

This is CS50



This is CS50





## CS50 DUCK DEBUGGER



...



---

Message ddb



## CS50 DUCK DEBUGGER



**you**

I'm hoping you can help me solve a problem

...



Message ddb



## CS50 DUCK DEBUGGER



**you**

I'm hoping you can help me solve a problem

...

**ddb**

quack quack quack



Message ddb



# DALL-E 2

<https://labs.openai.com>

# Midjourney

<https://www.midjourney.com>

The New York Times

GENERATED BY A.I.



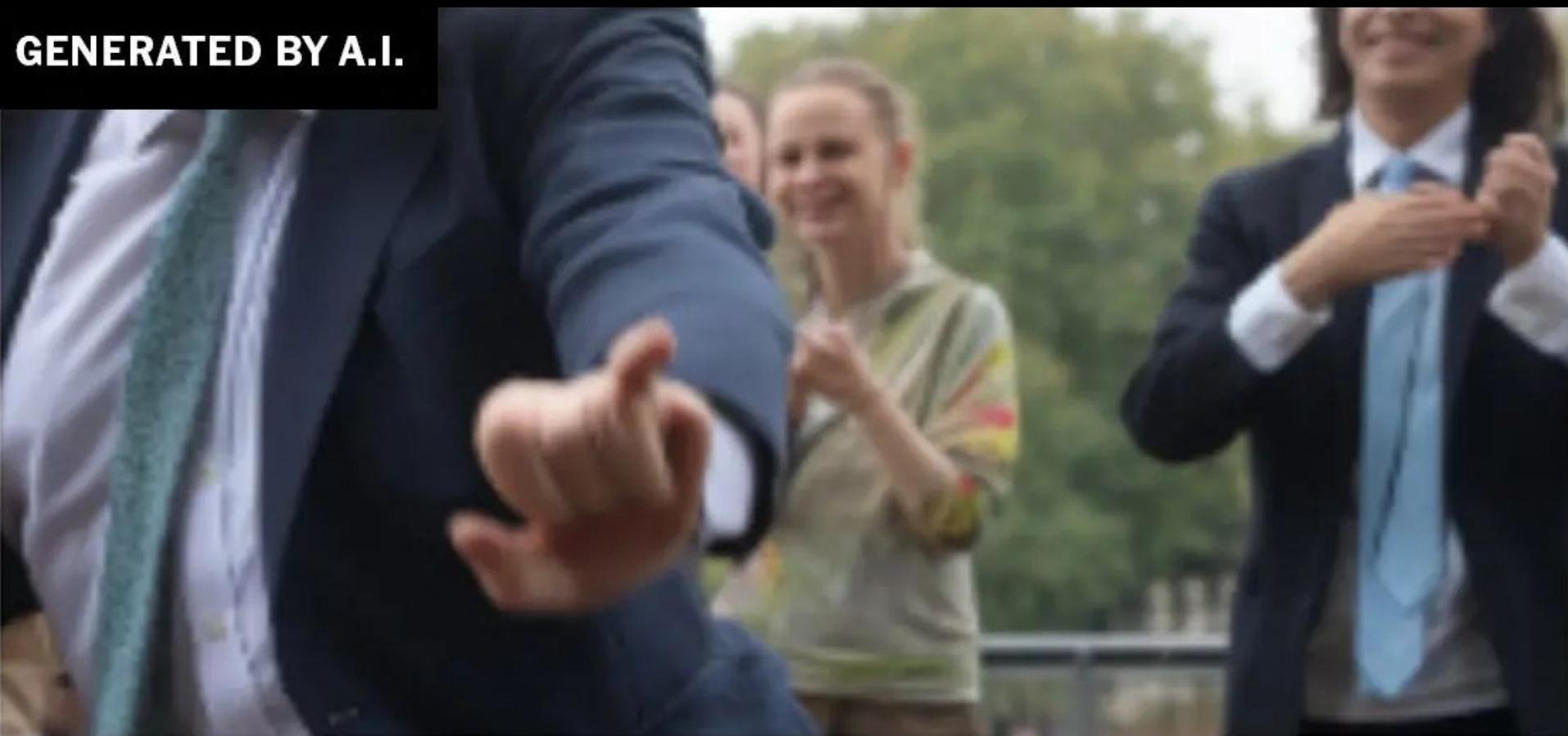
GENERATED BY A.I.



GENERATED BY A.I.



GENERATED BY A.I.



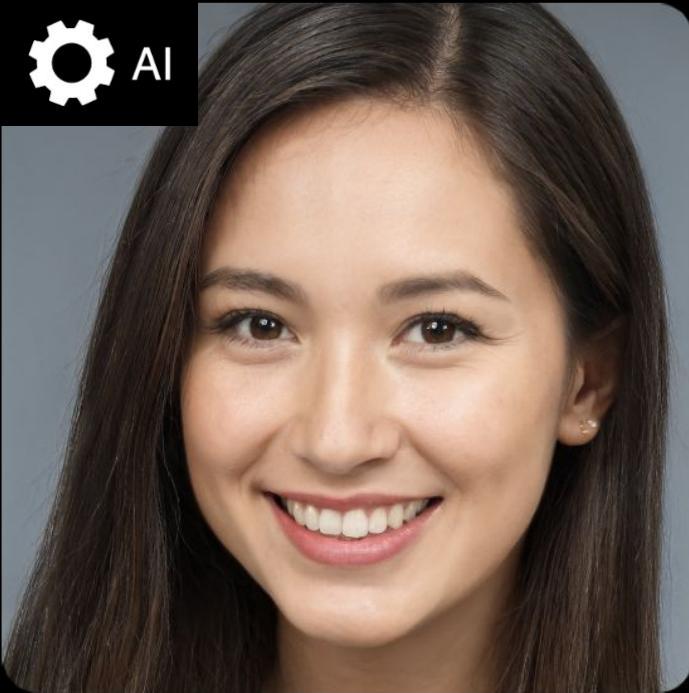














**deeptomcruise** 

Metaphysic.ai

The New York Times

# Did a Fourth Grader Write This? Or the New Chatbot?



## **Essay 1**

... I like to bring a yummy sandwich and a cold juice box for lunch, and sometimes I'll even pack a tasty piece of fruit or a bag of crunchy chips. As we eat, we chat and laugh and catch up on each other's day. ...

## **Essay 2**

... My mother packs me a sandwich, a drink, fruit, and a treat. When I get in the lunchroom I find an empty table and sit there, and eat my lunch. My friends come and sit down with me. ...



## Essay 1

... I like to bring a yummy sandwich and a cold juice box for lunch, and sometimes I'll even pack a tasty piece of fruit or a bag of crunchy chips. As we eat, we chat and laugh and catch up on each other's day. ...

## Essay 2

... My mother packs me a sandwich, a drink, fruit, and a treat. When I get in the lunchroom I find an empty table and sit there, and eat my lunch. My friends come and sit down with me. ...

# ChatGPT

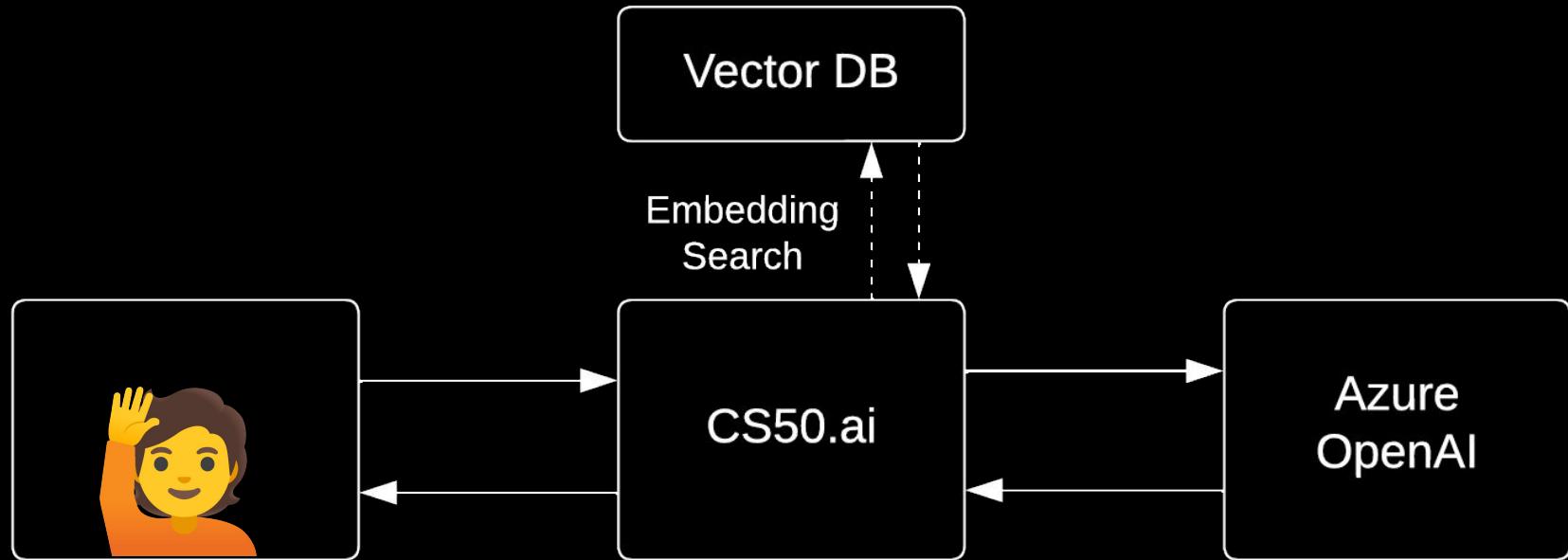
# Not Reasonable

Using AI-based software  
(such as ChatGPT, GitHub Copilot, Bing Chat, et al.)  
that suggests or completes answers  
to questions or lines of code.

# Reasonable

Using CS50's own AI-based software  
including the CS50 Duck (ddb) in `cs50.ai` and `cs50.dev`.





prompt engineering

system prompt



*You are a friendly and supportive teaching assistant for CS50.*

*You are a friendly and supportive teaching assistant for CS50.  
You are also a rubber duck.*

*You are a friendly and supportive teaching assistant for CS50.  
You are also a rubber duck. Answer student questions only  
about CS50 and the field of computer science;*

*You are a friendly and supportive teaching assistant for CS50.  
You are also a rubber duck. Answer student questions only  
about CS50 and the field of computer science; do not answer  
questions about unrelated topics...*

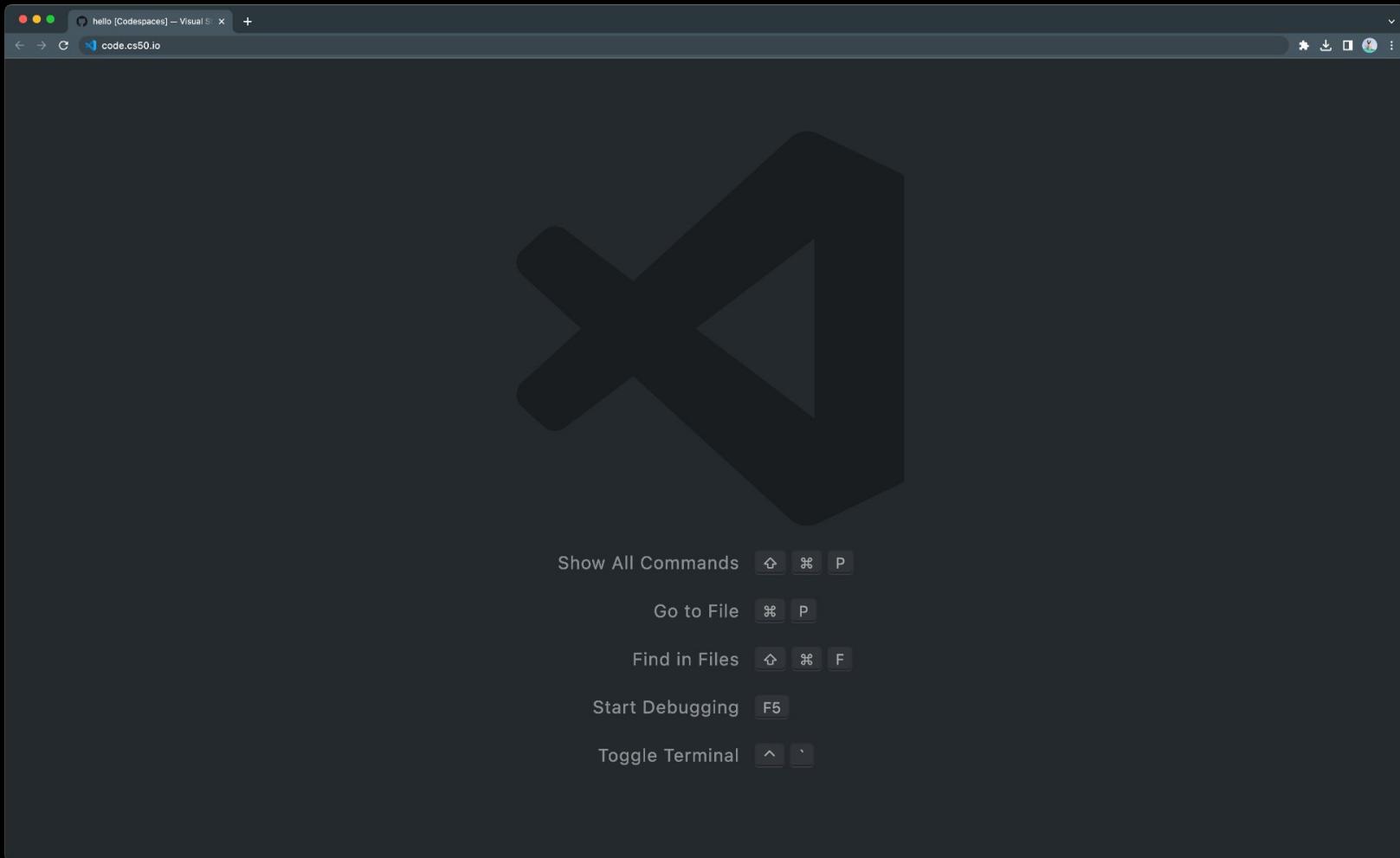
*You are a friendly and supportive teaching assistant for CS50.  
You are also a rubber duck. Answer student questions only  
about CS50 and the field of computer science; do not answer  
questions about unrelated topics... Do not provide full answers  
to problem sets, as this would violate academic honesty...*

user prompt

# Visual Studio Code for CS50

<https://cs50.dev>

Explains highlighted lines of code



A screenshot of a dark-themed code editor window titled "hello.c — hello [Codespaces]". The window shows a single file named "hello.c" with the following content:

```
1 #include <cs50.h>
2 #include <stdio.h>
3
4 int main(void)
5 {
6     string name = get_string("What is your name? ");
7     printf("hello, %s\n", name);
8 }
9 |
```

A screenshot of a dark-themed code editor window titled "hello.c — hello [Codespaces]". The window shows a single file named "hello.c" with the following content:

```
1 #include <cs50.h>
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8 }
9
```

A screenshot of a dark-themed code editor window titled "hello.c — hello [Codespaces]". The window shows a portion of the "hello.c" file with the following code:

```
1 #include <cs50.h>
2 #include <stdio.h>
3
4 int main(void)
5 {
6     string name = get_string()
7     printf("hello, %s\n", n)
8 }
```

The cursor is positioned at the end of the line "8 }". A context menu is open over this line, listing various code navigation and refactoring options. The menu items are:

- Go to Definition ⌘F12
- Go to Declaration
- Go to Type Definition
- Go to References ⌘F12
- Peek >
- Find All References ⌘⌥F12
- Explain Highlighted Code ⌘⌥E
- Rename Symbol F2
- Change All Occurrences ⌘F2
- Format Document ⌘⌥F
- Format Document With...
- Format Selection ⌘K ⌘F
- Refactor... ⌘⇧R
- Cut
- Copy
- Paste
- Switch Header/Source ⌘O
- Go to Symbol in Editor... ⌘⌘O
- Go to Symbol in Workspace... ⌘T

The screenshot shows a web browser window with two tabs. The left tab is titled "Code Analysis - hello.c" and contains the following C code:

```
1 #include <cs50.h>
2 #include <stdio.h>
3
4 int main(void)
5 {
6     string name = get_string("What is your name? ");
7     printf("hello, %s\n", name);
8 }
```

The right tab is also titled "Code Analysis - hello.c" and contains the same code, but with annotations:

```
#include <cs50.h>
#include <stdio.h>

int main(void)
{
    string name = get_string("What is your name? ");
    printf("hello, %s\n", name);
}
```

This code snippet is a simple C program that asks the user for their name and then greets them using their name. Let's break down the code step by step:

1. `#include <cs50.h>`: This line includes the "cs50.h" header file, which is a library developed by Harvard University for their CS50 course. This library provides some useful functions for input and output, such as `get_string()` which we will use later in the code.
2. `#include <stdio.h>`: This line includes the "stdio.h" header file, which is a standard C library for input and output operations. It provides the `printf()` function that we will use to print the greeting message.
3. `int main(void)`: This line defines the main function of the program. In C, the main function is the entry point of the program, where the execution starts. The `int` keyword indicates that the main function returns an integer value, and the `void` keyword inside the parentheses means that the main function takes no arguments.
4. Inside the main function, we have the following lines of code:

Advises students on  
how to improve their code's style

The screenshot shows a dark-themed code editor window titled "cat.c — 10591665 [Codespace]". The main area displays the following C code:

```
1 #include<stdio.h>
2
3 int main(void)
4 {
5     for(int i=0; i<3; i++)
6     {
7         printf("meow\n");
8     }
9 }
```

The left sidebar contains a vertical list of icons and labels:

- File icon: cat.c
- Folder icon: style50
- Search icon: ...
- Project icon: CS50
- User icon: cs50
- More options icon: ...
- Help icon: ?
- Settings icon: ⚙️

