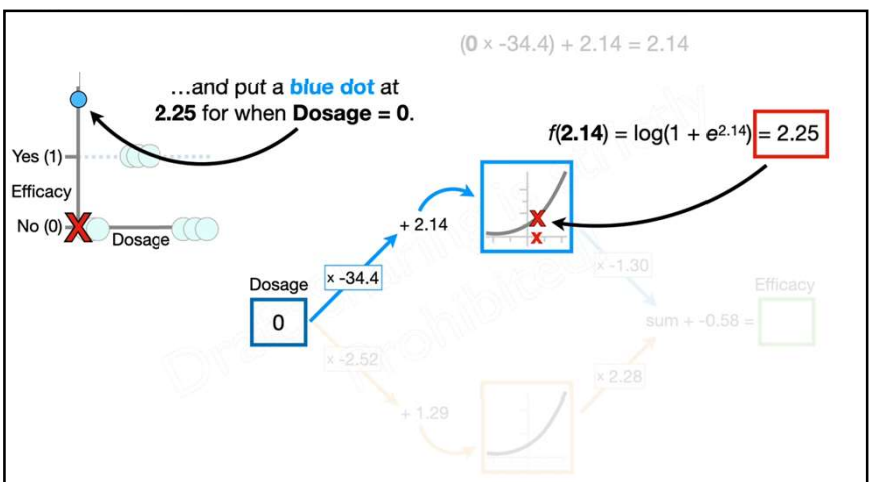

0 + 2.14 = 2.14
But since we are using
softplus for the
Activation Function…
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

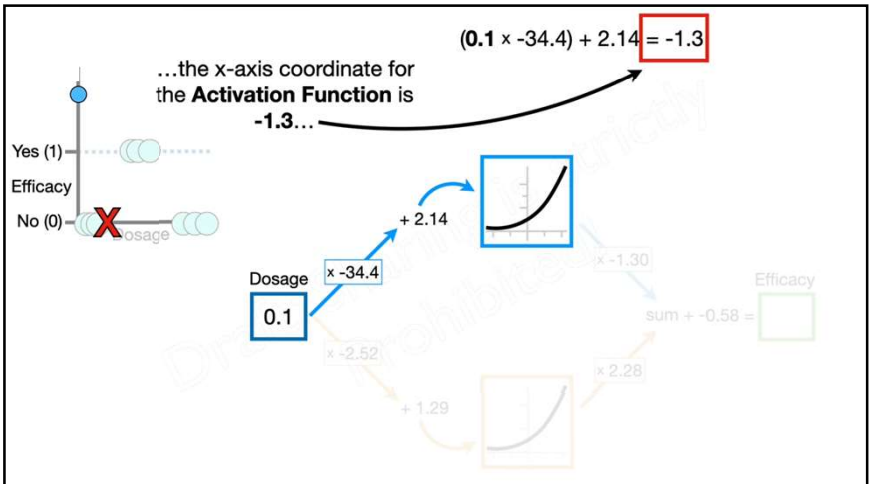

0 + 2.14 = 2.14
...we plug **2.14** into the **softplus** equation...
$f(\mathbf{2.14}) = \log(1 + e^{2.14})$
+ 2.14
Dosage
x -34.4
0
x -1.30
sum + -0.58 =
Efficacy
x -2.52
x 2.28
+ 1.29

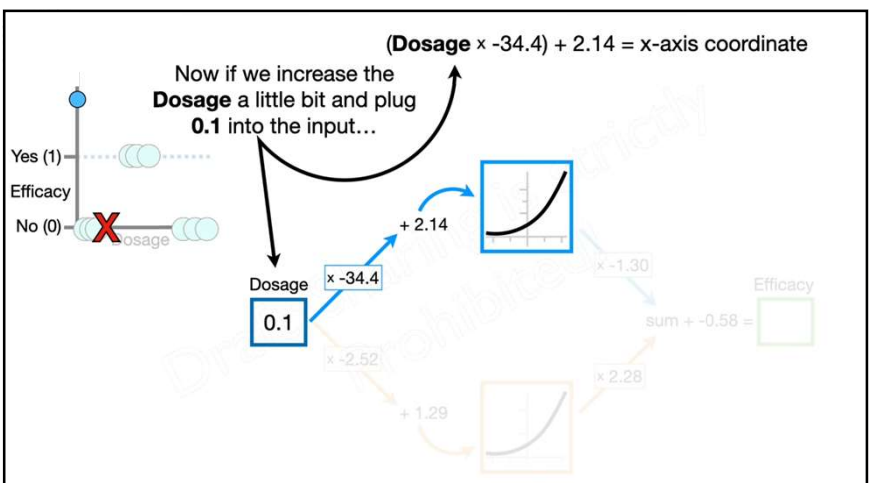

Anyway, the y-axis coordinate for the **Activation Function** is **2.25**.
$f(\mathbf{2.14}) = \log(1 + e^{2.14}) = 2.25$
+ 2.14
Dosage
x -34.4
0
x -2.52
+ 1.29
x 2.28
x -1.30
sum + -0.58 =
Efficacy
Yes (1)
Efficacy
No (0)
Dosage

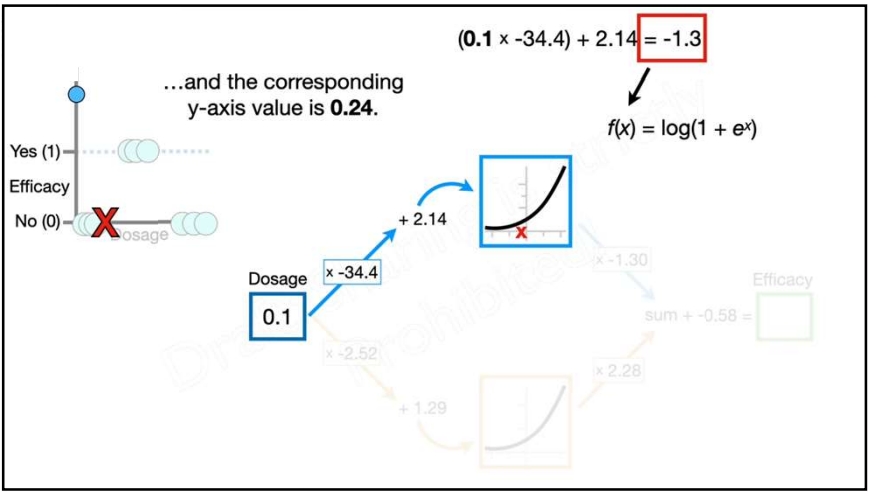

0 + 2.14 = 2.14
…2.25.
f(2.14) = log(1 + e^2.14) = 2.25
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

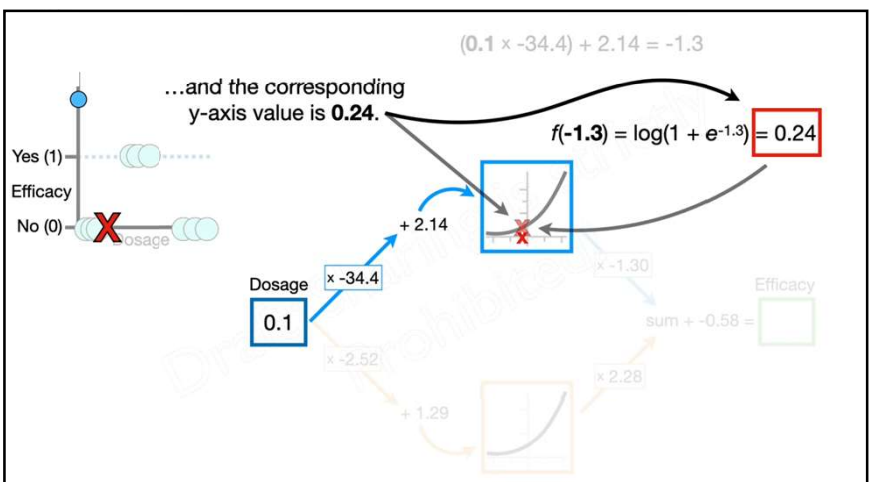

(0 x -34.4) + 2.14 = 2.14
…so let's extend this y-axis up a little bit…
Yes (1)
Efficacy
No (0)
Dosage
f(2.14) = log(1 + e^2.14) = 2.25
+ 2.14
Dosage
0
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

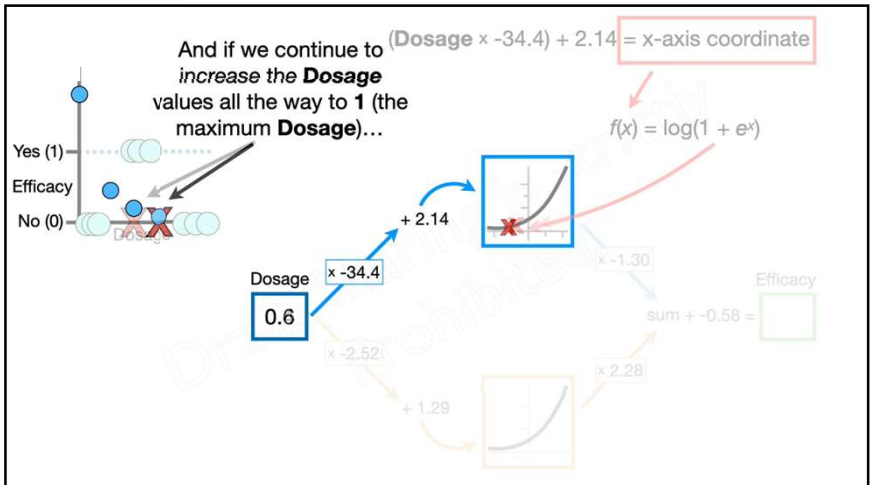

(0 × -34.4) + 2.14 = 2.14
…and put a blue dot at 2.25 for when Dosage = 0.
f(2.14) = log(1 + e^2.14) = 2.25
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

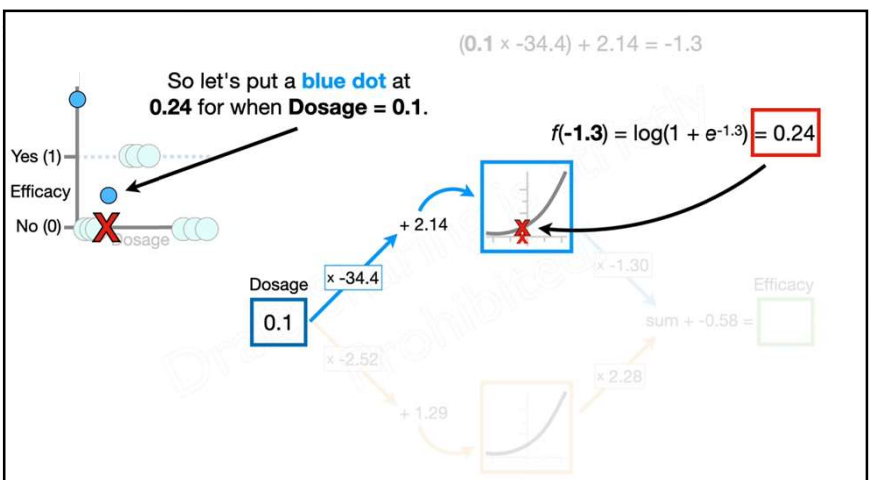

(0.1 x -34.4) + 2.14 = -1.3
…the x-axis coordinate for the Activation Function is -1.3…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.1
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

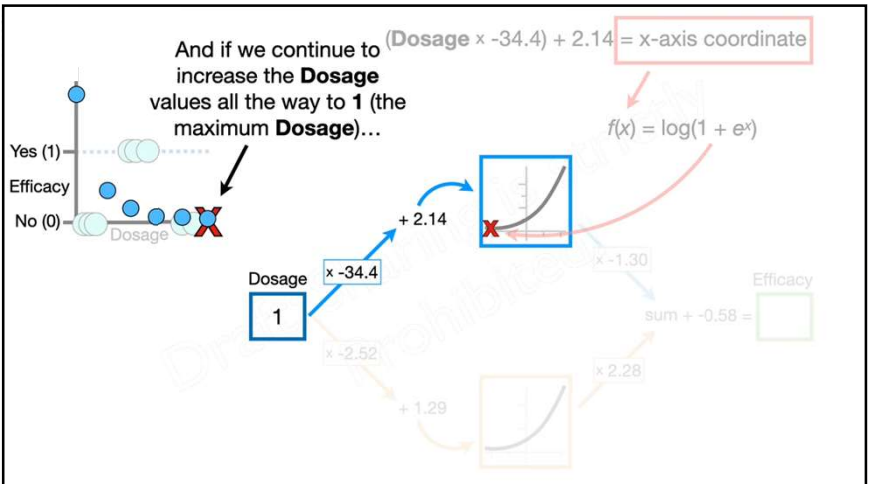

(**Dosage** x -34.4) + 2.14 = x-axis coordinate
Now if we increase the **Dosage** a little bit and plug **0.1** into the input…
Yes (1)
Efficacy
No (0)
osage
Dosage
0.1
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

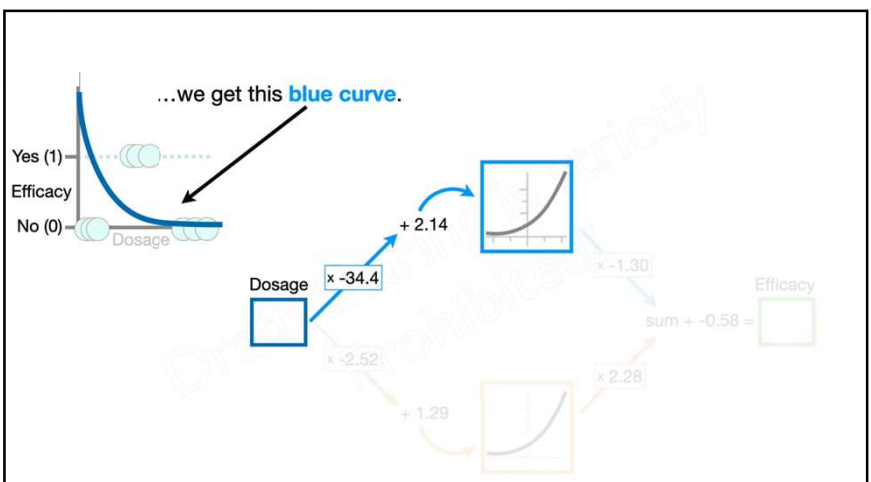

(0.1 x -34.4) + 2.14 = -1.3
…and the corresponding y-axis value is 0.24.
f(x) = log(1 + e^x)
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.1
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

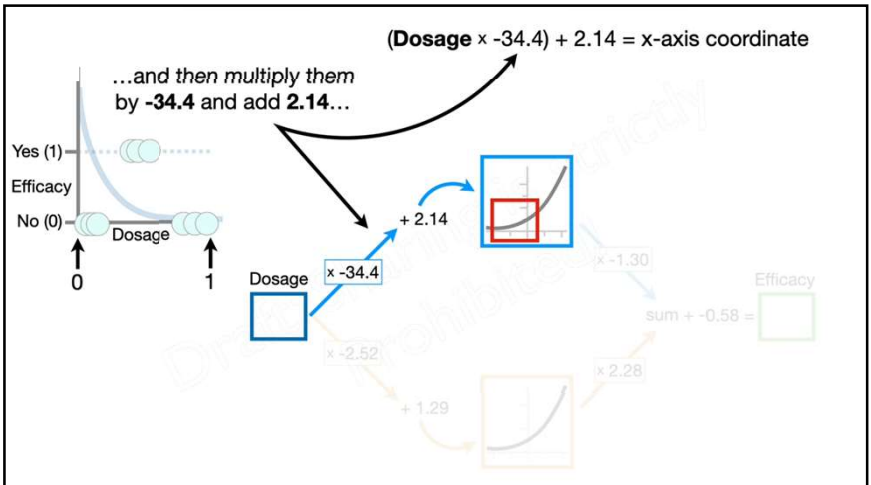

(0.1 x -34.4) + 2.14 = -1.3
...and the corresponding y-axis value is 0.24.
f(-1.3) = log(1 + e^-1.3) = 0.24
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
0.1
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

