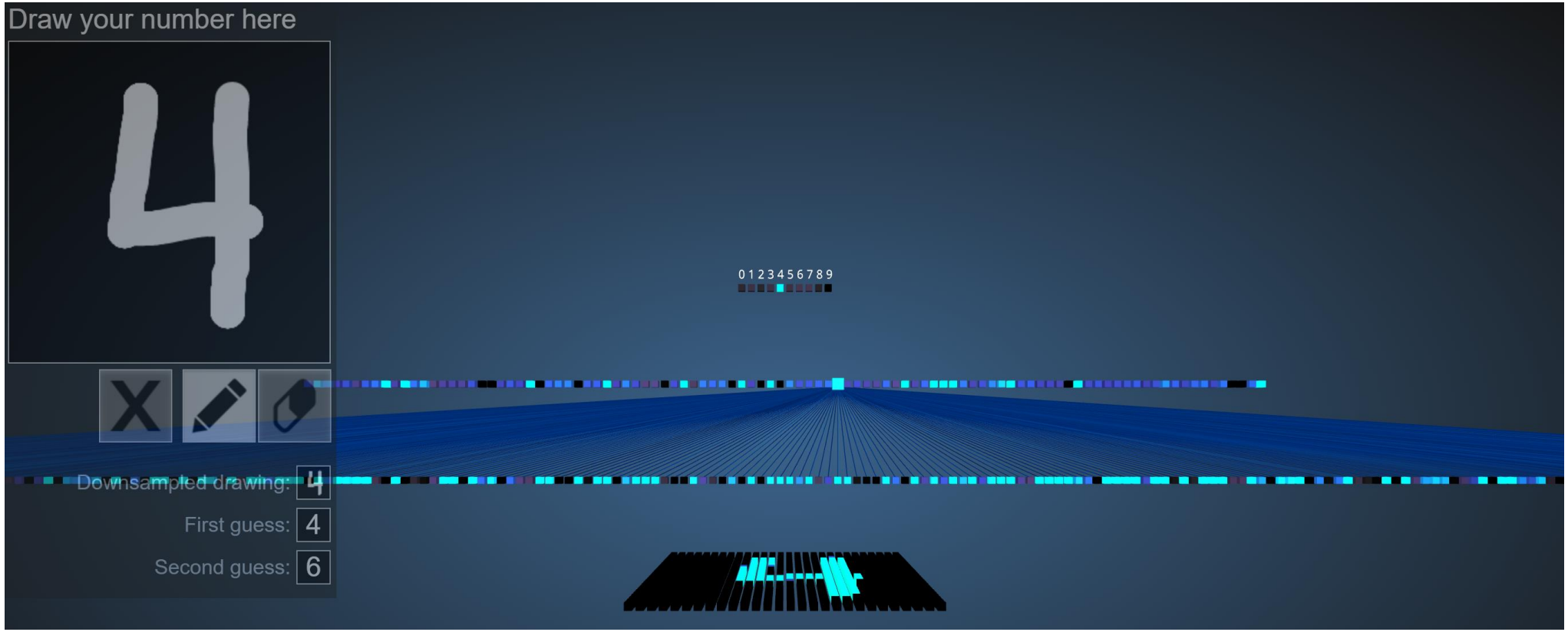
www.cs.cmu.edu/~112/gallery.html

As you walk in

Play with this demo of a neural network that classifies handwritten digits:

https://adamharley.com/nn_vis/mlp/3d.html



15-112
Lecture 2

Week 1 Thu
Getting Started

Instructor: Pat Virtue

Walk-through: Three-neuron neural network

Note: a quick example of real-world functions that we can start to write already!

Design example: Three-neuron neural network

Note:

The following slides were adjusted to match what we ended up covering in lecture.

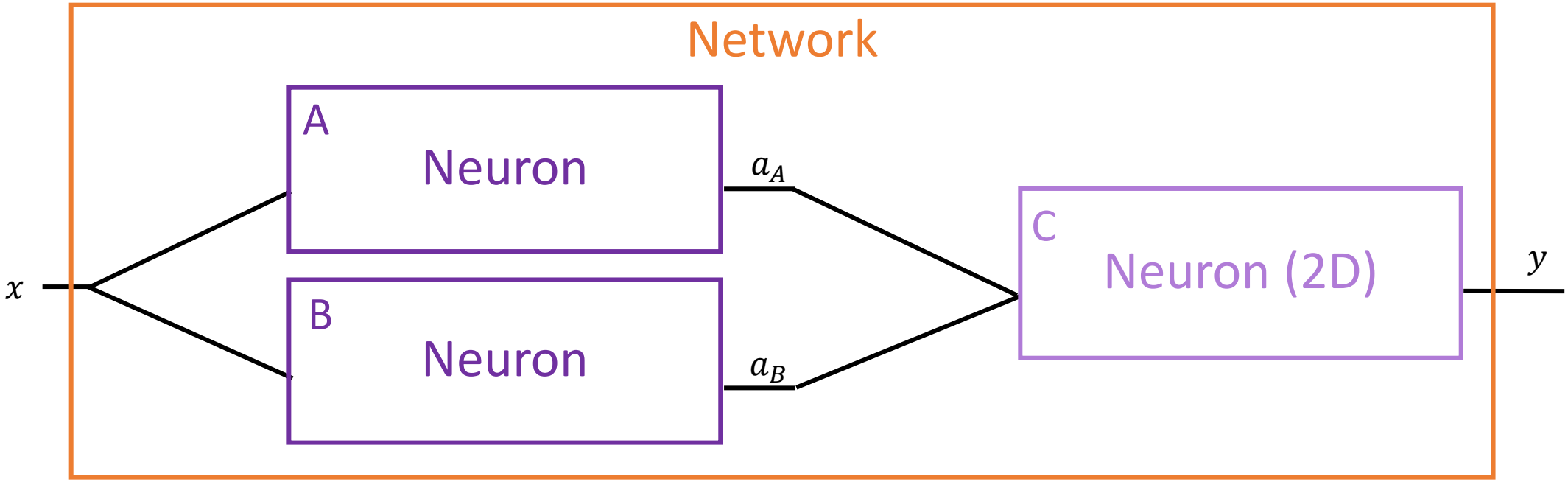
See the Appendix at the end of these slides for a few more steps to complete the three-neuron network code