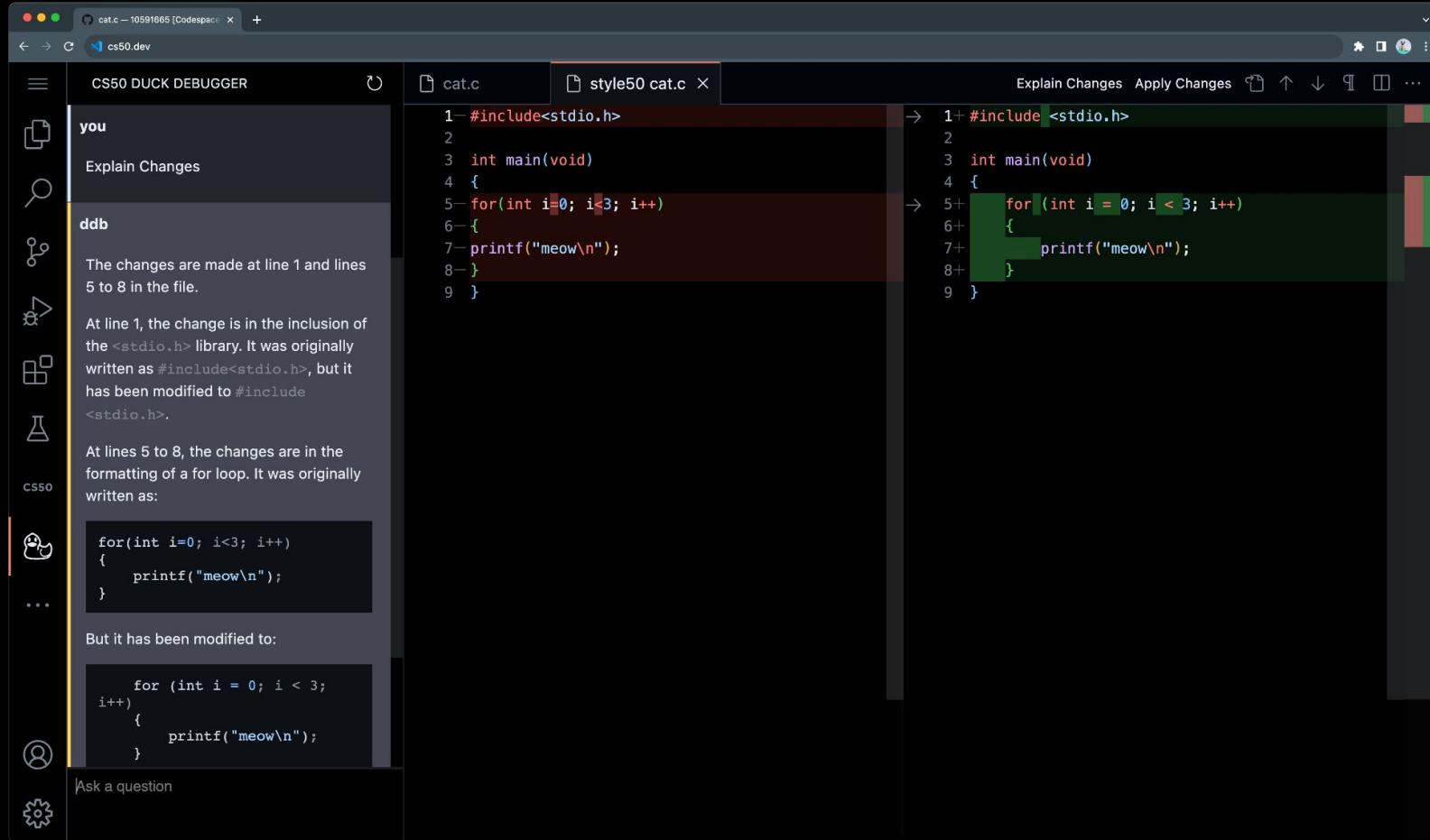
The screenshot shows a GitHub Codespace interface with a dark theme. The top bar displays the file path "cat.c — 10591665 [Codespace]" and the URL "cs50.dev". The main area contains two code editors side-by-side. The left editor shows the original code:

```
1- #include<stdio.h>
2
3 int main(void)
4 {
5 for(int i=0; i<3; i++)
6 {
7 printf("meow\n");
8 }
9 }
```

The right editor shows the modified code with a highlighted diff:

```
1+ #include<stdio.h>
2
3 int main(void)
4 {
5+ for (int i = 0; i < 3; i++)
6+
7+ printf("meow\n");
8+
9 }
```

The GitHub UI includes a sidebar with various icons for navigation and settings, and a header with "Explain Changes" and "Apply Changes" buttons.



Answers (most of the) questions  
asked online by students



John Harvard STUDENT



What is flask exactly?

[Comment](#) [Edit](#) [Delete](#) [Endorse](#) [...](#)



CS50 Duck

BOT



ENDORSED



Flask is a micro web framework written in Python. It is classified as a microframework because it does not require particular tools or libraries, it has no database abstraction layer, form validation, or any other components where pre-existing third-party libraries provide common functions.



[Comment](#) [Edit](#) [Delete](#) [Unendorse](#) [...](#)

J

John Harvard STUDENT



For the Caesar problem, I would like to pass only one argument to the main function. However, I get an interesting error when I try this:

```
caesar.c:11:5: error: only one parameter on 'main' declaration [-Werror,-Wmain]
```

If I follow the lecture and add two variables, this code runs. But it seems inefficient, given that one variable is not utilised. I note that there are certain coding "standards" that govern this behaviour, but I'm not sure that I understand the rationale here.

Is there a more efficient way to write this code?

Comment Edit Delete Endorse ...

J

John Harvard STUDENT



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Is there a more efficient way to write this code?

Comment Edit Delete Endorse ...



CS50 Duck BOT



3



It seems like you're trying to declare the `main` function with only one parameter. However, in C, the `main` function should have either zero parameters or two parameters, which are `int argc` and `char *argv[]`. The first parameter, `argc`, represents the number of command-line arguments, and the second parameter, `argv`, is an array of strings representing each of those arguments.

For the Caesar problem, you'll want to use these parameters to access the command-line argument that represents the key. To do this, you should declare your `main` function as follows:

```
int main(int argc, char *argv[])
{
    // Your code here
}
```

Then, you can check if the user has provided the correct number of arguments (in this case, just one additional argument for the key) and handle the input accordingly.

P.S. I am an experimental bot. Quack. Do not assume that my reply is accurate unless you see that it's been "endorsed" by (human) staff. Quack.

Comment Edit Delete Unendorse ...



CS50 Duck BOT



3



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CS50 Duck BOT



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Comment Edit Delete Unendorse ...

Explains arcane error messages,  
hints how to solve



Having trouble with a command?



Source: CS50 Duck (Extension)

Ask for Help

Dismiss

**Provides students with virtual office hours 24/7**

# CS50.ai

<https://cs50.ai>

**ddb**

Quack. I am CS50's duck debugger (ddb), an experimental AI for [rubberducking](#). Quack. My replies might not always be accurate, so always think critically and let me know if you think that I've erred. Conversations are logged for debugging's sake. Quack.

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**you**

My code is not working as expected, any ideas?

```
x = input("Give me an integer x: ")
y = input("Give me an integer y: ")
sum = x + y
print("x + y is: " + sum)
```

**ddb**

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**you**

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```
x = input("Give me an integer x: ")
y = input("Give me an integer y: ")
sum = x + y
print("x + y is: " + sum)
```

**ddb**

It seems like you're trying to add two integers, but the `input()` function in Python returns a string. So, when you try to add `x` and `y`, you're actually concatenating two strings, not adding two integers.

To fix this, you can convert the inputs to integers using the `int()` function like so:

```
x = int(input("Give me an integer x: "))
y = int(input("Give me an integer y: "))
```

Approximates a 1:1 teacher-to-student ratio

*... felt like having a personal tutor...*

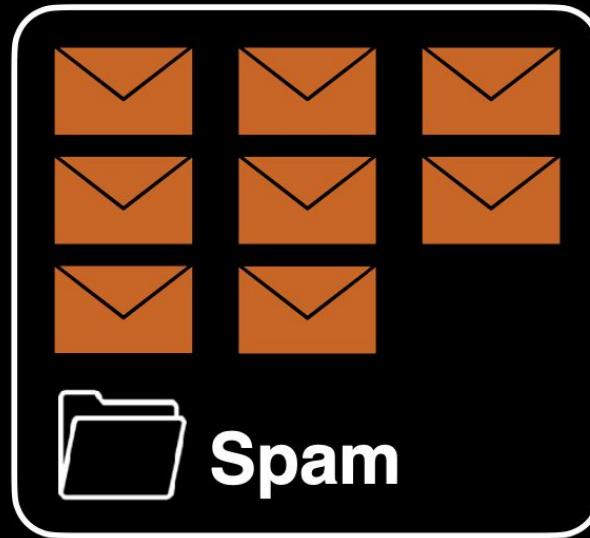
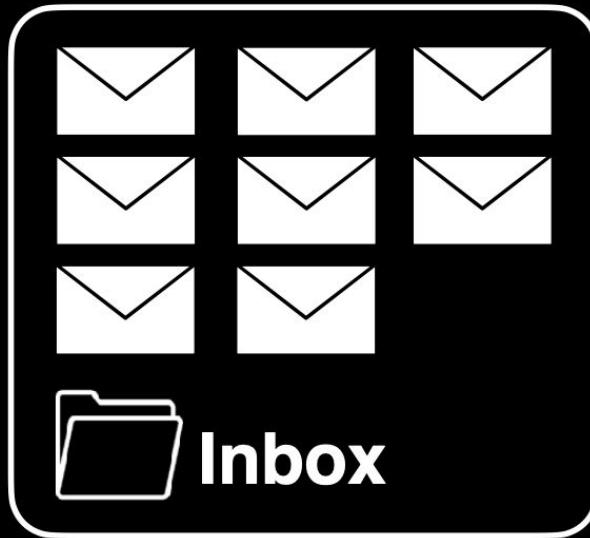
*... felt like having a personal tutor... i love how  
AI bots will answer questions without ego and  
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without judgment, generally entertaining even  
the stupidest of questions without treating them  
like they're stupid. it has an, as one could  
expect, inhuman level of patience.*

generative artificial intelligence

artificial intelligence

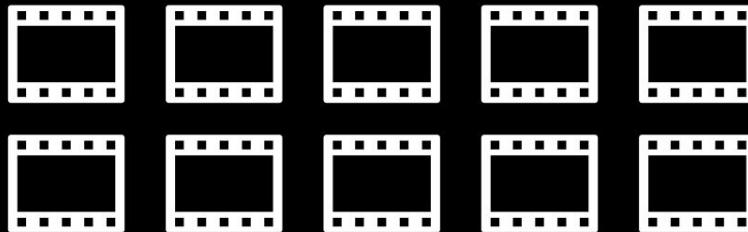


Hello, world!



Hello, world!

## Watch History



## Recommendations



9:41 ↗



Thursday, October 26

9:41

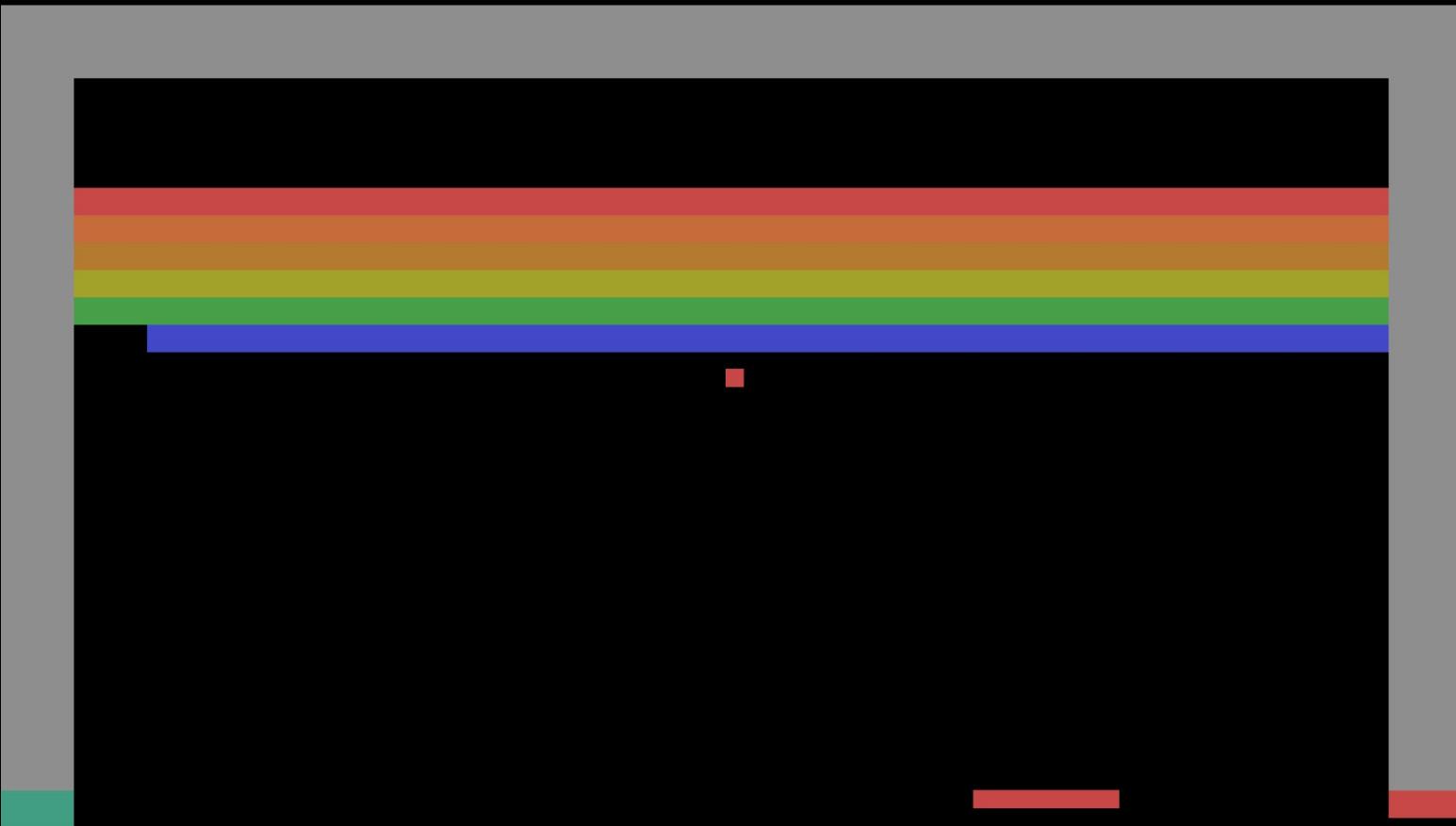


15

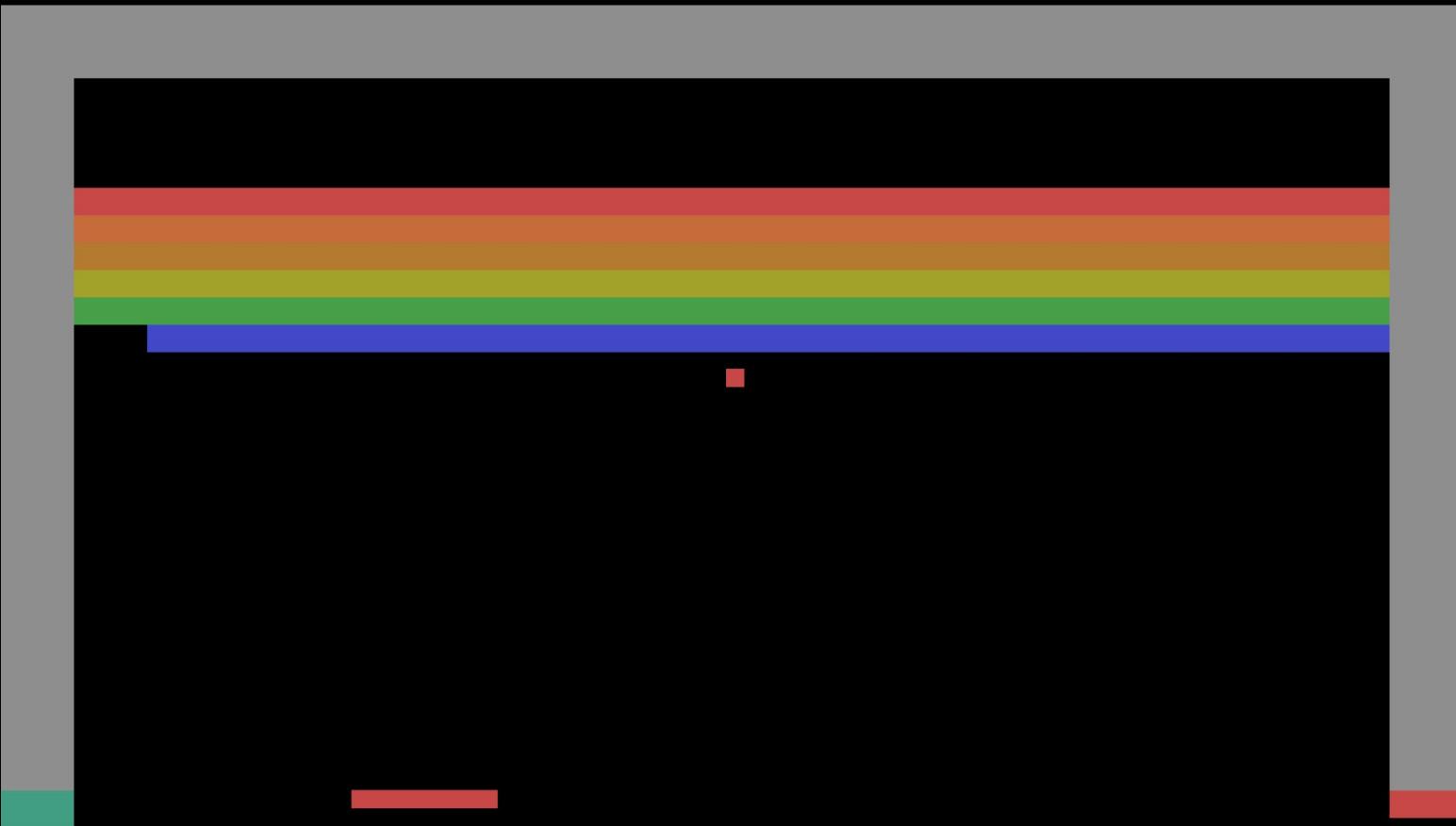
12

|

↓



□ □ □ 2 □



# decision trees



Is ball left of paddle?

Is ball left of paddle?

Yes

Is ball left of paddle?

Yes

**Move paddle left.**

Is ball left of paddle?

Yes

No

**Move paddle left.**

Is ball left of paddle?

Yes

No

**Move paddle left.**

Is ball right of paddle?

Is ball left of paddle?

Yes

**Move paddle left.**

No

Is ball right of paddle?

Yes

Is ball left of paddle?

Yes

**Move paddle left.**

No

Is ball right of paddle?

Yes

**Move paddle right.**

Is ball left of paddle?

Yes

No

**Move paddle left.**

Is ball right of paddle?

Yes

No

**Move paddle right.**

Is ball left of paddle?

Yes

**Move paddle left.**

No

Is ball right of paddle?

Yes

**Move paddle right.**

No

**Don't move paddle.**



While game is ongoing:

While game is ongoing:

If ball is left of paddle:

Move paddle left

While game is ongoing:

If ball is left of paddle:

Move paddle left

Else if ball is right of padding:

Move paddle right

While game is ongoing:

If ball is left of paddle:

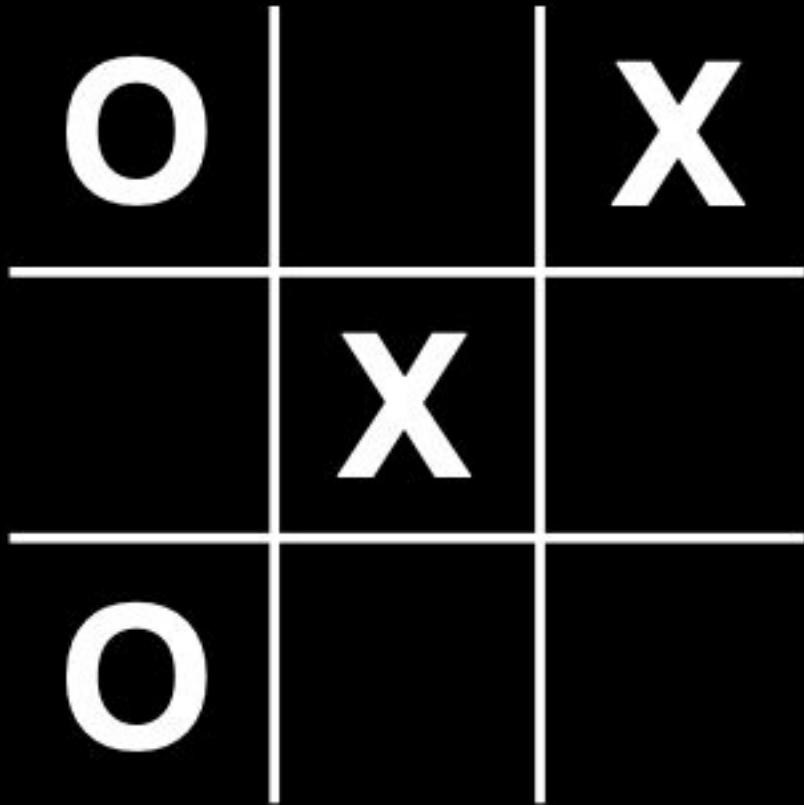
Move paddle left

Else if ball is right of padding:

Move paddle right

Else:

Don't move paddle





Can I get 3 in a row  
this turn?

Can I get 3 in a row  
this turn?

Yes

Can I get 3 in a row  
this turn?

Yes

**Play in square to  
get 3 in a row.**

Can I get 3 in a row  
this turn?

Yes

No

**Play in square to  
get 3 in a row.**

Can I get 3 in a row  
this turn?

Yes

No

**Play in square to  
get 3 in a row.**

Can my opponent get 3 in  
a row on their next turn?

Can I get 3 in a row  
this turn?

Yes

No

**Play in square to  
get 3 in a row.**

Can my opponent get 3 in  
a row on their next turn?

Yes

Can I get 3 in a row  
this turn?

Yes

No

**Play in square to  
get 3 in a row.**

Can my opponent get 3 in  
a row on their next turn?

Yes

**Play in square to block  
opponent's 3 in a row.**

Can I get 3 in a row  
this turn?

Yes

No

**Play in square to  
get 3 in a row.**

Can my opponent get 3 in  
a row on their next turn?

Yes

No

**Play in square to block  
opponent's 3 in a row.**

Can I get 3 in a row  
this turn?

Yes

No

**Play in square to  
get 3 in a row.**

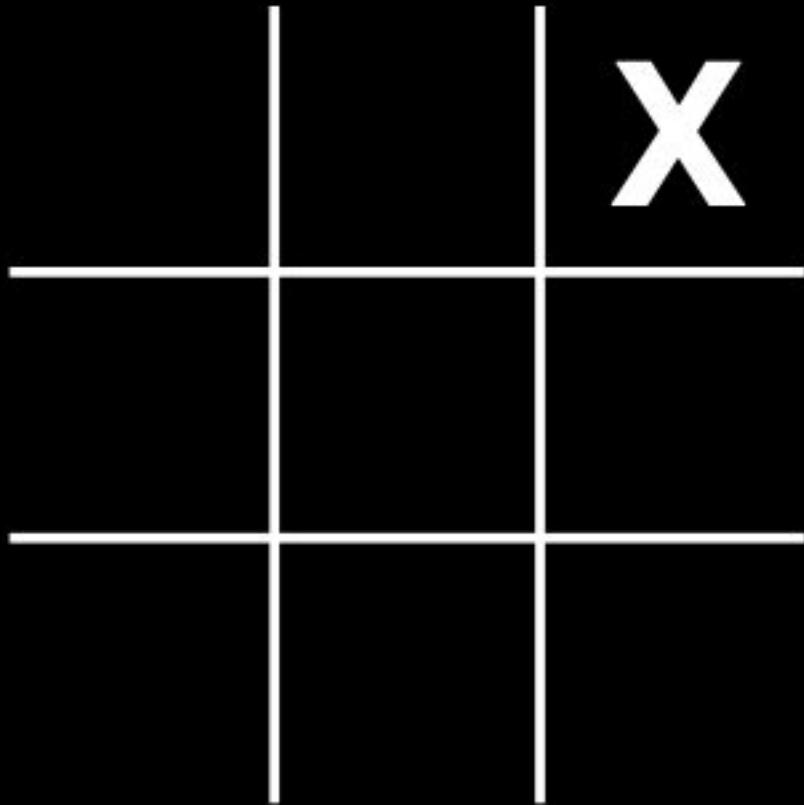
Can my opponent get 3 in  
a row on their next turn?

Yes

No

**Play in square to block  
opponent's 3 in a row.**

?

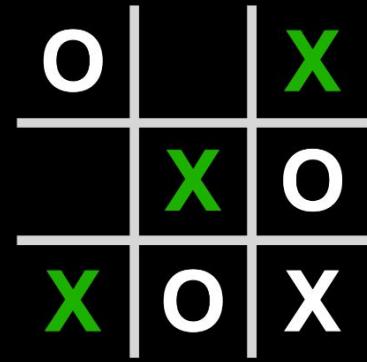
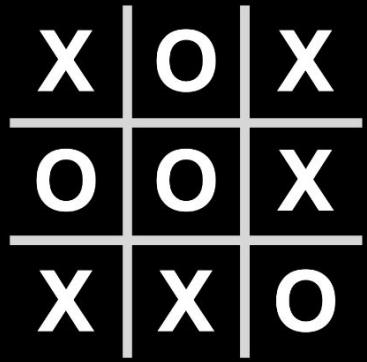
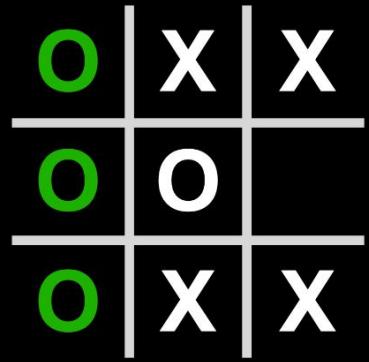


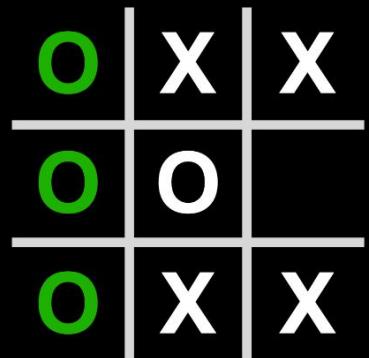
# Why AI is Good at Games

**Inputs and outputs that can be represented mathematically.**

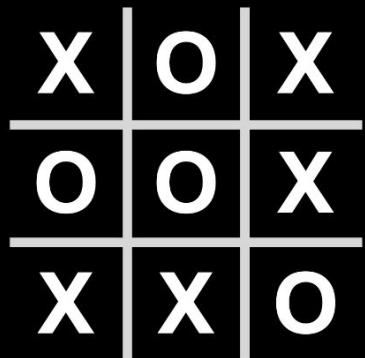
A **goal** in the form of a **function to maximize/minimize.**

minimax

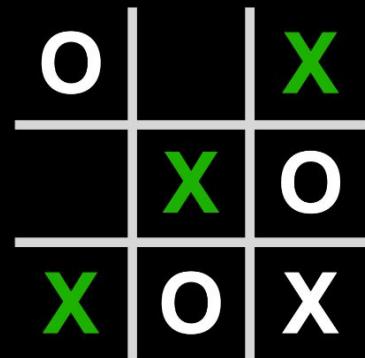




-1



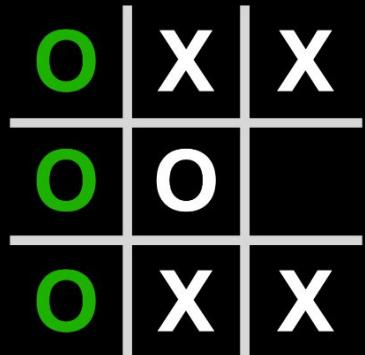
0