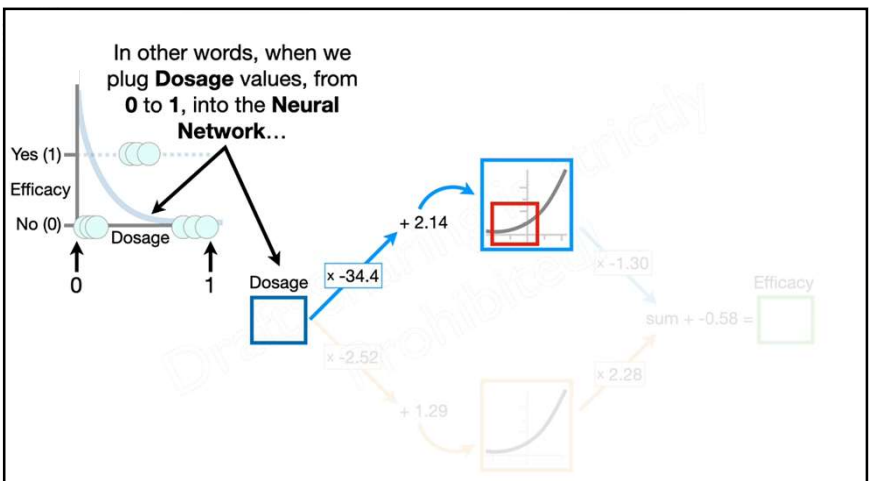

And if we continue to *increase the* **Dosage** values all the way to **1** (the maximum **Dosage**)…
(**Dosage** x -34.4) + 2.14 = x-axis coordinate
$f(x) = \log(1 + e^x)$
Yes (1)
Efficacy
No (0)
Dosage
0.6
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

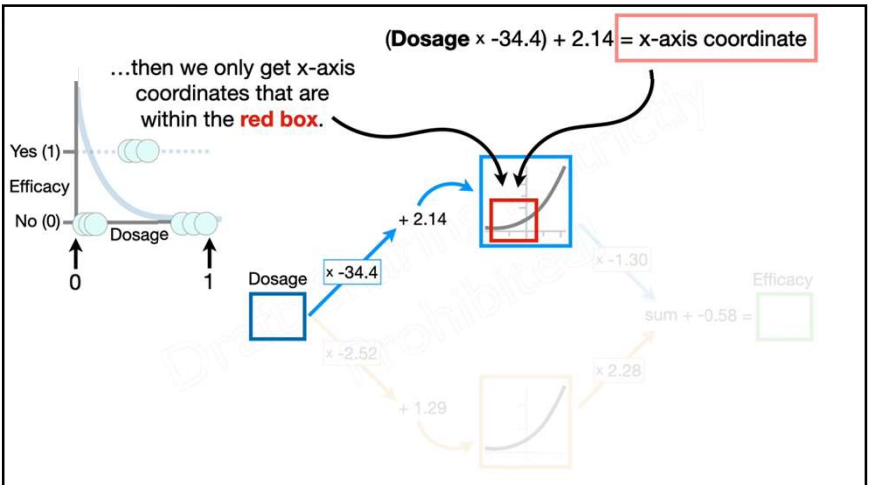

(0.1 x -34.4) + 2.14 = -1.3
So let's put a blue dot at 0.24 for when Dosage = 0.1.
Yes (1)
Efficacy
No (0)
Dosage
f(-1.3) = log(1 + e^-1.3) = 0.24
+ 2.14
Dosage
x -34.4
0.1
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

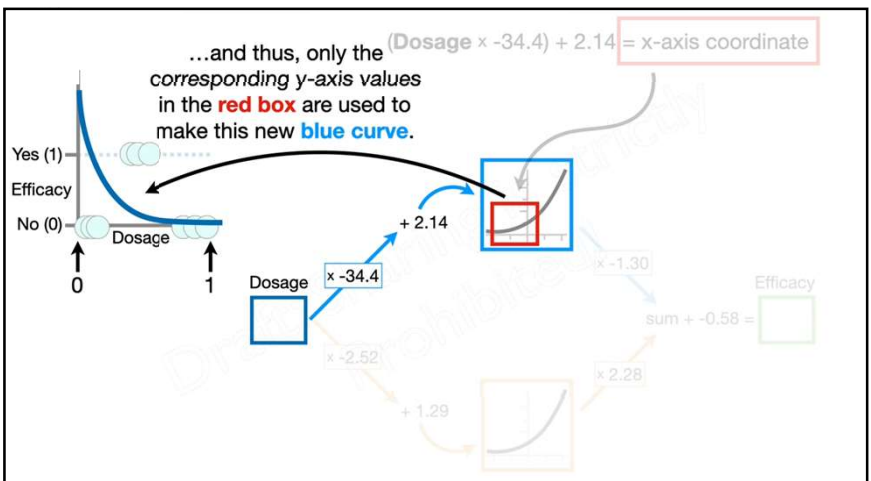

And if we continue to increase the **Dosage** values all the way to **1** (the maximum **Dosage**)…
Yes (1)
Efficacy
No (0)
Dosage
(Dosage x -34.4) + 2.14 = x-axis coordinate
f(x) = log(1 + e^x)
+ 2.14
Dosage
x -34.4
1
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

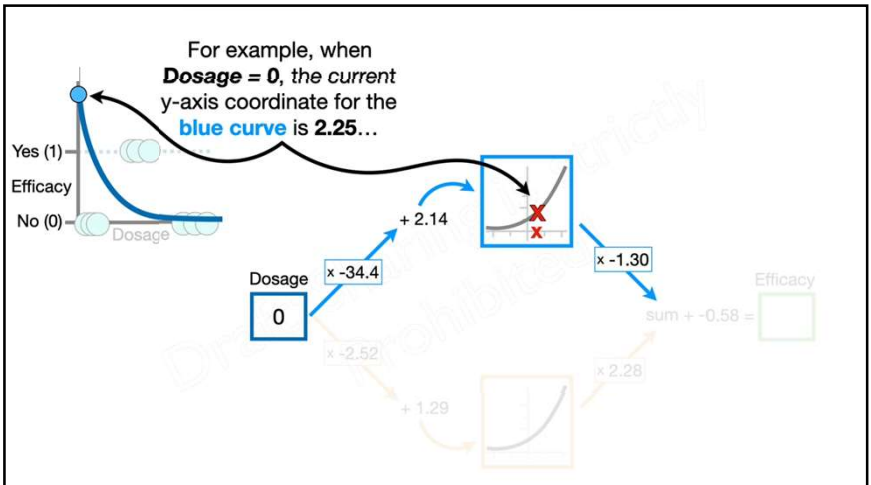

...we get this blue curve.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

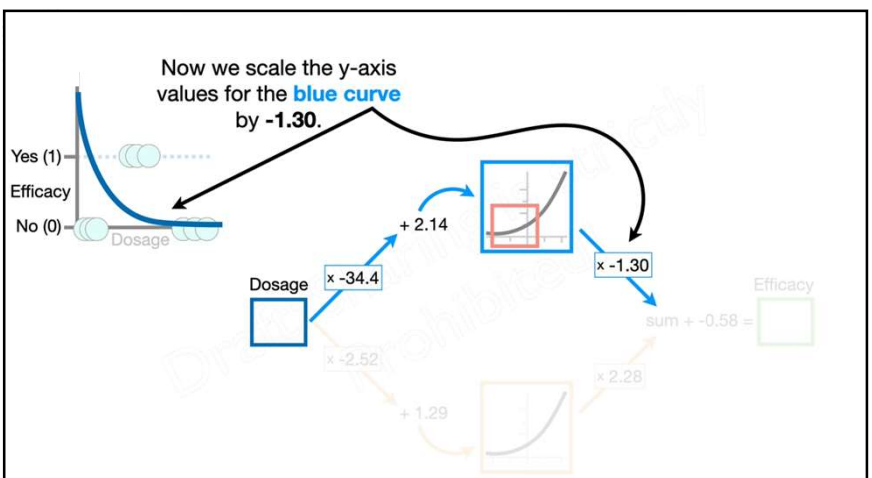

(Dosage x -34.4) + 2.14 = x-axis coordinate
…and then multiply them by -34.4 and add 2.14…
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

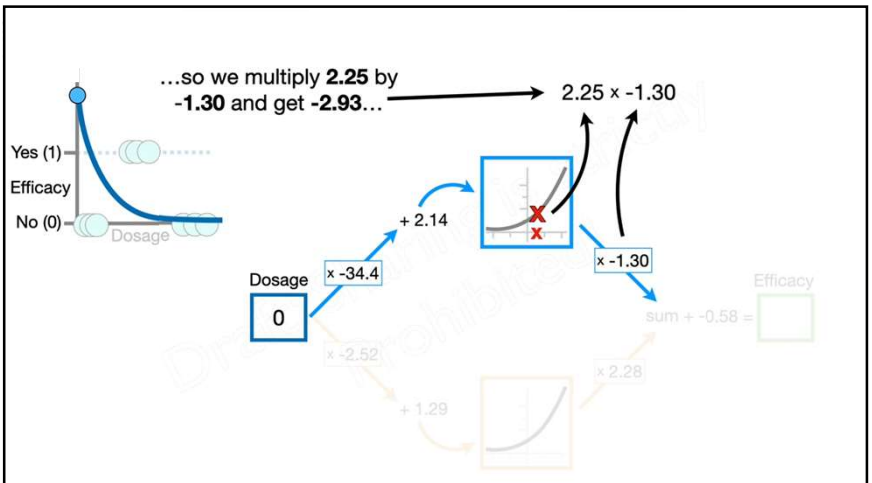

In other words, when we plug **Dosage** values, from **0** to **1**, into the **Neural Network**...
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

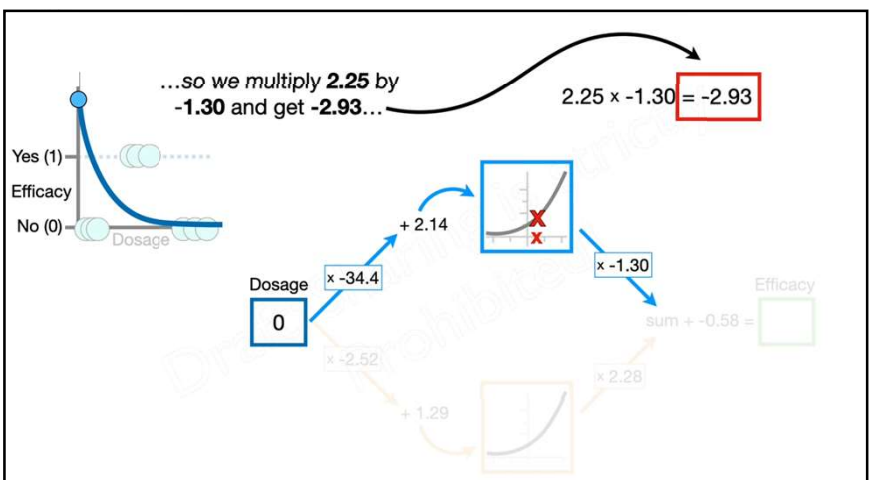

(Dosage x -34.4) + 2.14 = x-axis coordinate
...then we only get x-axis coordinates that are within the red box.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

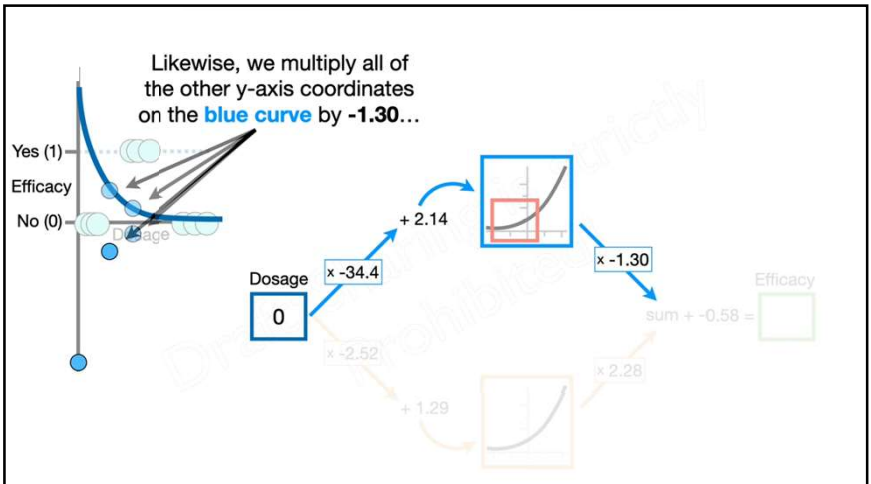

(Dosage x -34.4) + 2.14 = x-axis coordinate
…and thus, only the
corresponding y-axis values
in the red box are used to
make this new blue curve.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

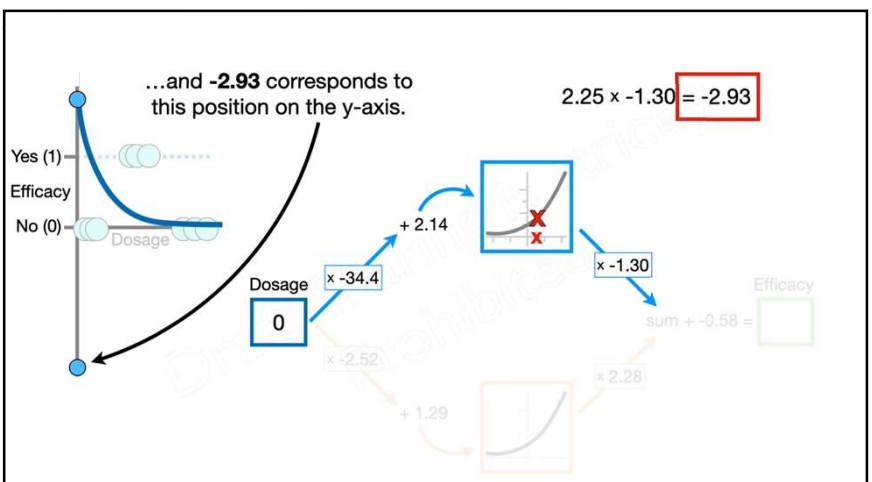

For example, when
Dosage = 0, the current
y-axis coordinate for the
blue curve is 2.25…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

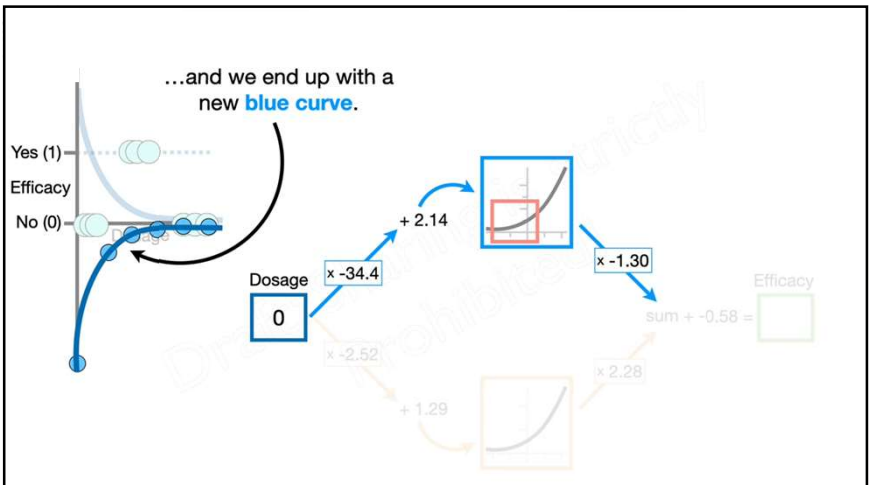

Now we scale the y-axis values for the blue curve by -1.30.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

