



DEEP LEARNING IN PYTHON

# **Introduction to deep learning**

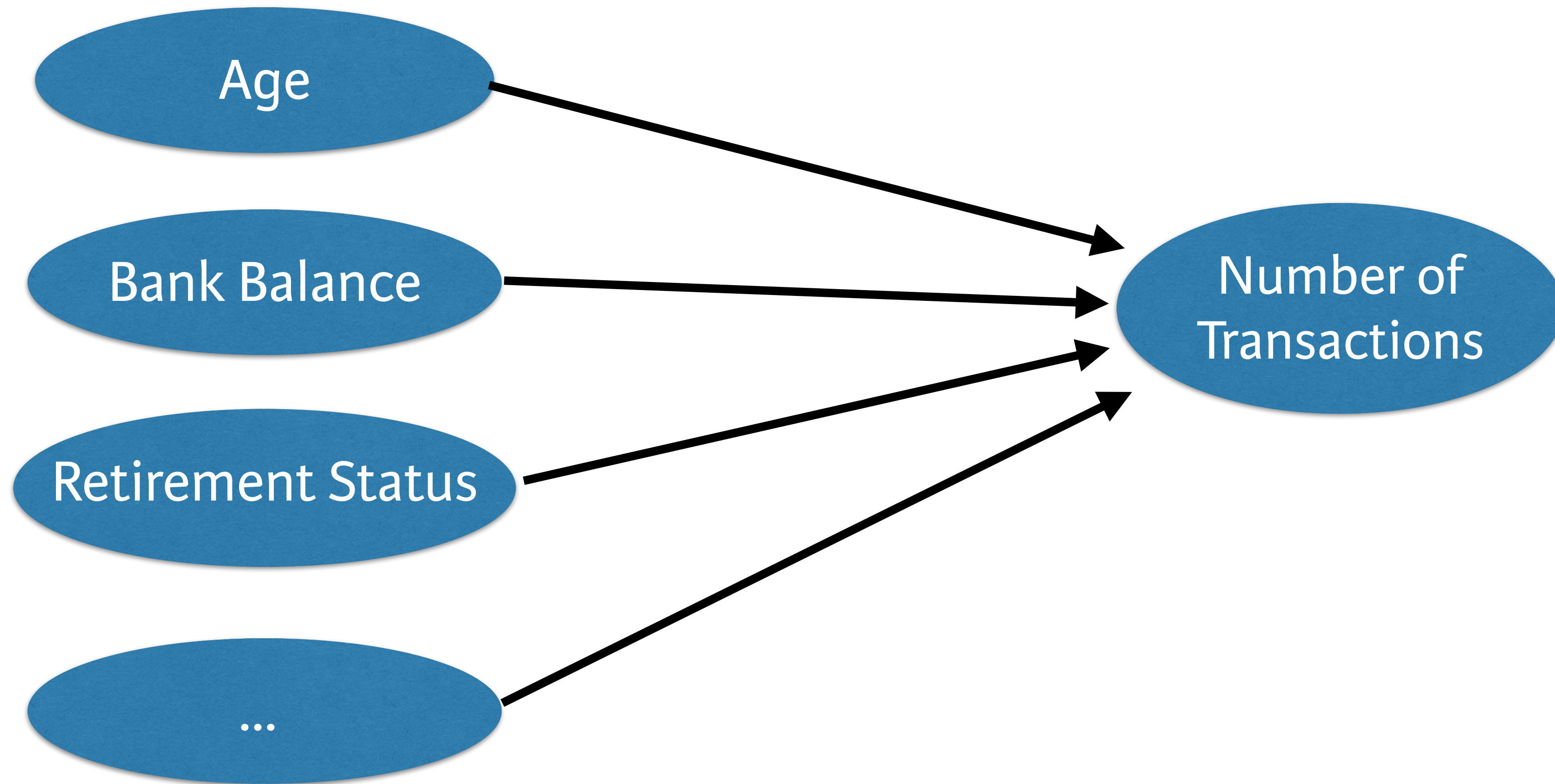


# Imagine you work for a bank

- You need to predict how many transactions each customer will make next year



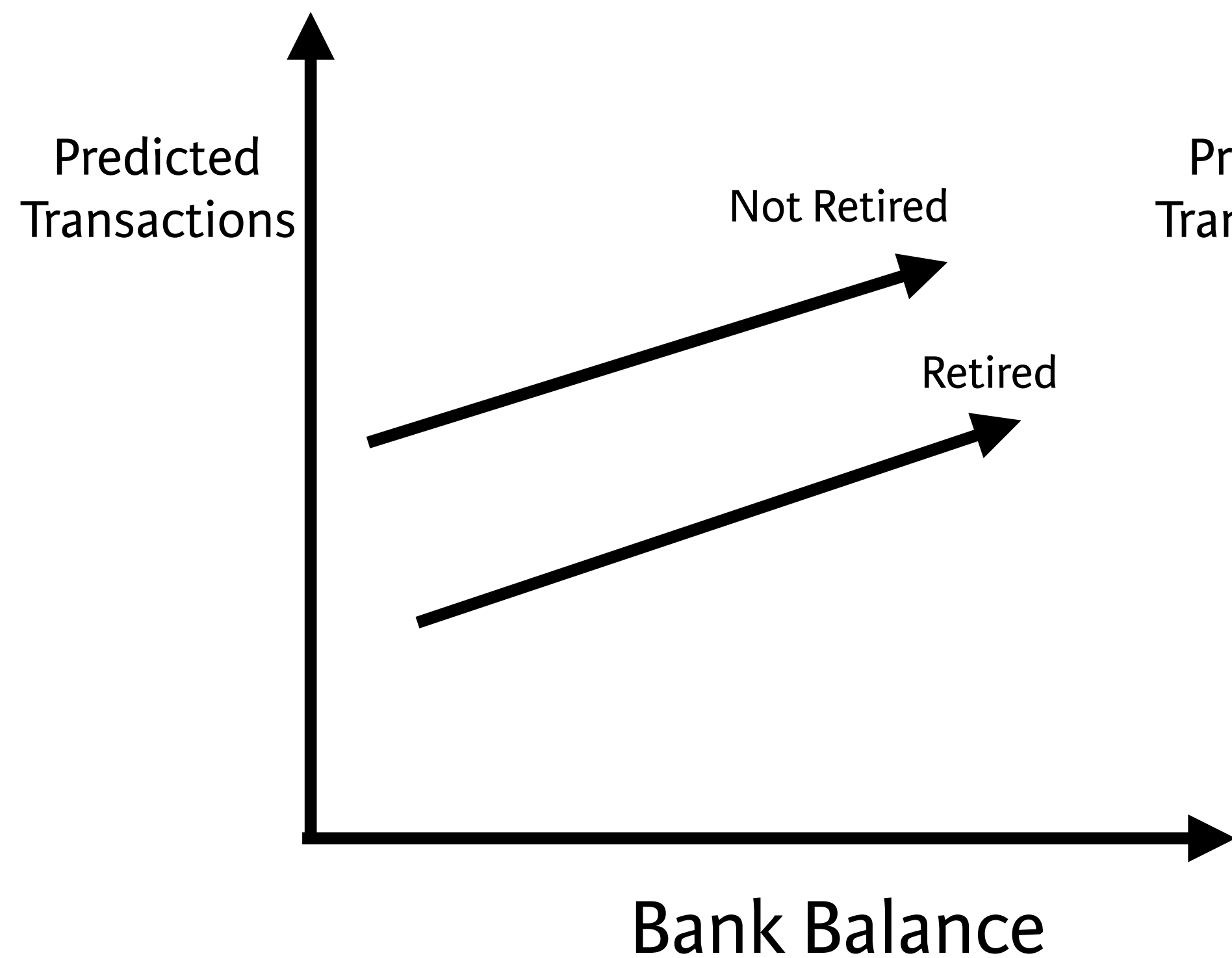
# Example as seen by linear regression



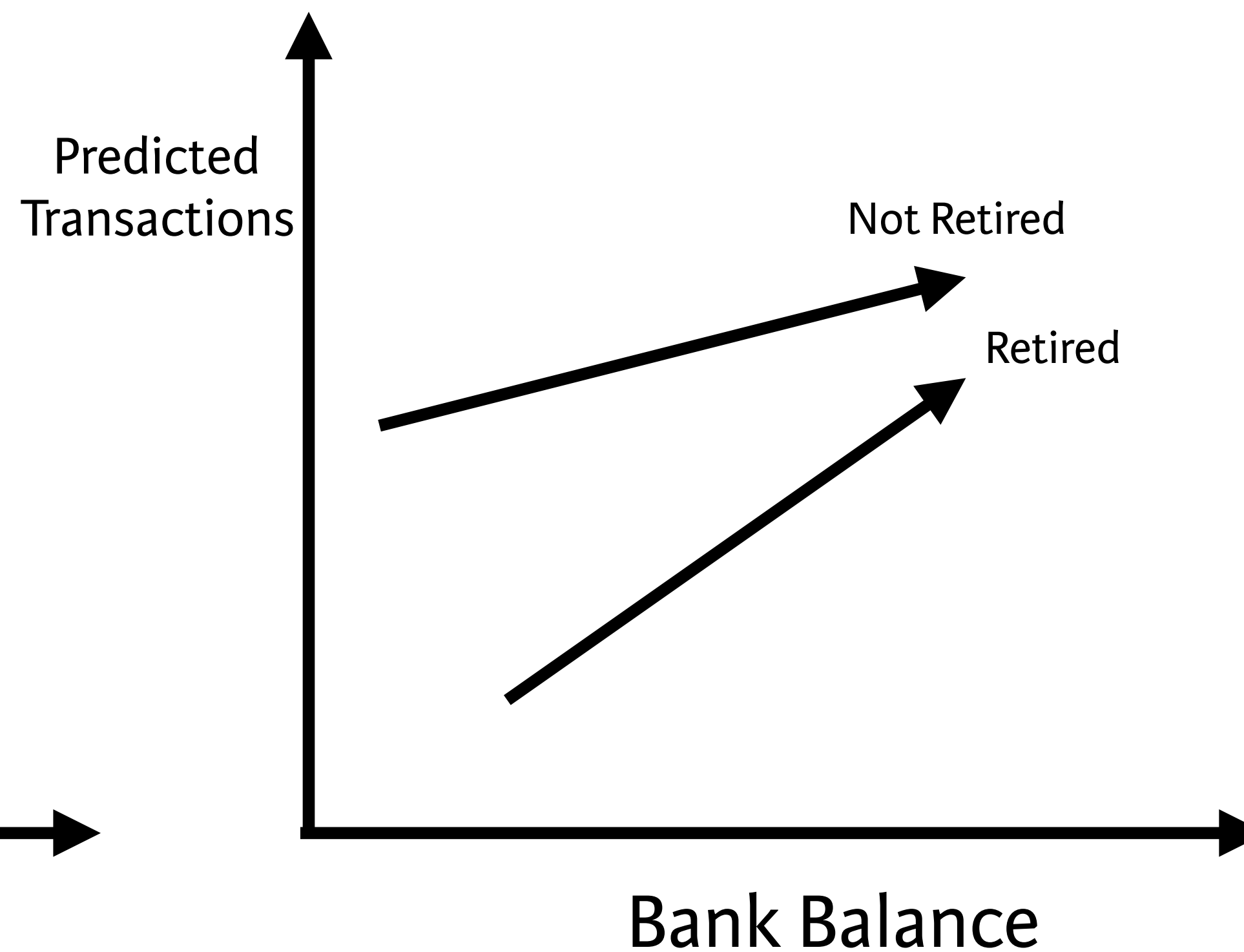


# Example as seen by linear regression

Model with no interactions



Model with interactions



# Interactions

- Neural networks account for interactions really well
- Deep learning uses especially powerful neural networks
  - Text
  - Images
  - Videos
  - Audio
  - Source code

# Course structure

- First two chapters focus on conceptual knowledge
  - Debug and tune deep learning models on conventional prediction problems
  - Lay the foundation for progressing towards modern applications
- This will pay off in the third and fourth chapters



# Build deep learning models with keras

```
In [1]: import numpy as np
```

```
In [2]: from keras.layers import Dense
```

```
In [3]: from keras.models import Sequential
```

```
In [4]: predictors = np.loadtxt('predictors_data.csv', delimiter=',')
```

```
In [5]: n_cols = predictors.shape[1]
```

```
In [6]: model = Sequential()
```

```
In [7]: model.add(Dense(100, activation='relu', input_shape = (n_cols,)))
```