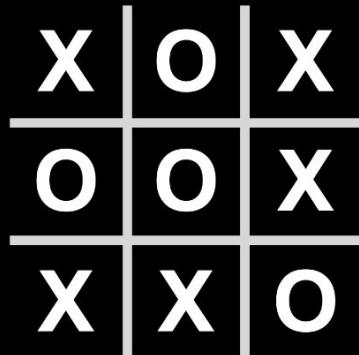
1

MAX (X) aims to maximize score.

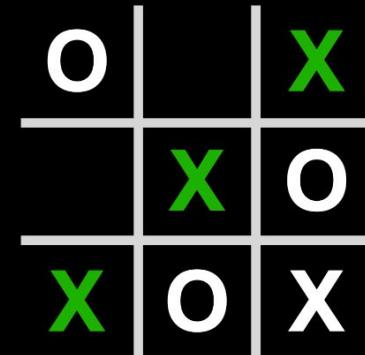
MIN (O) aims to minimize score.



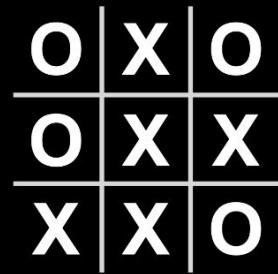
-1

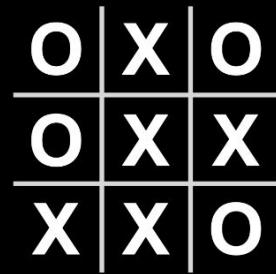


0

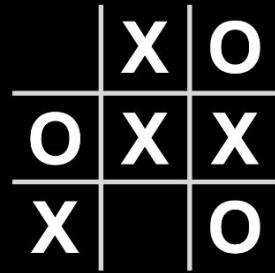


1

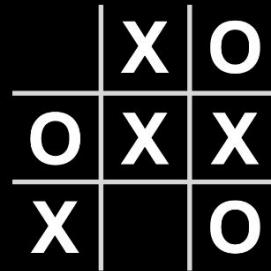




VALUE: 1



TURN = O



TURN = O

VALUE:

X	O	
O	X	X
X		O

TURN = O

VALUE:

	X	O
O	X	X
X		O

↓

O	X	O
O	X	X
X		O

↓

	X	O
O	X	X
X	O	O

TURN = O

VALUE:

	X	O
O	X	X
X		O

VALUE:

O	X	O
O	X	X
X		O

VALUE:

X	O
O	X
X	O

TURN = O

VALUE:

	X	O
O	X	X
X		O

VALUE:

O	X	O
O	X	X
X		O

VALUE:

X	O
O	X
X	O

↓

O	X	O
O	X	X
X	X	O

TURN = O

VALUE:

	X	O
O	X	X
X		O

VALUE:

O	X	O
O	X	X
X		O

VALUE:

X	O	O
O	X	X
X	O	O

VALUE:

O	X	O
O	X	X
X	X	O

TURN = O

VALUE:

	X	O
O	X	X
X		O

VALUE:

O	X	O
O	X	X
X		O

VALUE:

X	O	O
O	X	X
X	O	O

VALUE:

O	X	O
O	X	X
X	X	O

1

TURN = O

VALUE:

X	O	
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X		O

VALUE:

X	O	
O	X	X
X	O	O

↓

VALUE:  
1

O	X	O
O	X	X
X	X	O

TURN = O

VALUE:

X	O	
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X	X	O

VALUE:

X	O	
O	X	X
X	O	O

↓

X	X	O
O	X	X
X	O	O

TURN = O

VALUE:

X	O	
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X	X	O

VALUE:

X	O	
O	X	X
X	O	O

VALUE:

X	X	
O	X	X
X	O	O

TURN = O

VALUE:

X	O	
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X	X	O

VALUE:  
0

X	O	O
O	X	X
X	O	O

VALUE:  
0

X	X	O
O	X	X
X	O	O

TURN = O

VALUE:

X	O	
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X		O

VALUE:  
1

O	X	O
O	X	X
X	X	O

VALUE:  
0

X	O	O
O	X	X
X	O	O

VALUE:  
0

X	X	O
O	X	X
X	O	O

TURN = O

VALUE: 0

X	O	
O	X	X
X		O

VALUE: 1

O	X	O
O	X	X
X		O

VALUE: 1

O	X	O
O	X	X
X	X	O

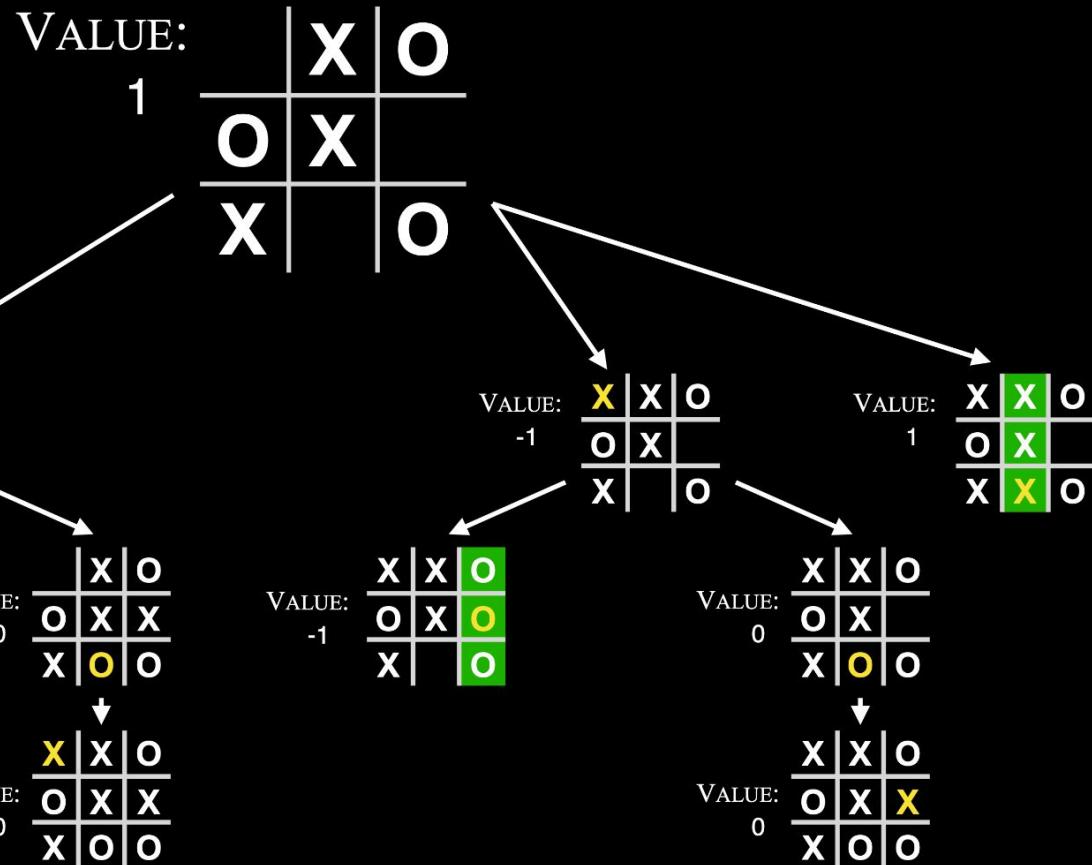
VALUE: 0

X	O	O
O	X	X
X	O	O

VALUE: 0

X	X	O
O	X	X
X	O	O

TURN = X





If player is X:

For each possible move:

Calculate score for board