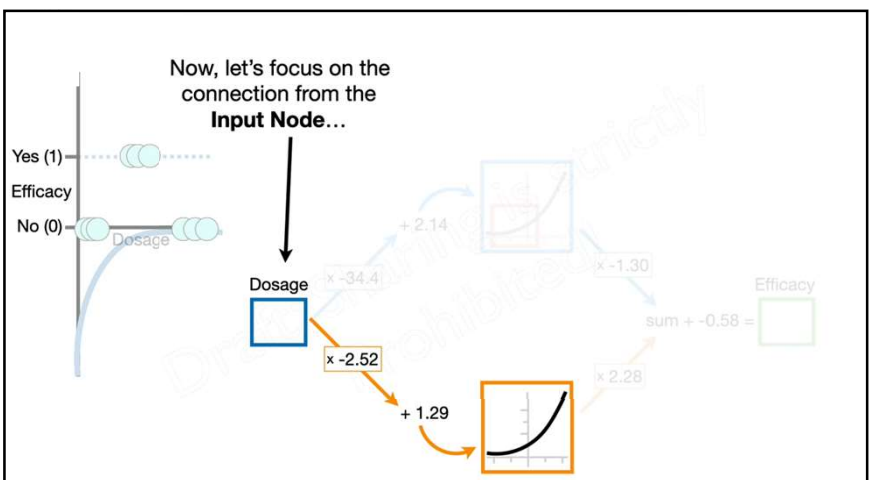

…so we multiply **2.25** by **-1.30** and get **-2.93**…
2.25 x -1.30
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

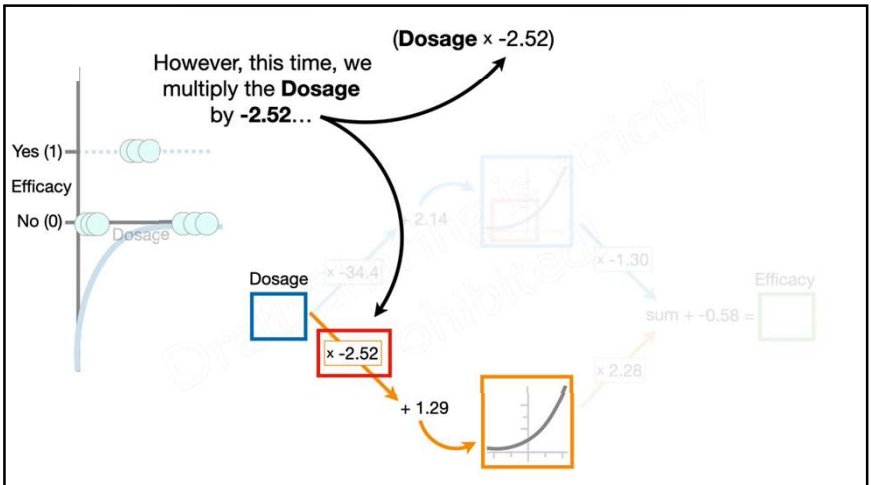

...so we multiply 2.25 by -1.30 and get -2.93...
2.25 x -1.30 = -2.93
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

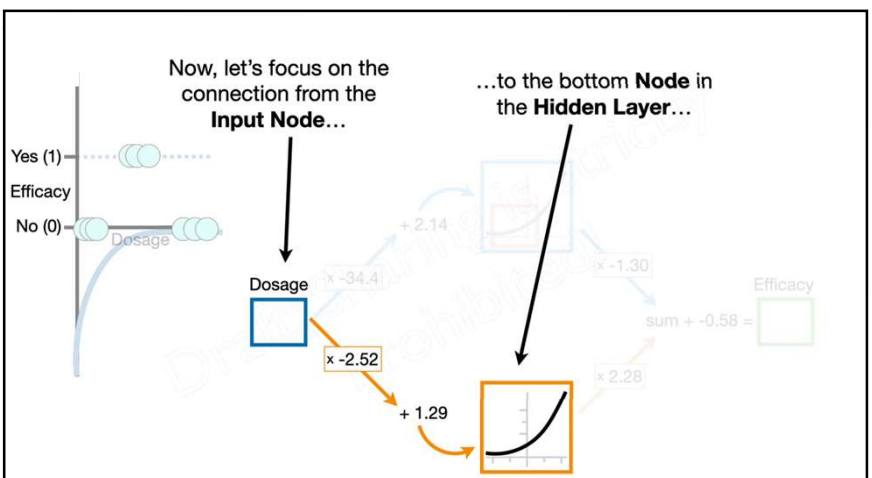

Likewise, we multiply all of the other y-axis coordinates on the blue curve by -1.30...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

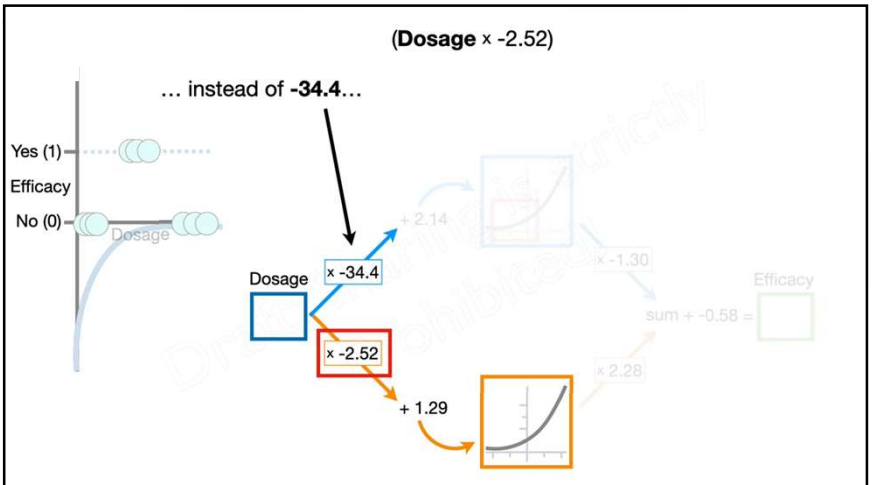

…and -2.93 corresponds to this position on the y-axis.
2.25 x -1.30 = -2.93
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

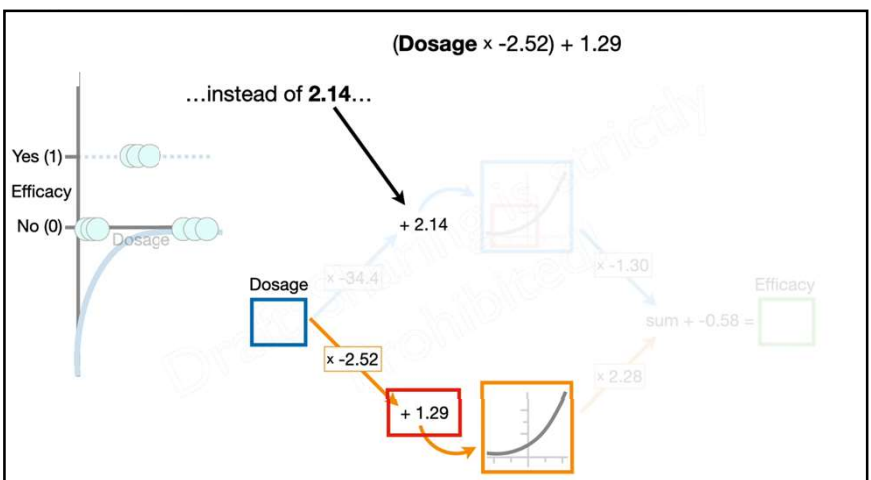

…and we end up with a
new blue curve.
Yes (1)
Efficacy
No (0)
Dosage
0
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

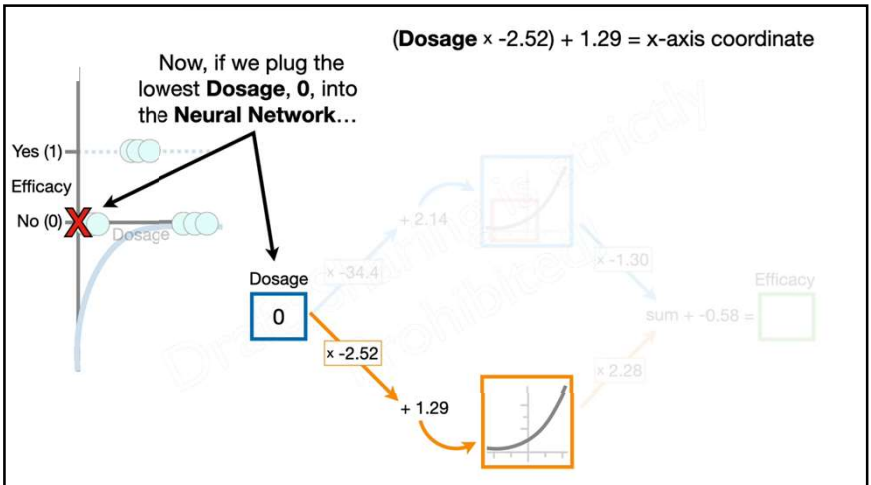

Now, let's focus on the connection from the **Input Node**...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy
x 2.28

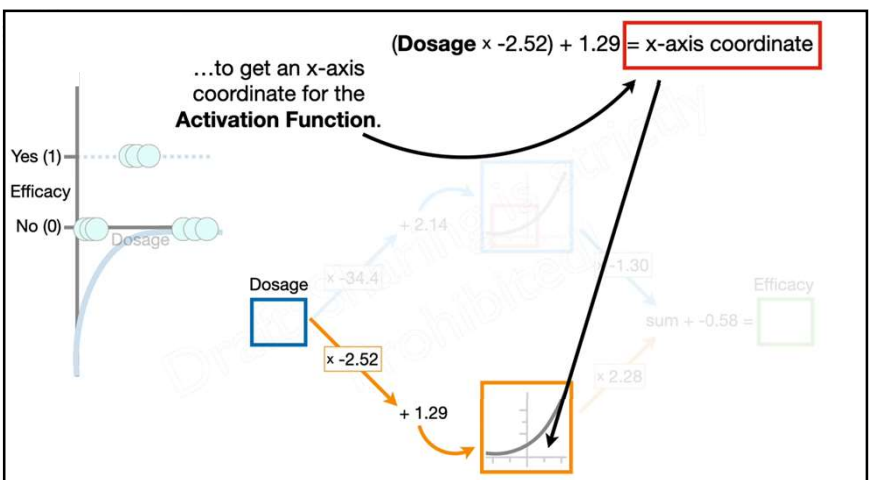

(Dosage x -2.52)
However, this time, we multiply the Dosage by -2.52...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28

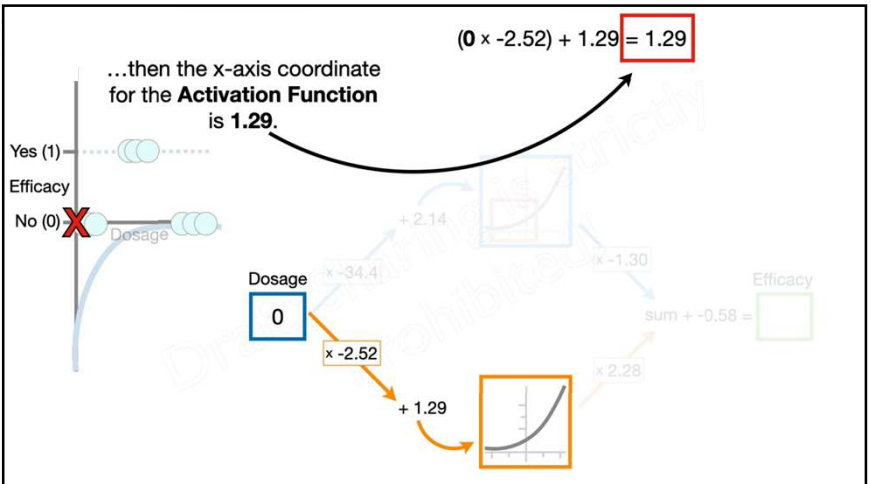

Now, let's focus on the connection from the **Input Node**...
...to the bottom **Node** in the **Hidden Layer**...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy
x 2.28

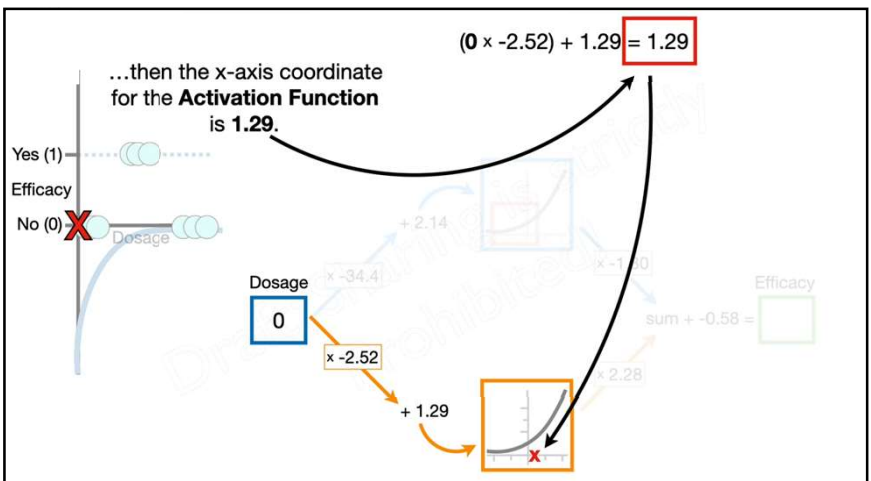

(Dosage x -2.52)
... instead of -34.4...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

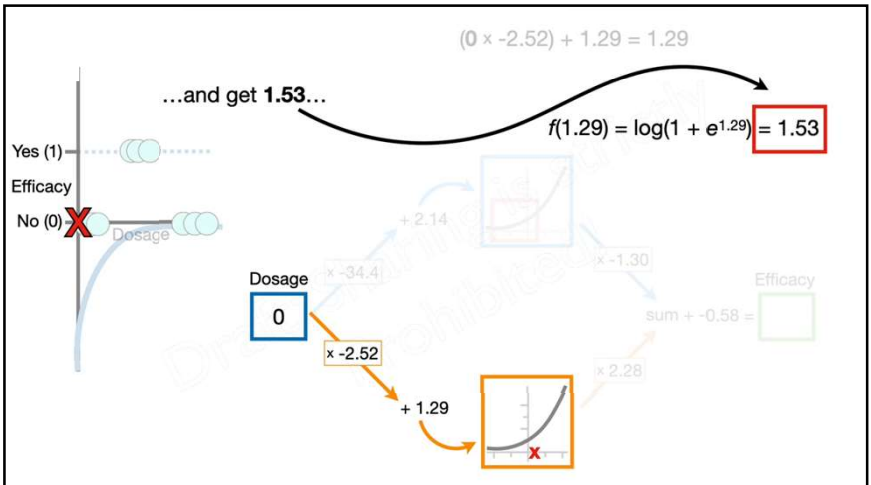

(**Dosage** x -2.52) + 1.29
…instead of **2.14**…
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
Dosage
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