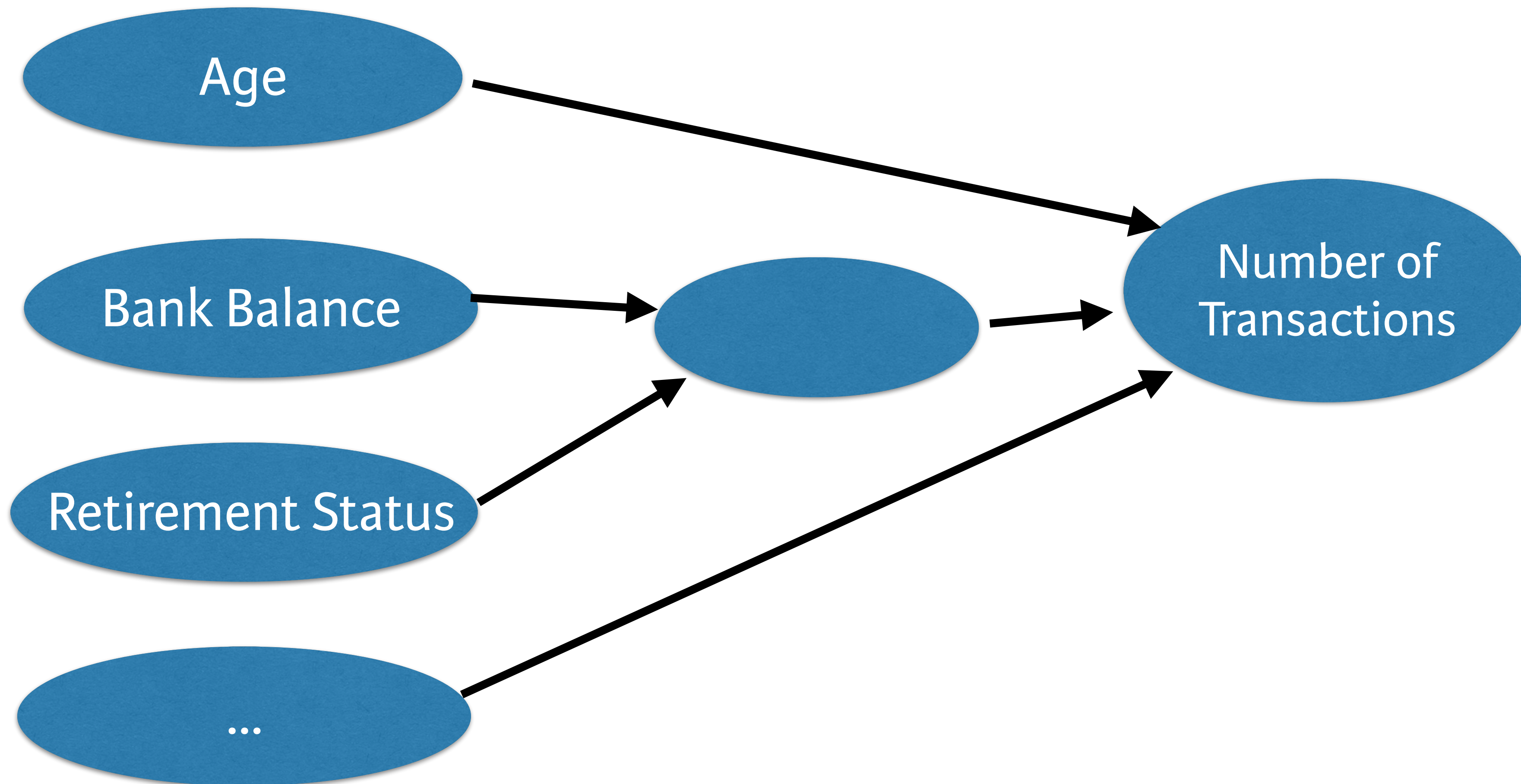
```
In [8]: model.add(Dense(100, activation='relu'))
```

```
In [9]: model.add(Dense(1))
```





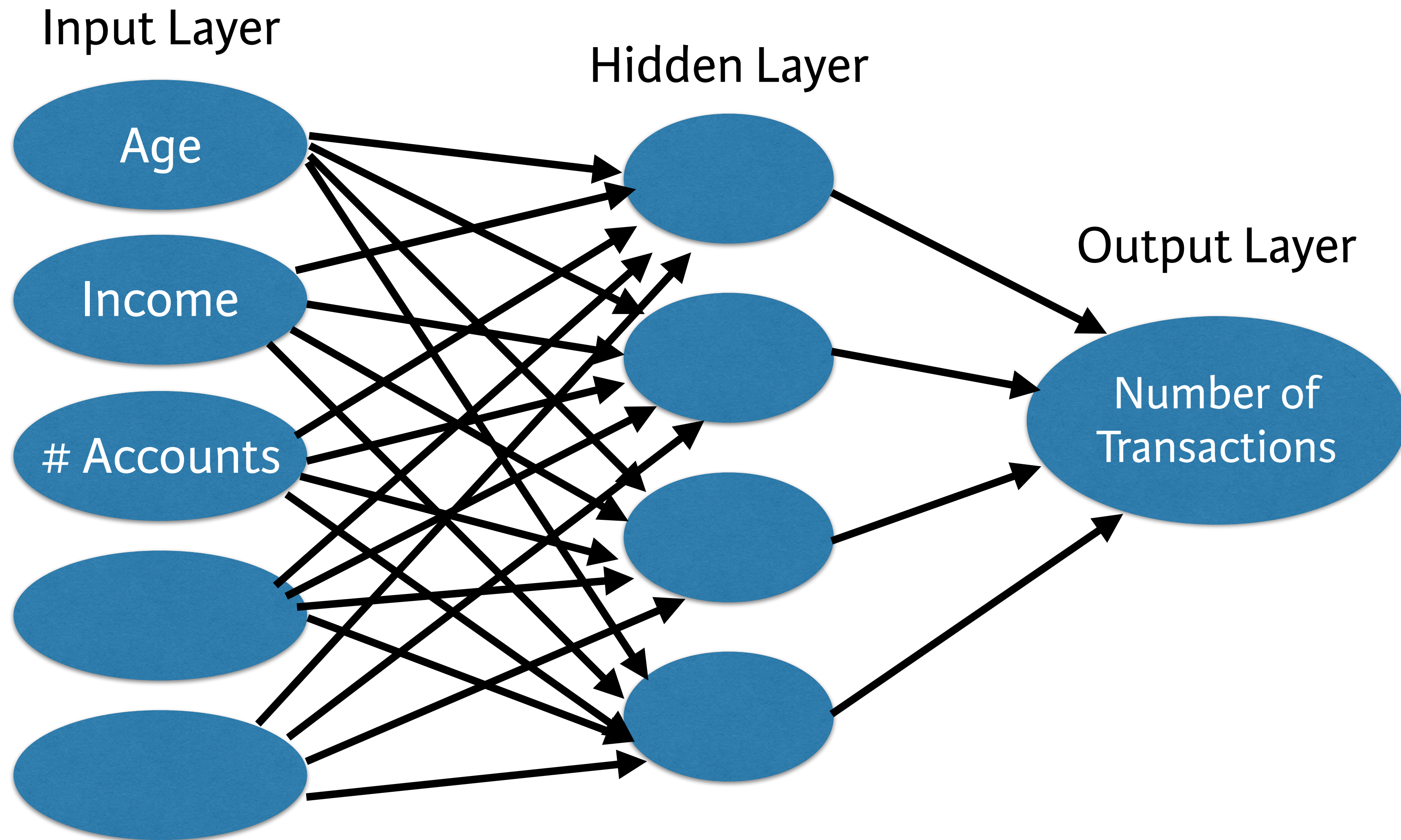
# Deep learning models capture interactions







# Interactions in neural network





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**Let's practice!**



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# Forward propagation

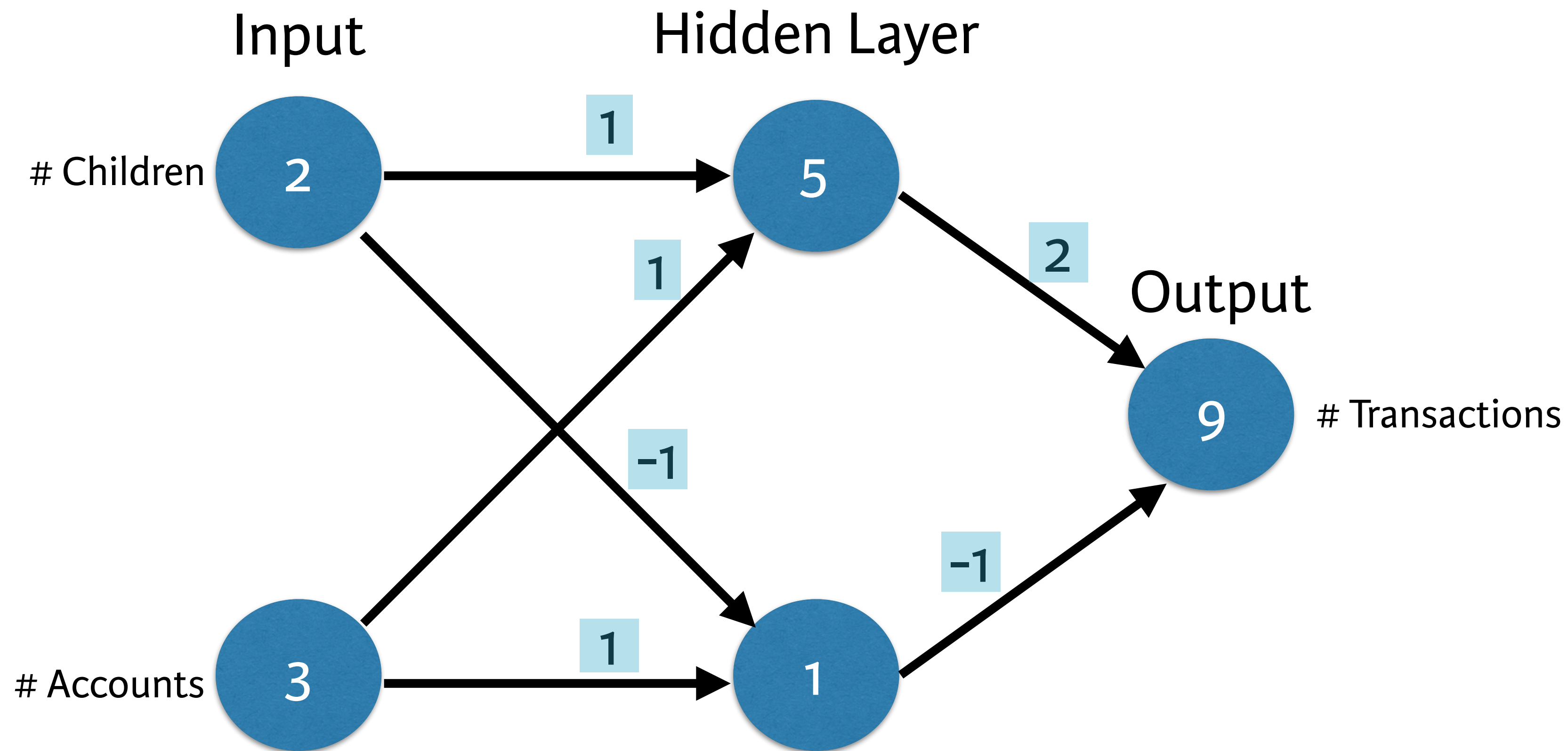


# Bank transactions example

- Make predictions based on:
  - Number of children
  - Number of existing accounts