Design example: Three-neuron neural network

High-level design of a small neural network

Input x: _____

Output y: _____



Temporary, intermediate values:

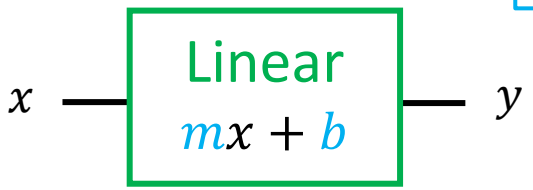
a_A: _____

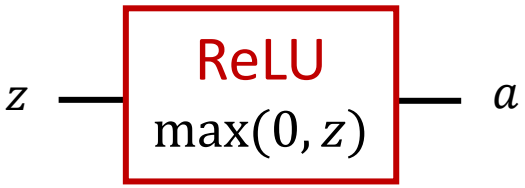
a_B: _____

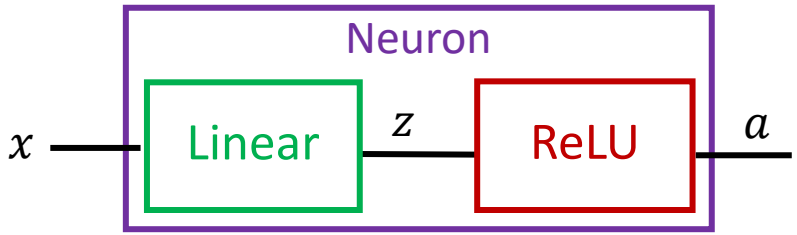
Design example: Neural Network Components

Handout

Parameters
m: slope
b: intercept







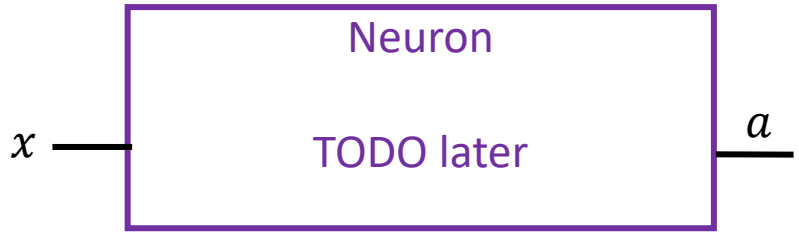
Example: Three-neuron neural network

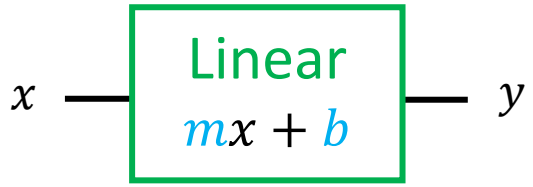
Code – first pass: moving top-down

```
def network(x):
    # Return y, the output of the network
    pass # for now

def neuron(x, m, b):
    # Return a, the output of one neuron
    pass # for now

def linear(x, m, b):
    # print(f'Inside linear({m}, {x}, {b}')
    return m*x + b
```





Example: Three-neuron neural network

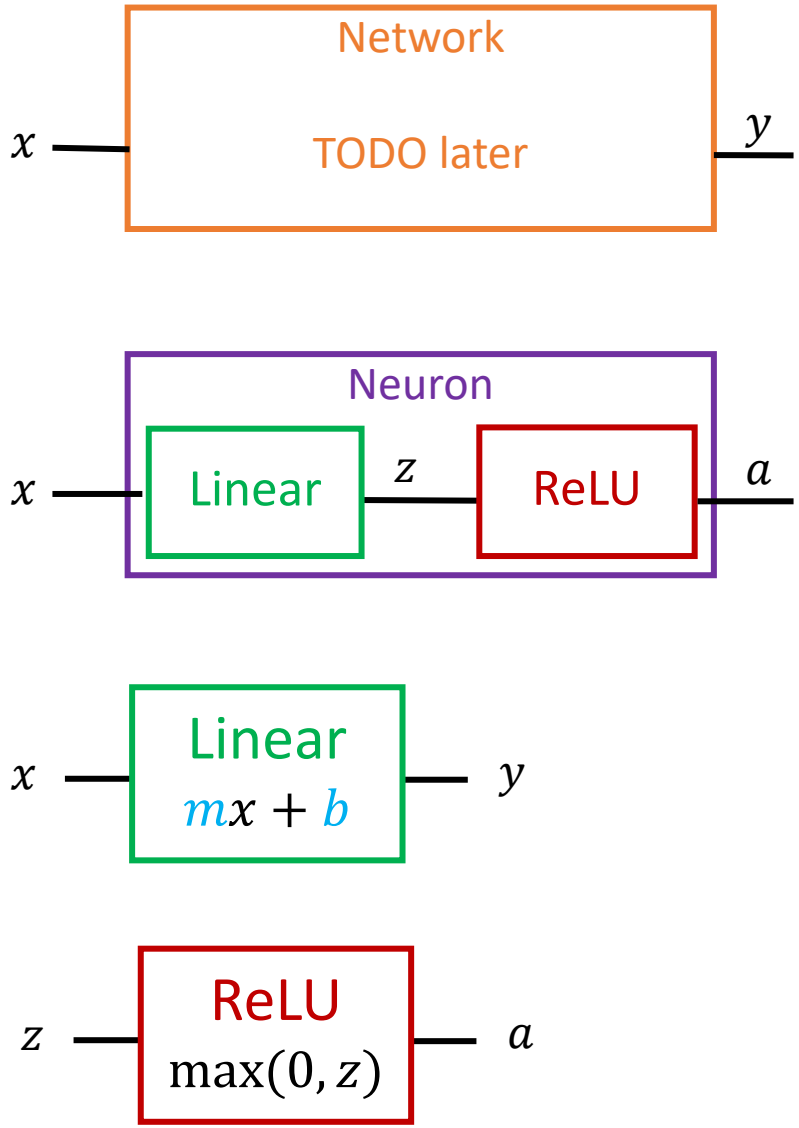
Code – move back up to implement neuron

```
def network(x):
    # Return y, the output of the network
    pass # for now

def neuron(x, m, b):
    z = linear(x, m, b)
    a = relu(z)
    return a

def linear(x, m, b):
    return m*x + b

def relu(z):
    return max(0, z)
```