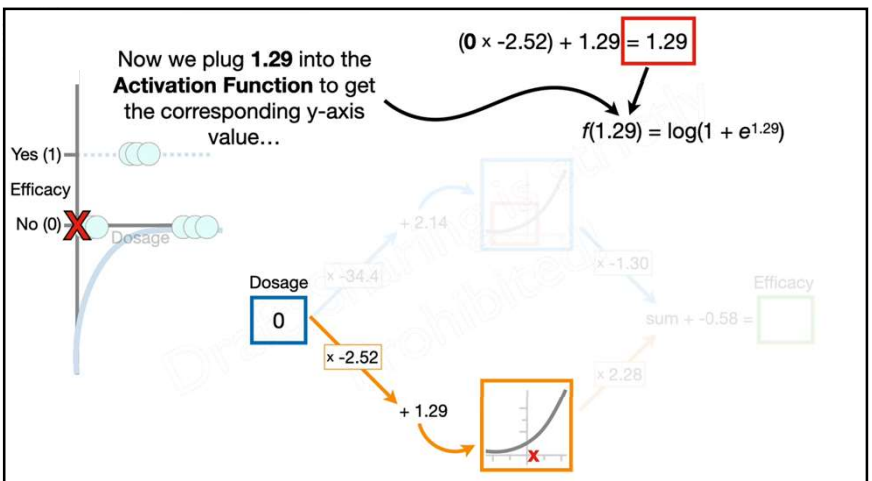

(Dosage x -2.52) + 1.29 = x-axis coordinate
Now, if we plug the lowest Dosage, 0, into the Neural Network...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28

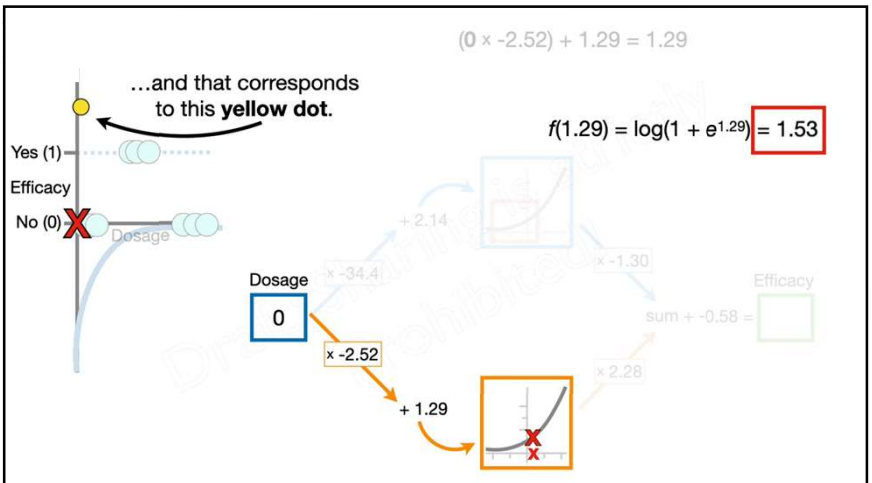

(Dosage x -2.52) + 1.29 = x-axis coordinate
…to get an x-axis coordinate for the Activation Function.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
1.30
Efficacy
sum + -0.58 =
x 2.28

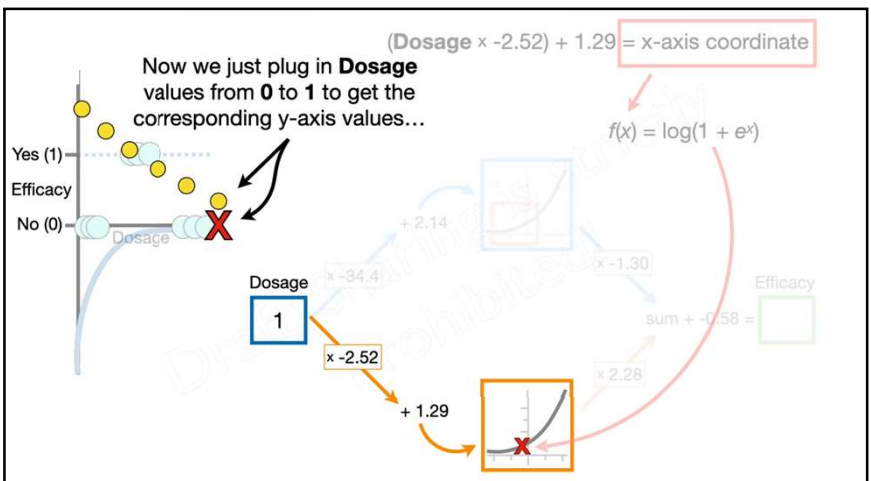

(0 x -2.52) + 1.29 = 1.29
...then the x-axis coordinate for the Activation Function is 1.29.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28

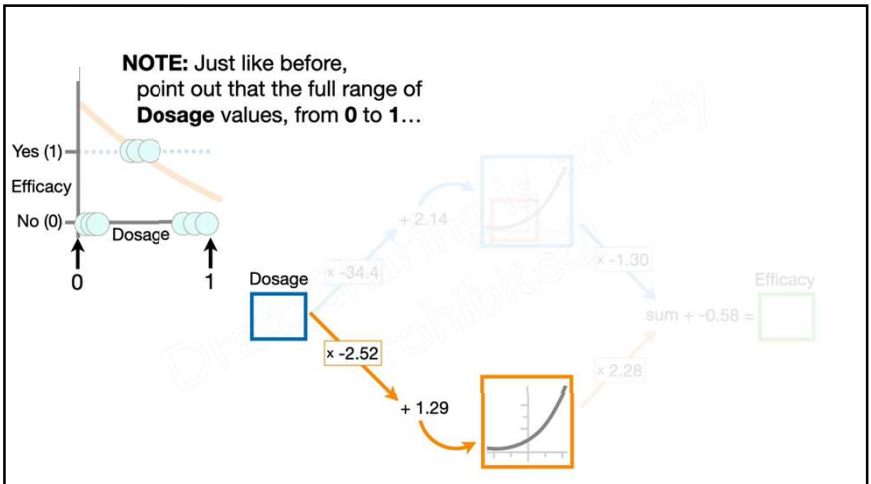

(0 x -2.52) + 1.29 = 1.29
...then the x-axis coordinate for the Activation Function is 1.29.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -2.52
+ 1.29
x
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28

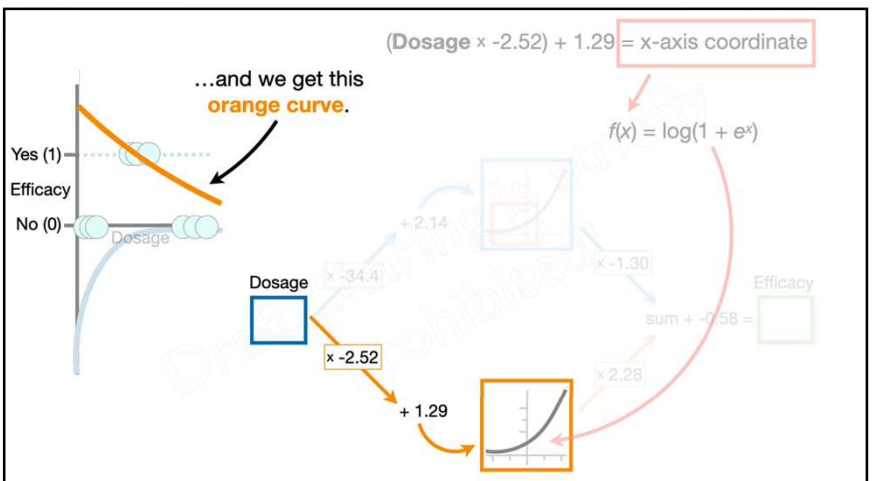

(0 x -2.52) + 1.29 = 1.29
...and get 1.53...
f(1.29) = log(1 + e^1.29) = 1.53
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28

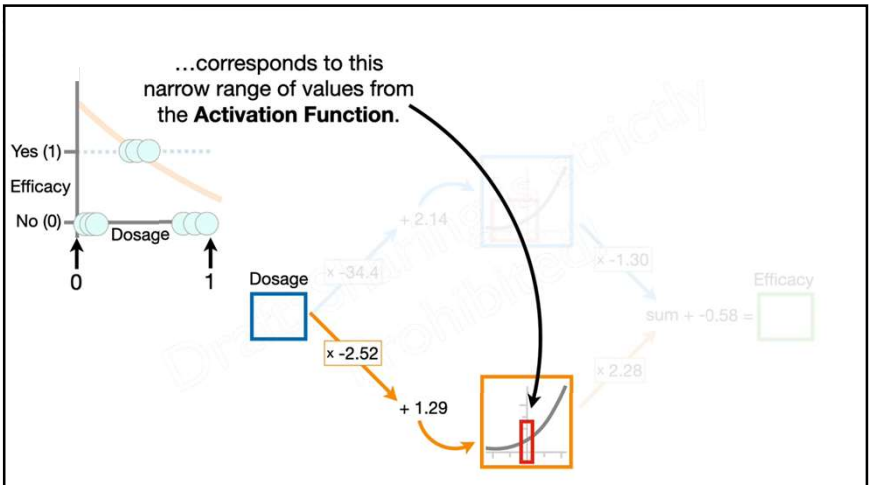

Now we plug **1.29** into the **Activation Function** to get the corresponding y-axis value…
(**0** x -2.52) + 1.29 = 1.29
$f(1.29) = \log(1 + e^{1.29})$
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0
x -2.52
+ 1.29
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x 2.28

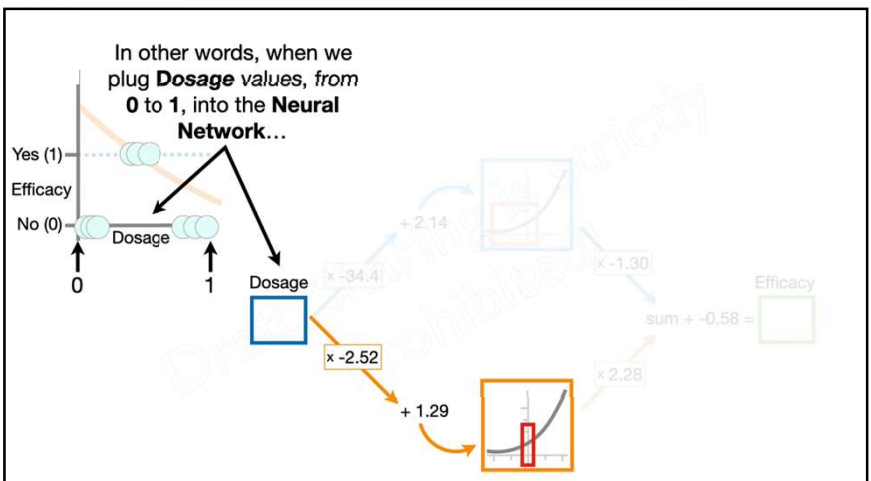

(0 x -2.52) + 1.29 = 1.29
...and that corresponds to this yellow dot.
Yes (1)
Efficacy
No (0)
Dosage
f(1.29) = log(1 + e^1.29) = 1.53
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
Dosage
0
x -2.52
x 2.28
+ 1.29

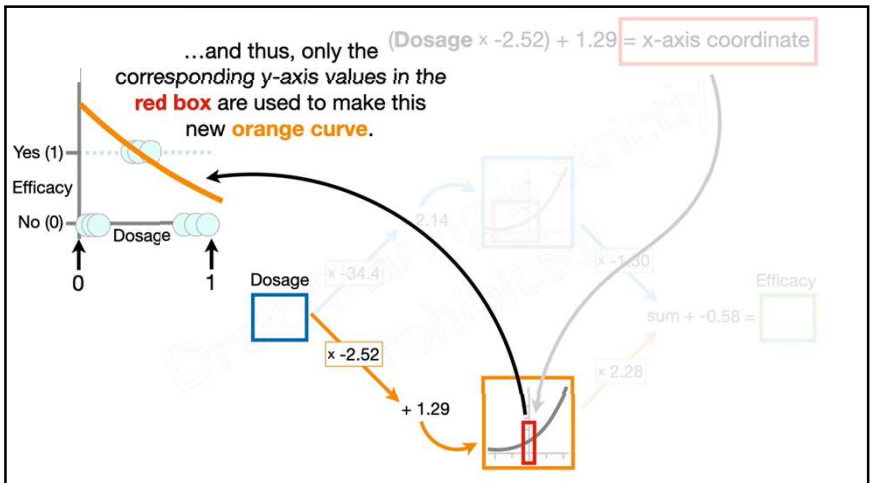

(Dosage x -2.52) + 1.29 = x-axis coordinate
Now we just plug in Dosage values from 0 to 1 to get the corresponding y-axis values…
Yes (1)
Efficacy
No (0)
Dosage
f(x) = log(1 + e^x)
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
Dosage
1
x -2.52
x 2.28
+ 1.29

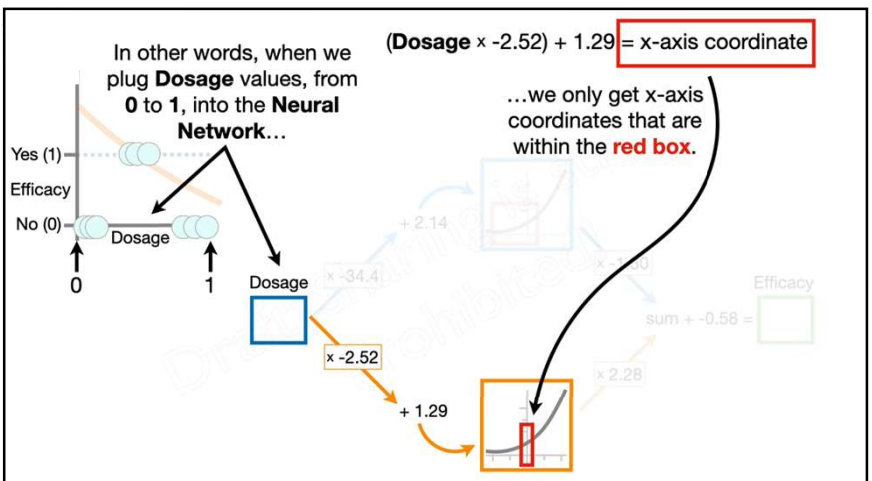

NOTE: Just like before, point out that the full range of Dosage values, from 0 to 1...
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

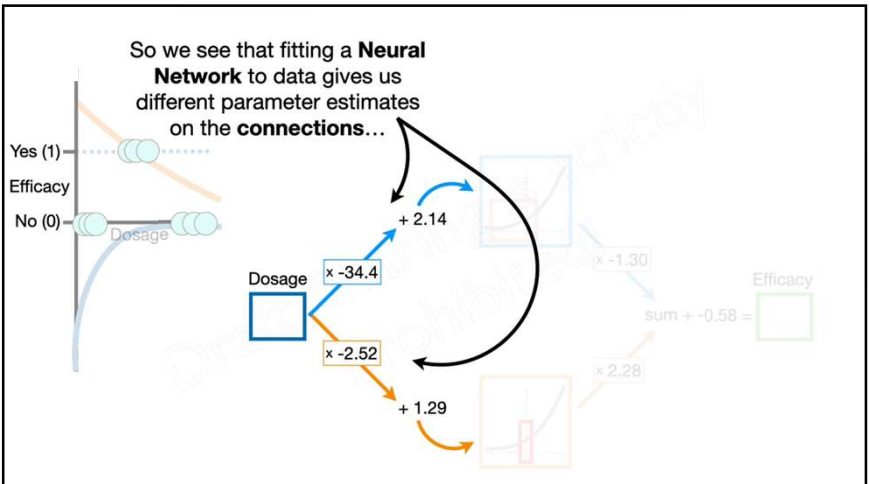

(Dosage x -2.52) + 1.29 = x-axis coordinate
...and we get this
orange curve.
Yes (1)
Efficacy
No (0)
Dosage
f(x) = log(1 + e^x)
+ 2.14
x -34.4
x -1.30
Efficacy
sum + -0.58 =
Dosage
x -2.52
x 2.28
+ 1.29