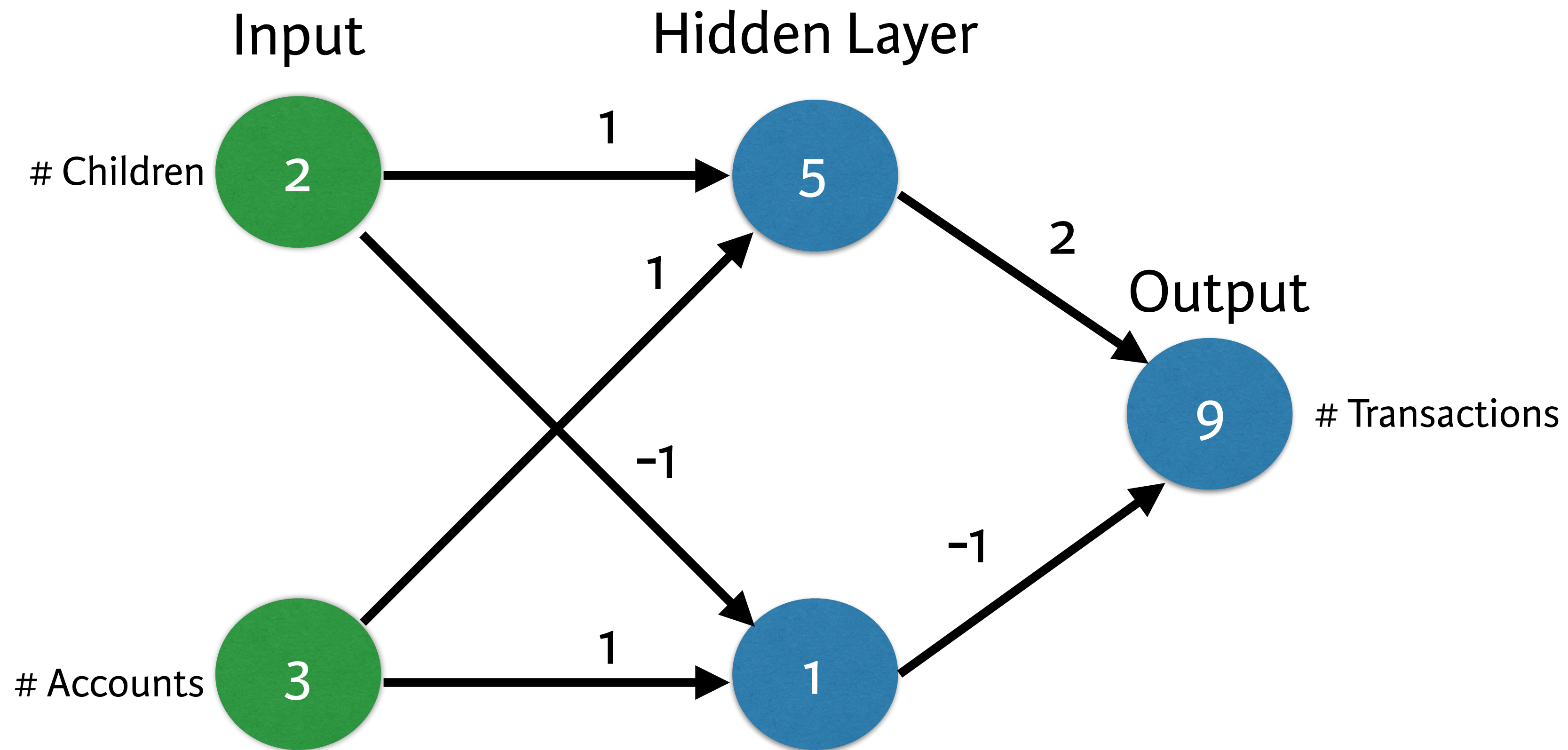
# Forward propagation





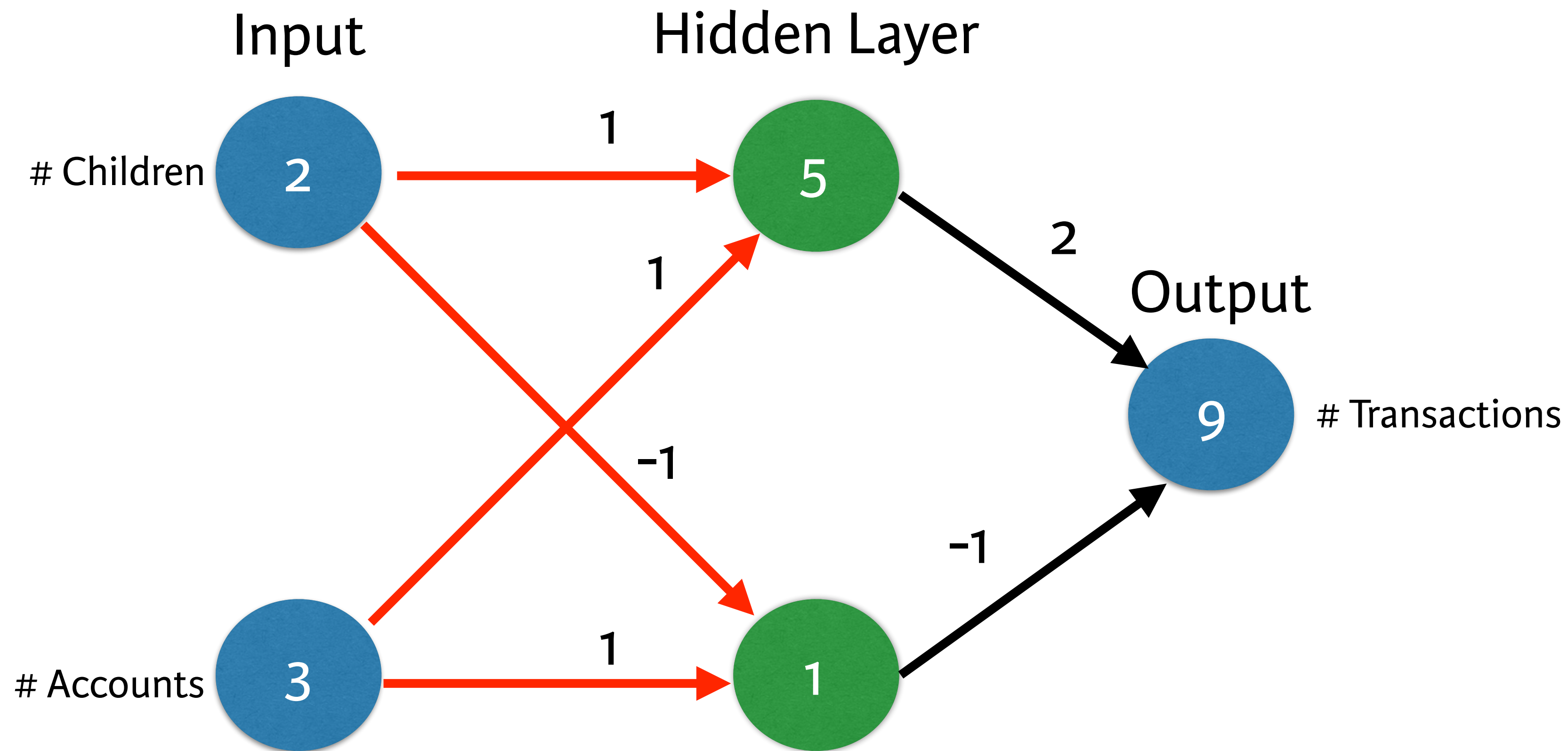


# Forward propagation



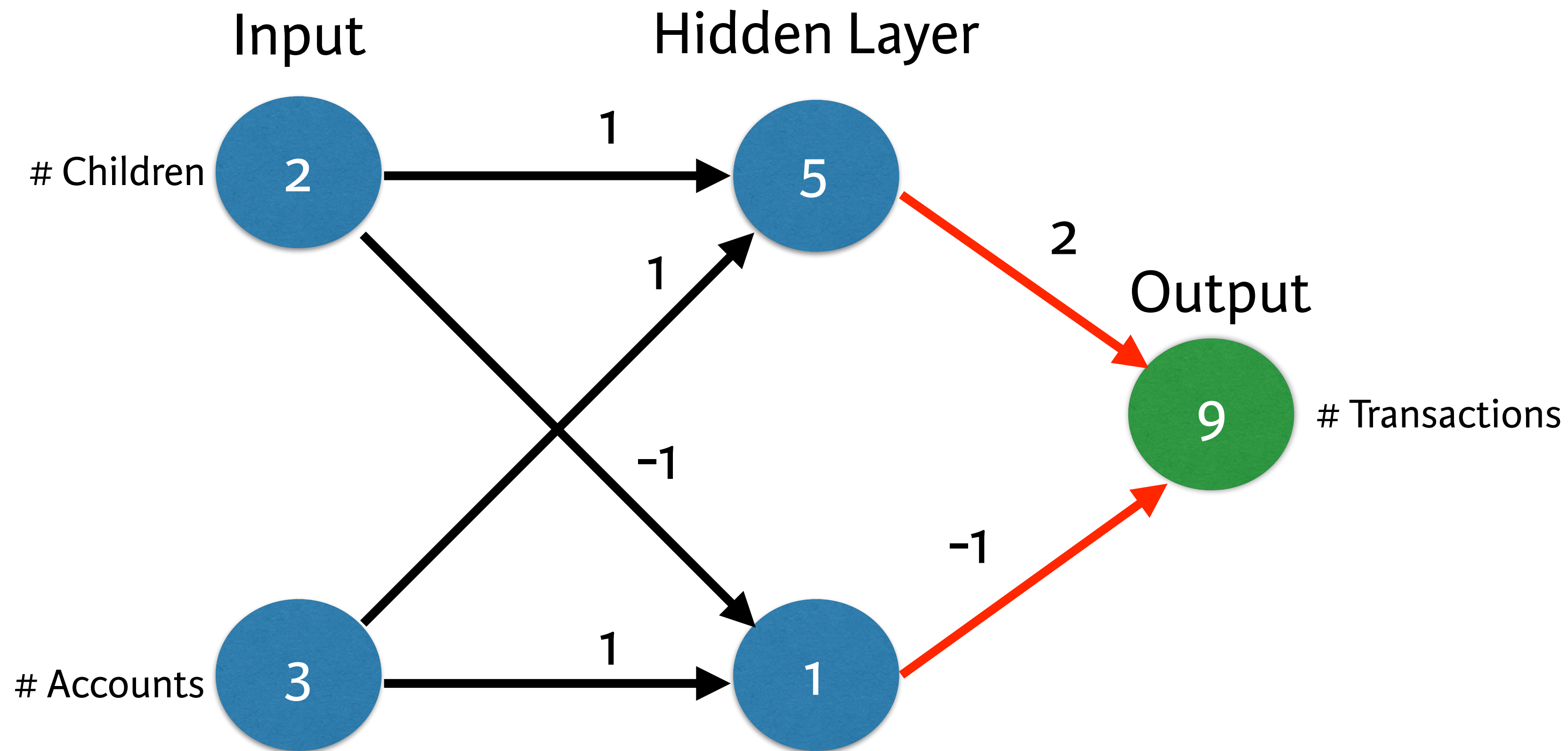


# Forward propagation





# Forward propagation





# Forward propagation

- Multiply - add process
- Dot product
- Forward propagation for one data point at a time
- Output is the prediction for that data point



# Forward propagation code

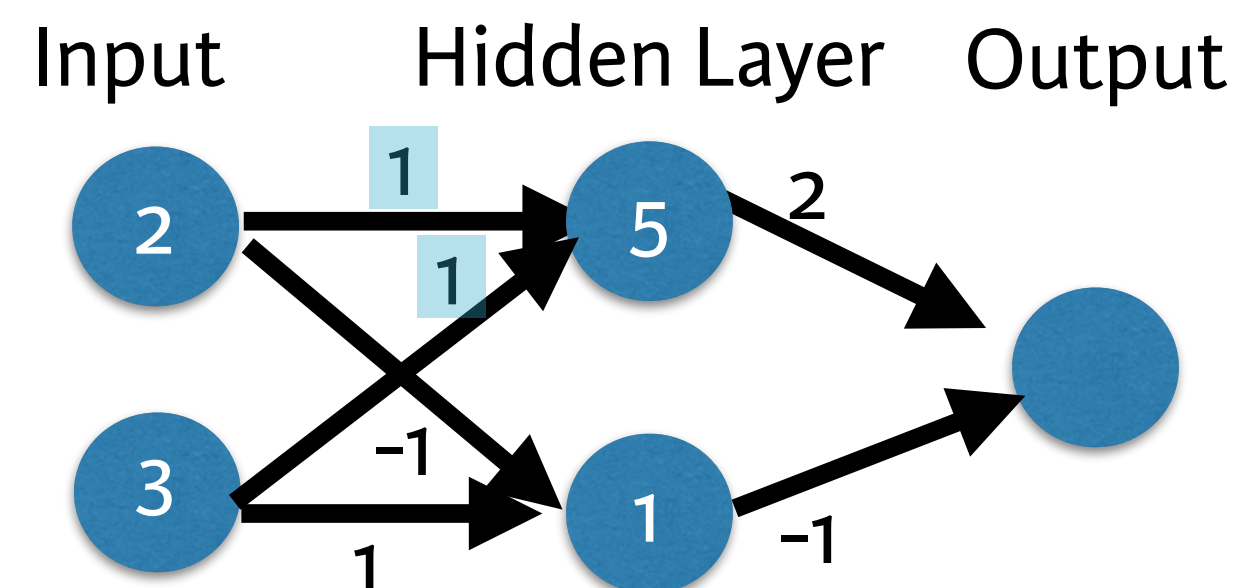
```
In [1]: import numpy as np

In [2]: input_data = np.array([2, 3])

In [3]: weights = {'node_0': np.array([1, 1]),
...:               'node_1': np.array([-1, 1]),
...:               'output': np.array([2, -1])}

In [4]: node_0_value = (input_data * weights['node_0']).sum()

In [5]: node_1_value = (input_data * weights['node_1']).sum()
```







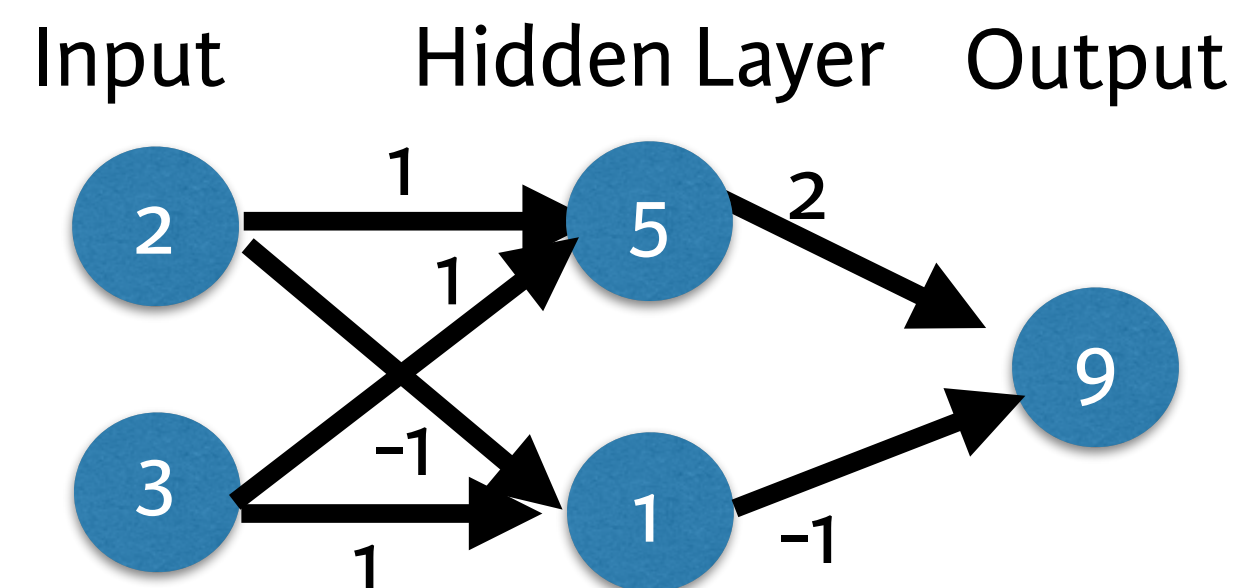
# Forward propagation code

```
In [6]: hidden_layer_values = np.array([node_0_value, node_1_value])
```

```
In [7]: print(hidden_layer_values)  
[5, 1]
```

```
In [8]: output = (hidden_layer_values * weights['output']).sum()
```

```
In [9]: print(output)  
9
```