Walk-through: Three-neuron neural network

Concepts highlighted

- Defining functions
- Calling functions
- Print vs return
- None type
- Helper functions
- Variable scope
- if-else statement
- Built-in functions (print, max)
- Function composition
- Top-down design (brief introduction)

Announcements

Assignments:

112 student contract

- Due already

Week 2 Pre-reading Checkpoint

- Due Fri 9/2, 8 pm

HW1

- Due Saturday 9/3, 8 pm

Announcements

Recitation

Friday

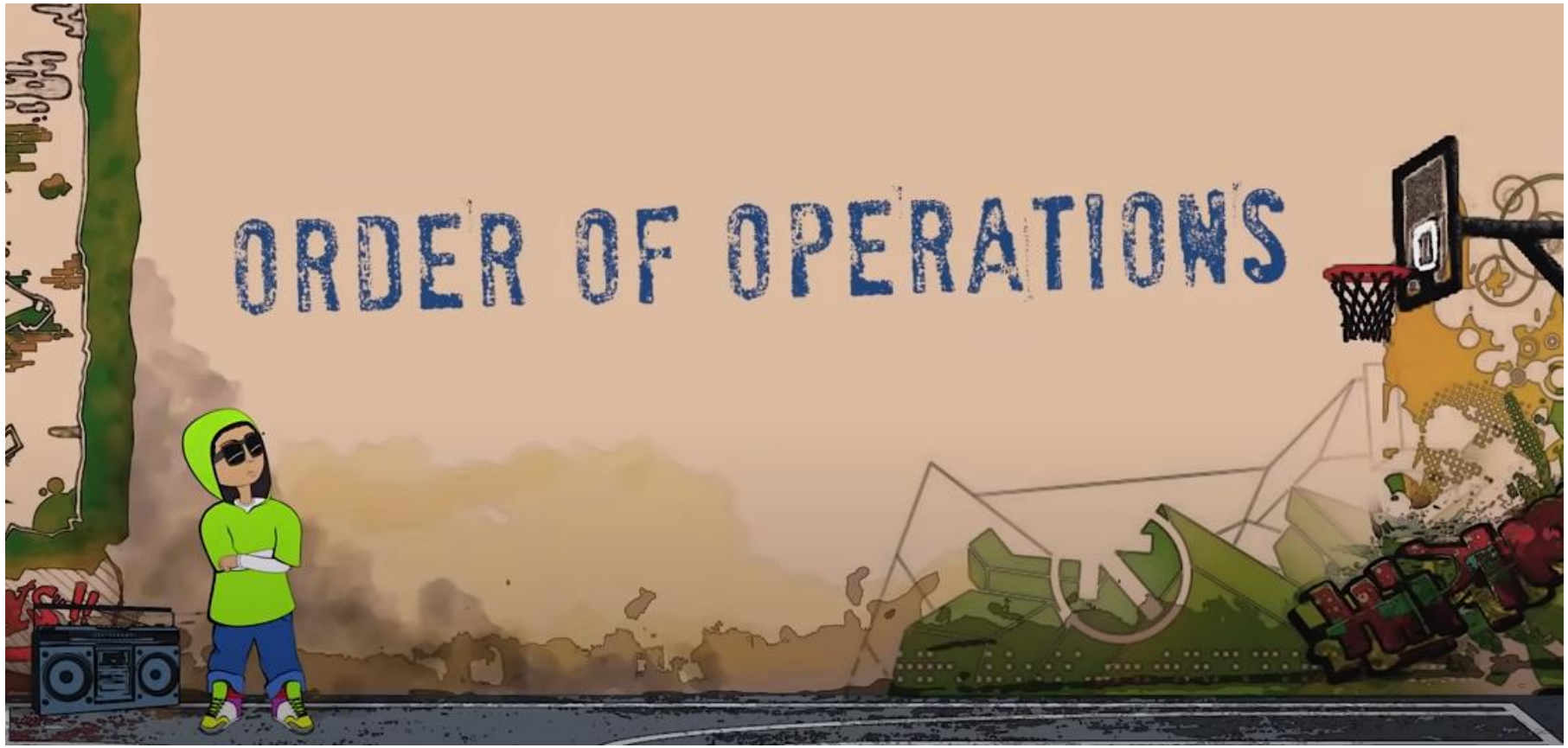
- Time reserved to work on Pre-reading and associated Checkpoint
- (Fix-it Fridays, but not in week 1)
- GHC 5th Floor Clusters

Operators and Order of Operations

Order of operations

PEMDAS

https://www.youtube.com/watch?v=ZzeDWFhYv3E



Poll 4 (unused)

What does this print?

```
print(2**3**2)
```

A) 7

B) 64

C) 512

D) Error

Debugging tip!

Expressions are things in Python that evaluate to a value

1) Save expressions (of all sizes) to variables
2) Use `print(expr)` to confirm values and order of operations

Poll 5

How many expressions are there in:

```
a % b == a - a // b * b
```

A) 4

B) 5

C) 6

D) 11

E) 21

F) Other

G) I have no idea

Operators

Arithmetic

- +, -, *, /, //, **, %, - (unary), + (unary)

Relational

- <, <=, >=, >, ==, !=

Assignment

- +=, -=, *=, /=, //=, **=, %=

Logical

- and, or, not

Note: not covering the bitwise operators (for now at least)

<<, >>, &, |, ^, ~, &=, |=, ^=, <<=, >>=

Strings and Comments

Poll 6 (unused)

Which one does the right thing?