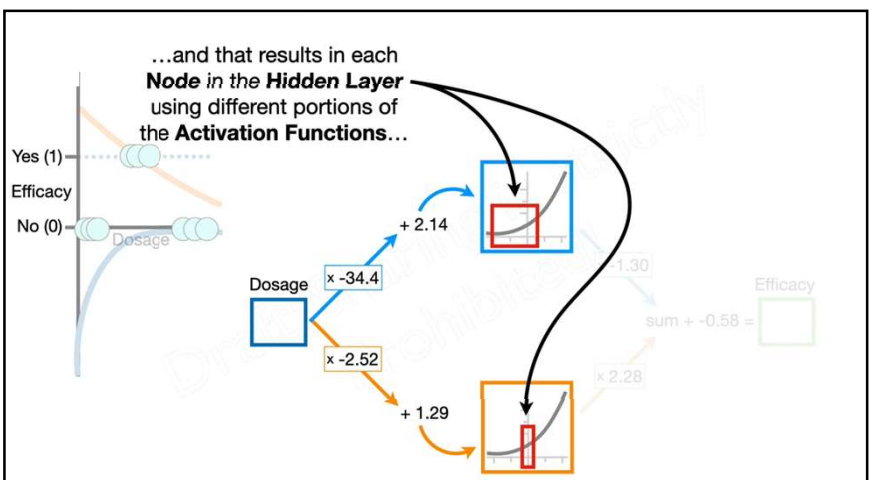

…corresponds to this narrow range of values from the **Activation Function**.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -2.52
+ 1.29

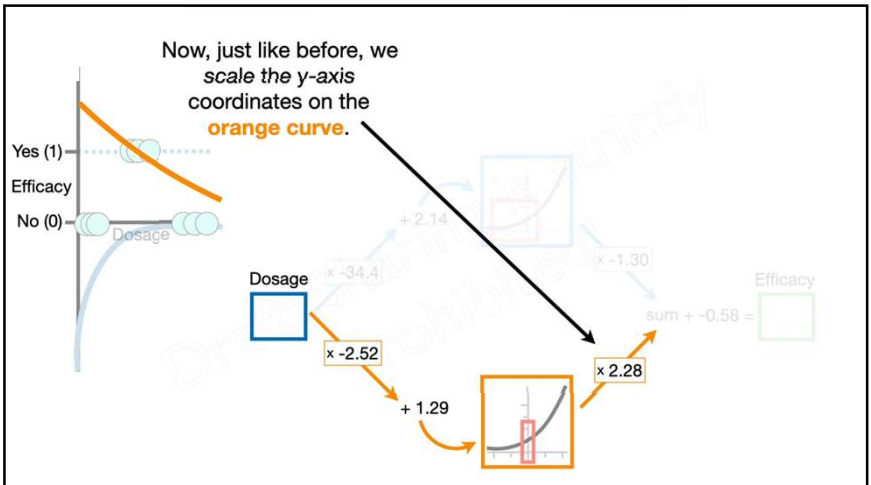

In other words, when we plug **Dosage** *values, from* **0** to **1**, into the **Neural Network**…
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

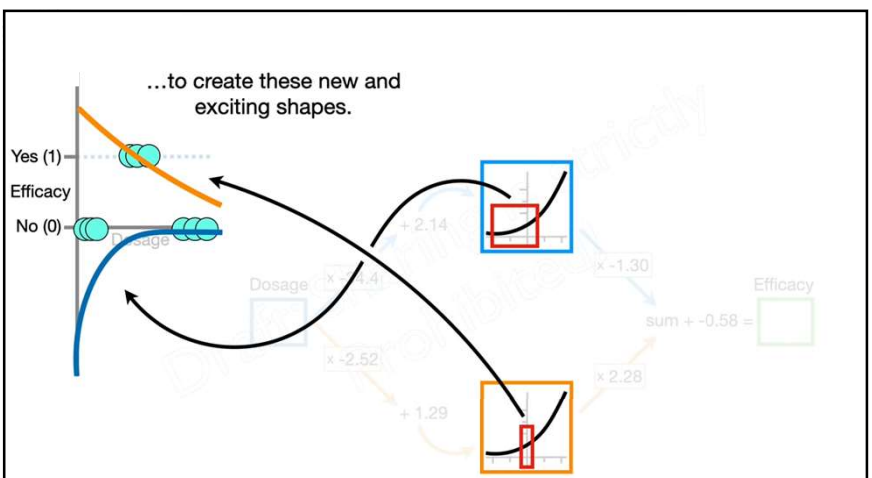

(Dosage x -2.52) + 1.29 = x-axis coordinate
…and thus, only the corresponding y-axis values in the red box are used to make this new orange curve.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -2.52
+ 1.29

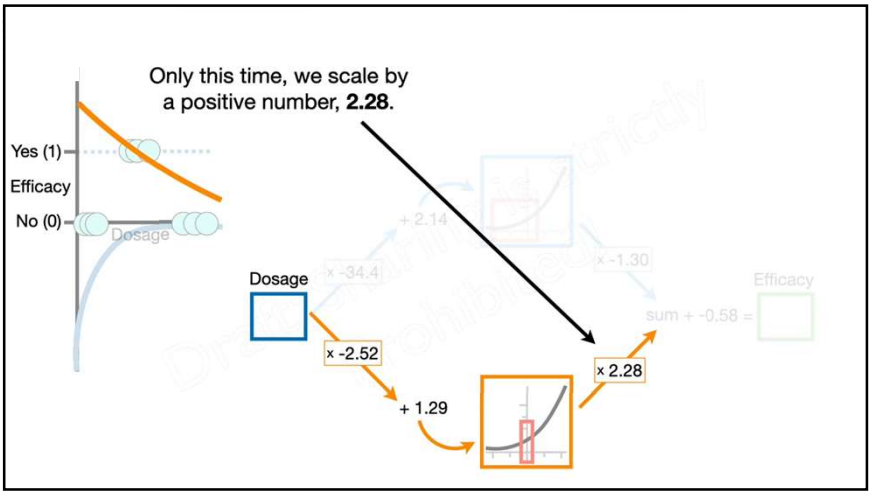

(Dosage x -2.52) + 1.29 = x-axis coordinate
In other words, when we plug Dosage values, from 0 to 1, into the Neural Network...
...we only get x-axis coordinates that are within the red box.
Yes (1)
Efficacy
No (0)
Dosage
0
1
Dosage
x -2.52
+ 1.29
+ 2.14
x -34.4
Efficacy
sum + -0.58 =
x 2.28

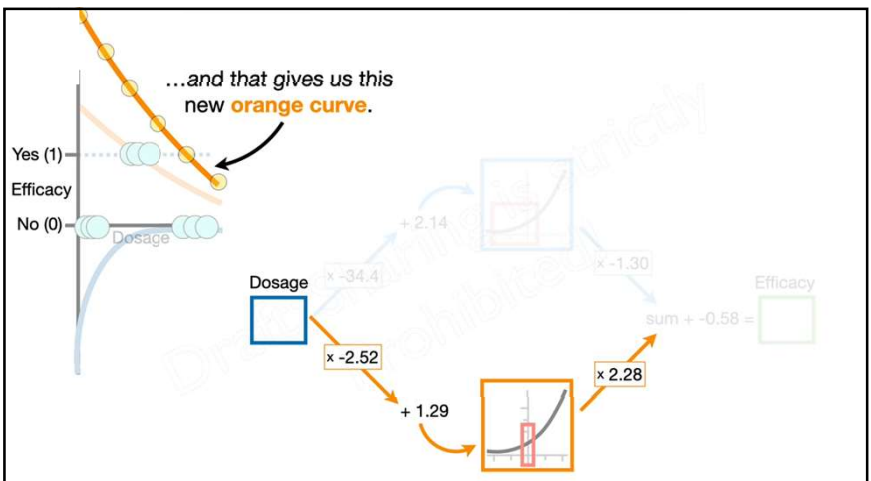

So we see that fitting a **Neural Network** to data gives us different parameter estimates on the **connections**…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
Efficacy
sum + -0.58 =
x 2.28

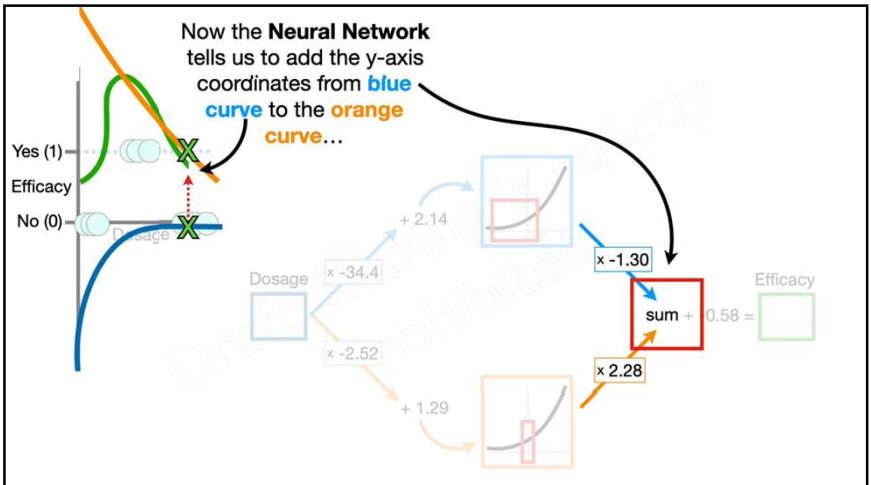

…and that results in each
Node *in the* ***Hidden Layer***
using different portions of
the **Activation Functions**…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
1.30
sum + -0.58 =
Efficacy
x 2.28

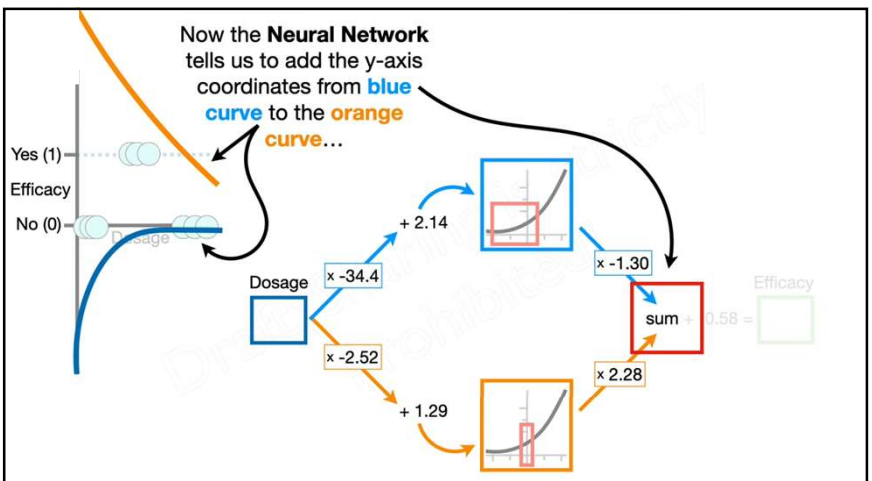

Now, just like before, we
scale the y-axis
coordinates on the
orange curve.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28

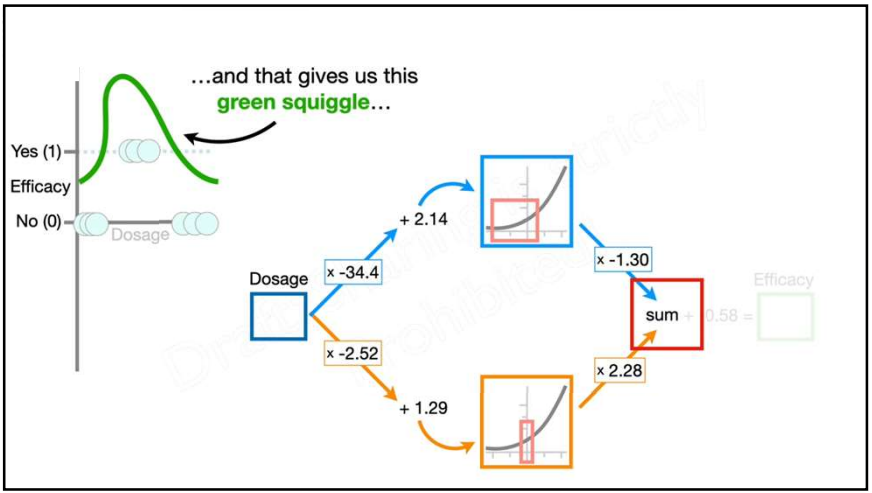

...to create these new and exciting shapes.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

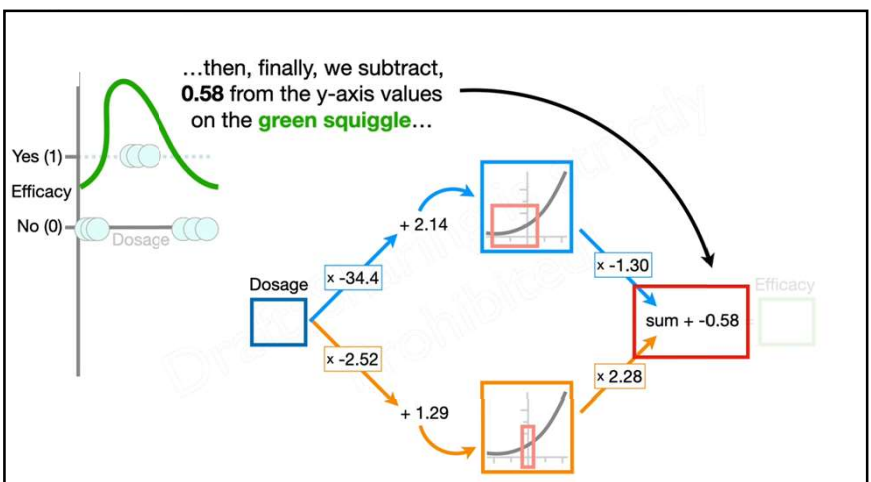

Only this time, we scale by a positive number, 2.28.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

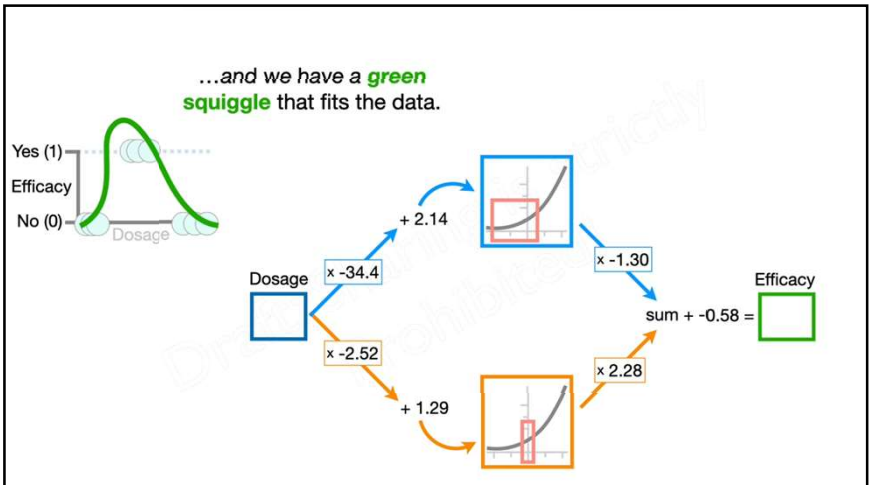

...and that gives us this
new orange curve.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.52
+ 1.29
x 2.28
+ 2.14
x -34.4
x -1.30
sum + -0.58 =
Efficacy