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**Let's practice!**

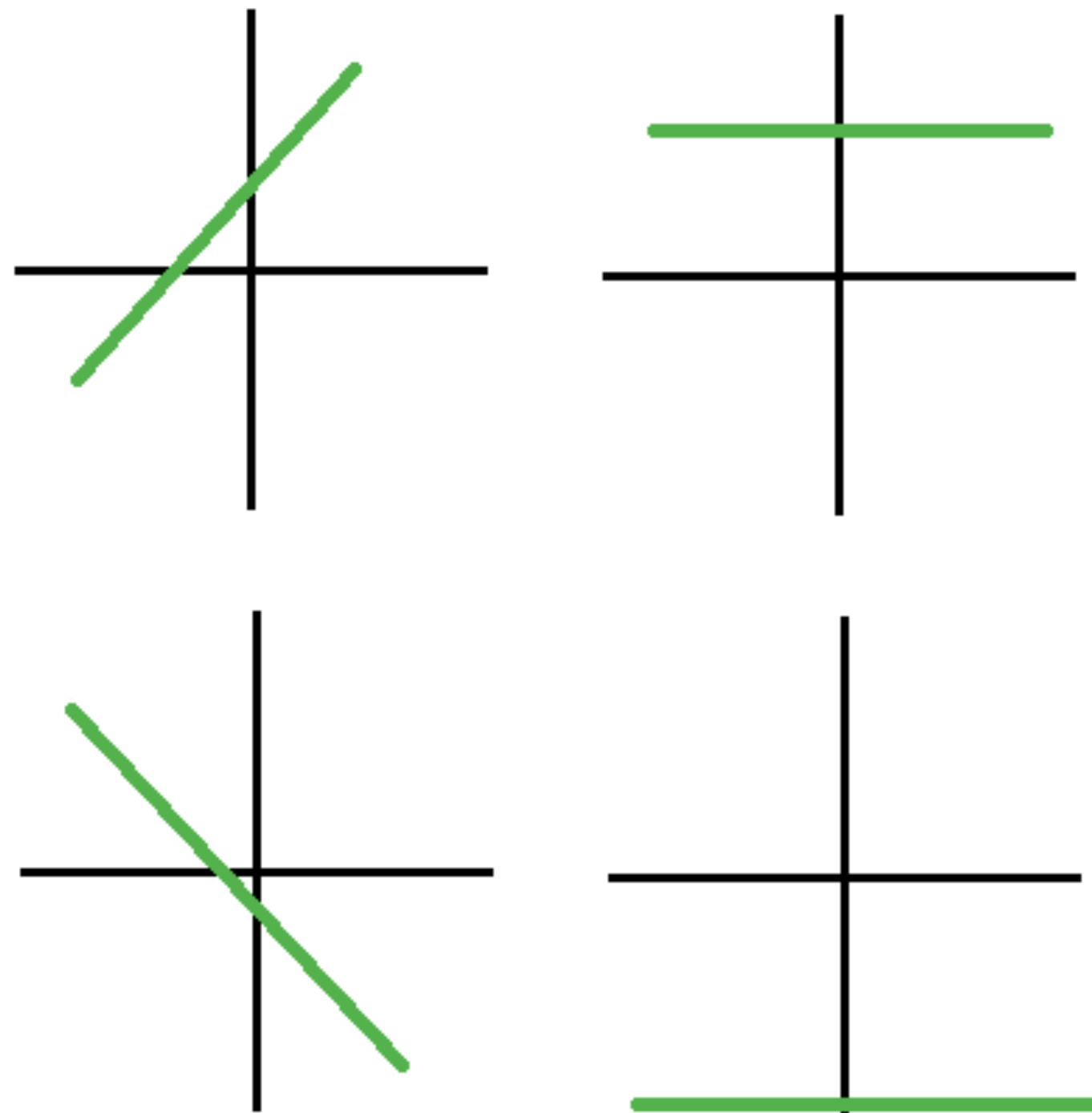


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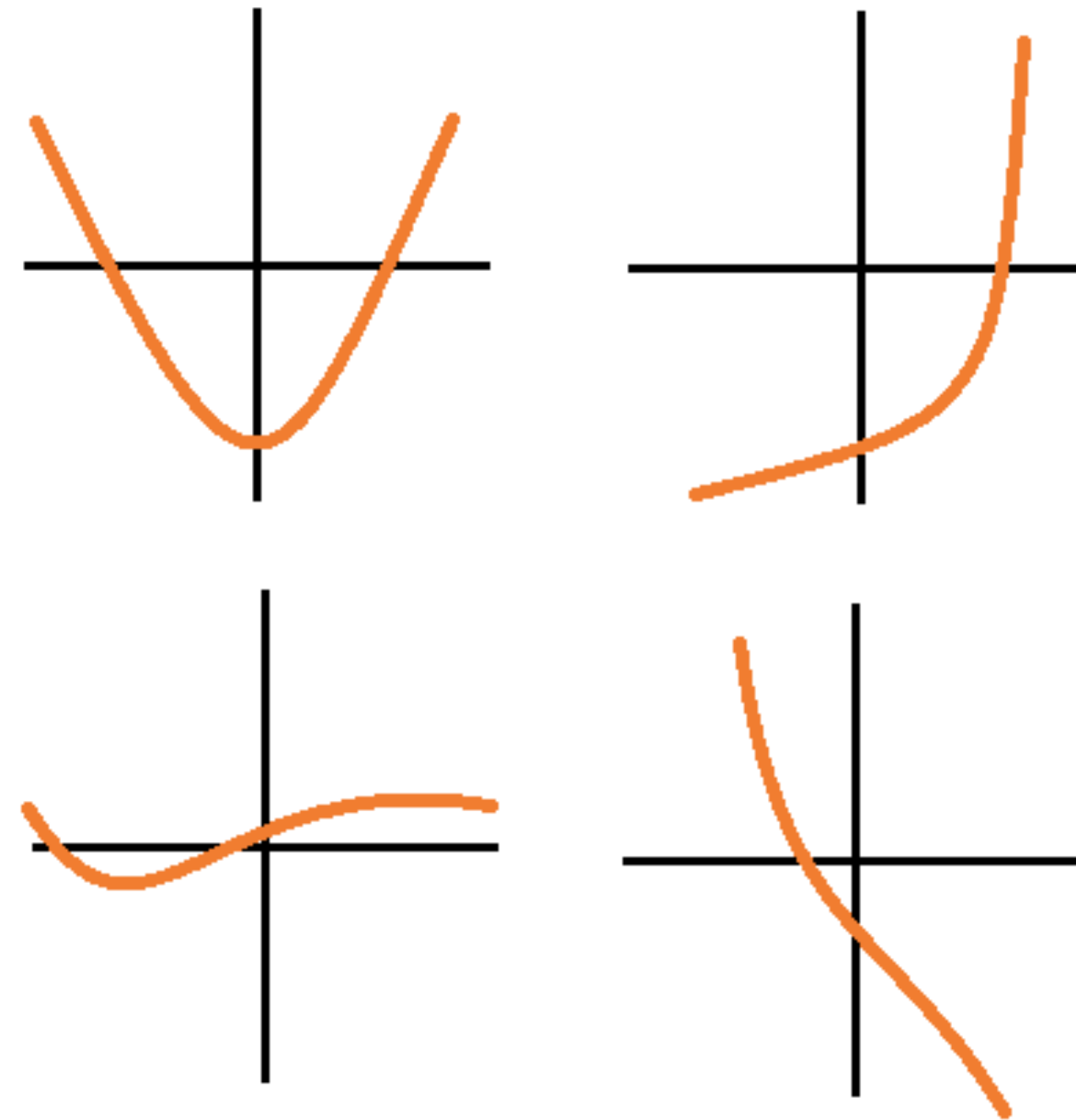
# Activation functions