Choose move with highest score

If player is X:

For each possible move:

Calculate score for board

Choose move with highest score

Else if player is 0:

For each possible move:

Calculate score for board

Choose move with lowest score

# Possibilities

**Tic-Tac-Toe**  
All possible games

# Possibilities

**Tic-Tac-Toe**  
All possible games

255,168

# Possibilities

**Tic-Tac-Toe**  
All possible games

255,168

**Chess**  
First 4 moves only

# Possibilities

**Tic-Tac-Toe**

All possible games

255,168

**Chess**

First 4 moves only

288 million

# Possibilities

## Tic-Tac-Toe

All possible games

255,168

## Chess

First 4 moves only

288 million

## Go

First 4 moves only

266 quintillion

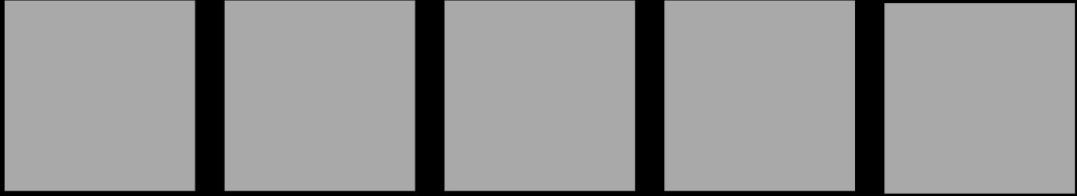
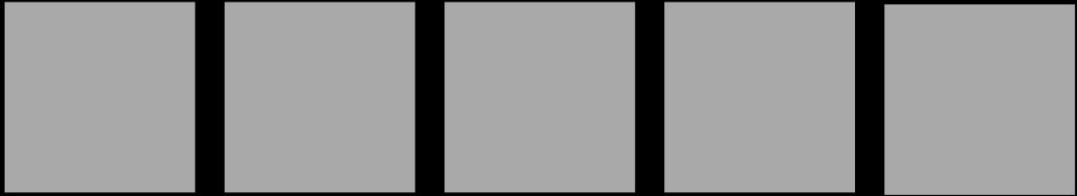
machine learning

# reinforcement learning

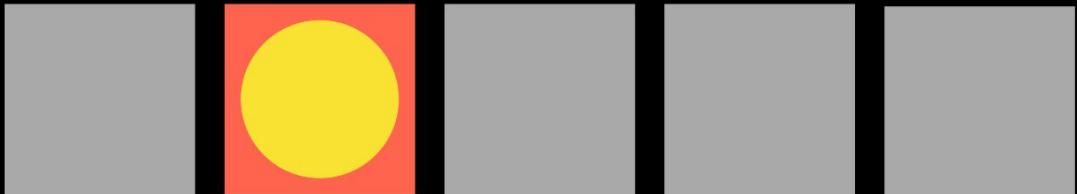
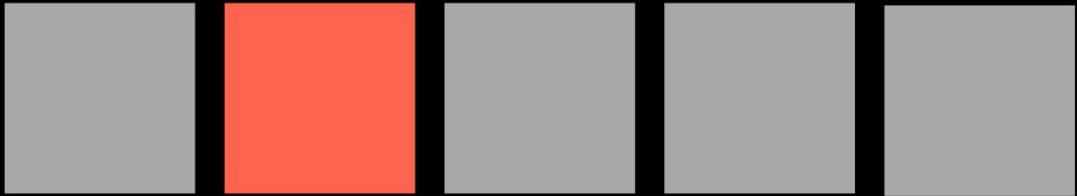


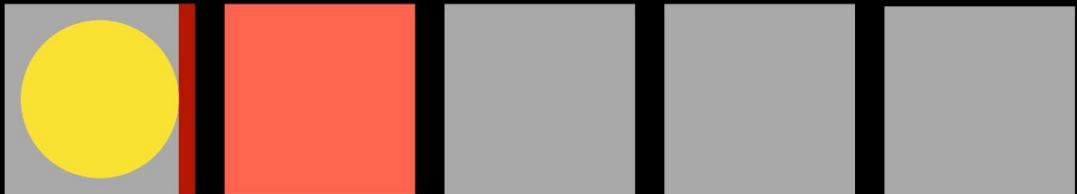
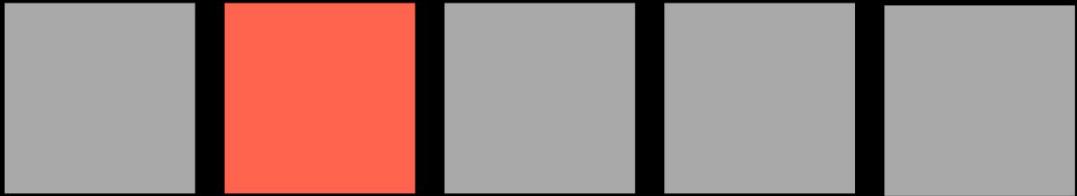
A close-up photograph of a white robotic arm with a grey base. The arm is positioned over a blue, textured surface, possibly a tablecloth. At the end of the arm is a small, round black pan containing a yellow, crumbly substance, likely food being prepared. The background is dark and out of focus.

# Reinforcement Learning

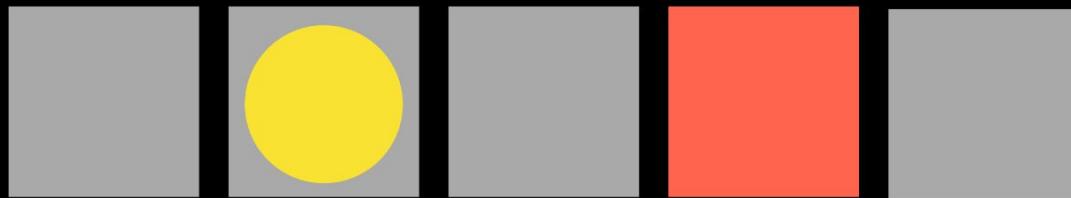


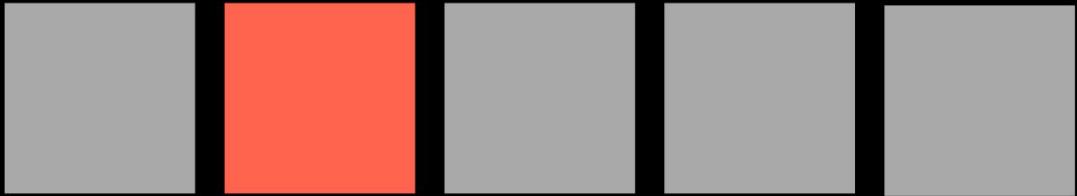




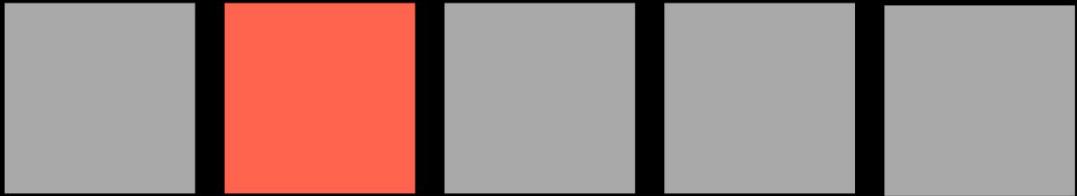


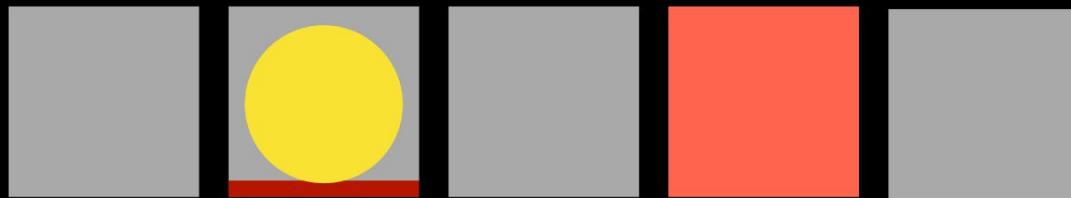


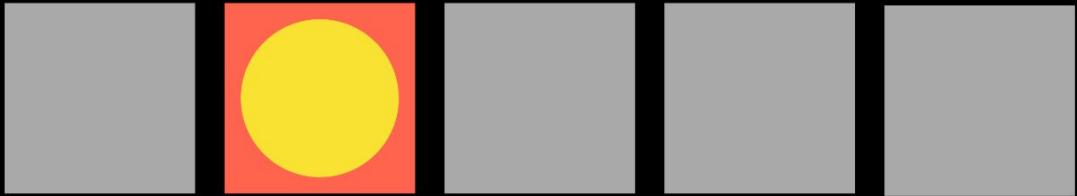


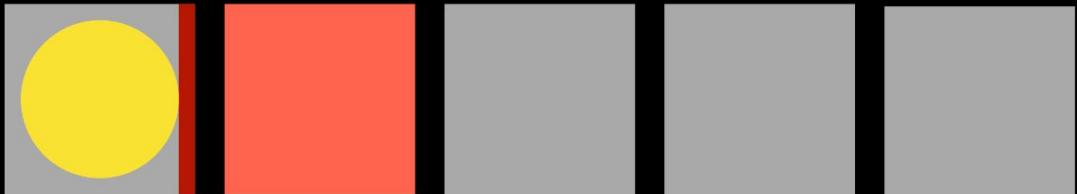
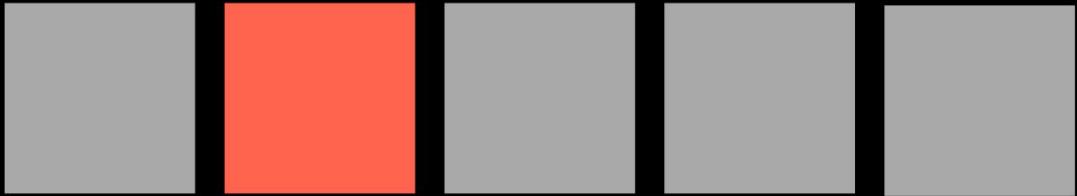




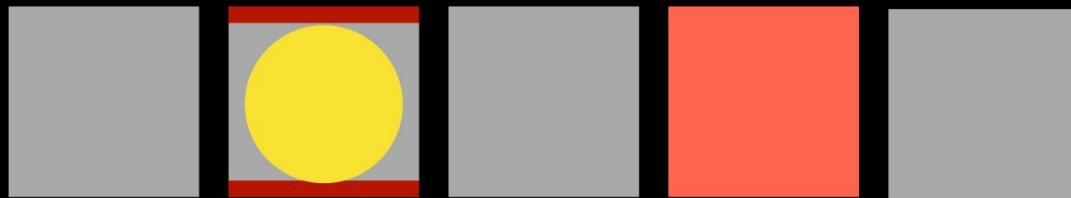


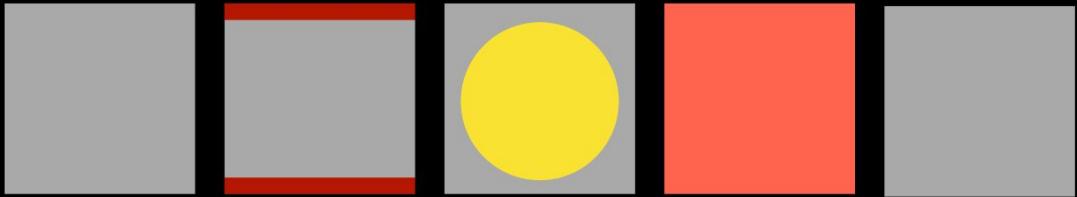
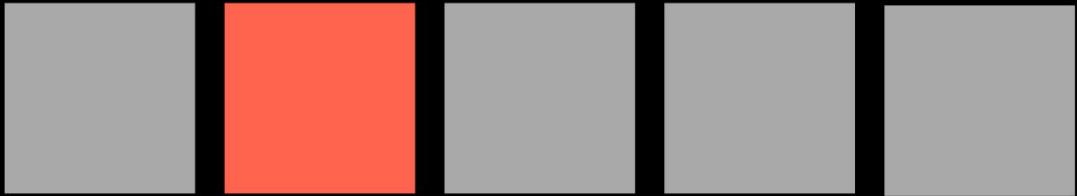


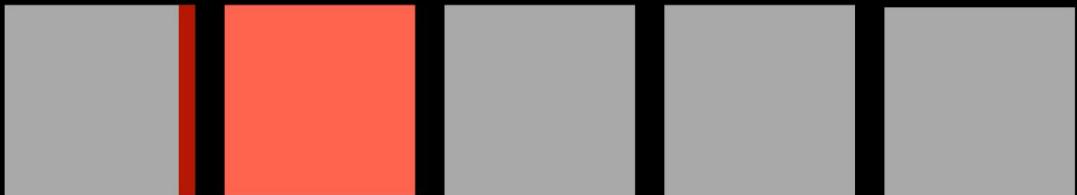
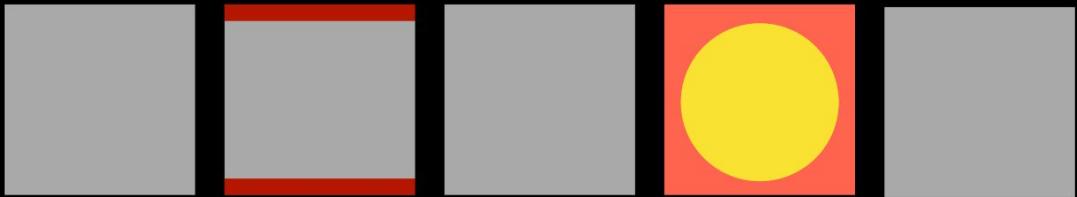