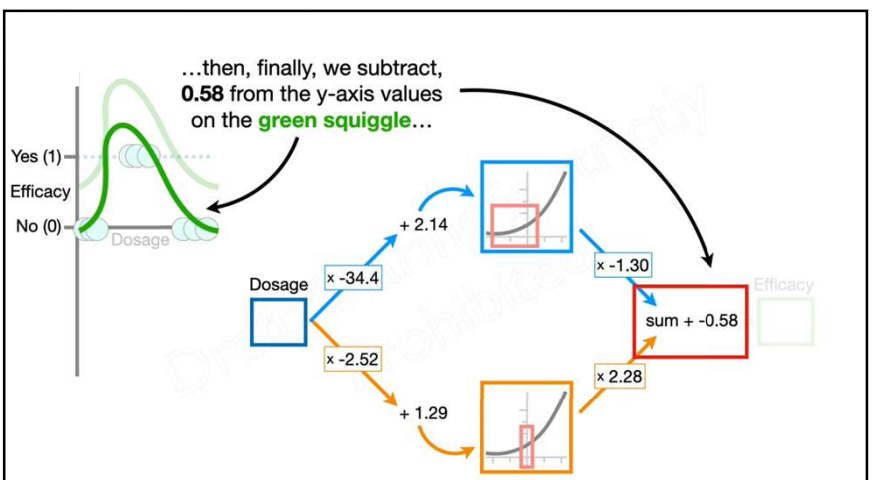

Now the Neural Network tells us to add the y-axis coordinates from blue curve to the orange curve…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + 0.58 =
Efficacy

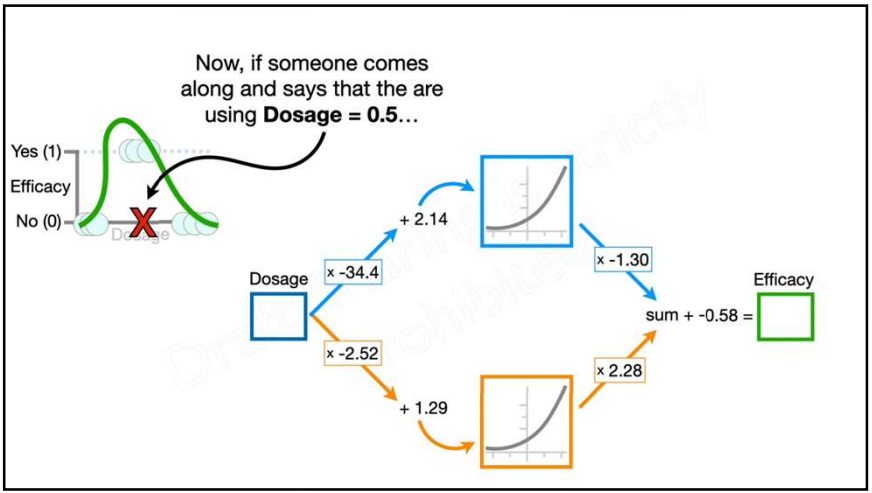

Now the Neural Network tells us to add the y-axis coordinates from blue curve to the orange curve...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum
+ 0.58 =
Efficacy

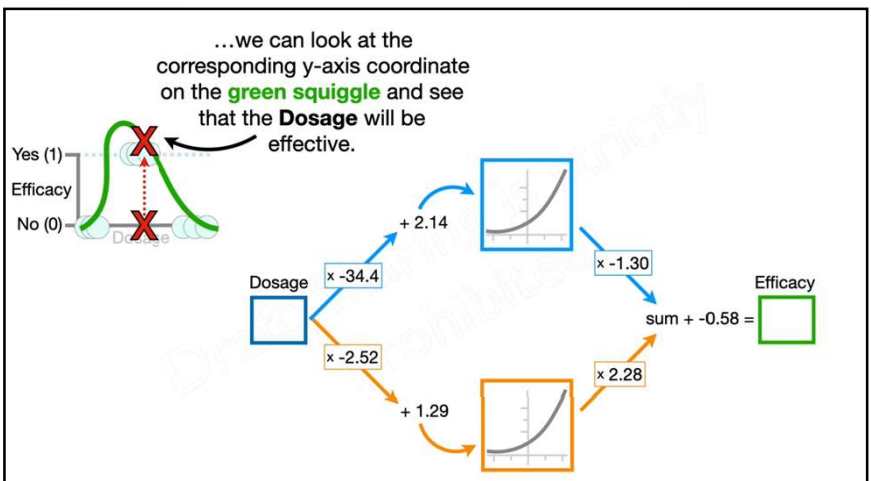

…and that gives us this
green squiggle…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
sum
Efficacy
x -2.52
+ 1.29
x 2.28

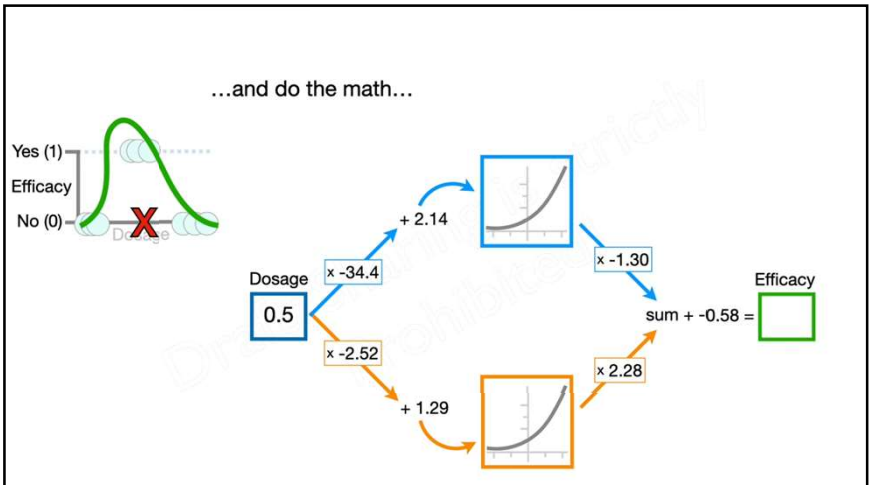

…then, finally, we subtract,
0.58 from the y-axis values
on the green squiggle…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58
Efficacy

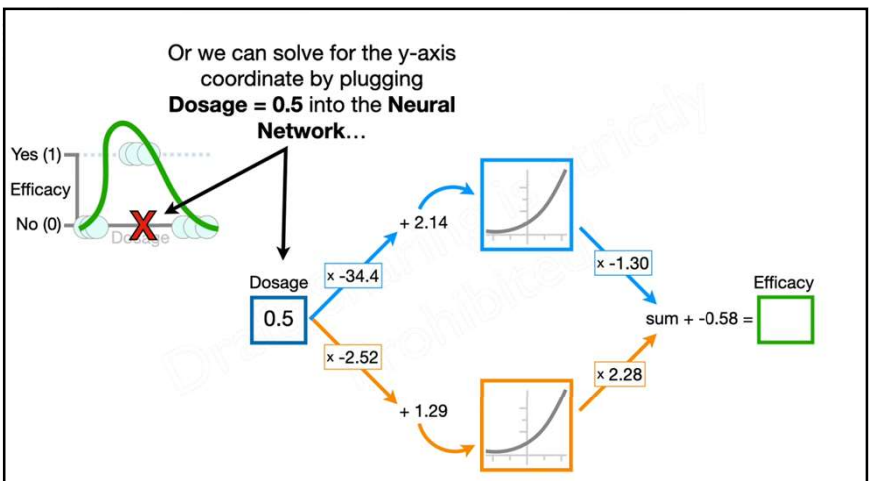

...and we have a green squiggle that fits the data.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

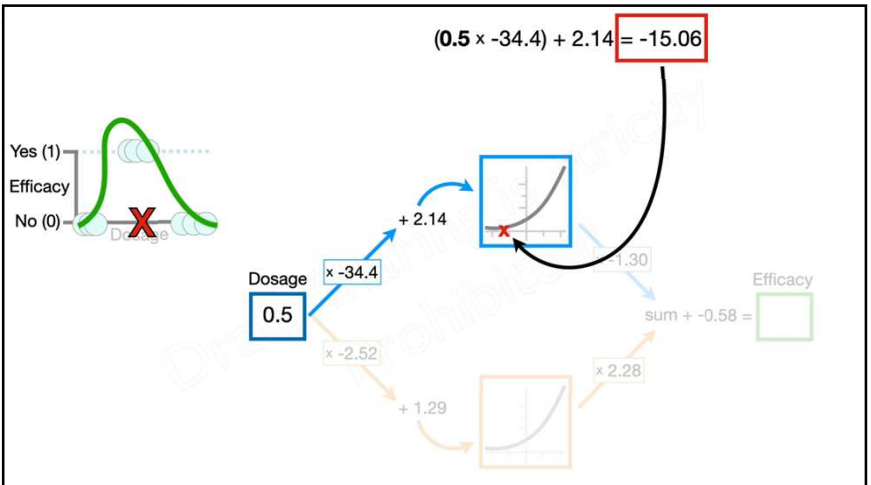

…then, finally, we subtract,
0.58 from the y-axis values
on the green squiggle…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58
Efficacy

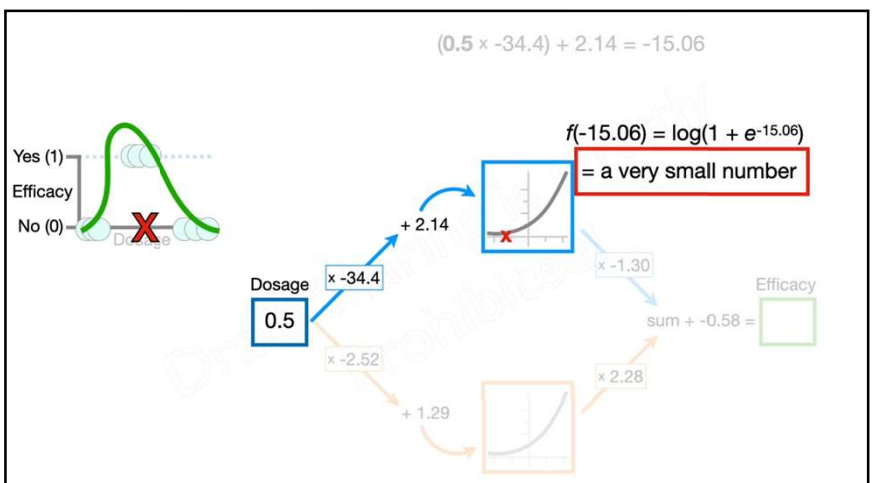

Now, if someone comes along and says that the are using **Dosage = 0.5**...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

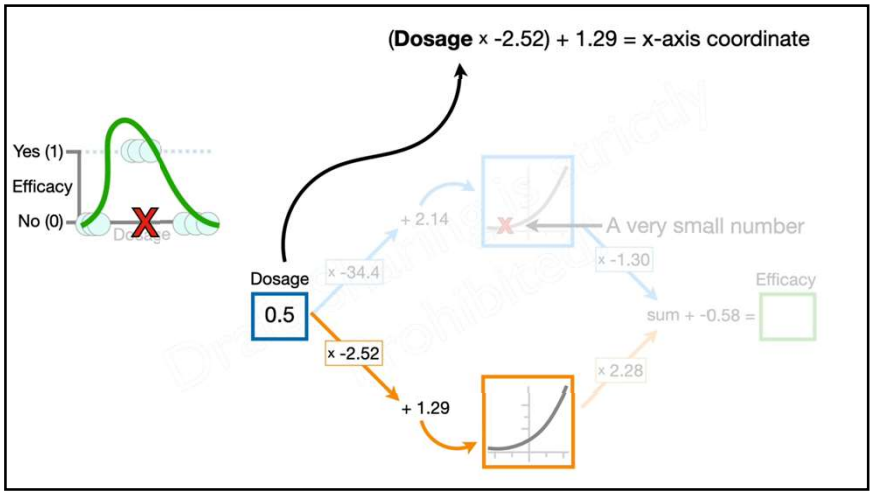

…we can look at the corresponding y-axis coordinate on the green squiggle and see that the Dosage will be effective.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

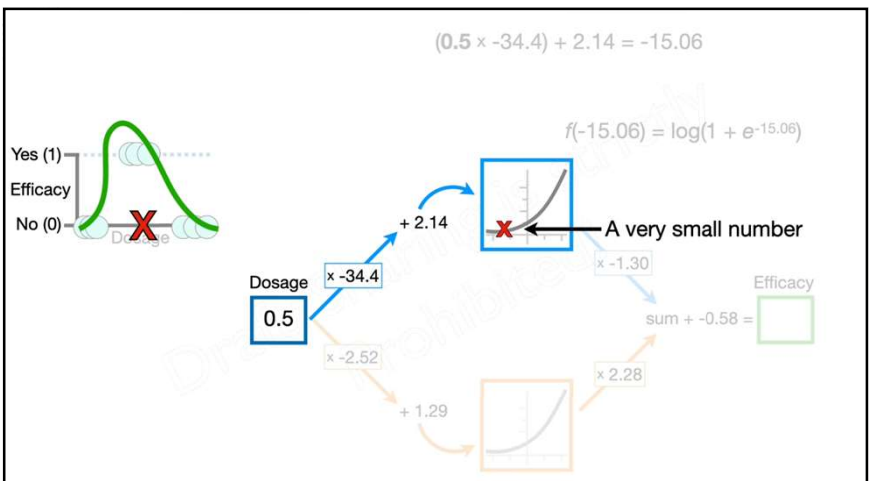

…and do the math…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

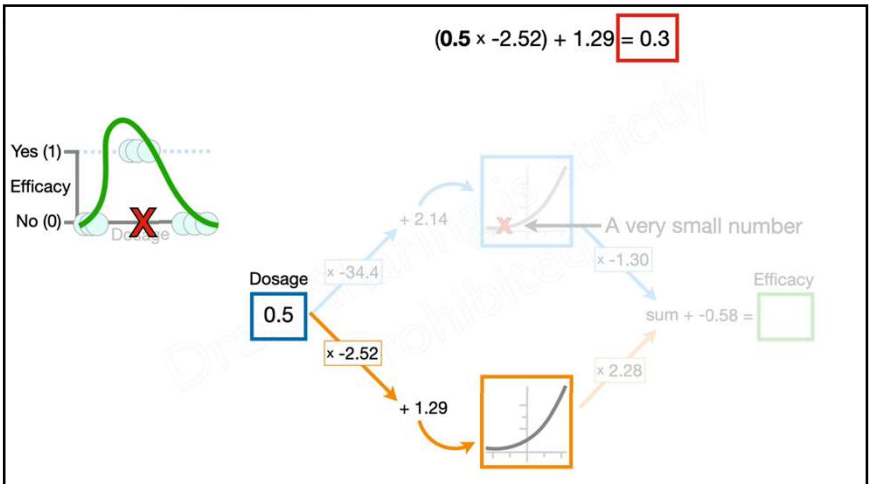

Or we can solve for the y-axis coordinate by plugging **Dosage = 0.5** into the **Neural Network**…
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy

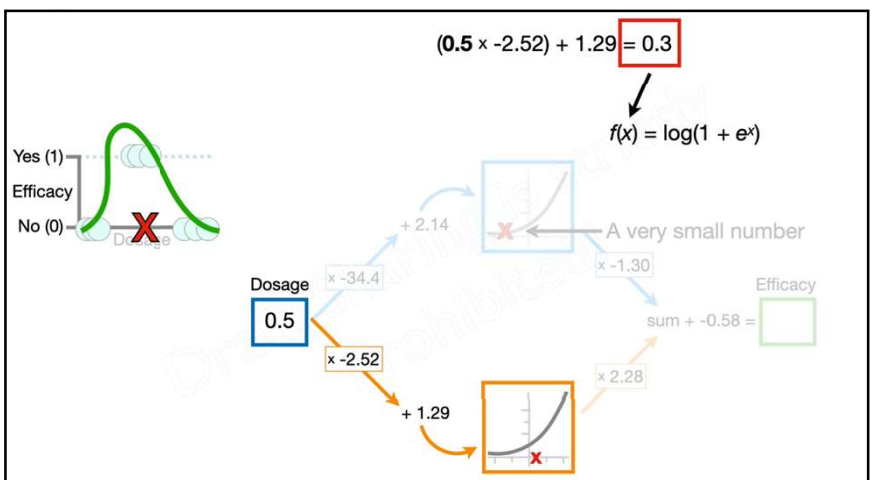

(0.5 x -34.4) + 2.14 = -15.06
Yes (1)
Efficacy
No (0)
Dosage
0.5
x -34.4
+ 2.14
x -2.52
+ 1.29
x 2.28
-1.30
sum + -0.58 =
Efficacy