# Linear vs Nonlinear Functions



Linear Functions



Nonlinear Functions

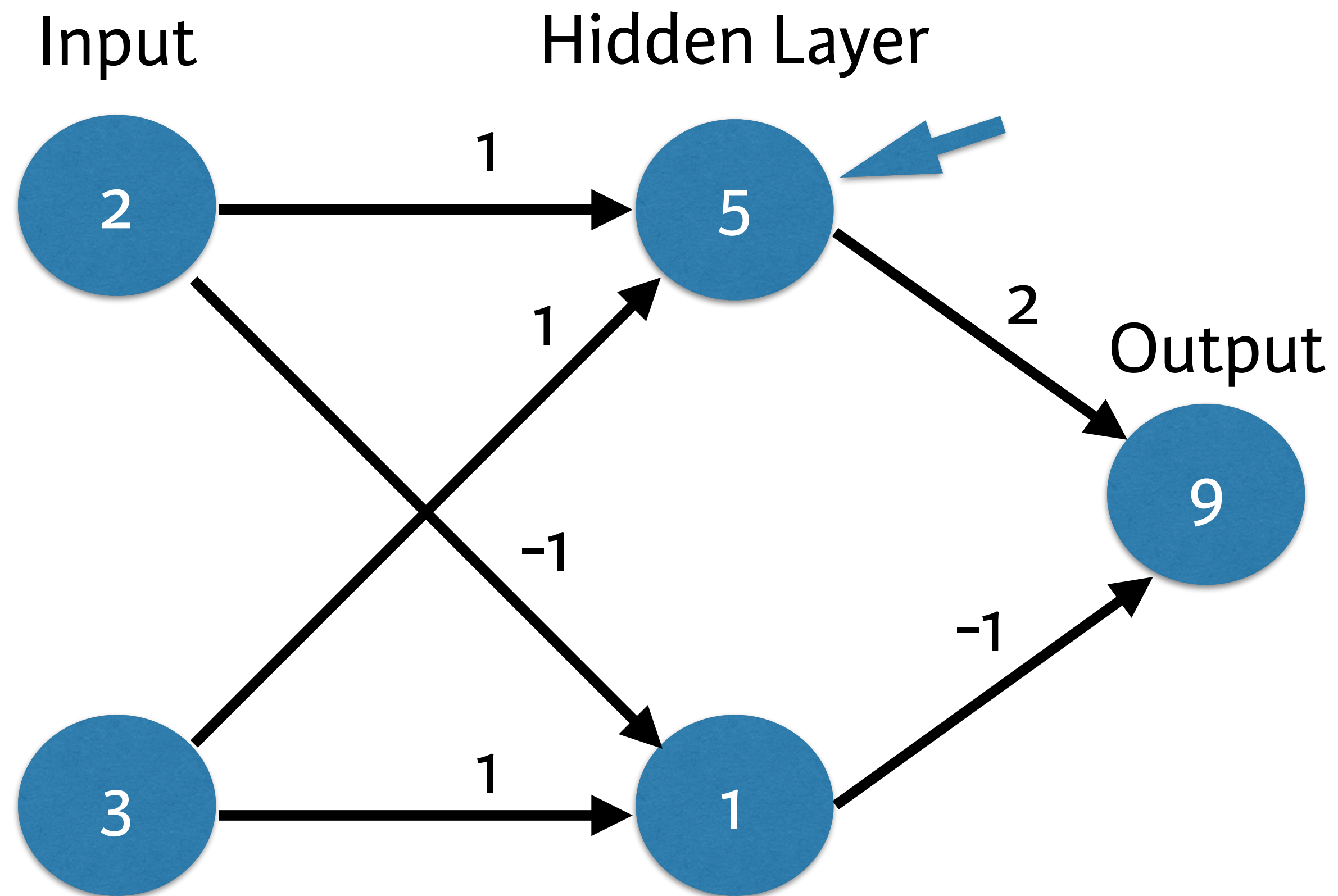
# Activation functions

- Applied to node inputs to produce node output



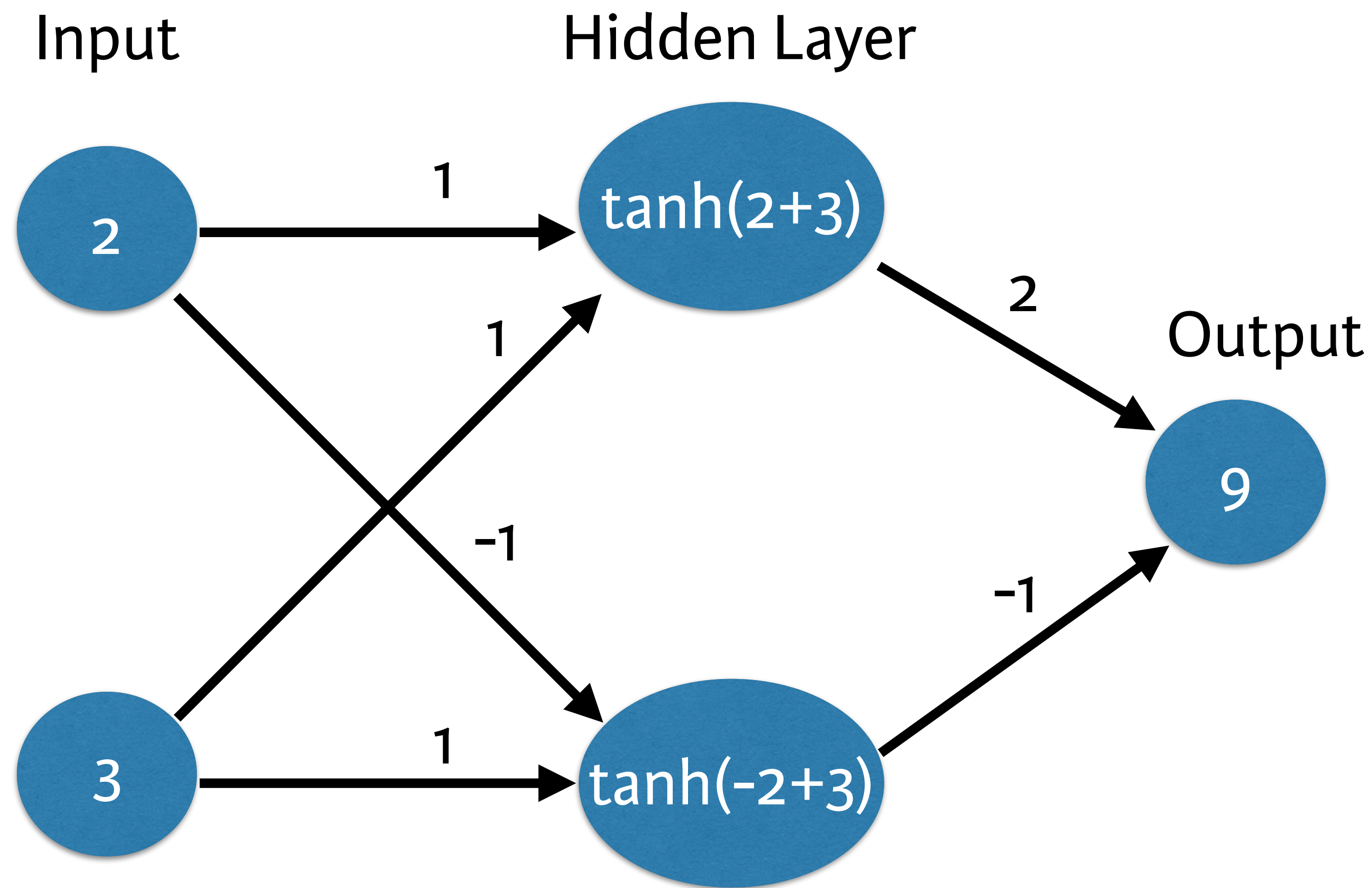


# Improving our neural network



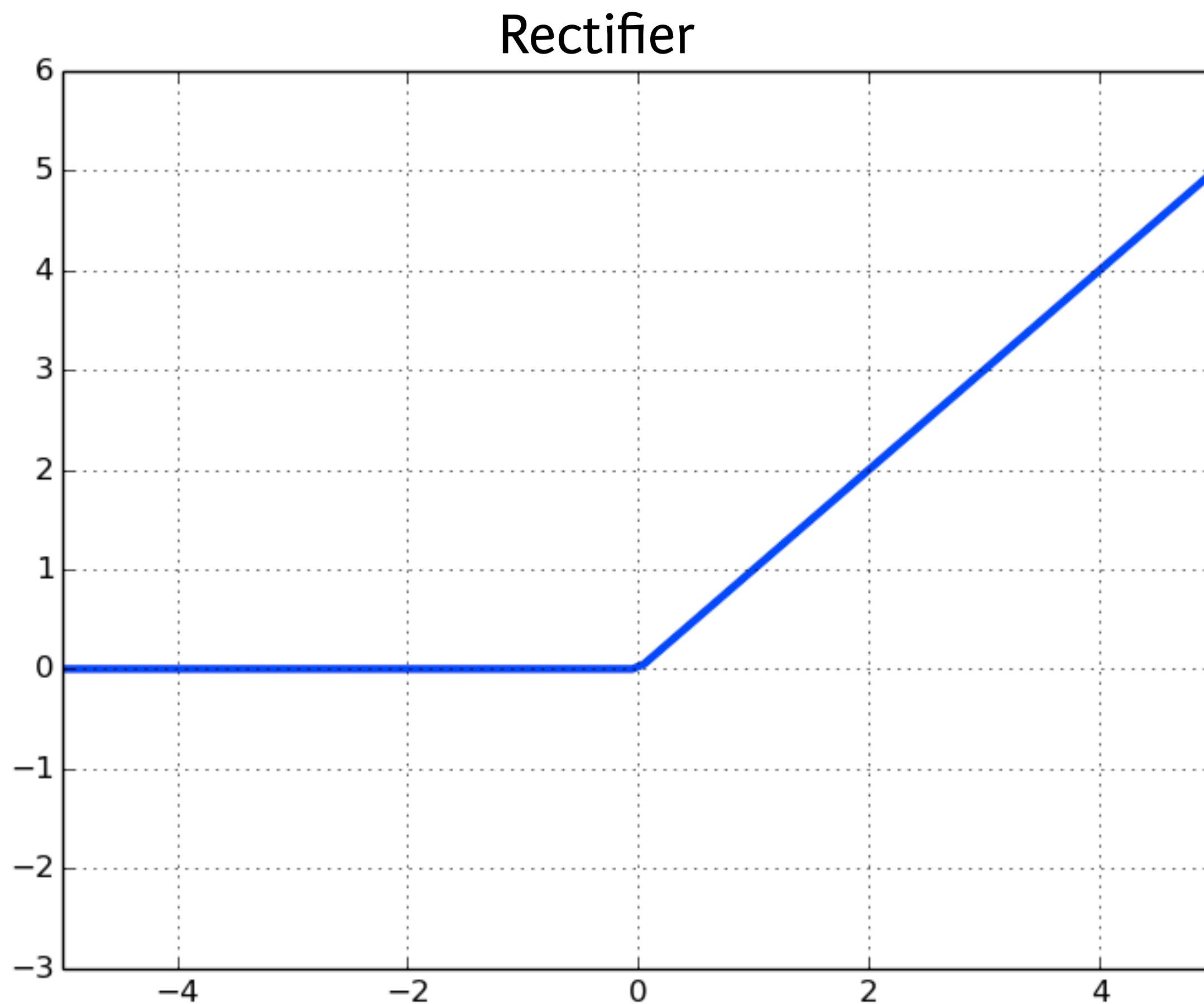


# Activation functions





# ReLU (Rectified Linear Activation)



$$ReLU(x) = \begin{cases} 0 & \text{if } x < 0 \\ x & \text{if } x \geq 0 \end{cases}$$



# Activation functions

```
In [1]: import numpy as np

In [2]: input_data = np.array([-1, 2])

In [3]: weights = {'node_0': np.array([3, 3]),
...:               'node_1': np.array([1, 5]),
...:               'output': np.array([2, -1])}

In [4]: node_0_input = (input_data * weights['node_0']).sum()

In [5]: node_0_output = np.tanh(node_0_input)

In [6]: node_1_input = (input_data * weights['node_1']).sum()

In [7]: node_1_output = np.tanh(node_1_input)

In [8]: hidden_layer_outputs = np.array([node_0_output, node_1_output])

In [9]: output = (hidden_layer_output * weights['output']).sum()

In [10]: print(output)
1.2382242525694254
```