A) `print("Have you read "Pride and Prejudice" by Jane Austen?")`

B) `print("Have you read 'Pride and Prejudice' by Jane Austen?")`

C) `print('Have you read 'Pride and Prejudice" by Jane Austen?')`

D) `print('Have you read "Pride and Prejudice" by Jane Austen?')`

Poll 6 (unused)

Which one does the right thing?

A) `print("Have you read "Pride and Prejudice" by Jane Austen?")`

B) `print("Have you read 'Pride and Prejudice' by Jane Austen?")`

C) `print('Have you read 'Pride and Prejudice" by Jane Austen?')`

D) `print('Have you read "Pride and Prejudice" by Jane Austen?’)`

```
print("Have you read "Pride and Prejudice" by Jane Austen?")
print("Have you read 'Pride and Prejudice' by Jane Austen?")
print('Have you read 'Pride and Prejudice" by Jane Austen?')
print('Have you read "Pride and Prejudice" by Jane Austen?')
```

Comments

Notes for humans (really important!)

```
# Comments can go on their own line
i = 0 # Comments can go at the end of a line

def squared(x):
    """ This is technically a multiline string
        but is often used as a comment
    """
    return x**2
```

Strings

Single or double quote are fine

- Can be useful for quotes withing strings (but alternated correctly)
- Escape characters are needed sometimes

```
print('Have you read Jane Austen\'s "Pride and Prejudice" recently?')
```

- There are also triple quotes for multiline strings (actually, often used for comments)

f-Strings

- Really useful to print a combination of strings and expressions

```
x = 42
y = 99
print(f'Did you know that {x} + {y} is {x+y}?')
```

Errors

Prev Poll 3

What college are you in?

A) Letss eat Grandma
B) Letss eat, Grandma
C) Lets eat Grandma
D) Lets eat, Grandma
E) Let’s eat Grandma
F) Let’s eat, Grandma

Lessons learned

- Sensitive to small things
  - Like spelling, grammar, usage
  - Different kinds of error
- Different from language to language
- Be patient while you learn
  - With yourselves
  - With each other
- Commas save lives
- Don’t consume your relatives

Errors

Syntax error

```
print("100") # Never prints
1 ? 0
print("200") # Never prints
```

Runtime error

```
print("100") # Prints!
1 / 0
print("200") # Never prints
```

Logical error

```
print(f"100:, {x}") # Prints!
if x % 2 == 1:
    print(f"{x} is even") # Prints?
print("200") # Prints!
```

Debugging tip!

- Use print functions to help learn where runtime errors are happening

Debugging tip!

- Use print functions to see if branches of code are being entered

Poll 7 (unused)

What happens when we run the following line?

```
x = 3(2+7)
```

A) x takes on the value 27
B) Syntax error
C) Runtime error
D) Logical error
E) I have no idea

Errors

Tip

Keep a list of errors that you encounter along with what they might mean

```
TypeError: 'int' object is not callable
```

→ Hmm, I probably have number, variable, or expression followed by a (

e.g., `x = 3(2+7)` should be `x = 3*(2+7)`

```
NameError: name 'total' is not defined
```

→ Hmm, I probably have variable named total that I never assigned a value

```
num = 10
mean = total/num
```

Functions

Variables and Types

type vs isinstance

Both work to check

More complex

Poll 8 (unused)

What is this?

A) Apple
B) Banana
C) Fruit
D) Food

type vs isinstance

Both work to check

More complex

Poll 9 (unused)

What should this print?

```
print(0.1 + 0.1 + 0.1 == 0.3)
```

A) bool
B) True
C) False
D) Yes
E) No

Issues with floats

Equality

```
x = 0.1 + 0.1 + 0.1
y = 0.3
x == y # Doesn’t work well with floats
```