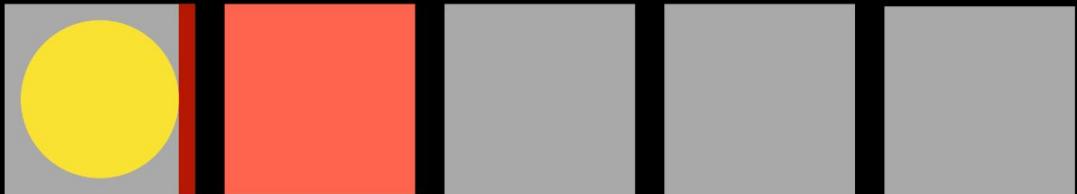
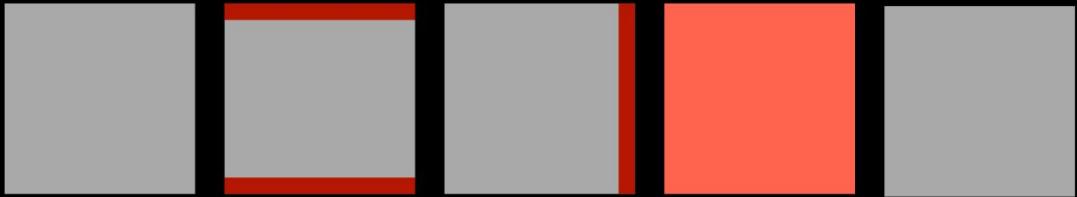


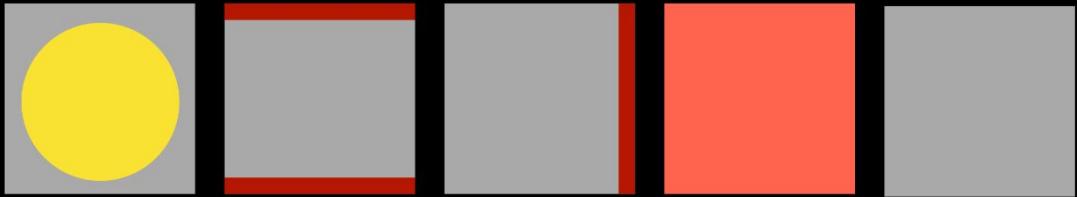
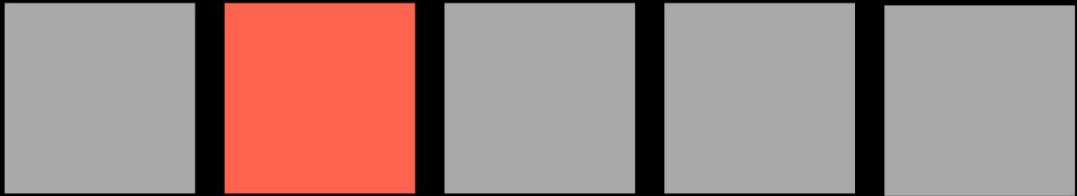


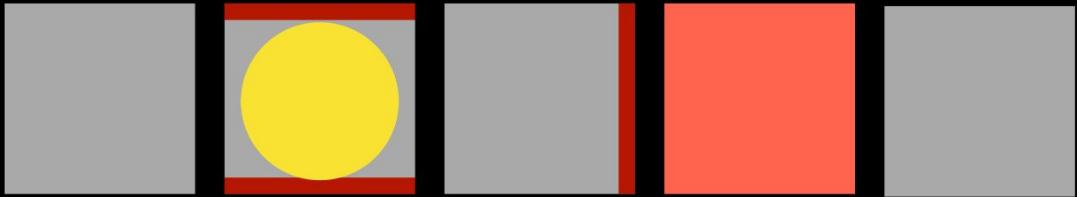
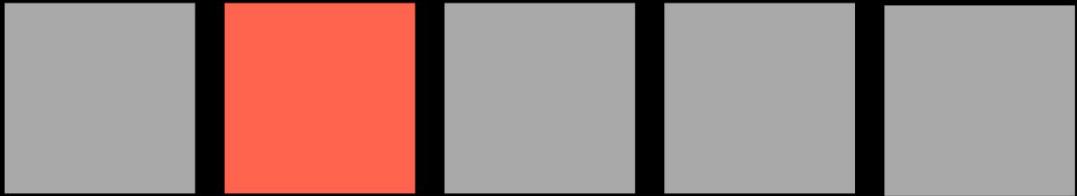


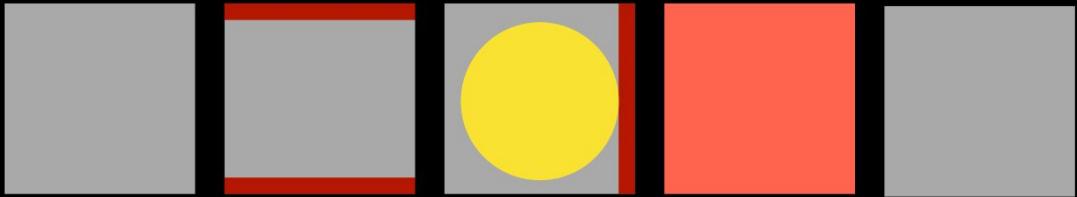


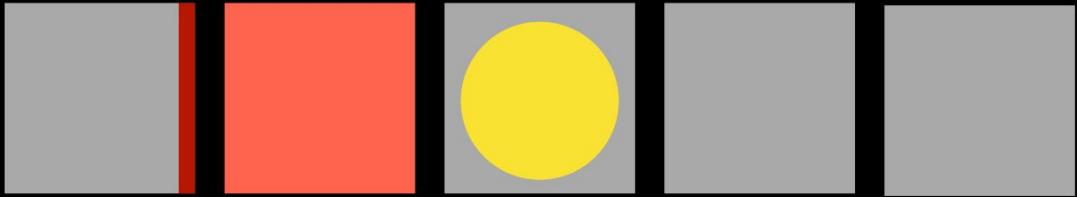
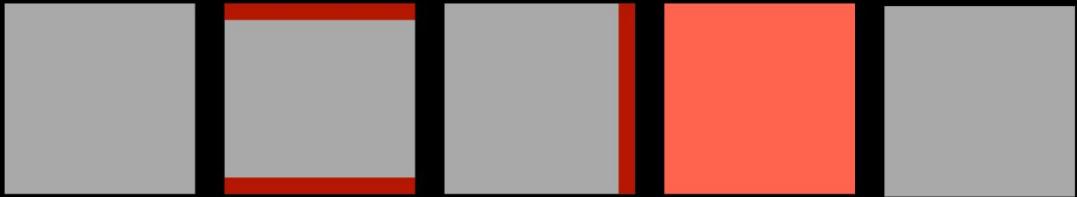
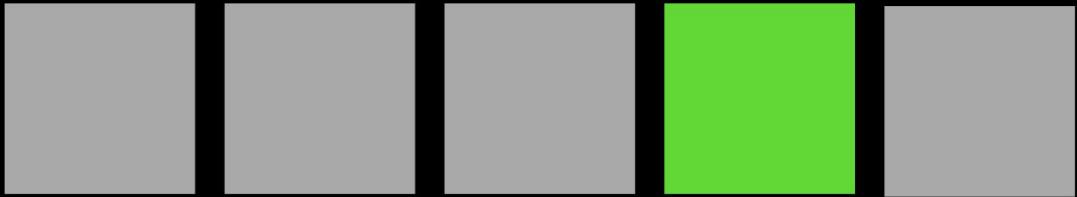


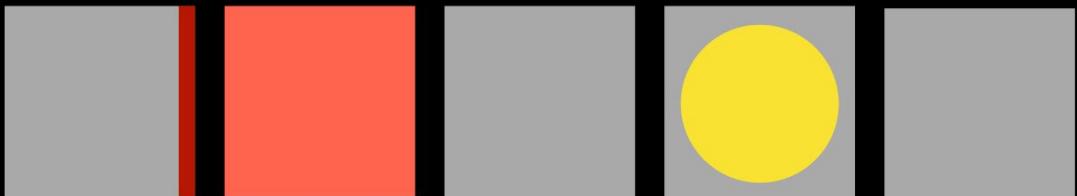
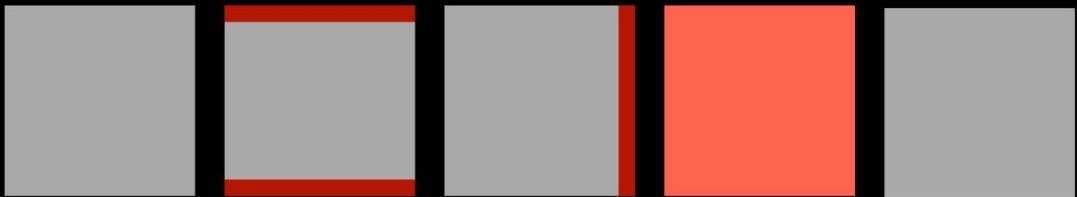


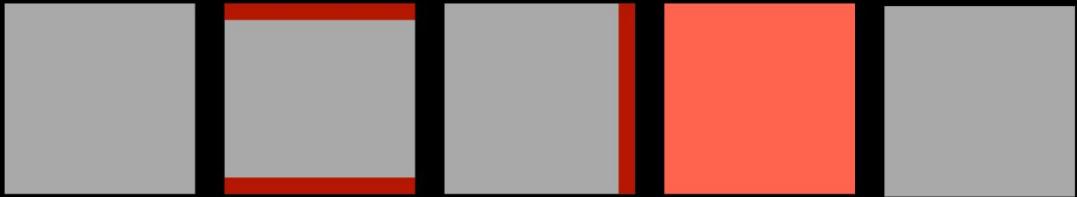
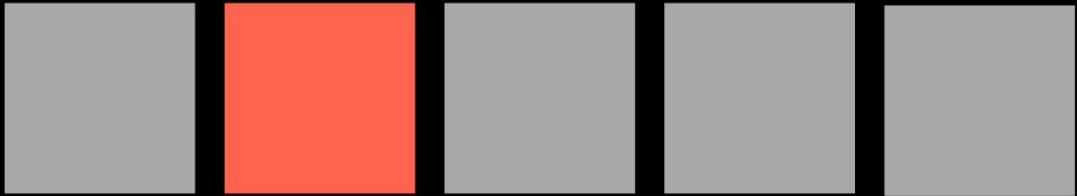


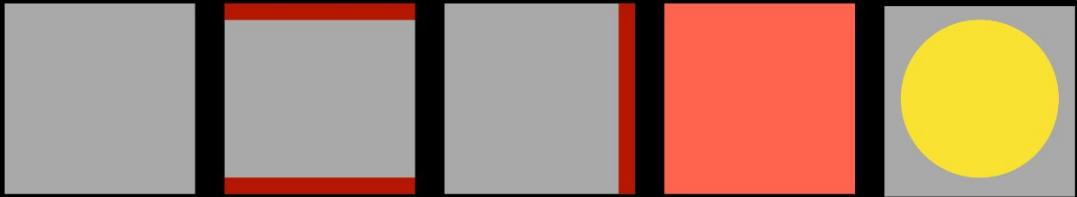


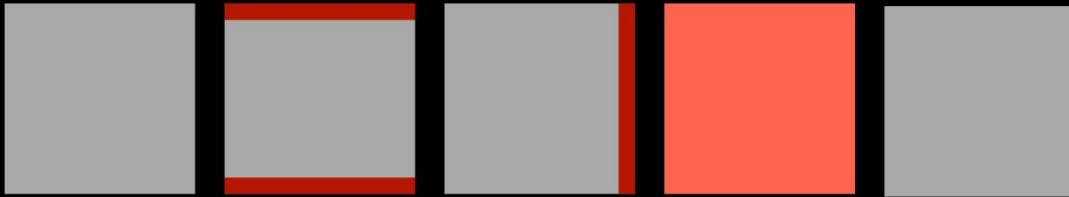


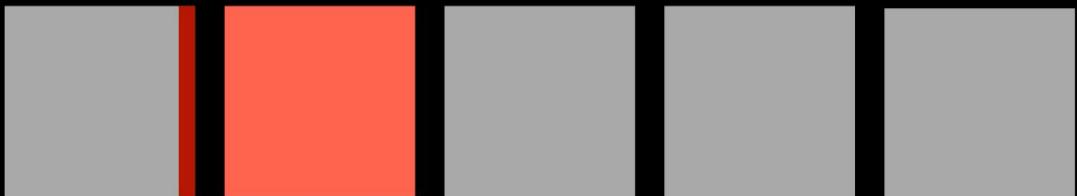
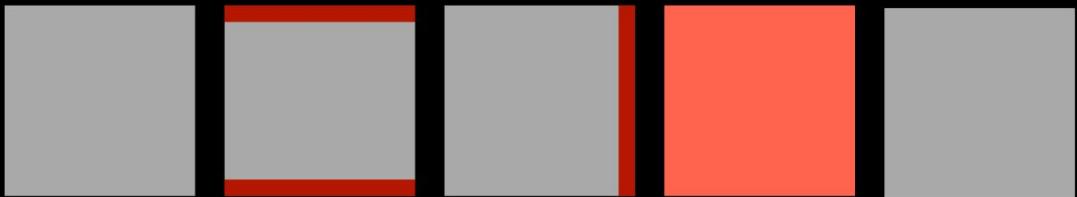


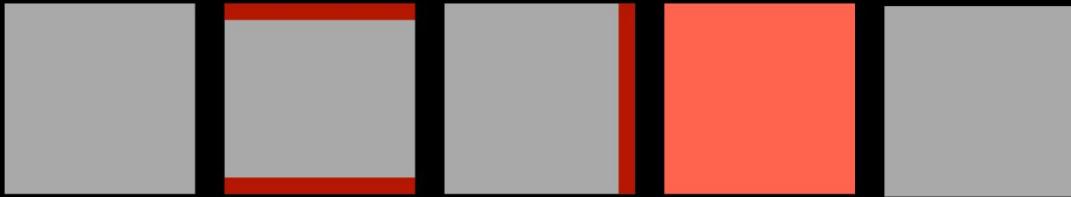


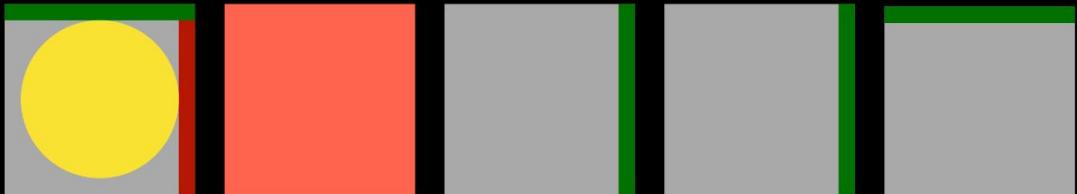


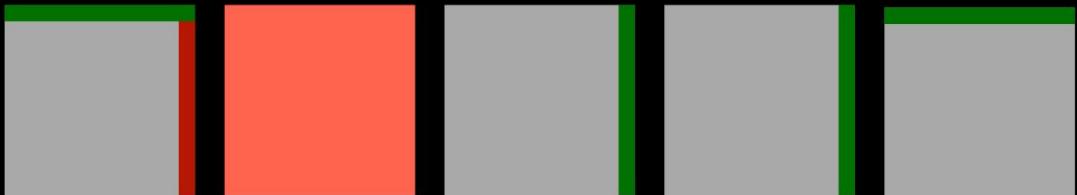
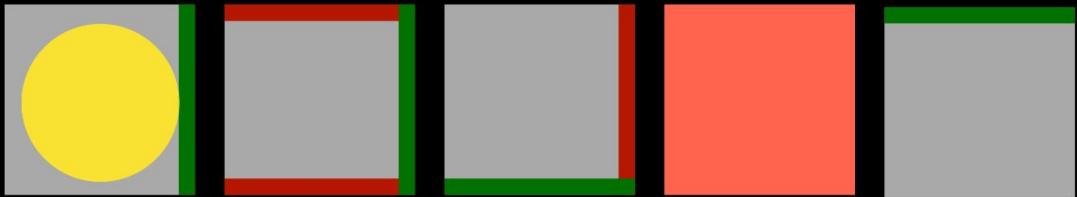
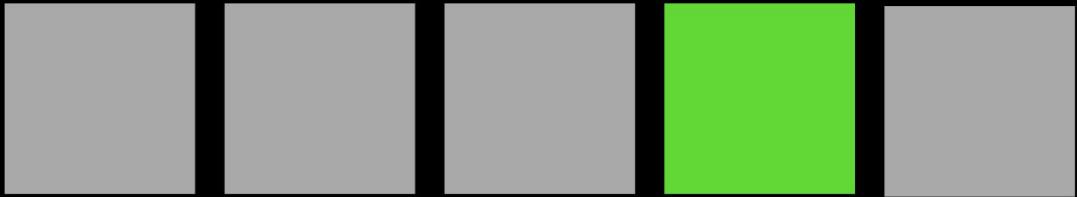


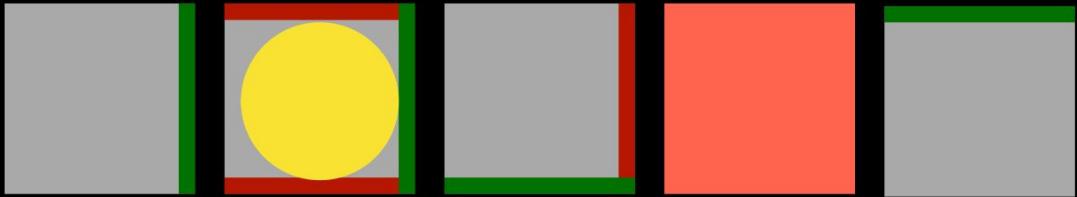


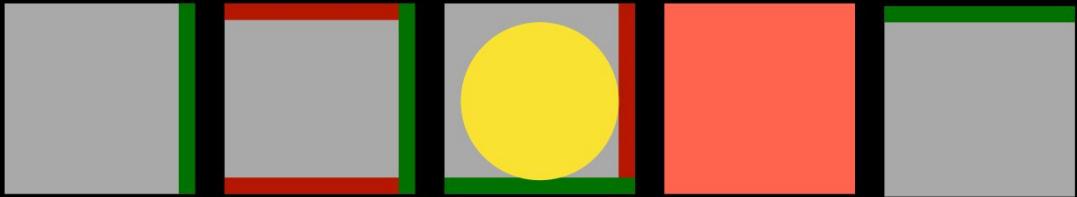
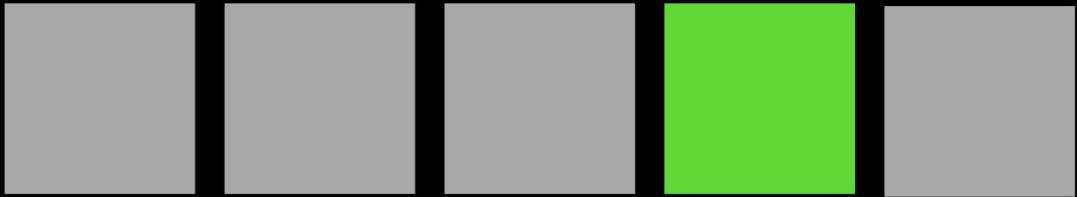


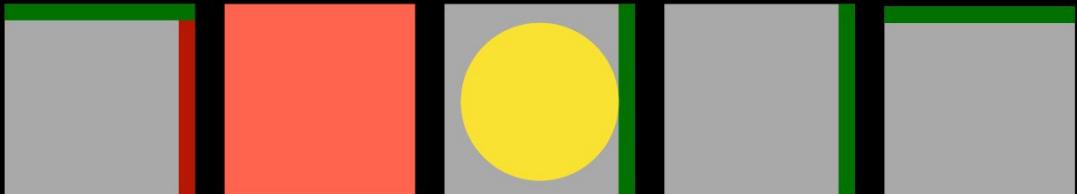


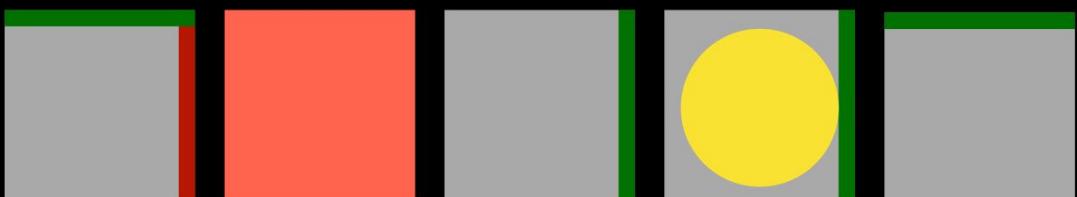
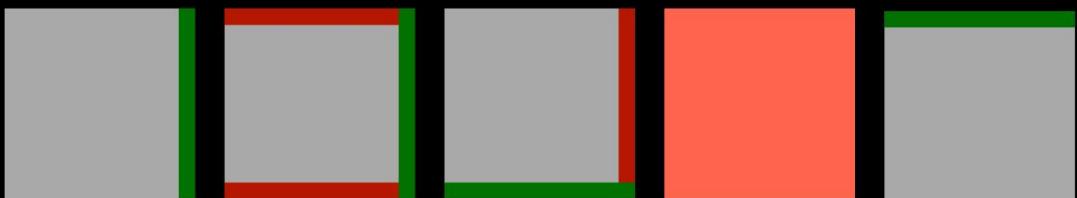
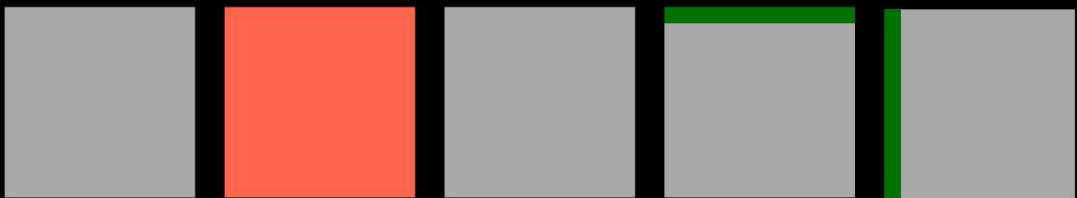


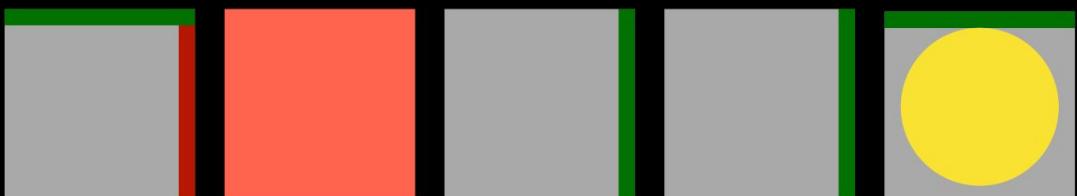
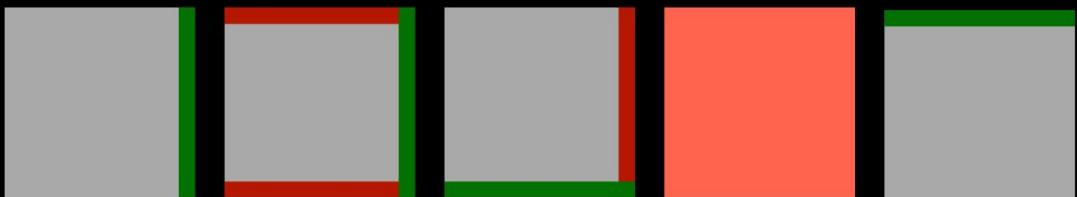
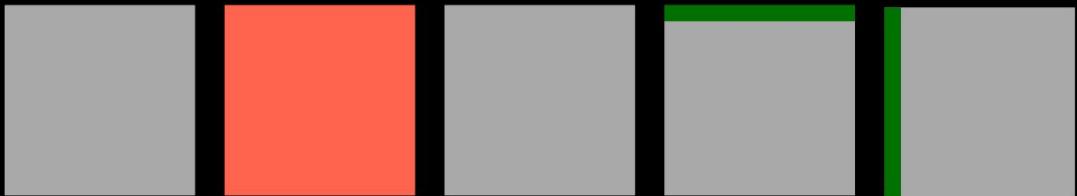
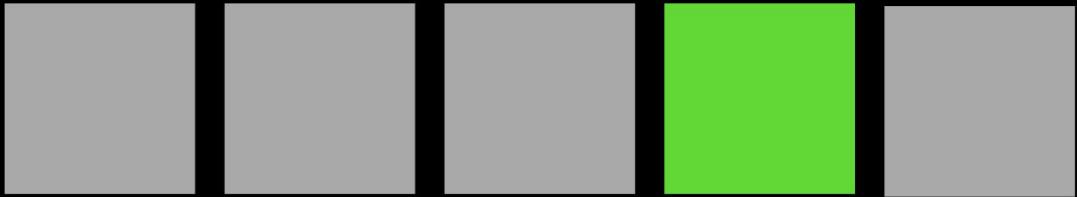


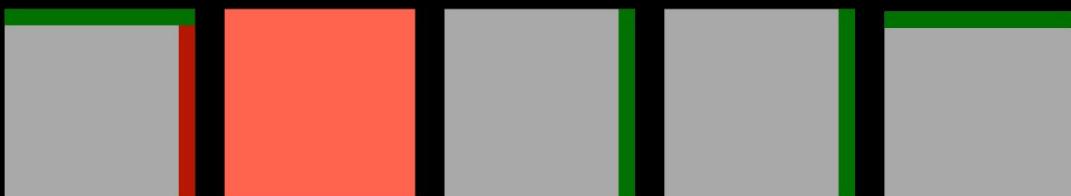
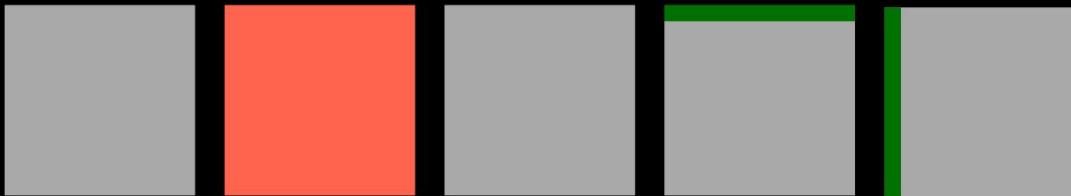


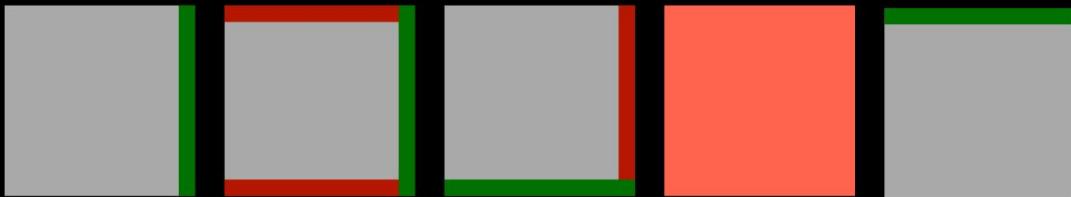


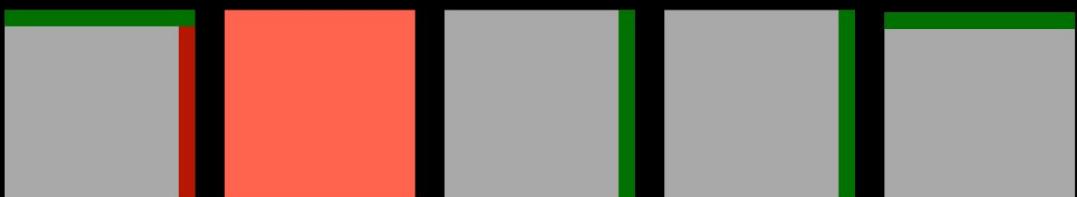
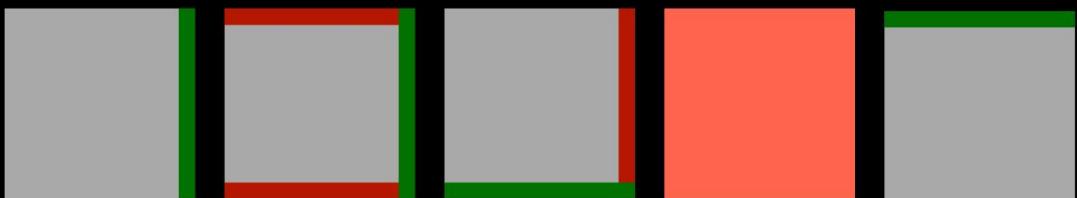
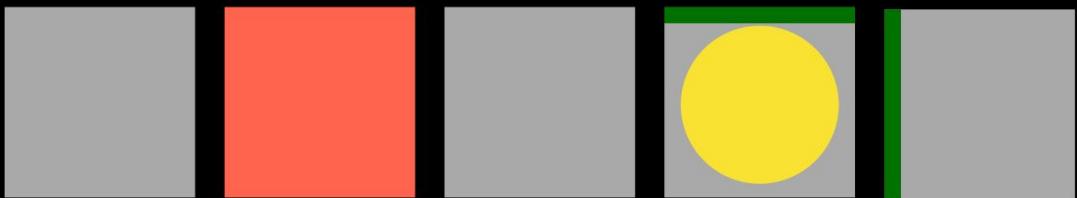


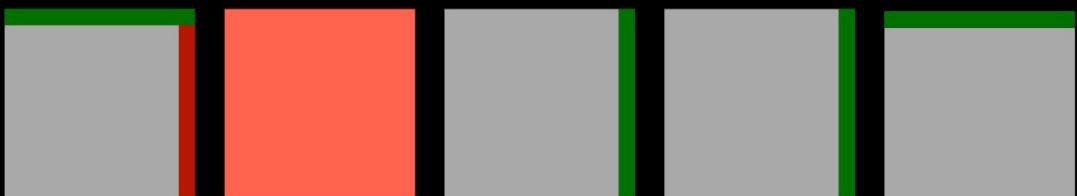
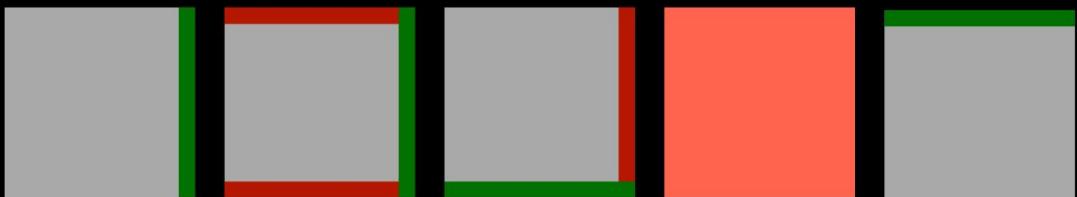
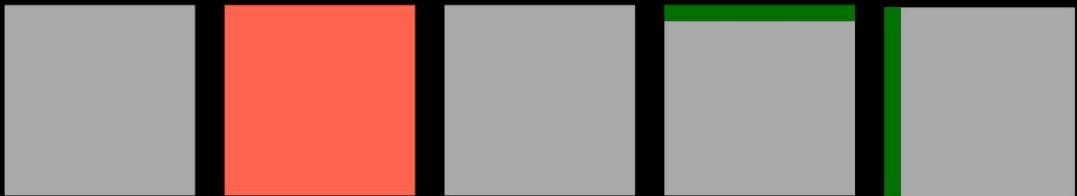












explore vs. exploit

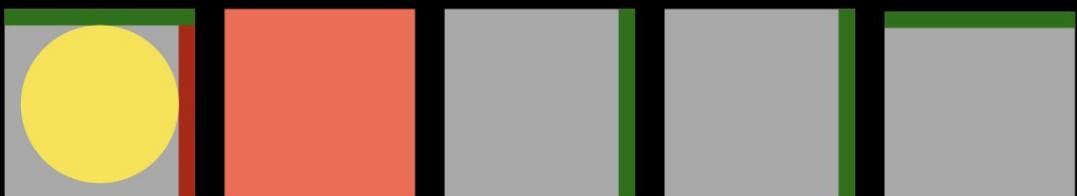