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**Let's practice!**

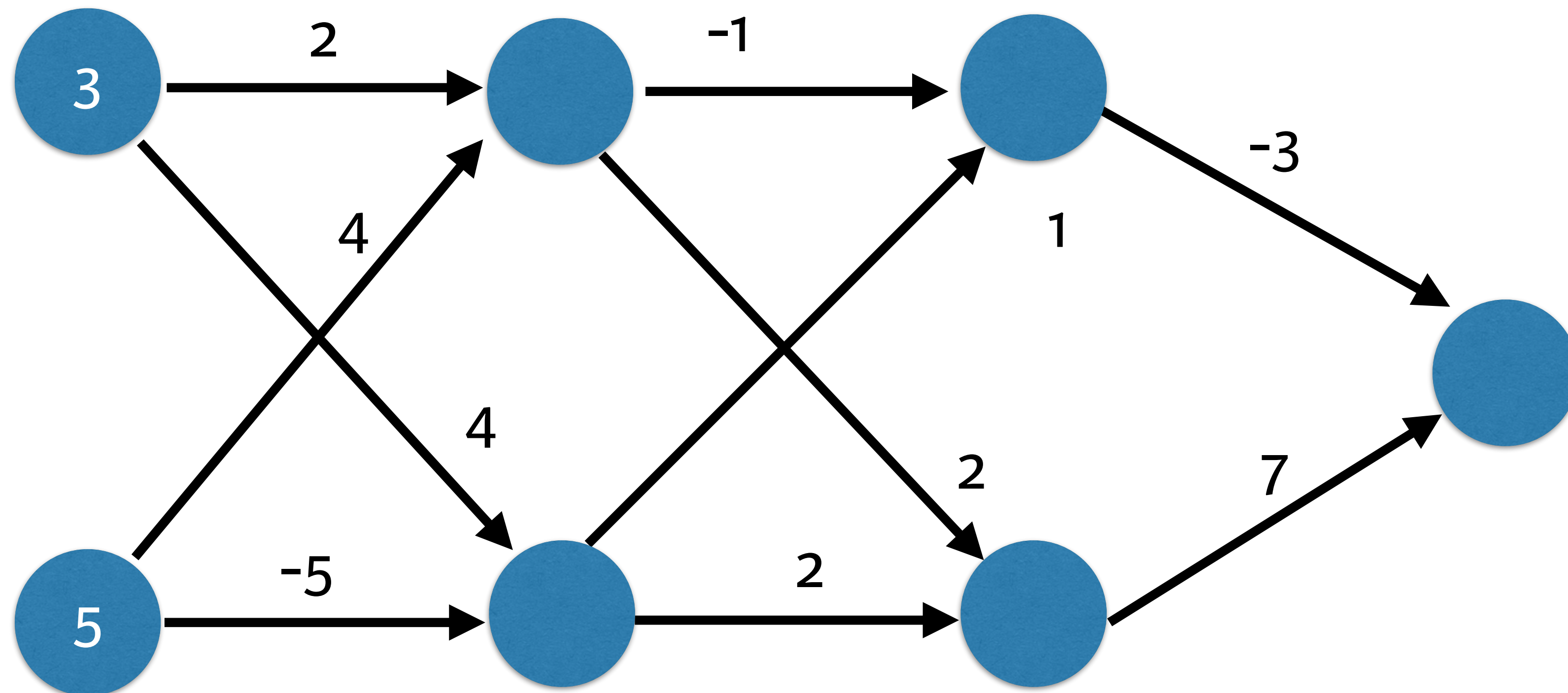




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# Deeper networks

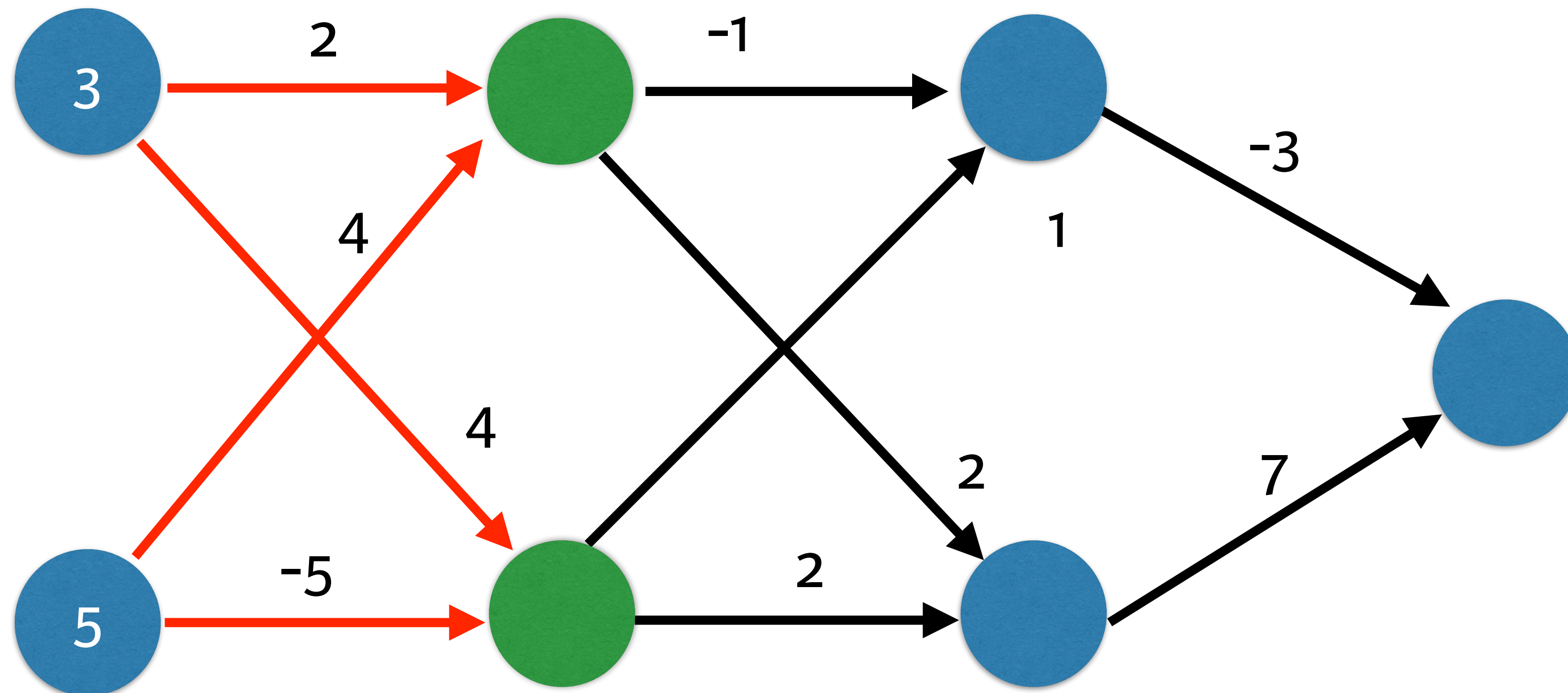
# Multiple hidden layers



Calculate with ReLU Activation Function

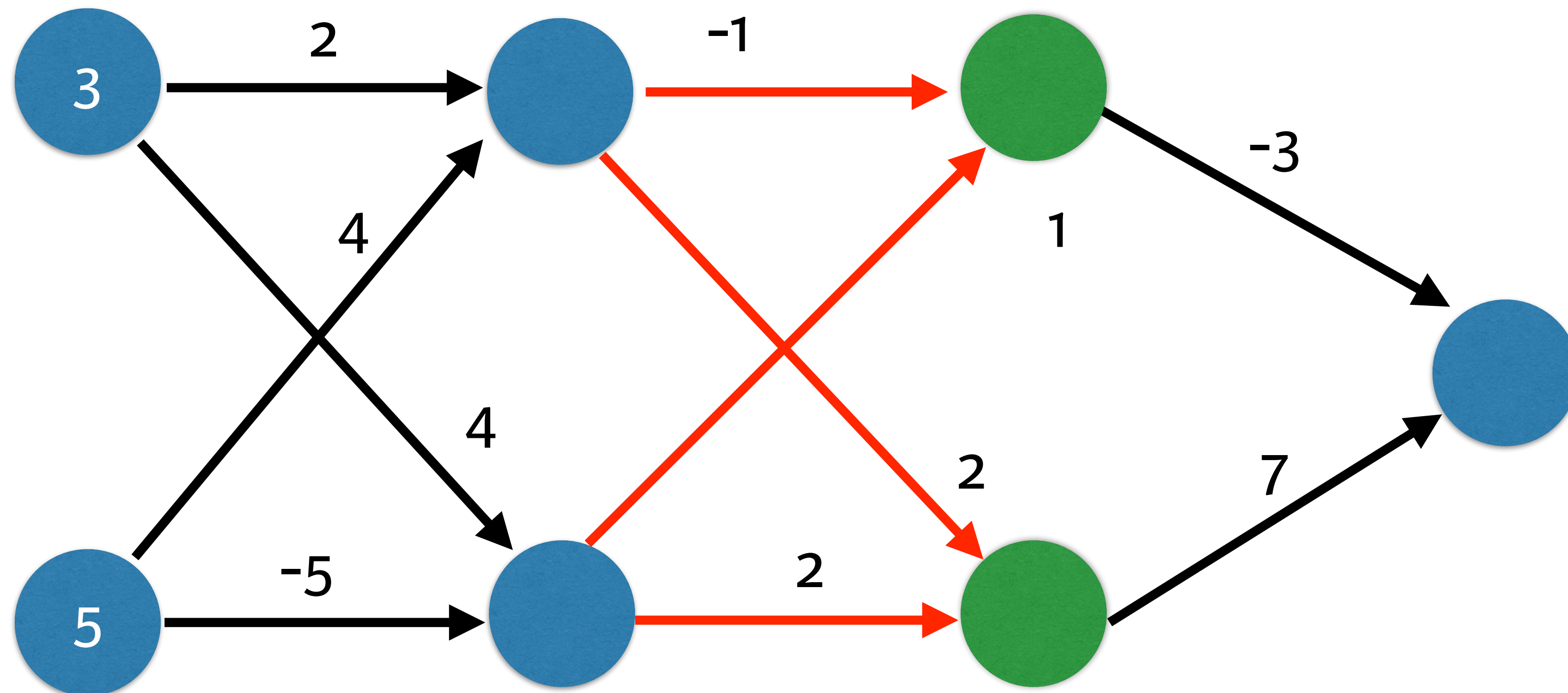


# Multiple hidden layers



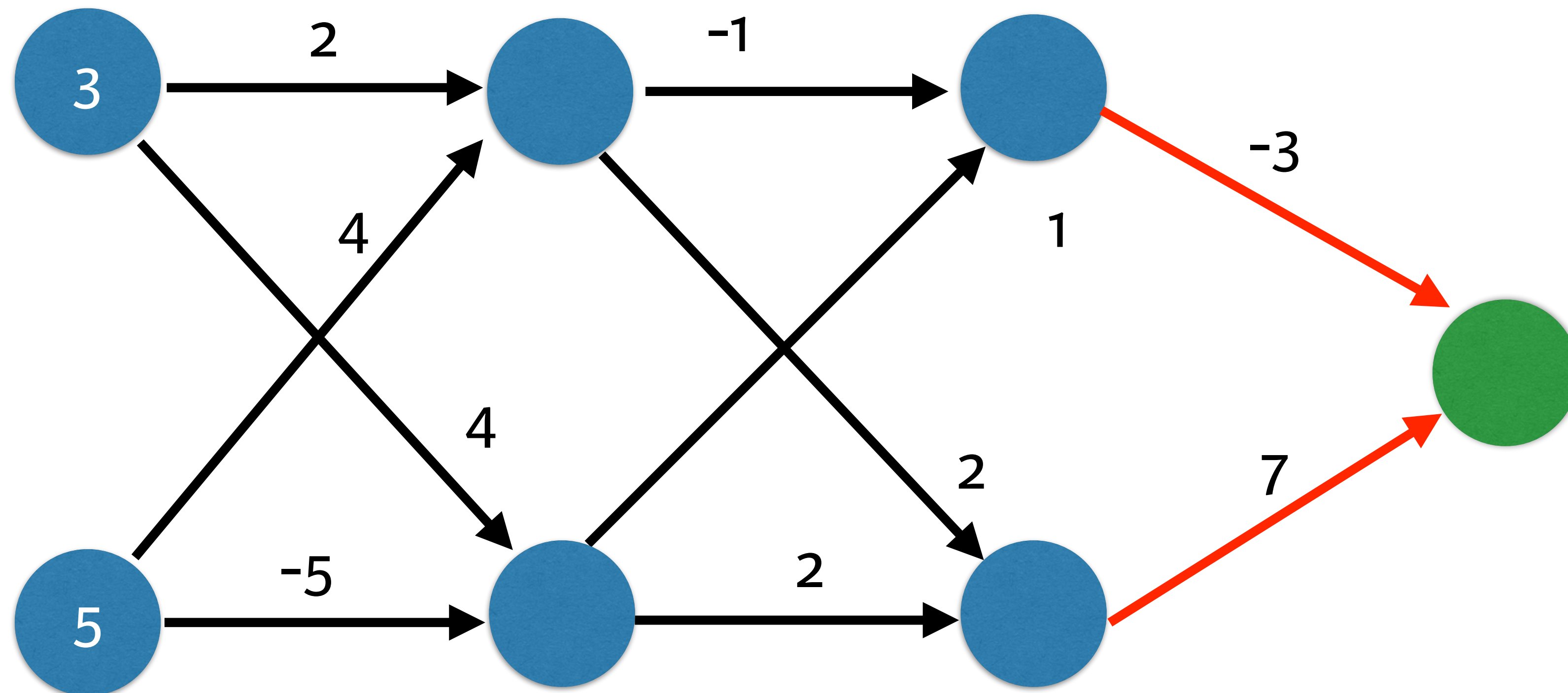
Calculate with ReLU Activation Function

# Multiple hidden layers



Calculate with ReLU Activation Function

# Multiple hidden layers

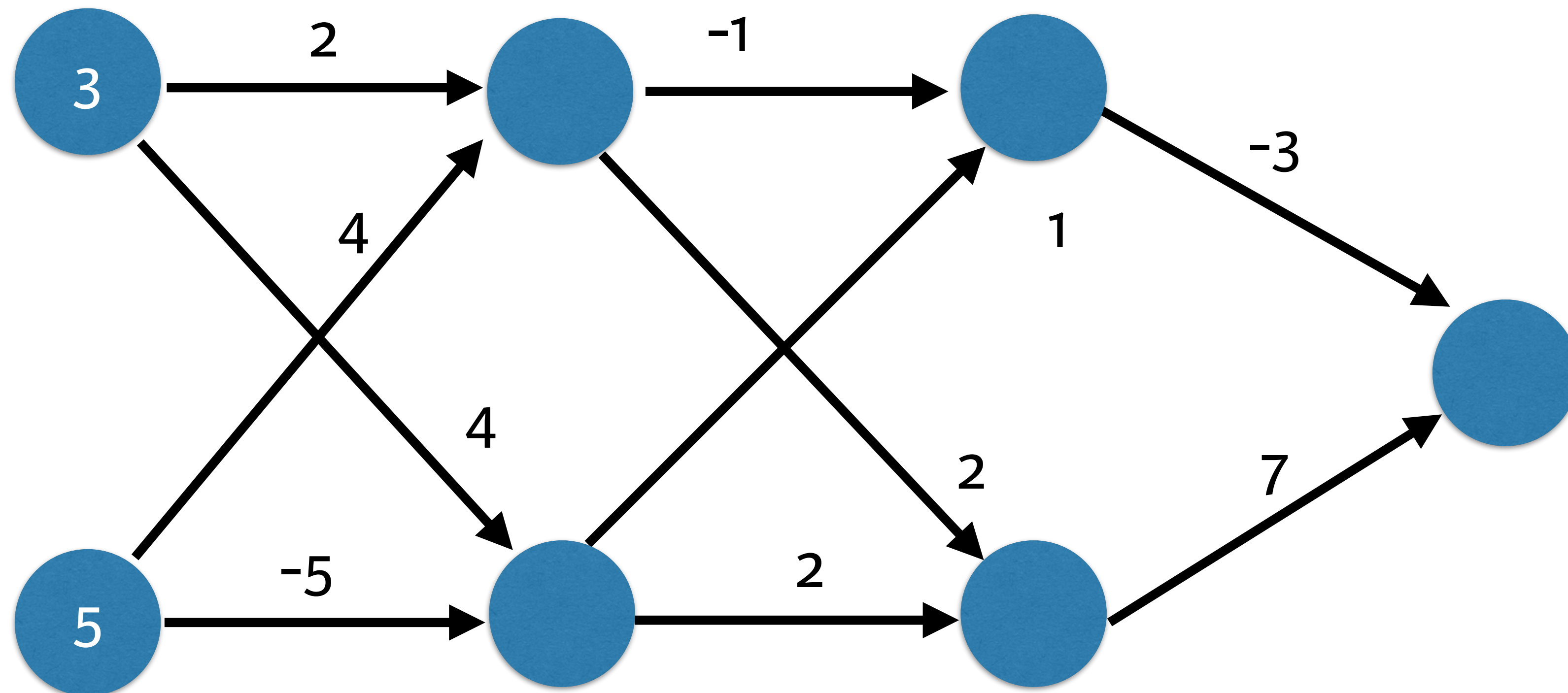


Calculate with ReLU Activation Function





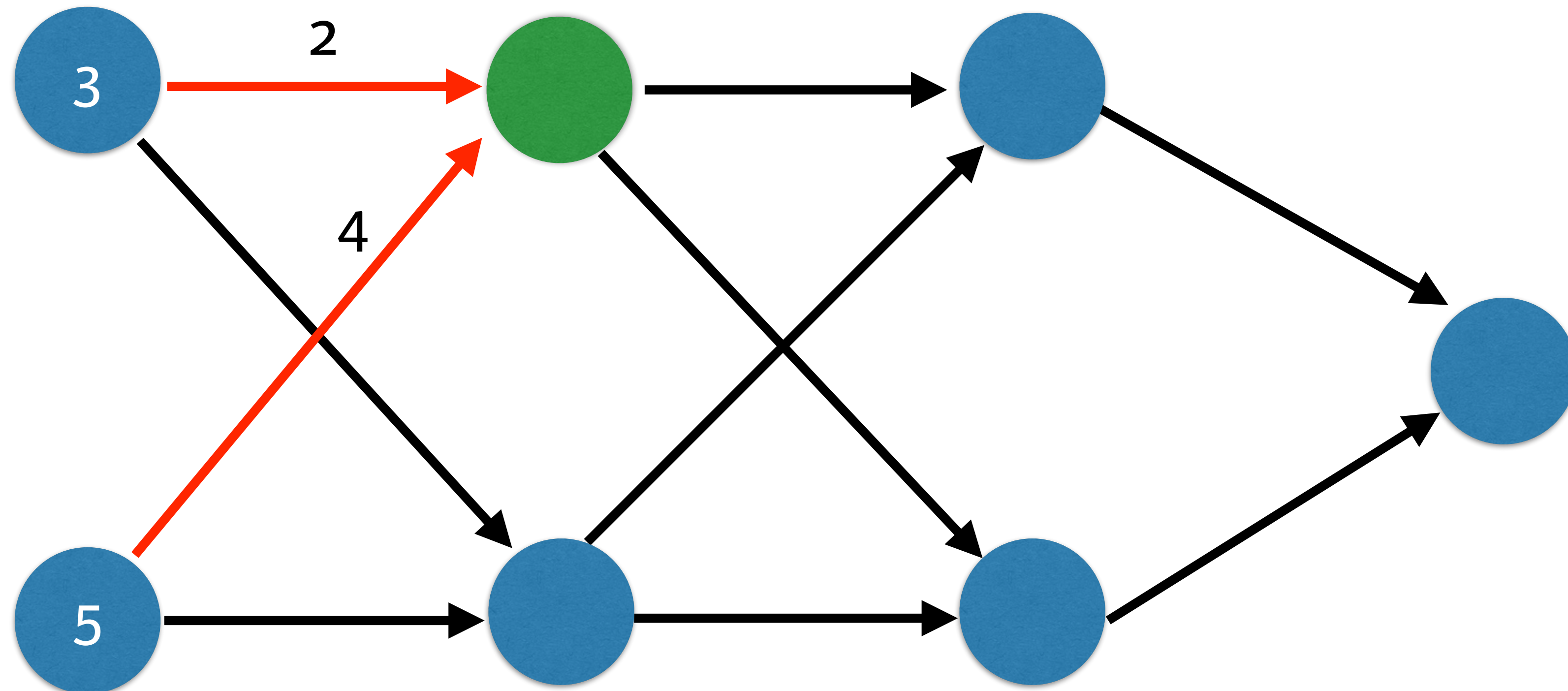
# Multiple hidden layers



Calculate with ReLU Activation Function