- Use 112: `almostEqual(x, y)`

Rounding

```
round(x) # Doesn’t work as you might expect
```

- Use 112: `roundHalfUp(x)`

Conditionals

Appendix

Additional examples with neural networks

Three-neuron neural network

Handout

Input x: _____

Output y: _____

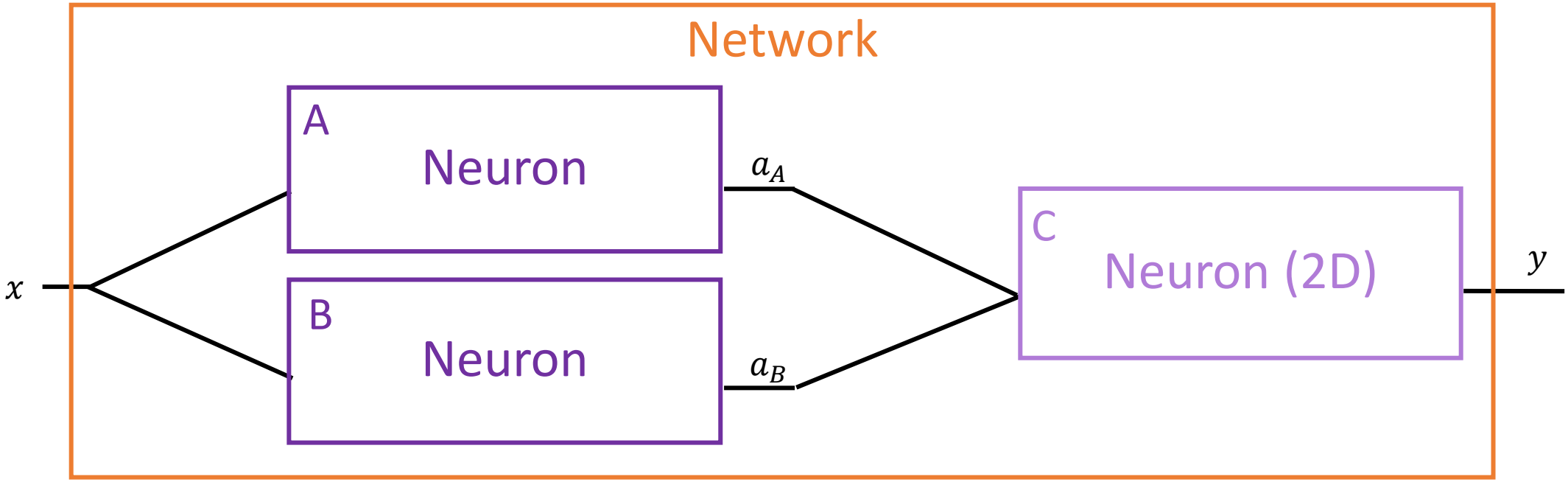
Parameters

m_A: -0.01 b_A: 0.7

m_B: 0.05 b_B: -3.5

$m_{C,1}$: 1.0 b_C: 1.5

$m_{C,2}$: 1.0



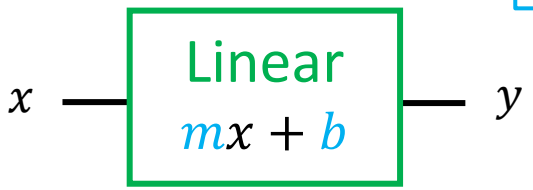
a_A: _____

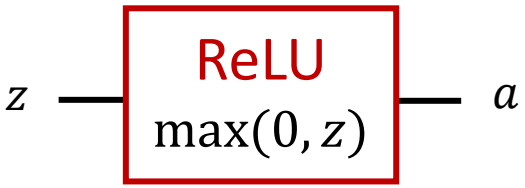
a_B: _____

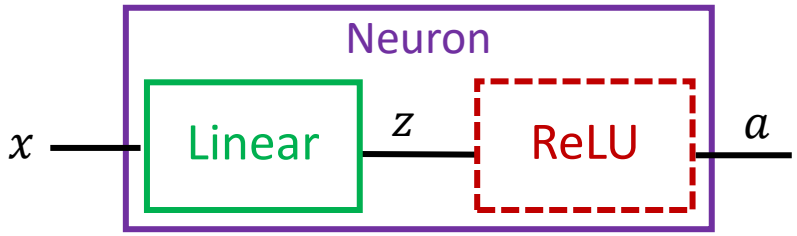
Neural Network Components

Handout

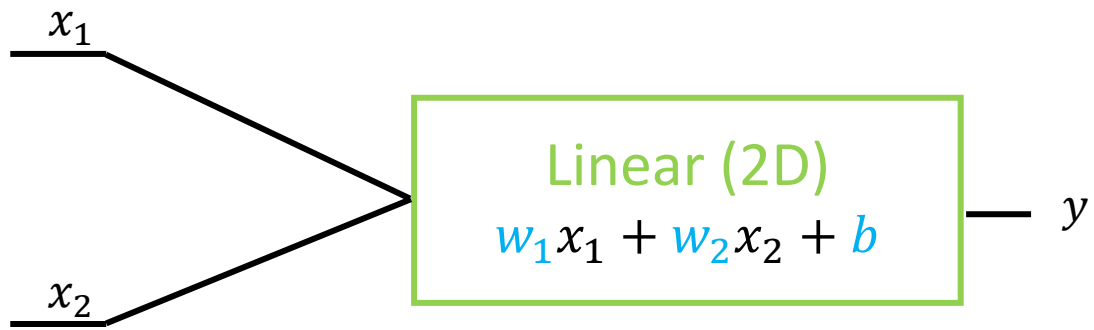
Parameters
m: slope
b: intercept

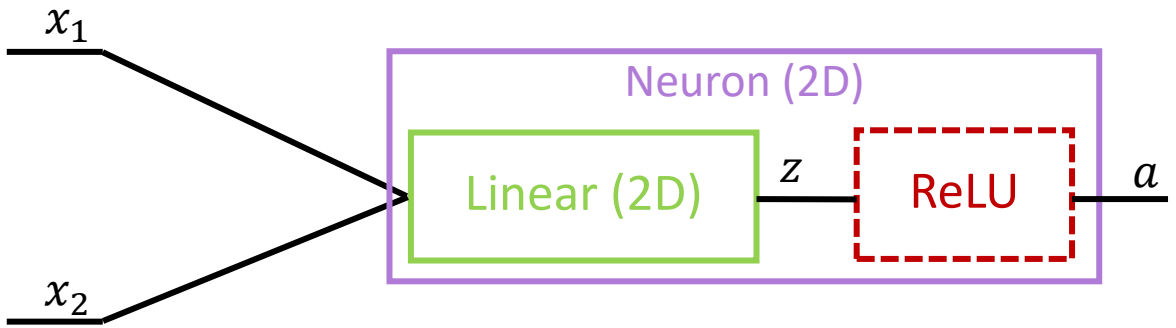






Parameters
m_1: slope
m_2: slope
b: offset





Three-neuron neural network

Handout

Input x: _____

Output y: _____

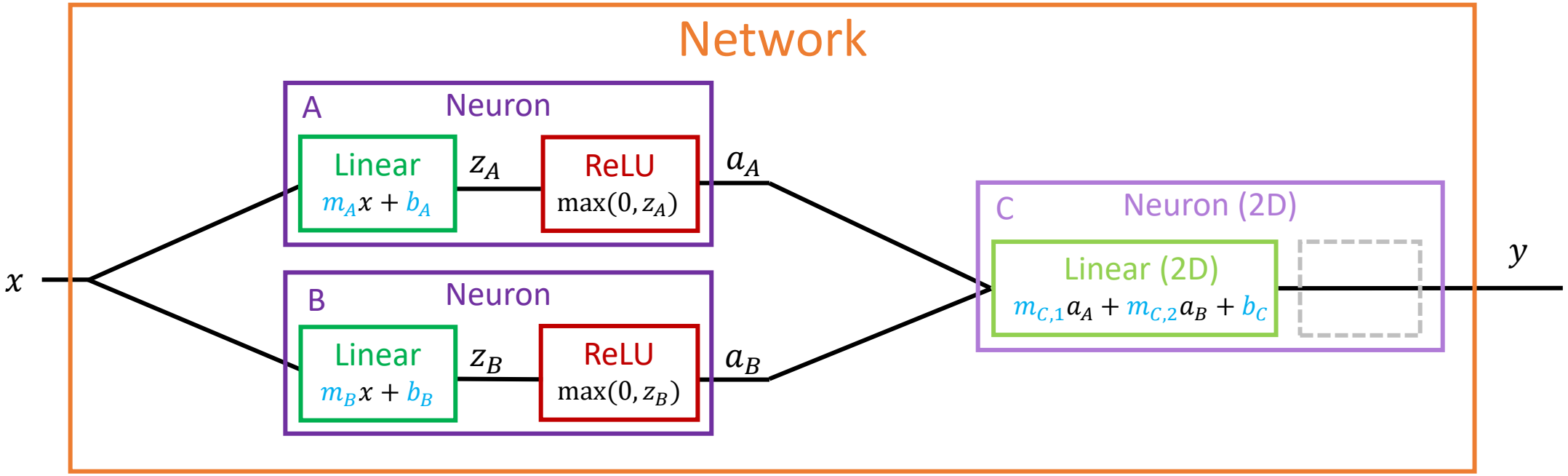
Parameters

m_A: -0.01 b_A: 0.7

m_B: 0.05 b_B: -3.5

$m_{C,1}$: 1.0 b_C: 1.5

$m_{C,2}$: 1.0