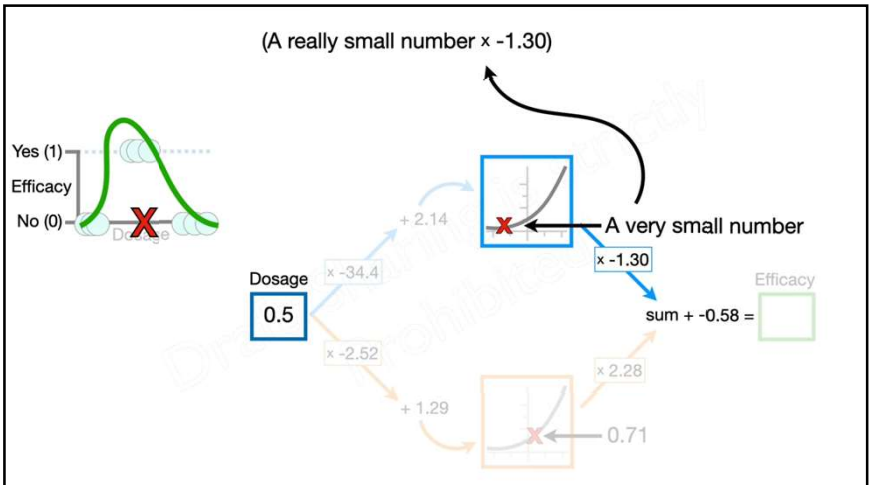

(0.5 x -34.4) + 2.14 = -15.06
Yes (1)
Efficacy
No (0)
Dosage
f(-15.06) = log(1 + e^-15.06)
= a very small number
+ 2.14
Dosage
0.5
x -34.4
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

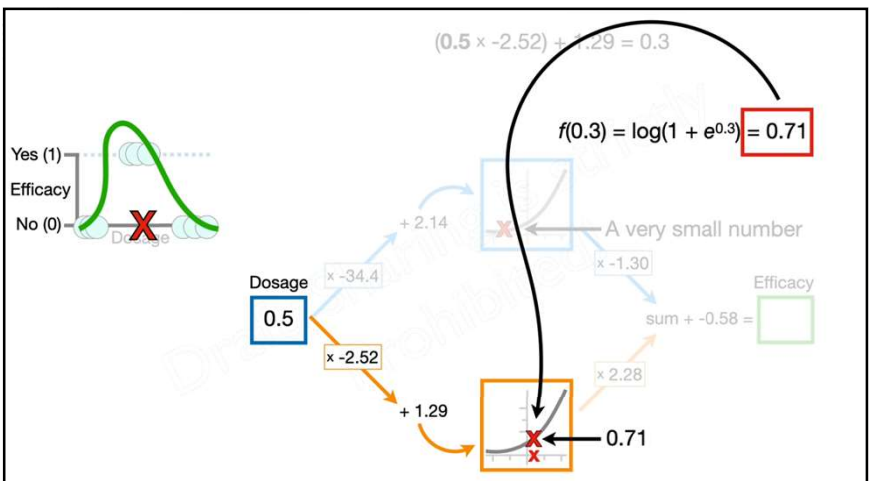

(Dosage x -2.52) + 1.29 = x-axis coordinate
Yes (1)
Efficacy
No (0)
Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

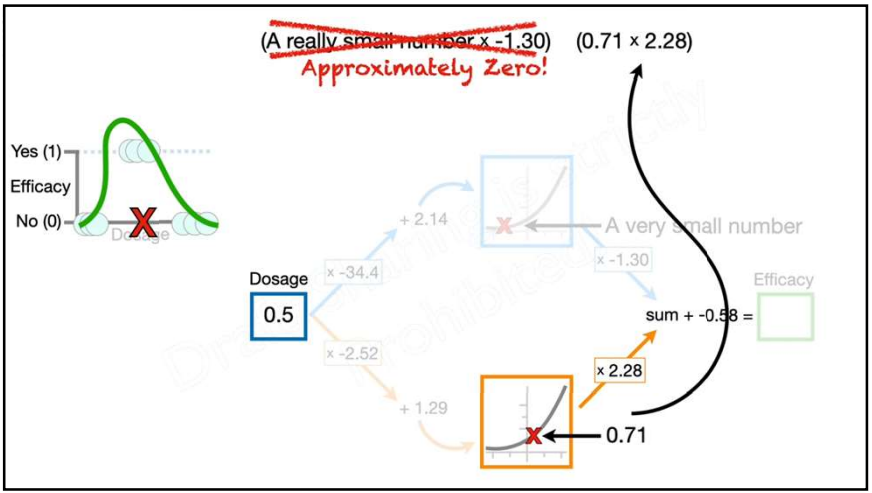

(0.5 x -34.4) + 2.14 = -15.06
f(-15.06) = log(1 + e^-15.06)
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

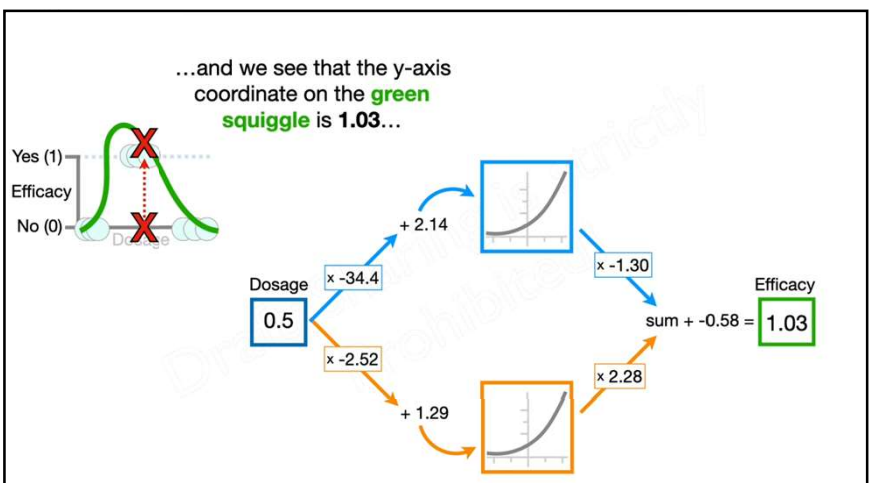

(0.5 x -2.52) + 1.29 = 0.3
Yes (1)
Efficacy
No (0)
Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

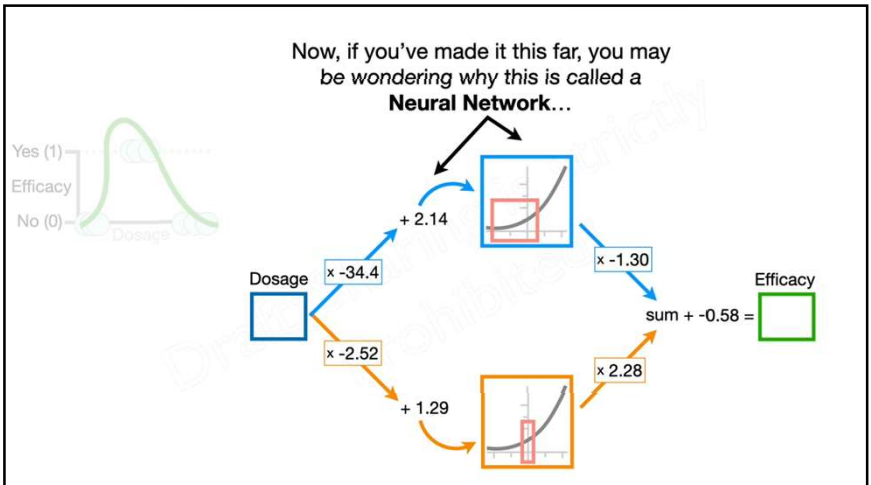

(0.5 x -2.52) + 1.29 = 0.3
f(x) = log(1 + e^x)
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
A very small number
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

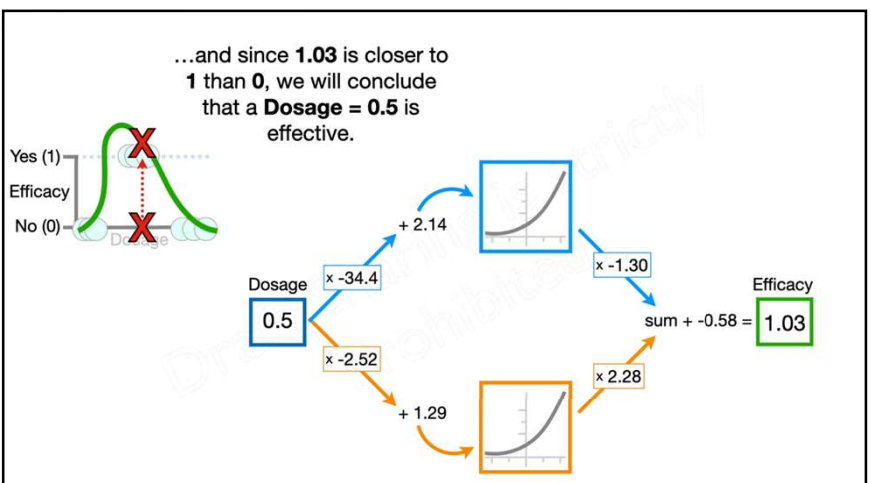

(A really small number x -1.30)
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
A very small number
x -1.30
Dosage
0.5
x -34.4
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29
0.71

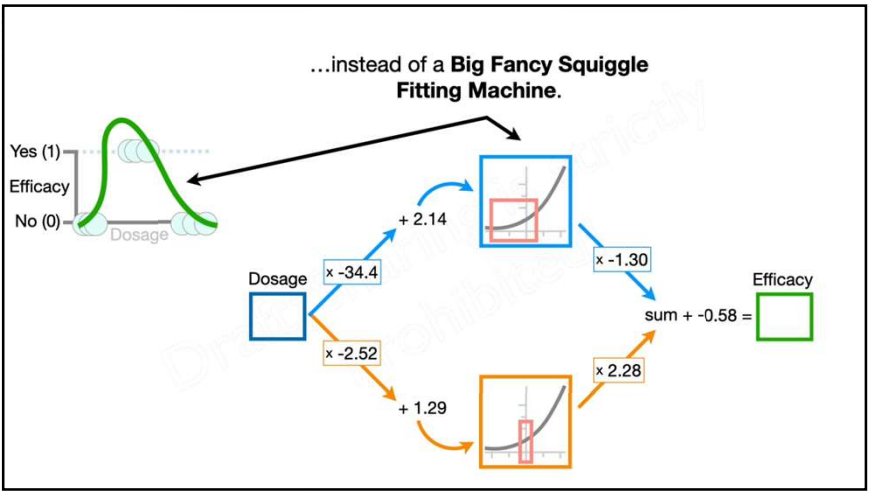

(0.5 x -2.52) + 1.29 = 0.3
f(0.3) = log(1 + e^0.3) = 0.71
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
A very small number
x -34.4
x -1.30
Efficacy
Dosage
0.5
sum + -0.58 =
x -2.52
x 2.28
+ 1.29
0.71

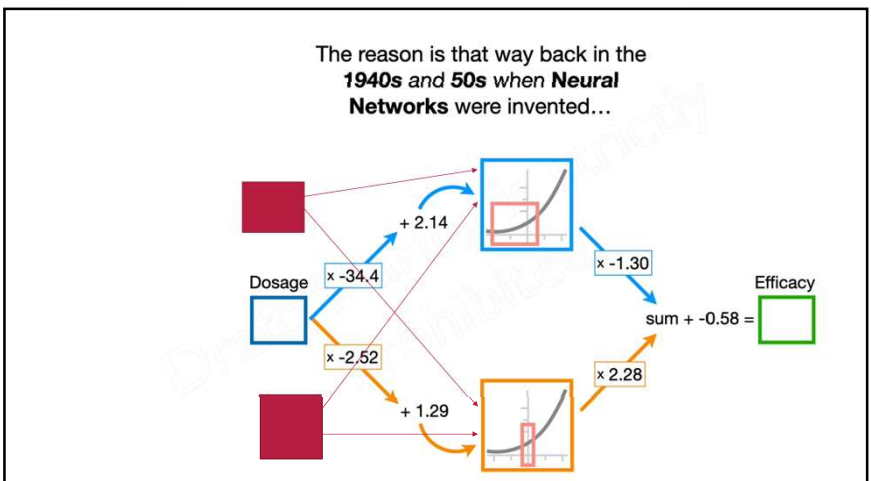

(A really small number x -1.30)
Approximately Zero!
(0.71 x 2.28)
Yes (1)
Efficacy
No (0)
Dosage
+ 2.14
A very small number
x -1.30
Dosage
0.5
x -34.4
x -2.52
Efficacy
sum + -0.58 =
x 2.28
+ 1.29
0.71

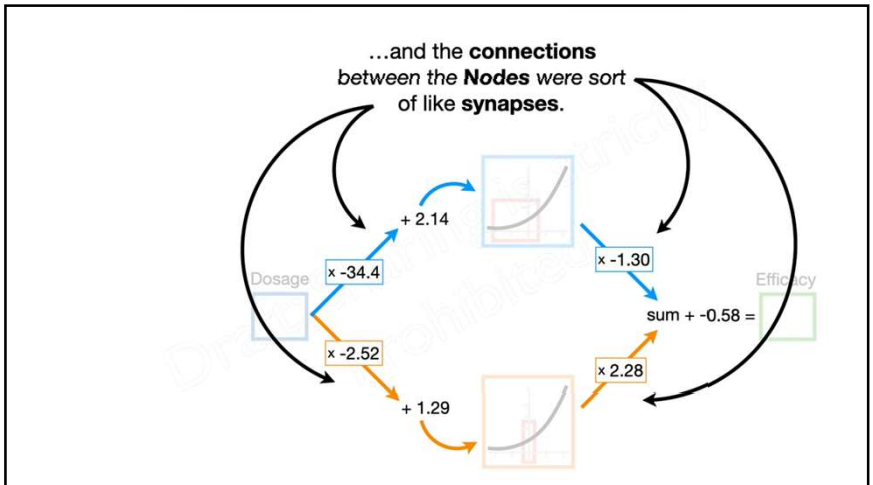

...and we see that the y-axis coordinate on the green squiggle is 1.03...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy
1.03

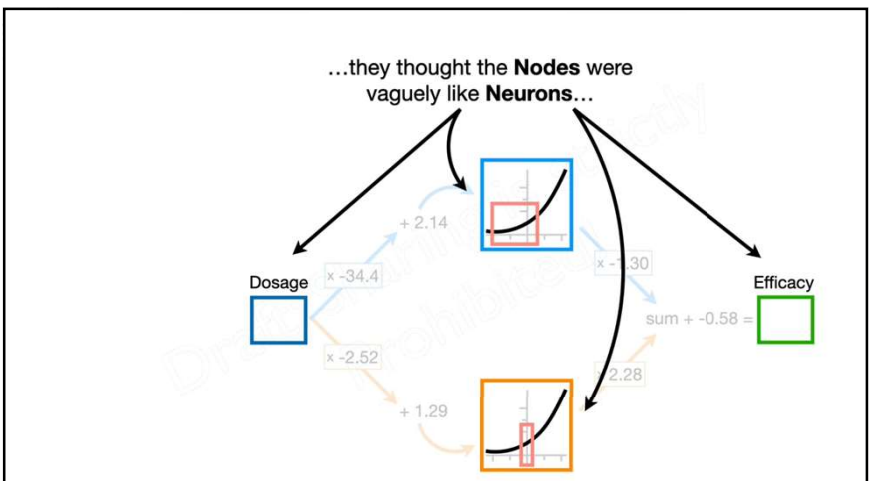

Now, if you've made it this far, you may
be wondering why this is called a
Neural Network...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
sum + -0.58 =
Efficacy
x -2.52
+ 1.29
x 2.28