# Multiple hidden layers

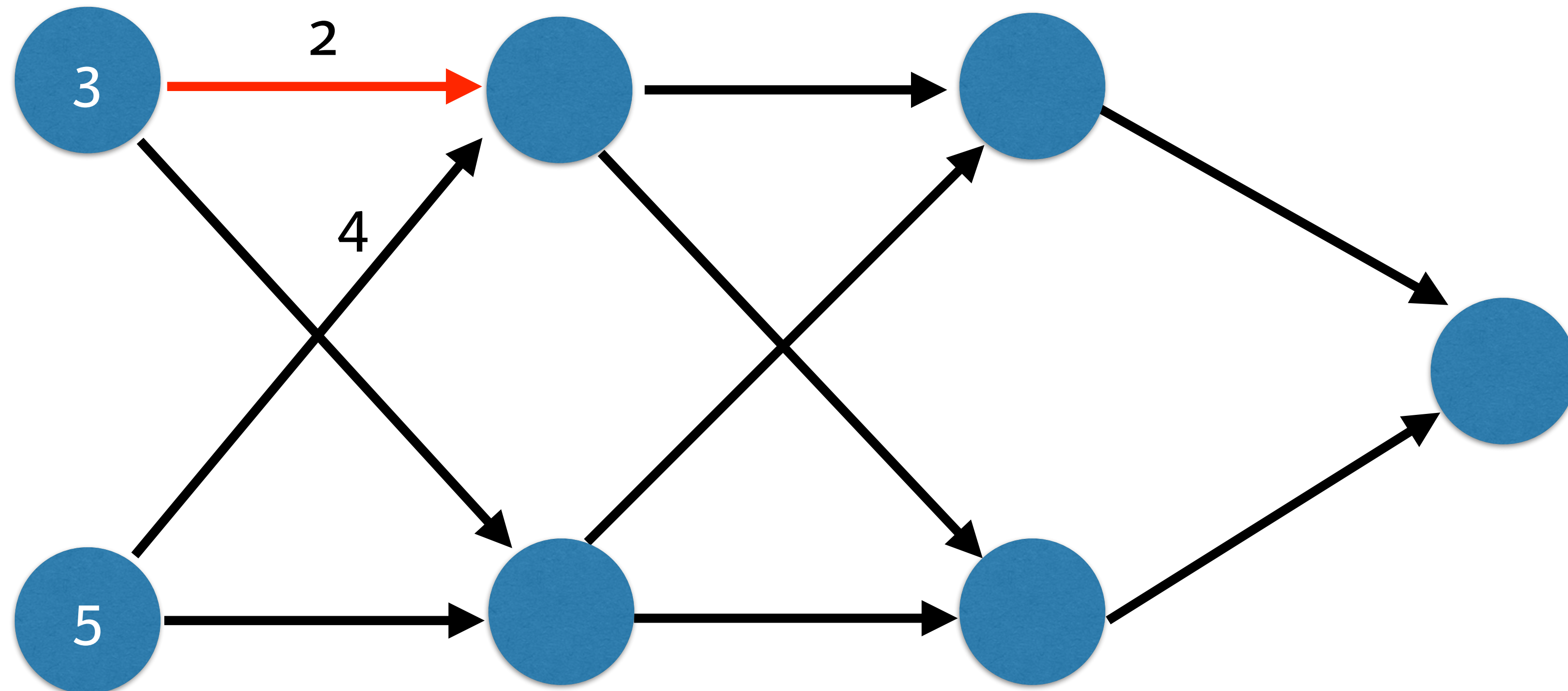


Calculate with ReLU Activation Function





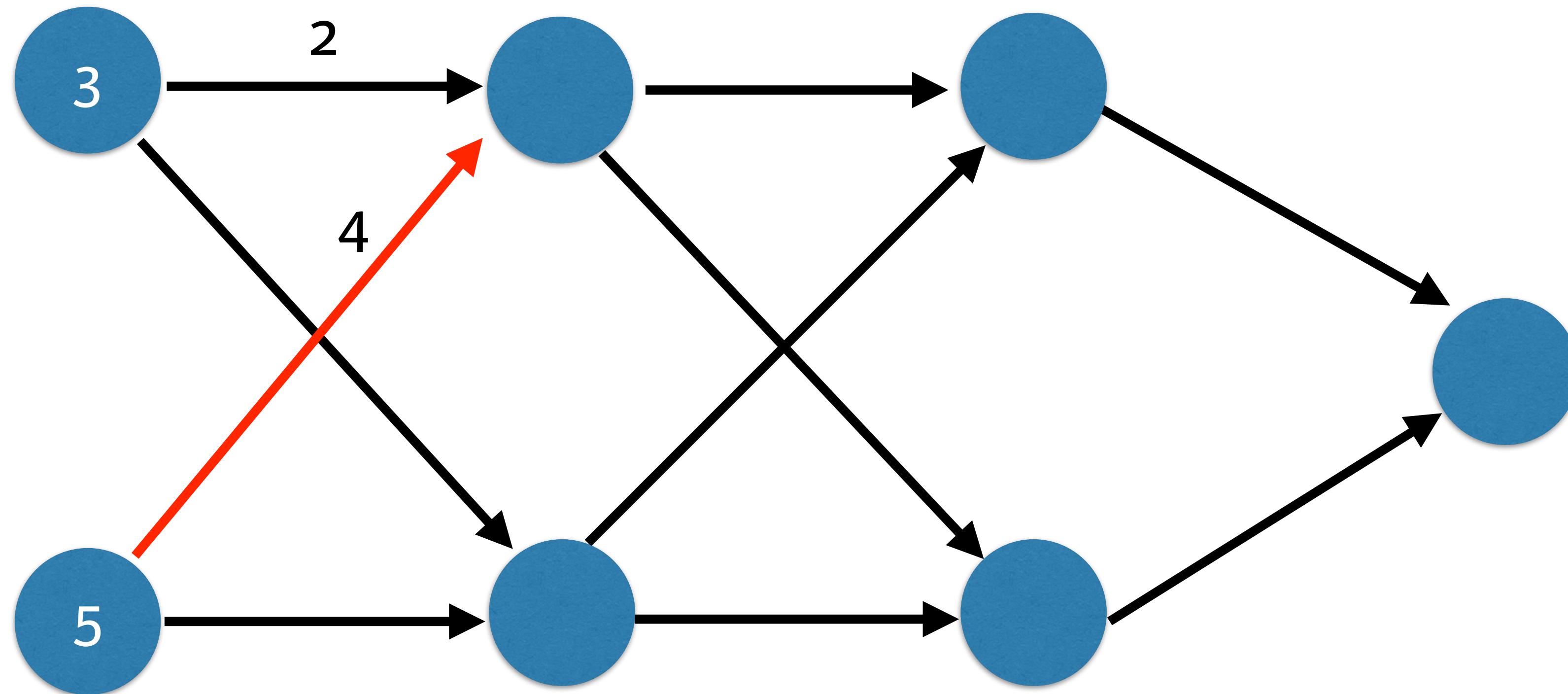
# Multiple hidden layers



Calculate with ReLU Activation Function



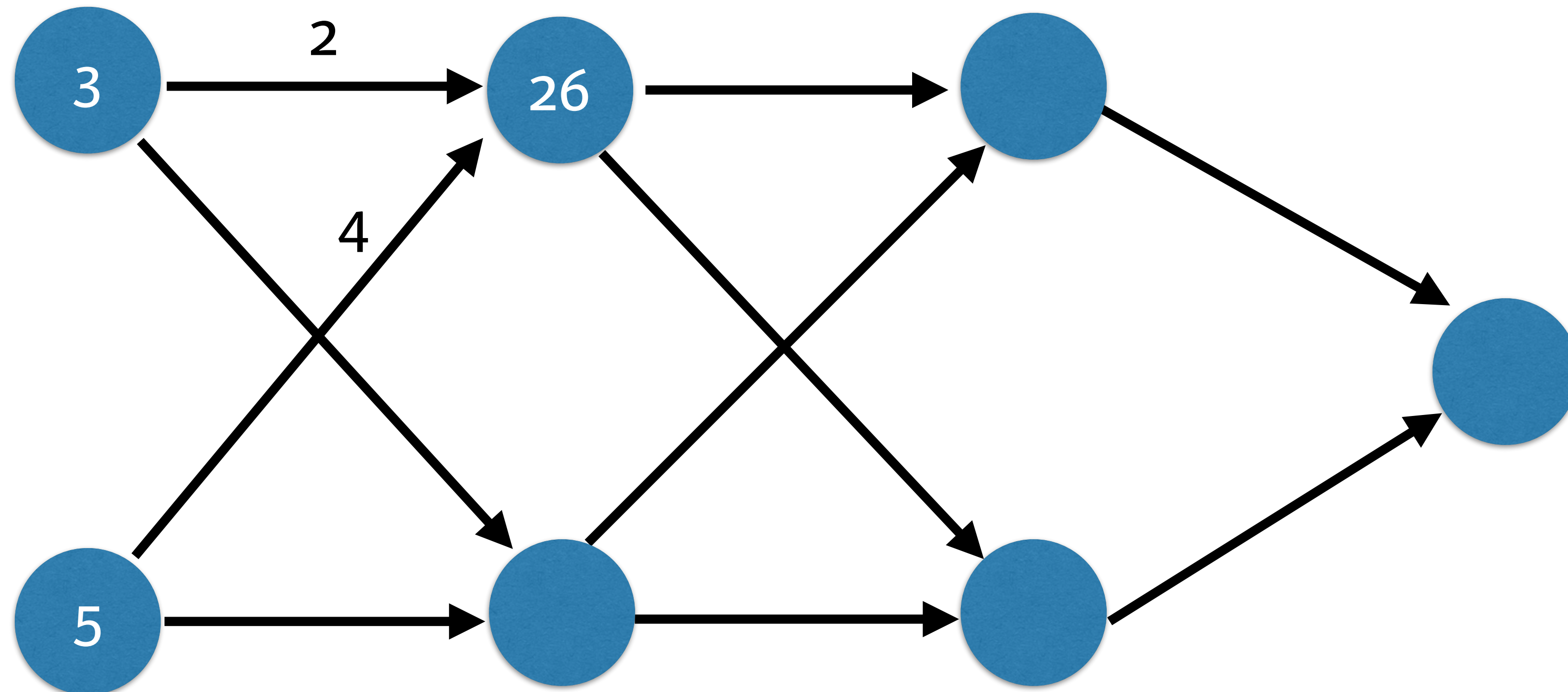
# Multiple hidden layers



Calculate with ReLU Activation Function



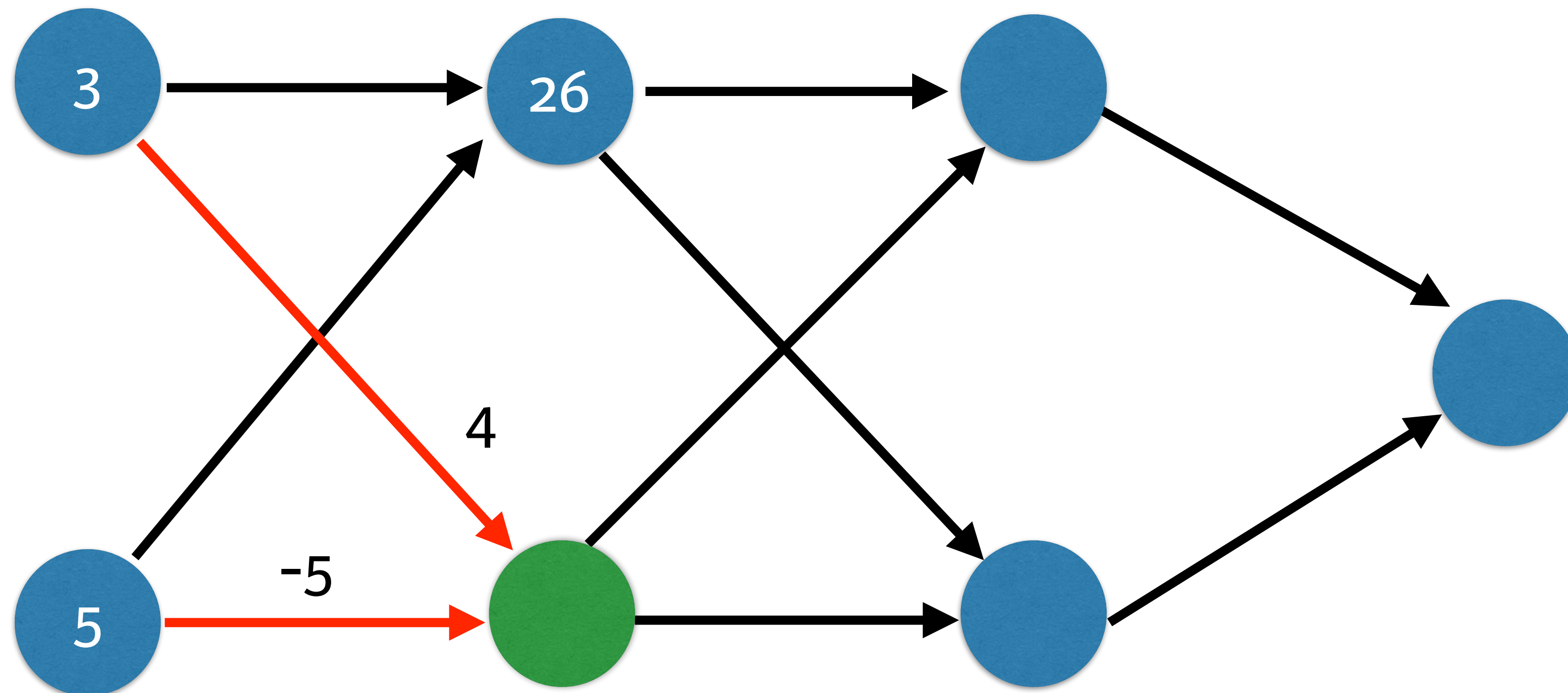
# Multiple hidden layers



Calculate with ReLU Activation Function

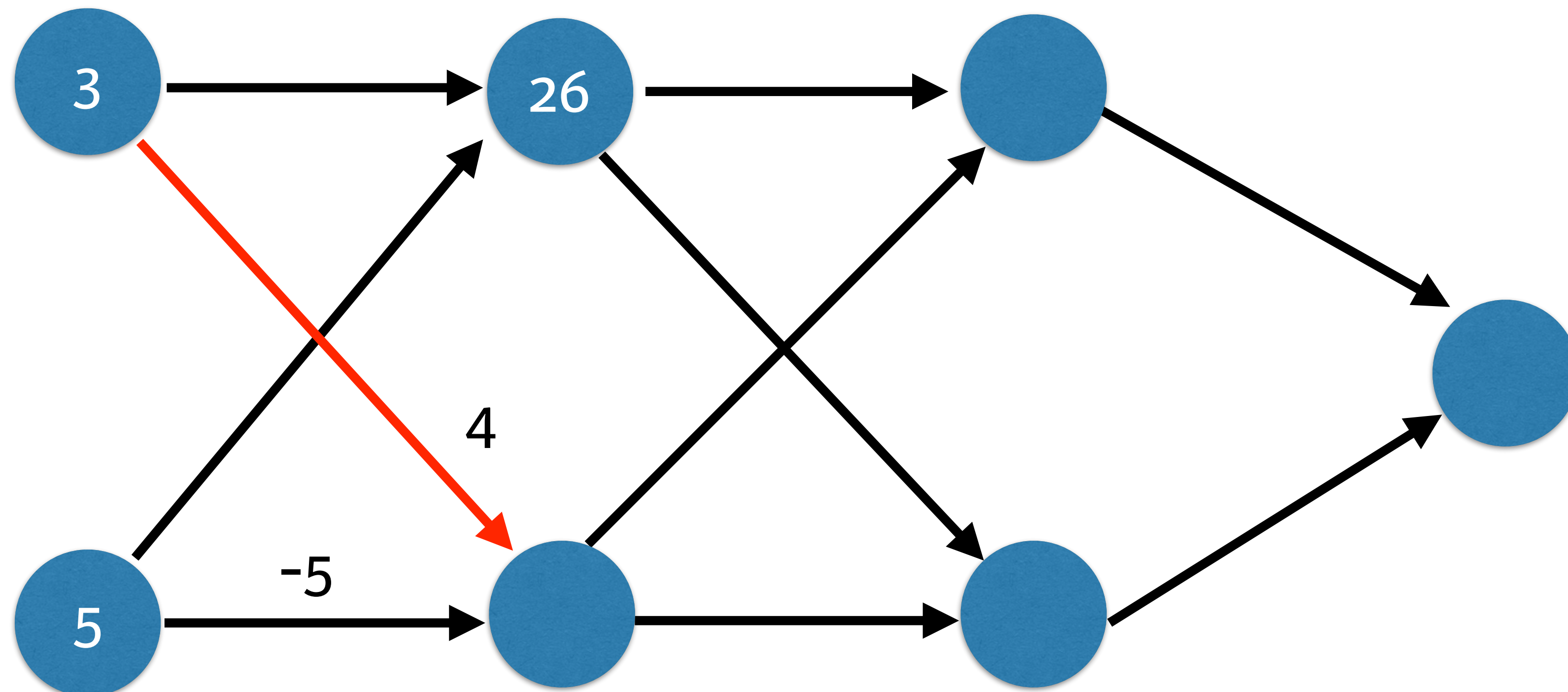


# Multiple hidden layers



Calculate with ReLU Activation Function

# Multiple hidden layers

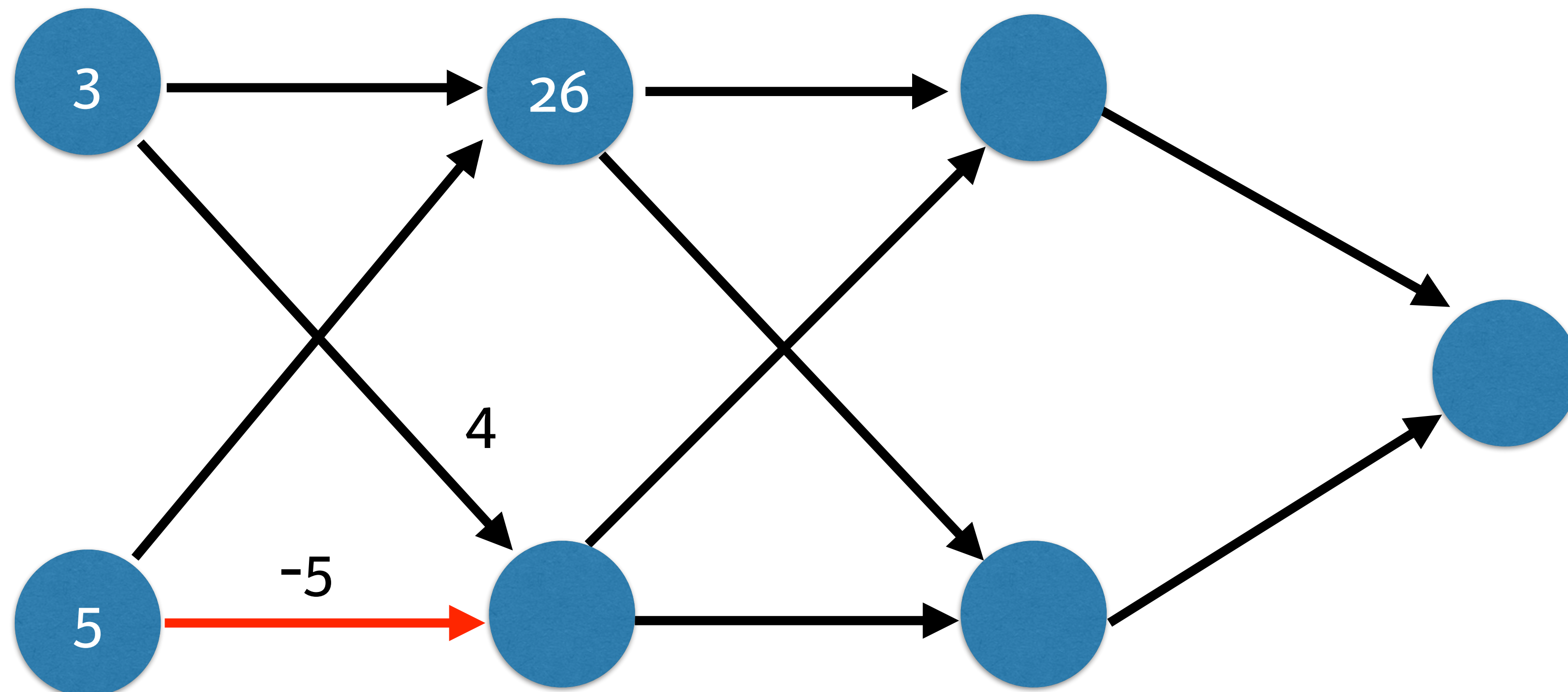


Calculate with ReLU Activation Function





# Multiple hidden layers

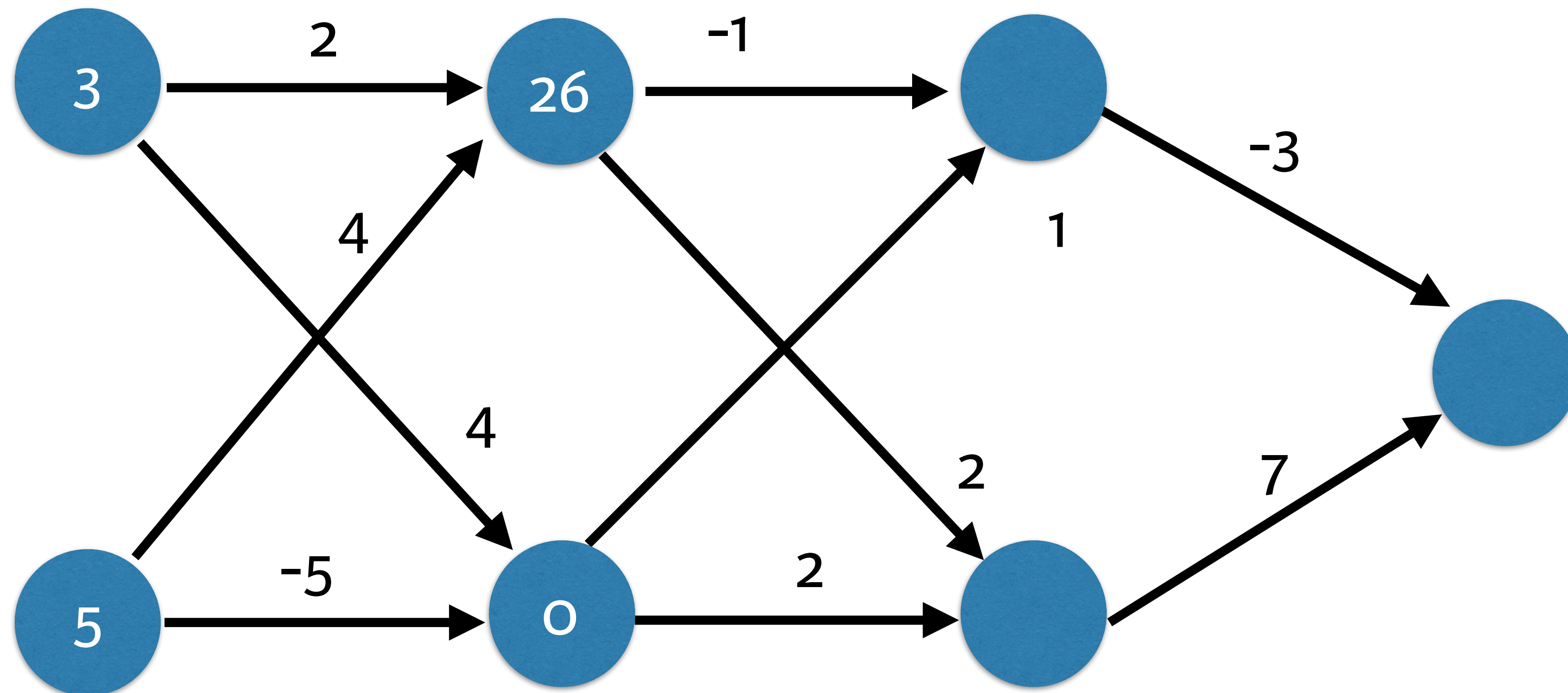


Calculate with ReLU Activation Function