z_A: _____ a_A: _____

z_B: _____ a_B: _____

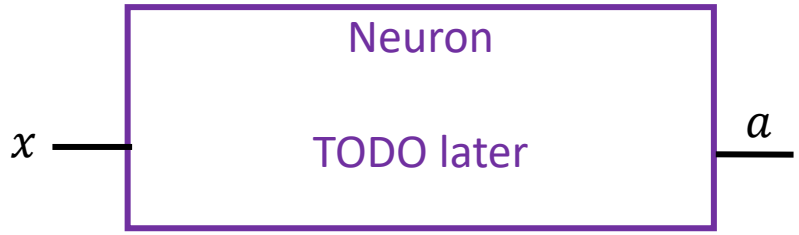
Example: Three-neuron neural network

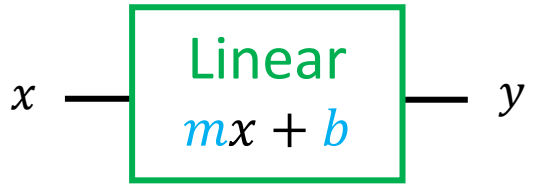
Code – first pass: moving top-down

```
def network(x):
    # Return y, the output of the network
    pass # for now

def neuron(x, m, b):
    # Return a, the output of one neuron
    pass # for now

def linear(x, m, b):
    # print(f'Inside linear({m}, {x}, {b}')
    return m*x + b
```





Example: Three-neuron neural network

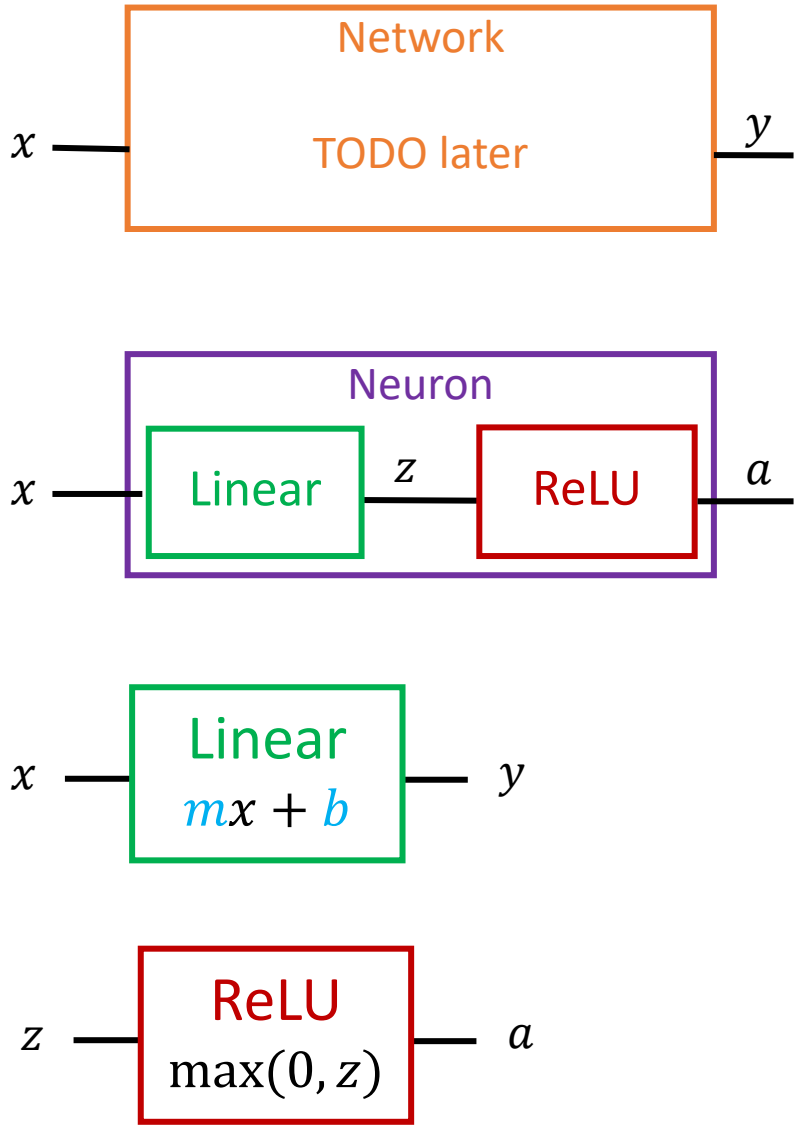
Code – move back up to implement neuron

```
def network(x):
    # Return y, the output of the network
    pass # for now

def neuron(x, m, b):
    z = linear(x, m, b)
    a = relu(z)
    return a

def linear(x, m, b):
    return m*x + b

def relu(z):
    return max(0, z)
```



Example: Three-neuron neural network

Adding slightly different versions of linear and neuron to handle two input values rather than just one