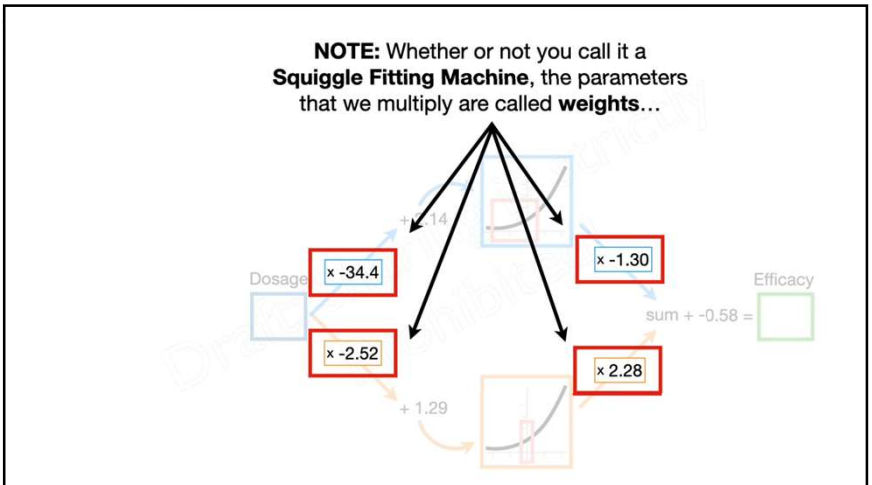

...and since **1.03** is closer to **1** than **0**, we will conclude that a **Dosage = 0.5** is effective.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
0.5
x -34.4
+ 2.14
x -1.30
x -2.52
+ 1.29
x 2.28
sum + -0.58 =
Efficacy
1.03

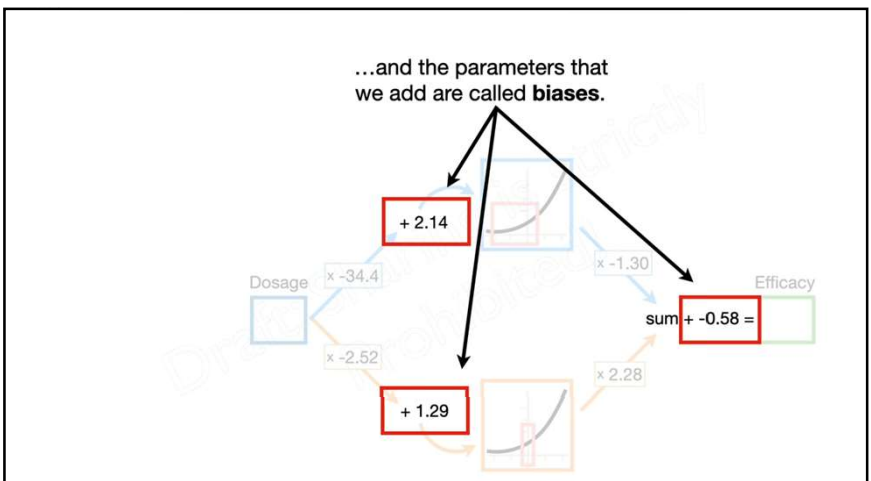

...instead of a **Big Fancy Squiggle Fitting Machine.**
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
+ 1.29
x 2.28

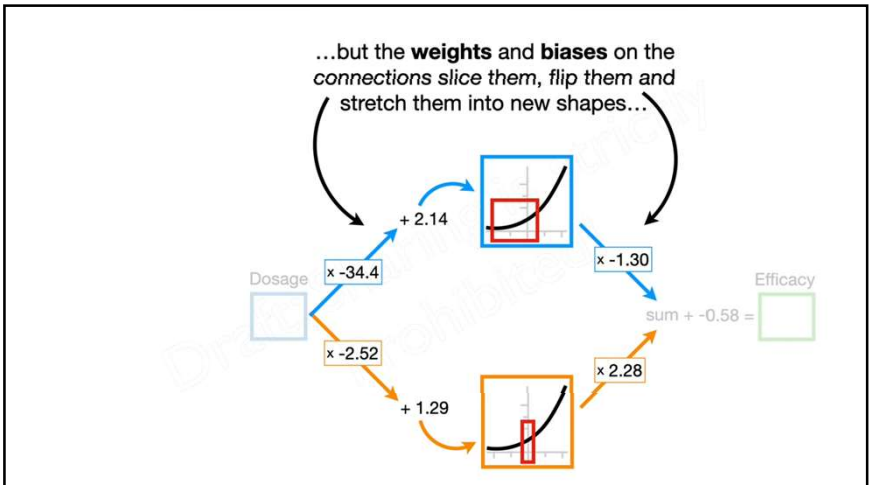

The reason is that way back in the
1940s and 50s when Neural
Networks were invented…
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

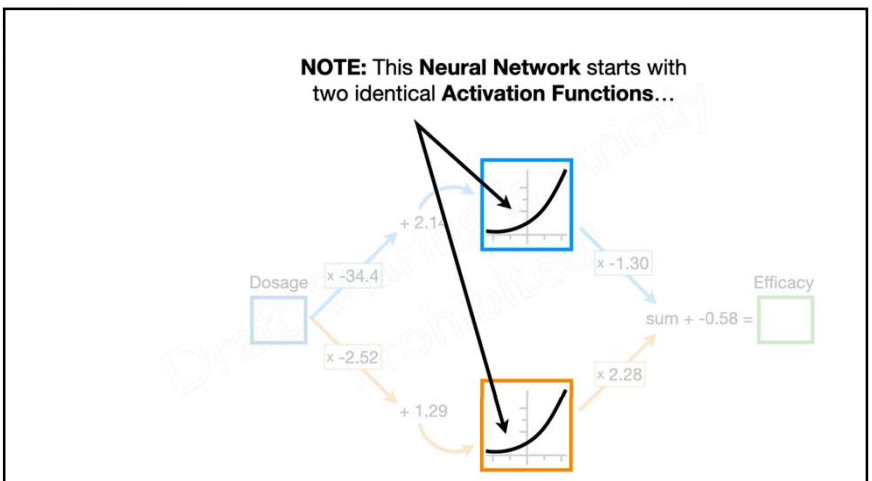

…and the **connections**
between the **Nodes** *were sort*
of like **synapses**.
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
sum + -0.58 =
x 2.28
Efficacy

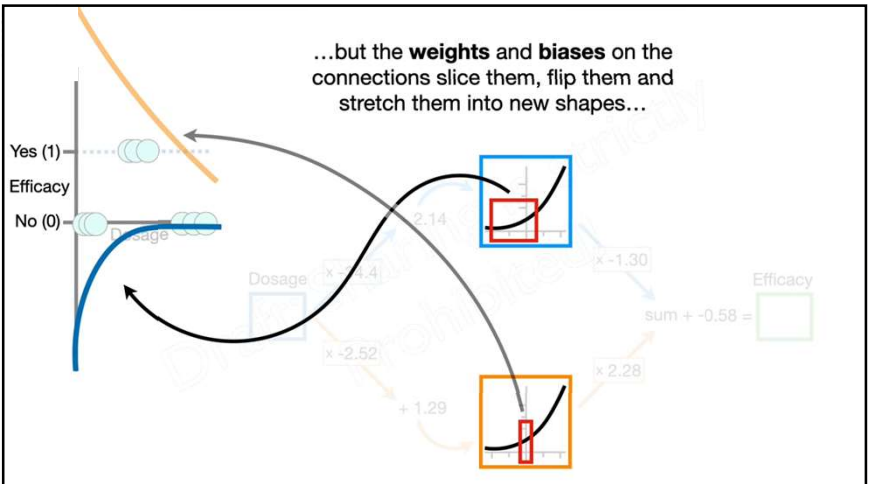

…they thought the **Nodes** were vaguely like **Neurons**…
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
sum + -0.58 =
Efficacy

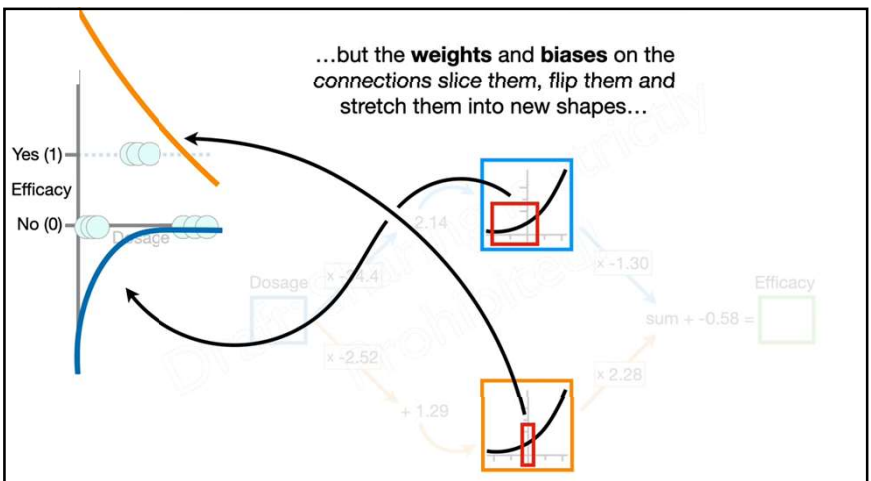

NOTE: Whether or not you call it a
Squiggle Fitting Machine, the parameters
that we multiply are called weights…
Dosage
x -34.4
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

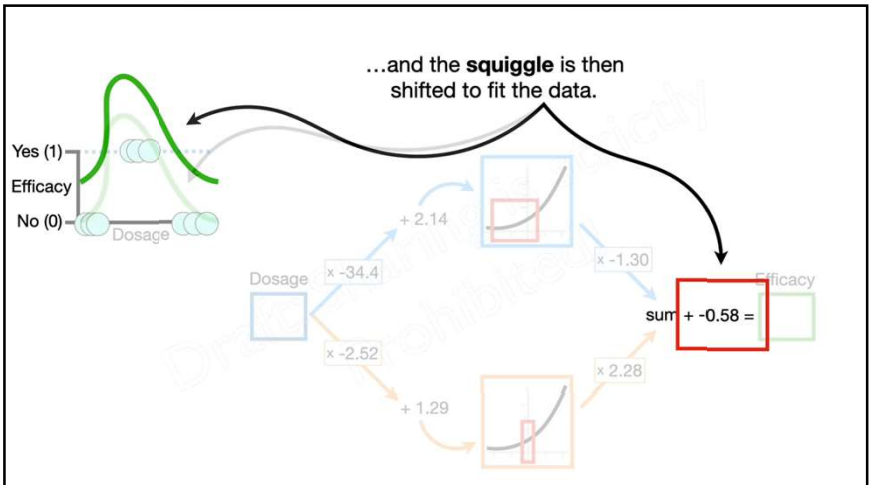

…and the parameters that
we add are called **biases**.
+ 2.14
Dosage
x -34.4
x -1.30
Efficacy
sum
+ -0.58 =
x -2.52
x 2.28
+ 1.29

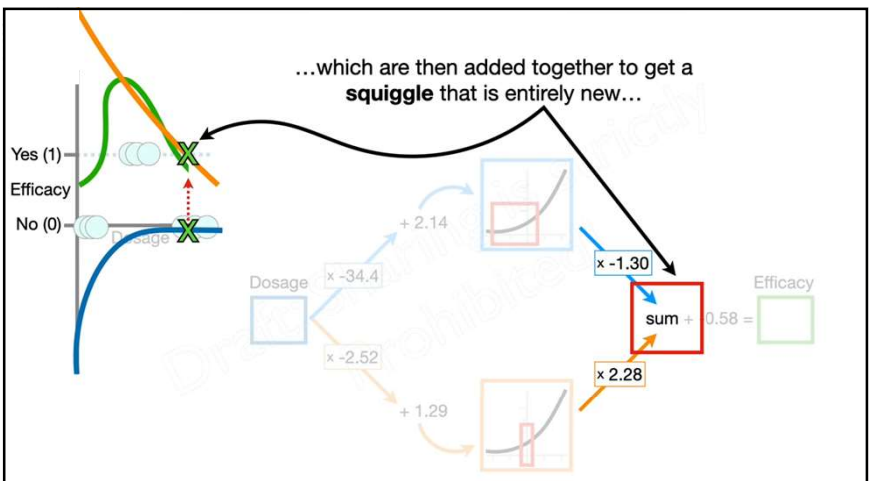

...but the **weights** and **biases** on the *connections slice them, flip them and* stretch them into new shapes...
Dosage
x -34.4
+ 2.14
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy

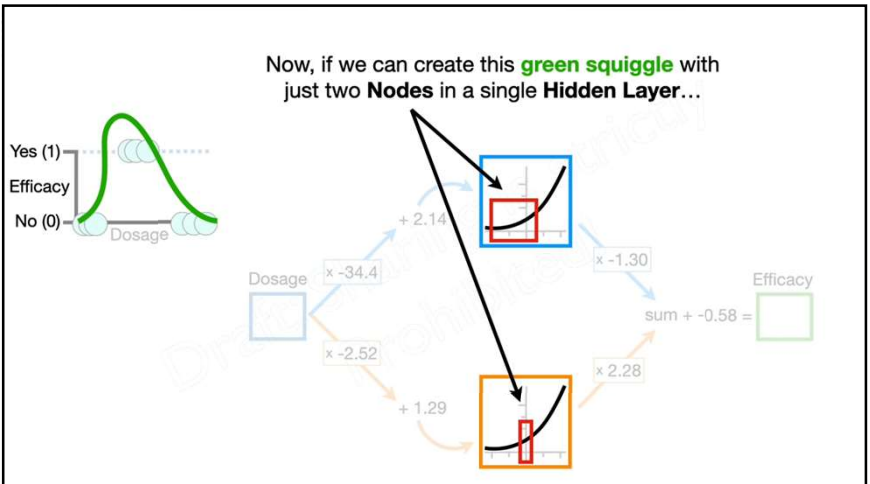

NOTE: This Neural Network starts with two identical Activation Functions...
Dosage
x -34.4
+ 2.1
x -2.52
+ 1.29
x -1.30
x 2.28
sum + -0.58 =
Efficacy


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

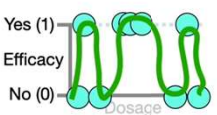

...but the **weights** and **biases** on the *connections slice them, flip them and* stretch them into new shapes...
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -2.14
x -1.30
Efficacy
sum + -0.58 =
x -2.52
x 2.28
+ 1.29

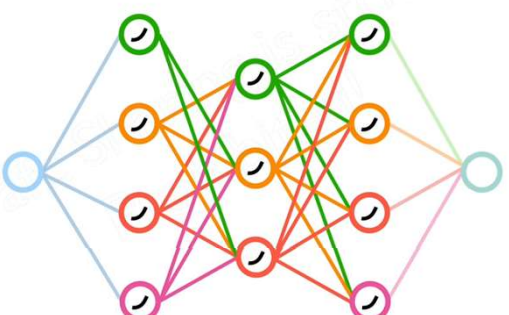

…and the squiggle is then shifted to fit the data.
Yes (1)
Efficacy
No (0)
Dosage
Dosage
x -34.4
+ 2.14
x -1.30
Efficacy
sum
+ -0.58 =
x -2.52
+ 1.29
x 2.28


...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


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

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





THANK YOU!

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