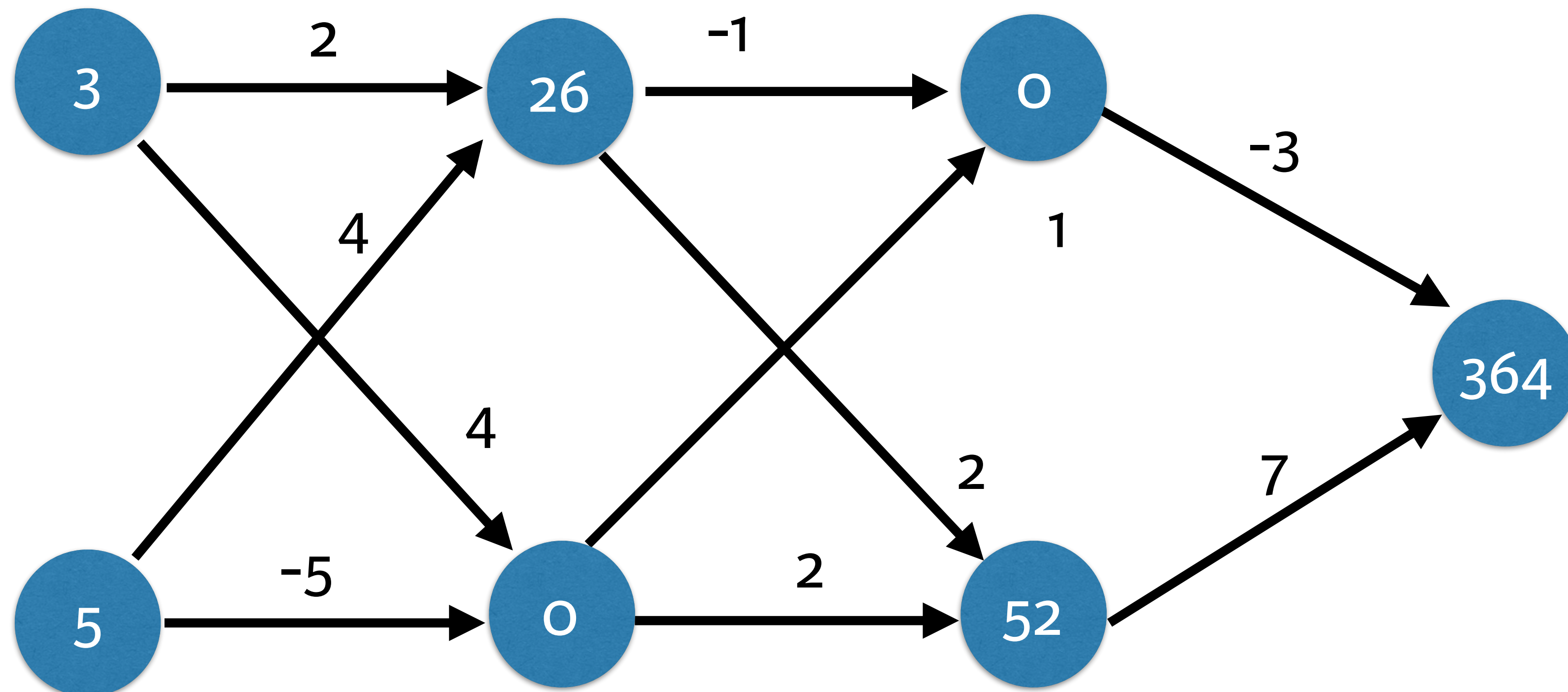


# Multiple hidden layers



Calculate with ReLU Activation Function

# Multiple hidden layers

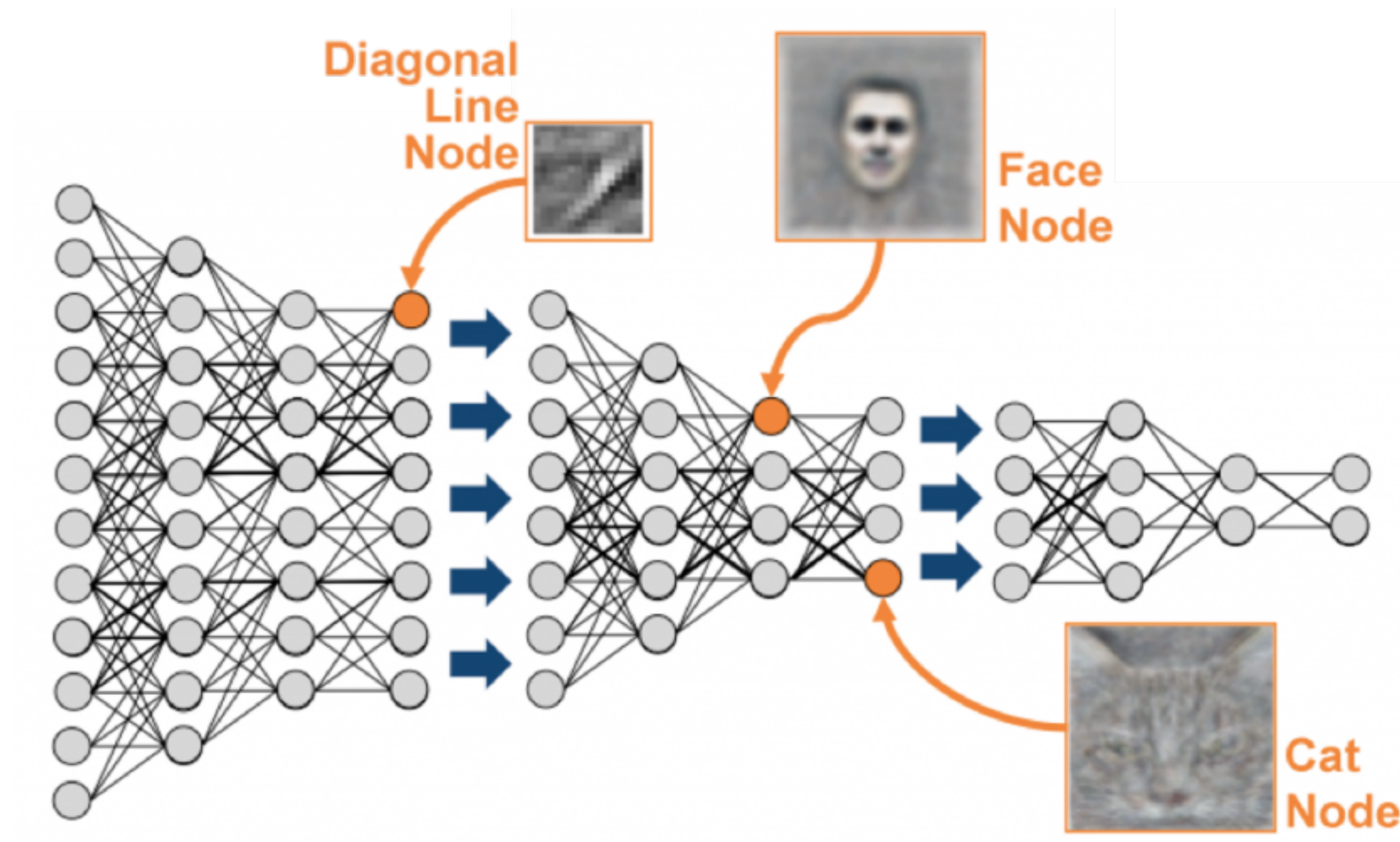


Calculate with ReLU Activation Function

# Representation learning

- Deep networks internally build representations of patterns in the data
- Partially replace the need for feature engineering
- Subsequent layers build increasingly sophisticated representations of raw data

# Representation learning







# Deep learning

- Modeler doesn't need to specify the interactions
- When you train the model, the neural network gets weights that find the relevant patterns to make better predictions



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**Let's practice!**