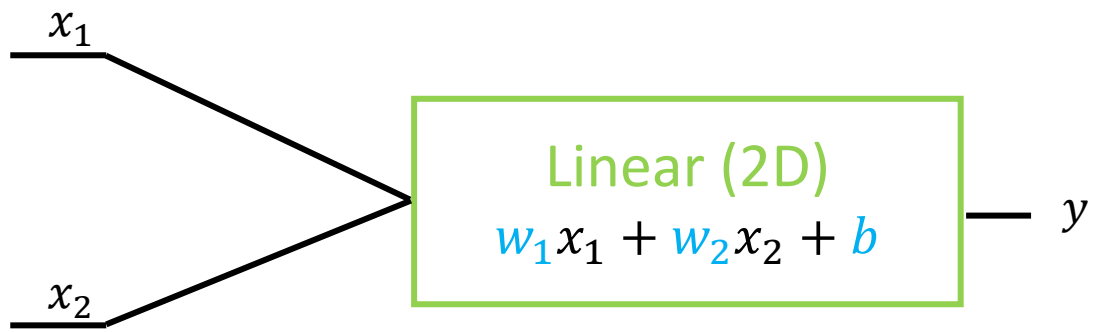
- Side-note: once we get to lists, we won't need different versions

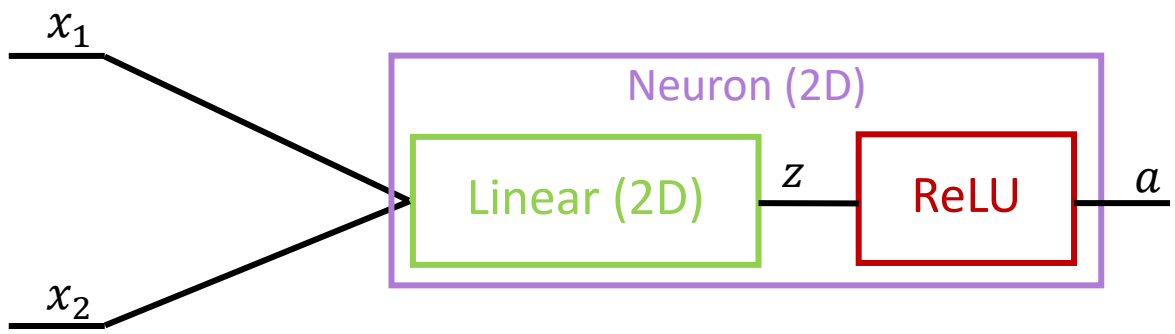
Parameters
m_1: slope
m_2: slope
b: offset

```
def linear2D(x1, x2, m1, m2, b):
    return m1*x1 + m2*x2 + b

def neuron2D(x1, x2, m1, m2, b):
    z = linear2D(x1, x2, m1, m2, b)
    a = relu(z)
    return a

# relu still just takes on input
```

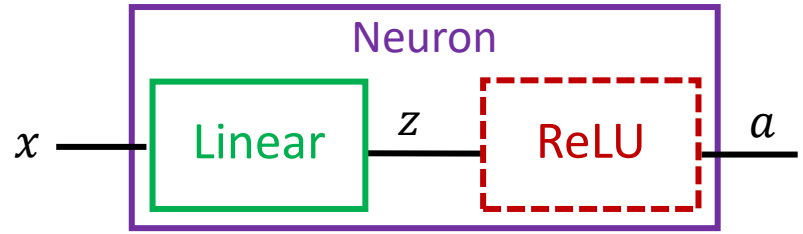


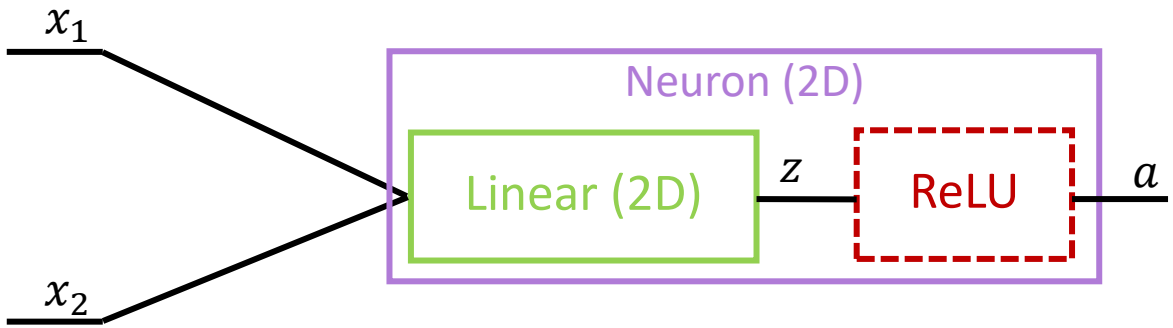


Example: Three-neuron neural network

Code – quick adjustment to neuron code: sometimes ReLU is optional

```
def neuron(x, m, b, useReLU):
    z = linear(x, m, b)
    if useReLU:
        a = relu(z)
    else:
        a = z
    return a
def neuron2D(x1, x2, m1, m2, b, useReLU):
    z = linear2D(x1, x2, m1, m2, b)
    if useReLU:
        a = relu(z)
    else:
        a = z
    return a
```





Example: Three-neuron neural network

Code – Putting the network together!!

```
def network(x, mA, bA, mB, bB, mC1, mC2, bC):
    aA = neuron(x, mA, bA, useReLU=True)
    aB = neuron(x, mB, bB, useReLU=True)

    y = neuron2D(aA, aB, mC1, mC2, bC, useReLU=False)
    return y
```

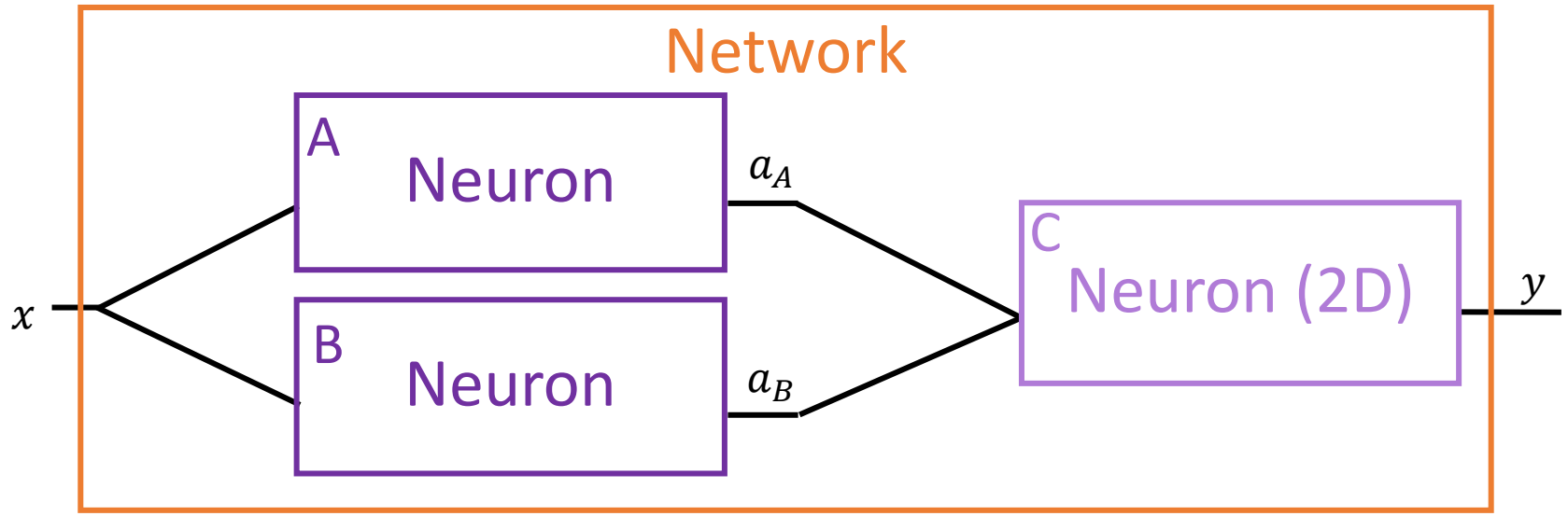
Parameters

m_A: -0.01 b_A: 0.7

m_B: 0.05 b_B: -3.5

$m_{C,1}$: 1.0 b_C: 1.5

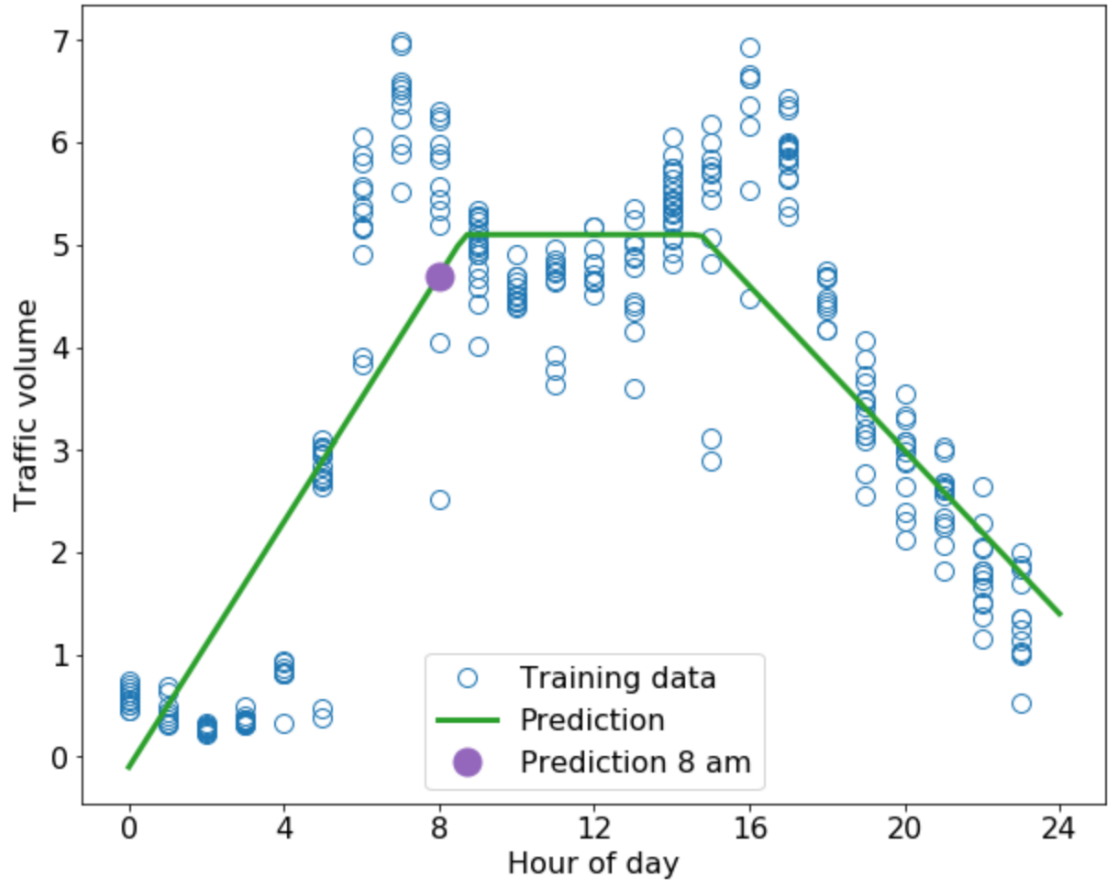
$m_{C,2}$: 1.0



Example: Three-neuron neural network

Code – Using to predict traffic in Minneapolis, Minnesota

```
xNew = 8 # What is the traffic like at 8 am?
yPredicted = network(xNew, mA, bA, mB, bB, mC1, mC2, bC)
```



Parameters

m_A: 0.4 b_A: -5.9

m_B: -0.6 b_B: 5.2

$m_{C,1}$: -1.0 b_C: 5.1

$m_{C,2}$: -1.0