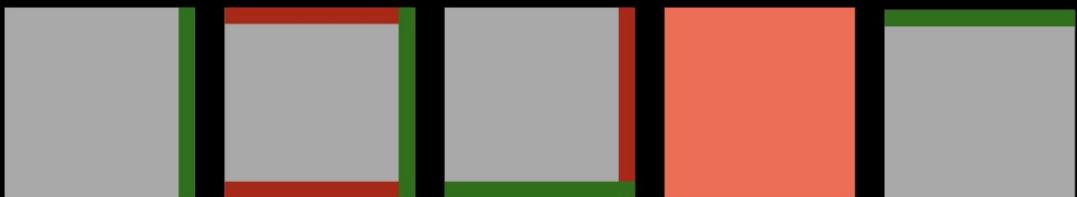
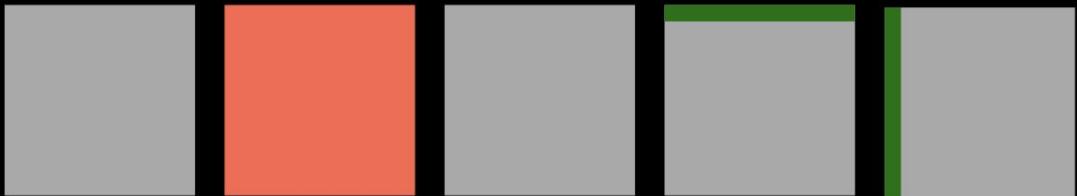
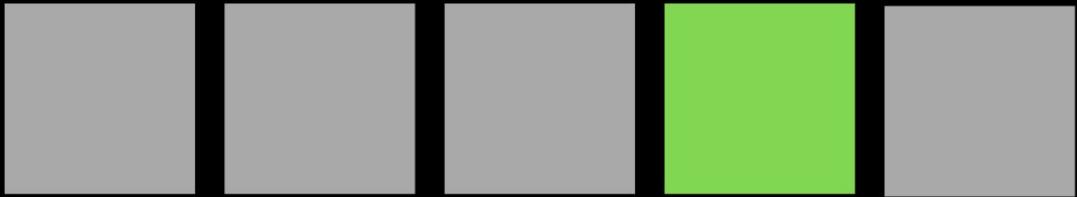
```
epsilon = 0.10
```

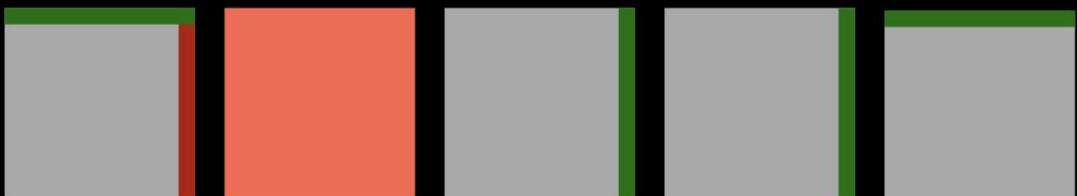
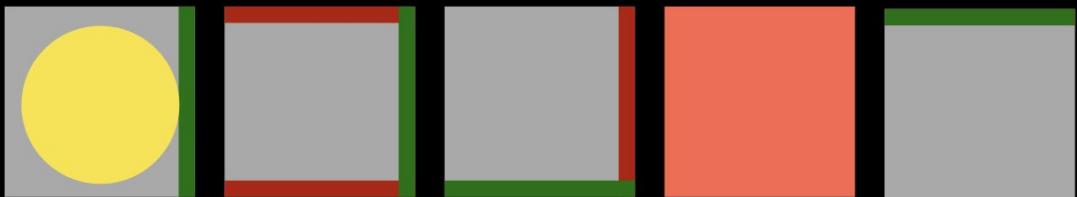
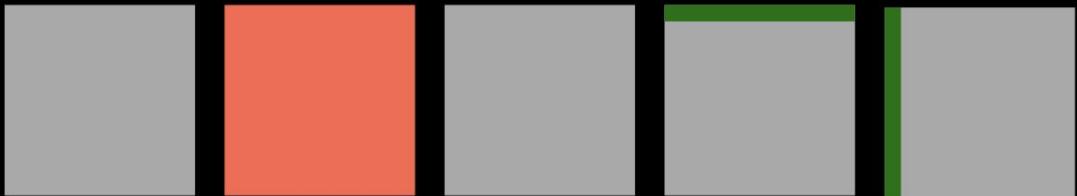
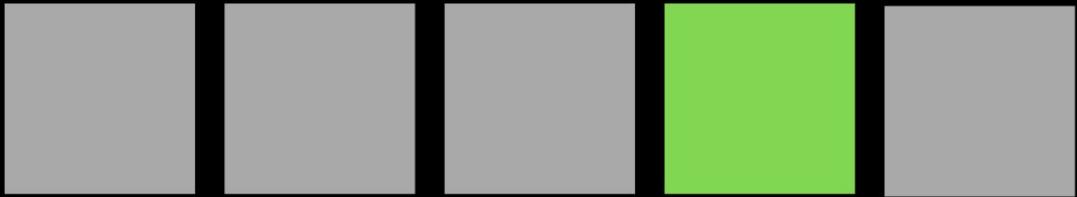
```
If random() < epsilon:
```

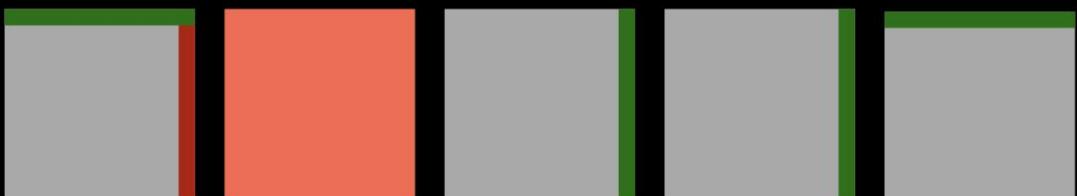
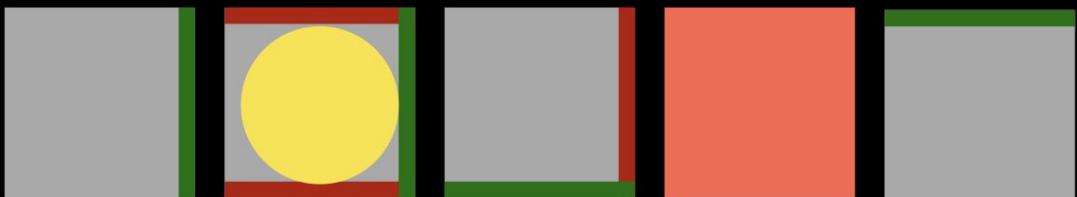
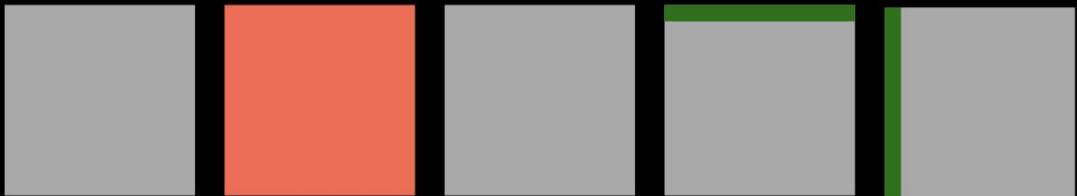
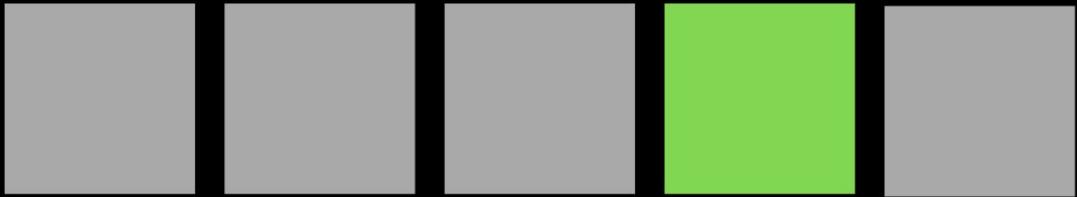
```
    Make a random move
```

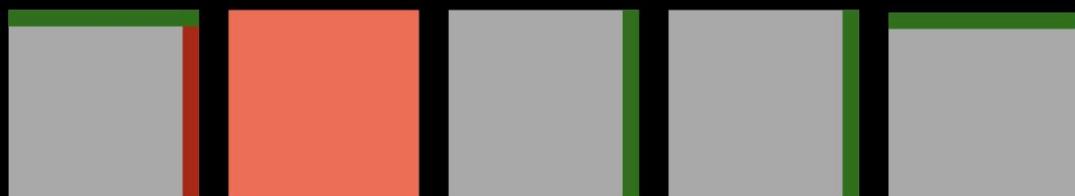
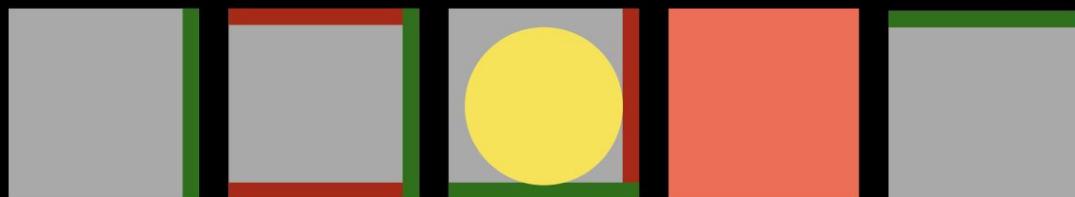
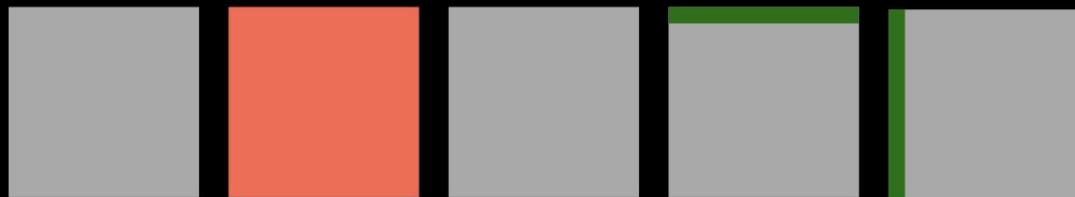
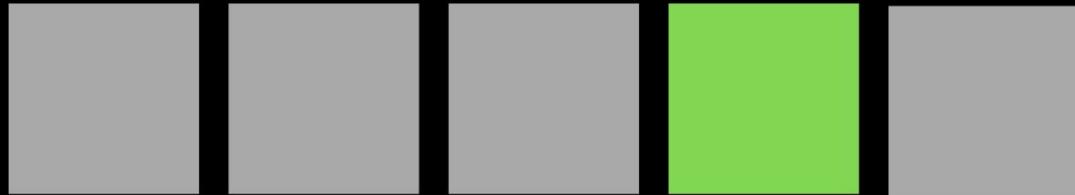
```
Else:
```

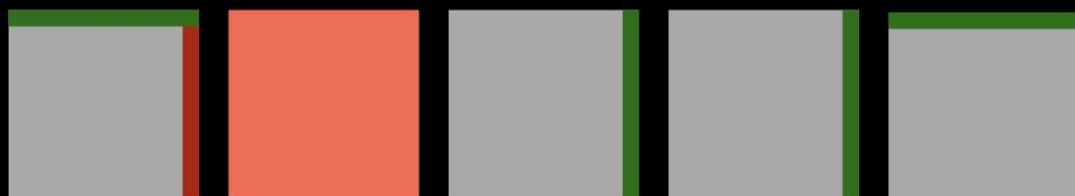
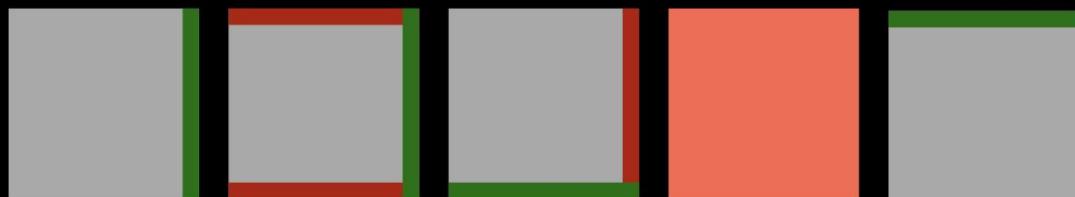
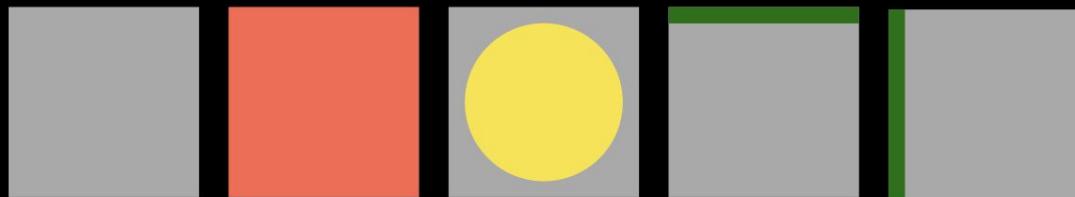
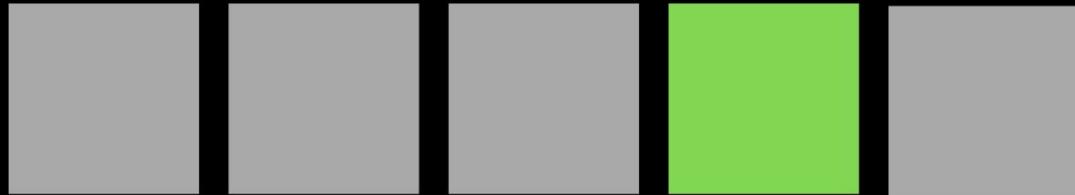
```
    Make the move with the highest value
```

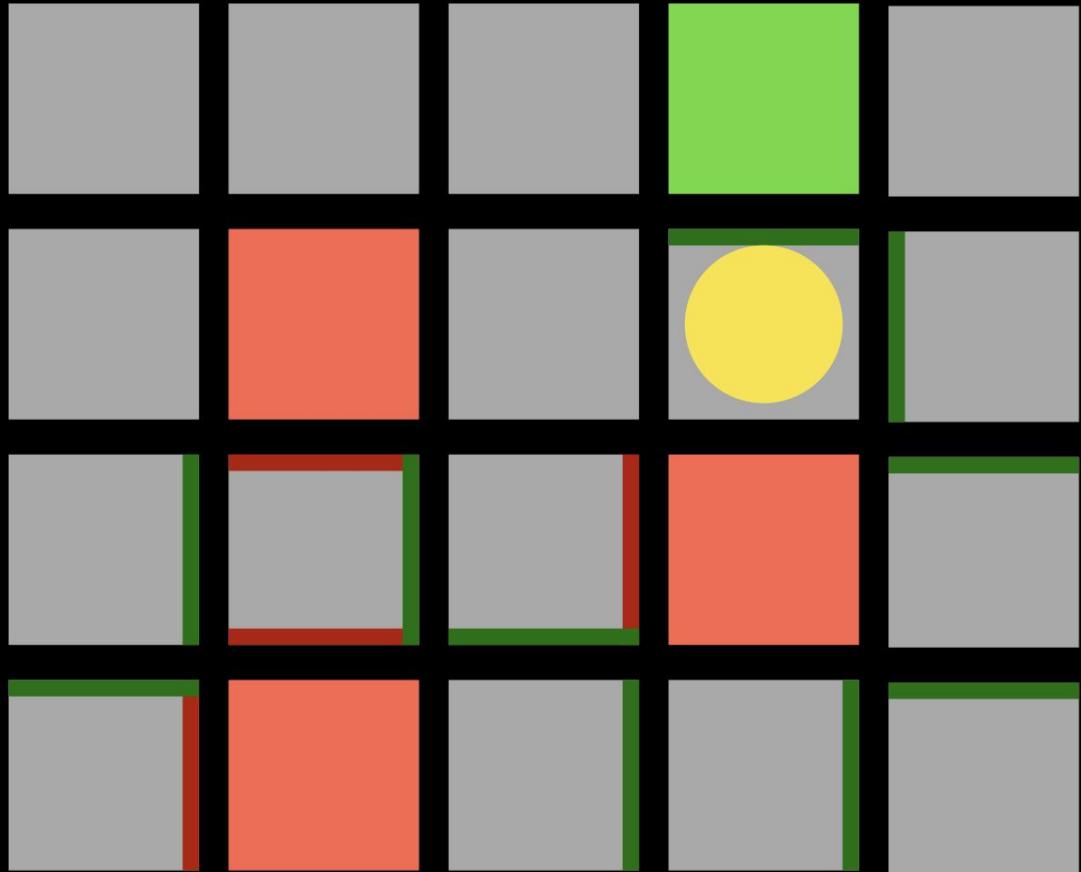


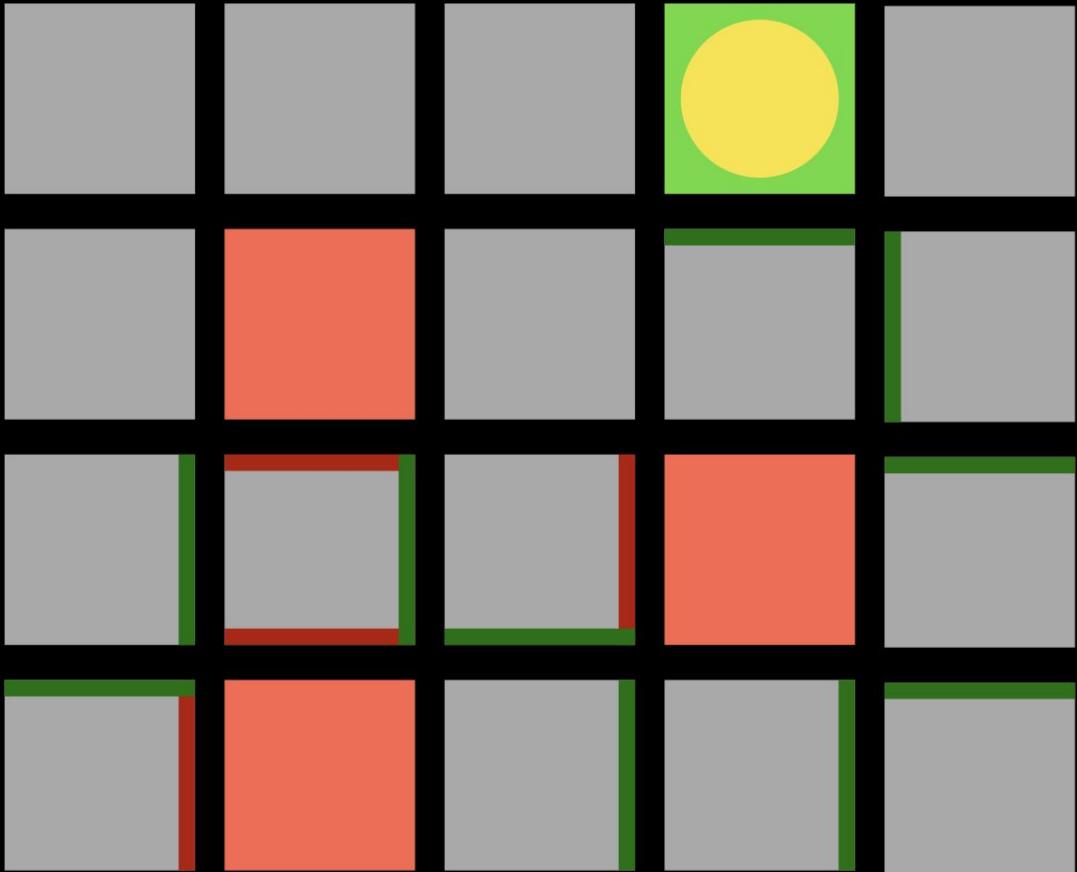






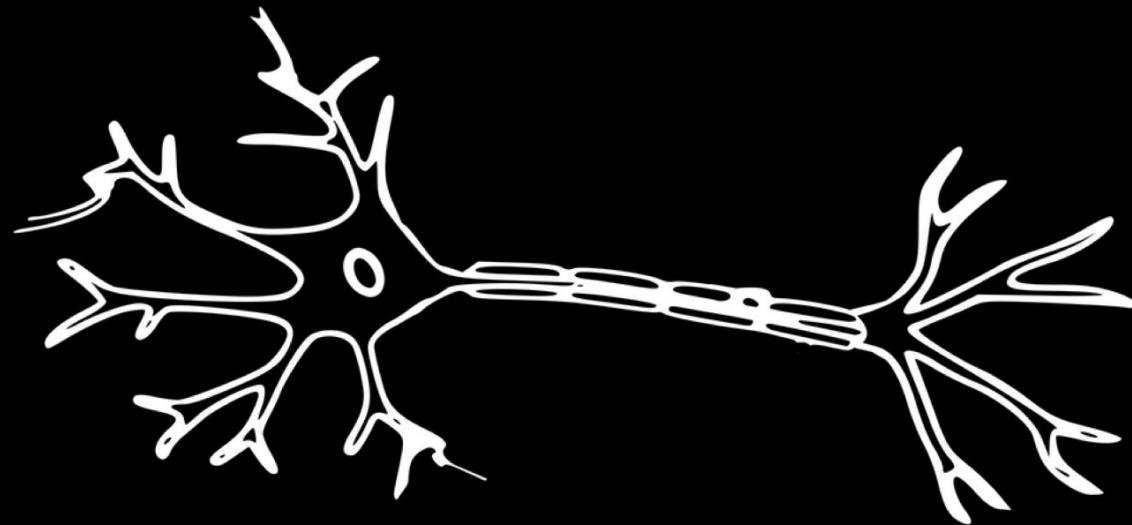




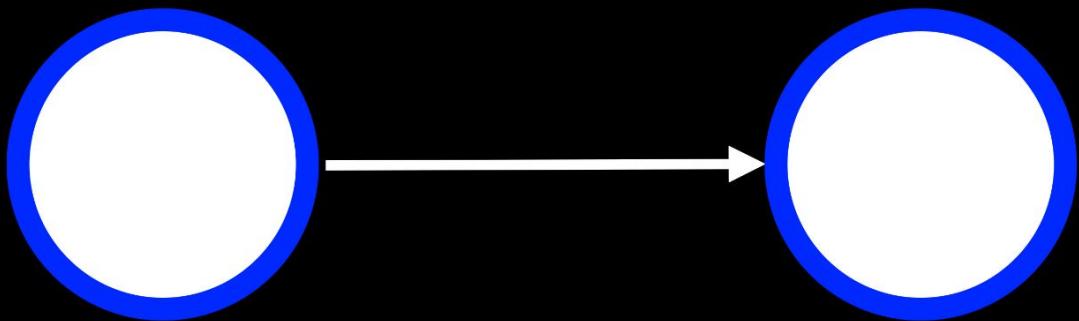


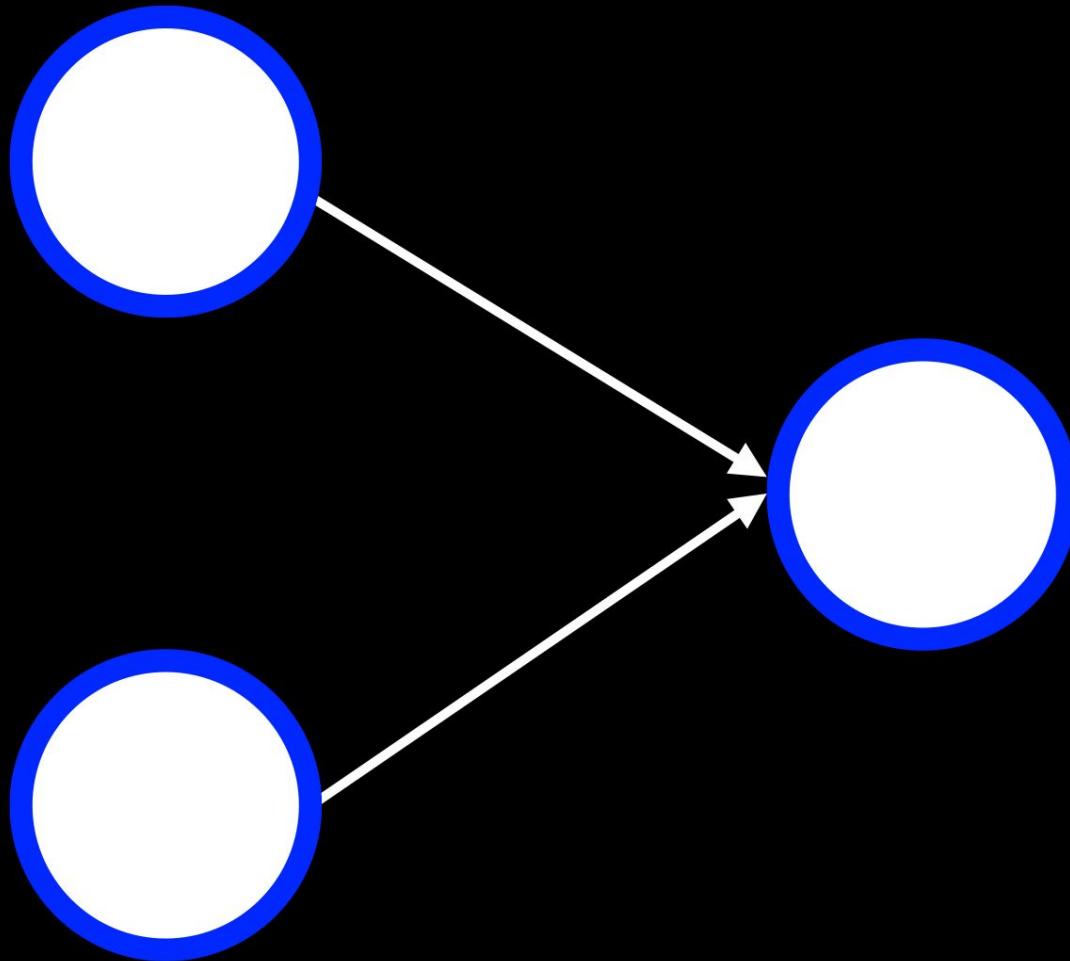
deep learning

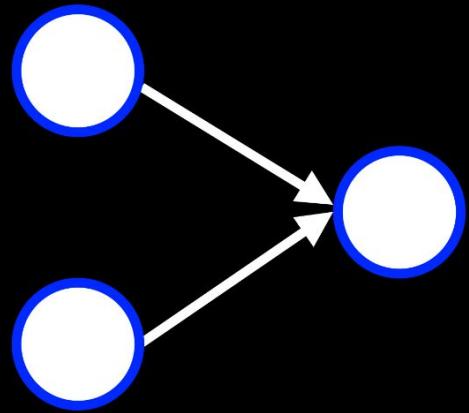
# neural networks

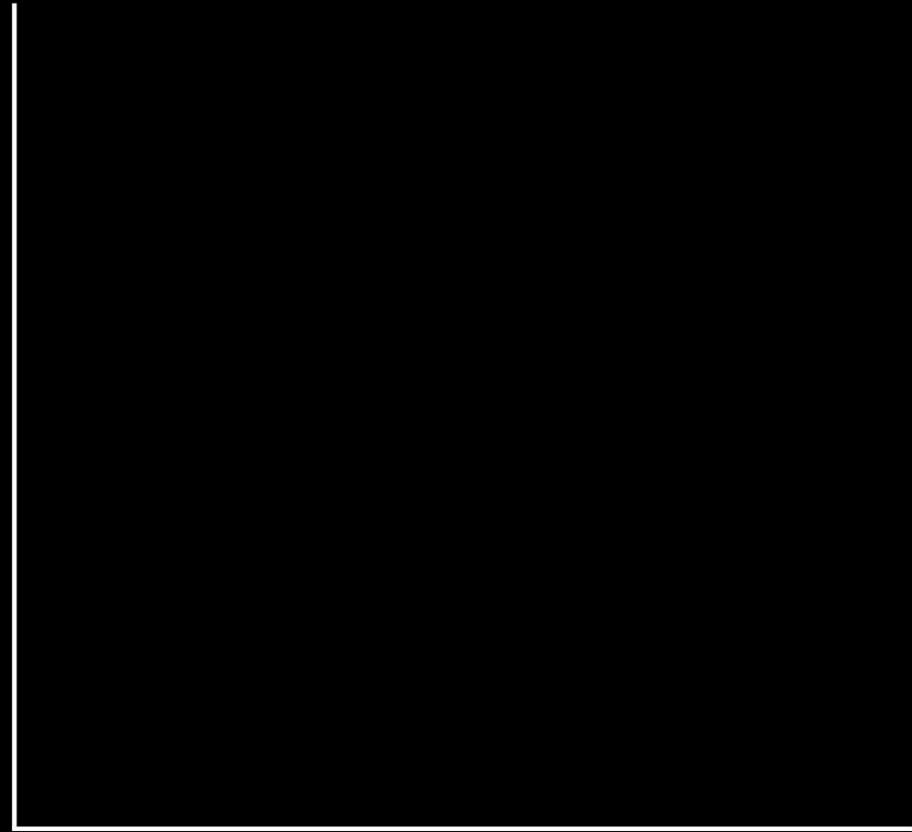
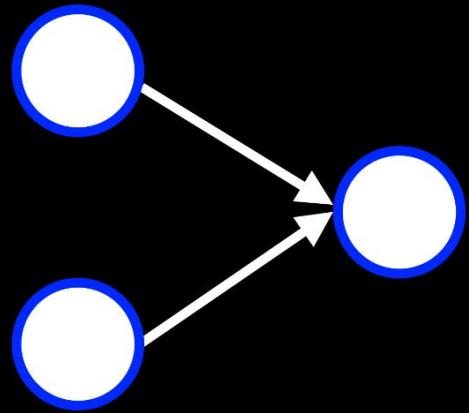


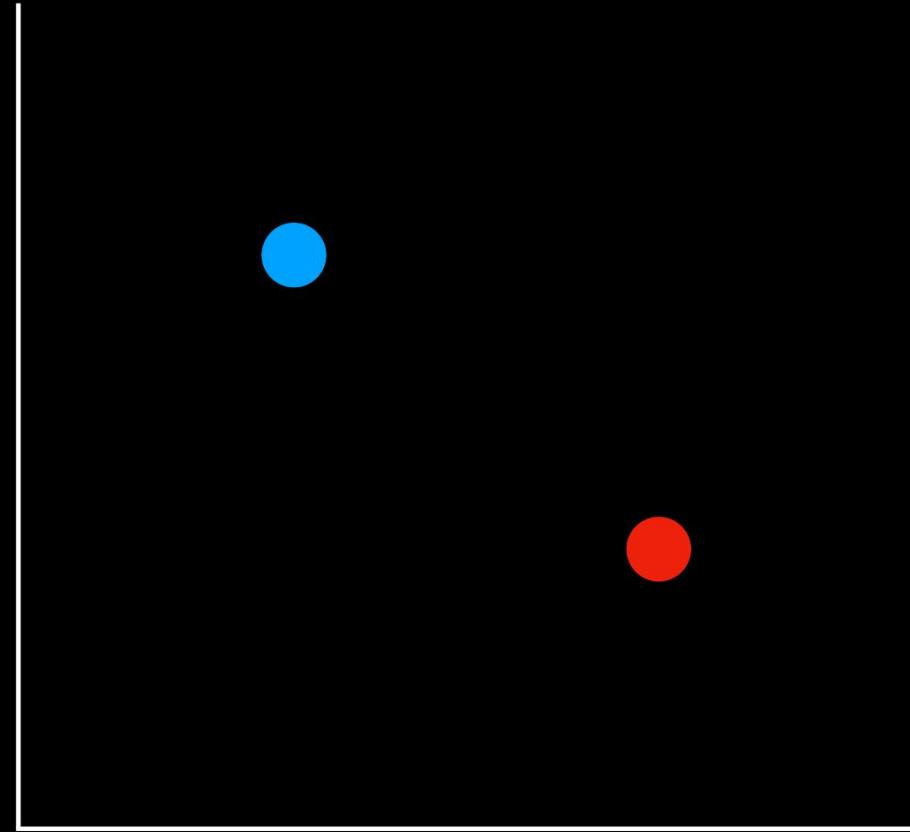
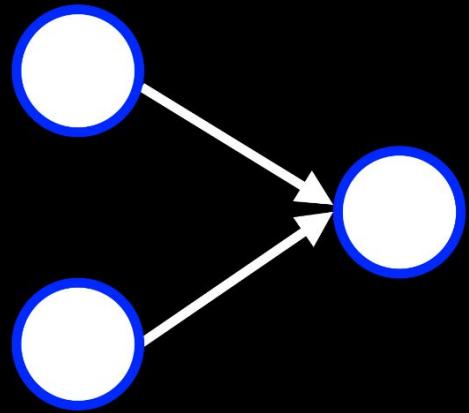


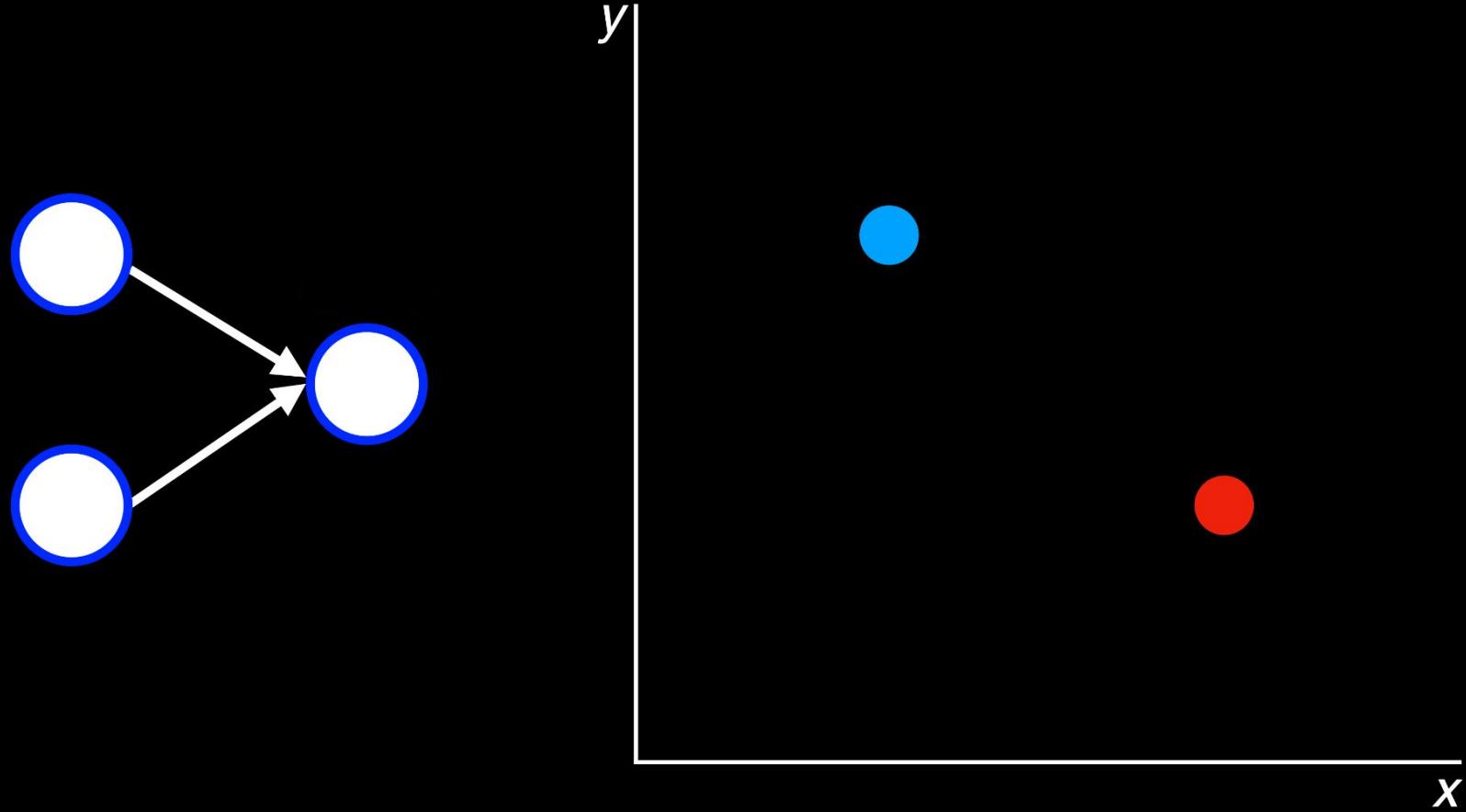


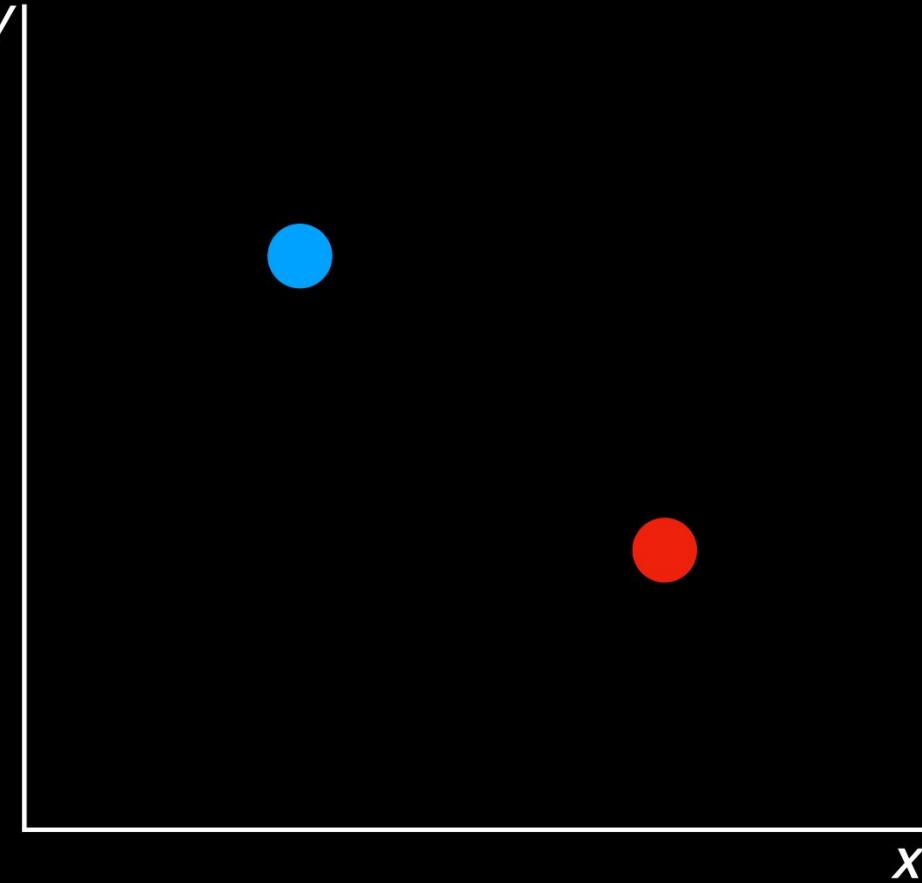
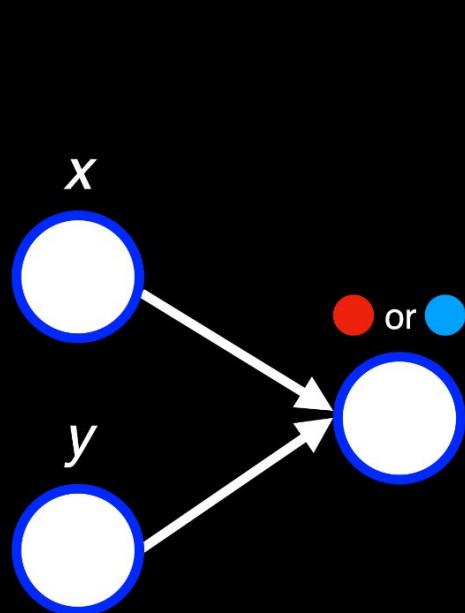


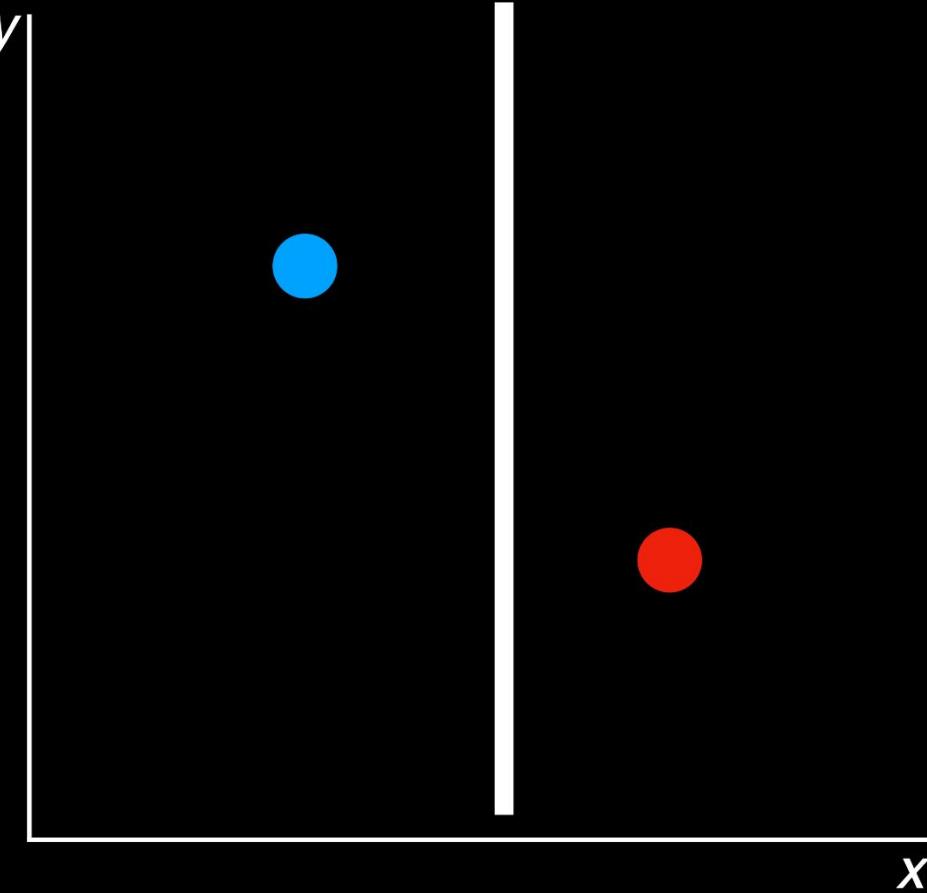
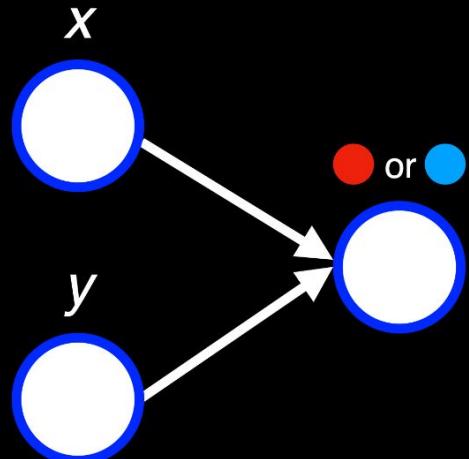


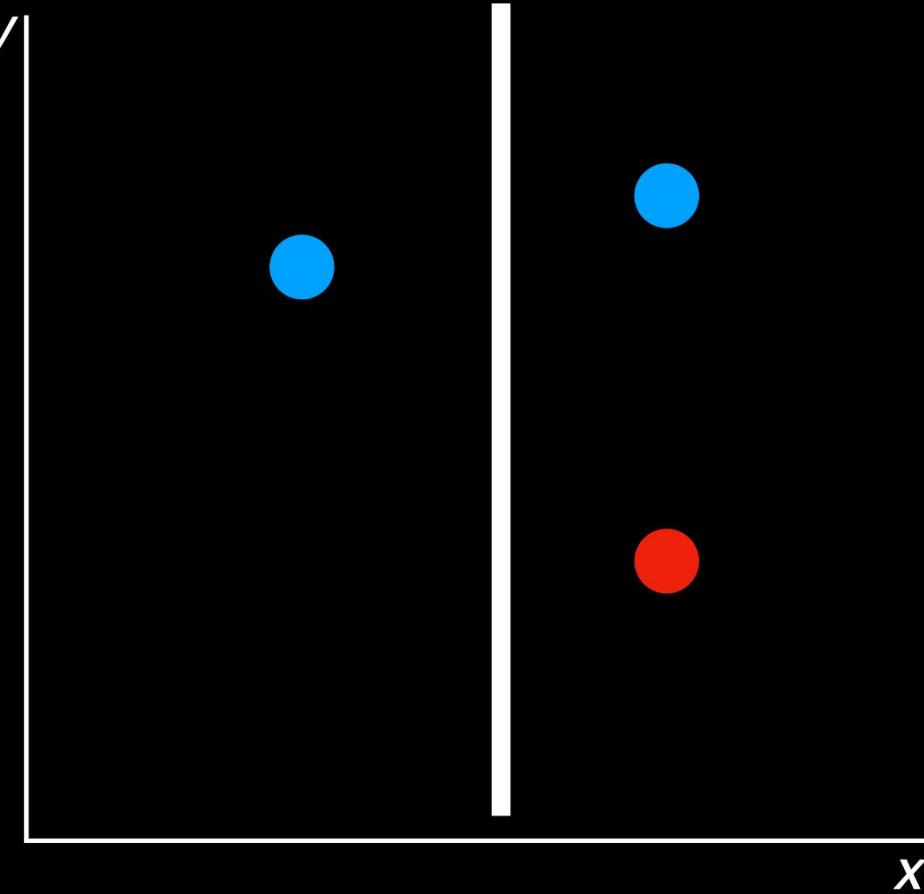
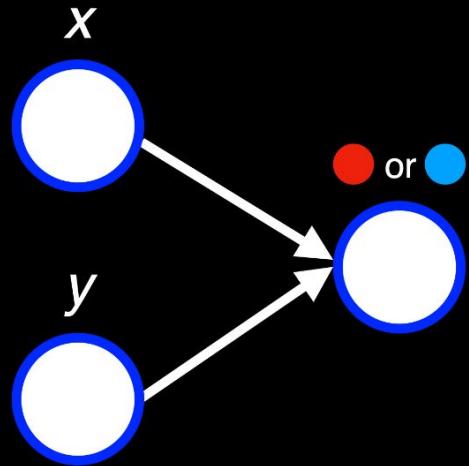


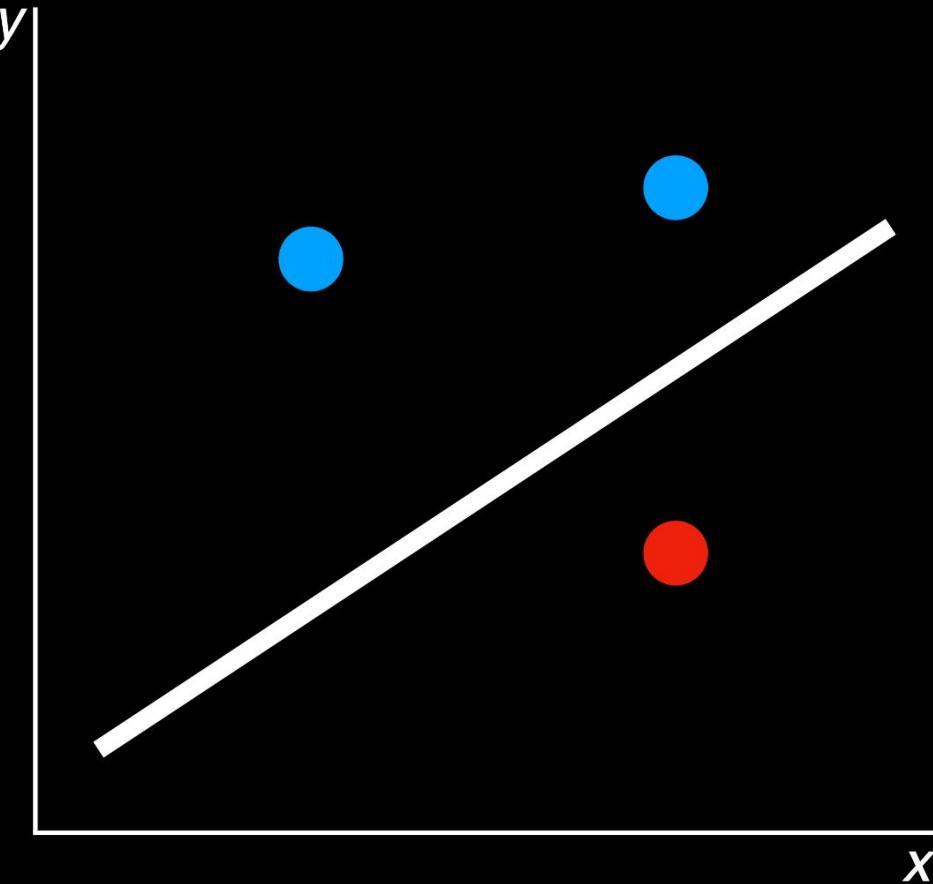
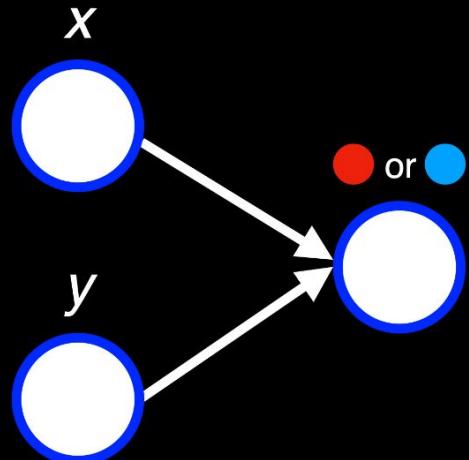


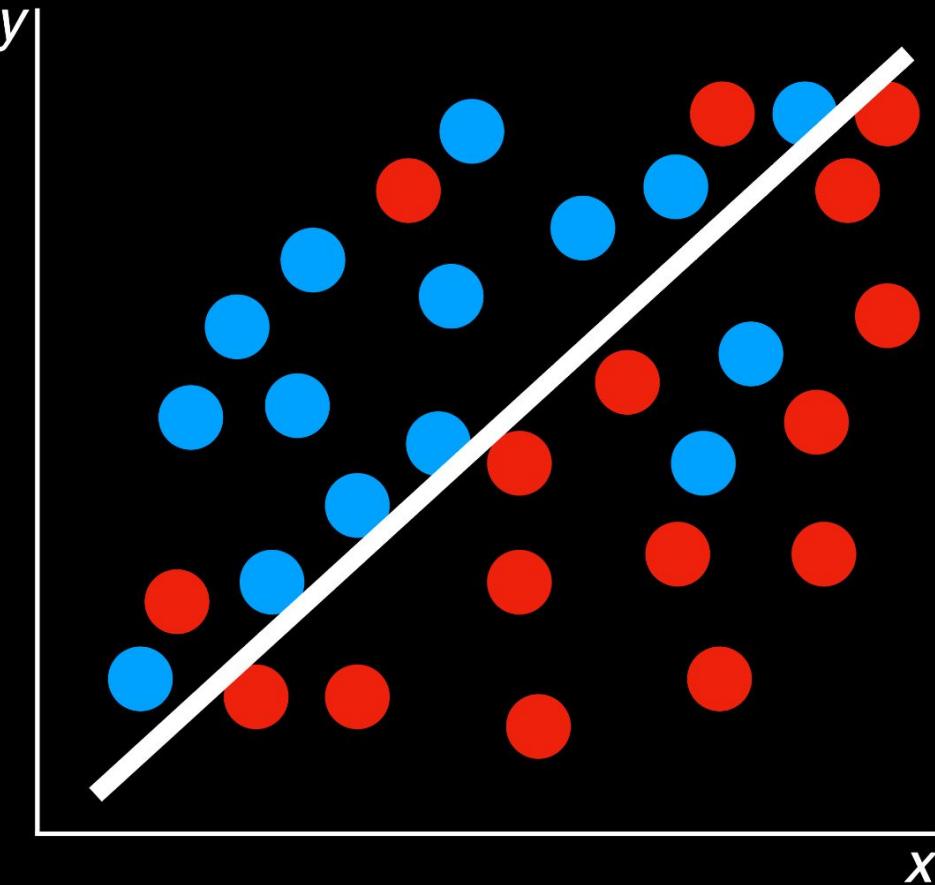
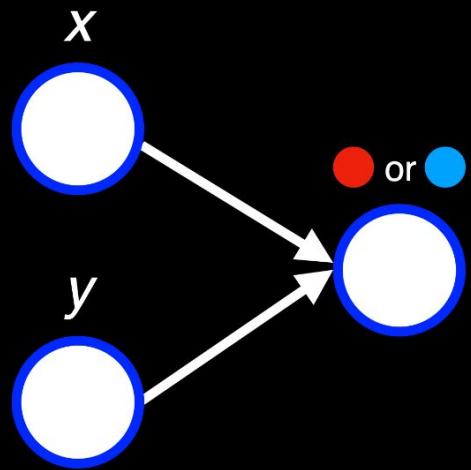


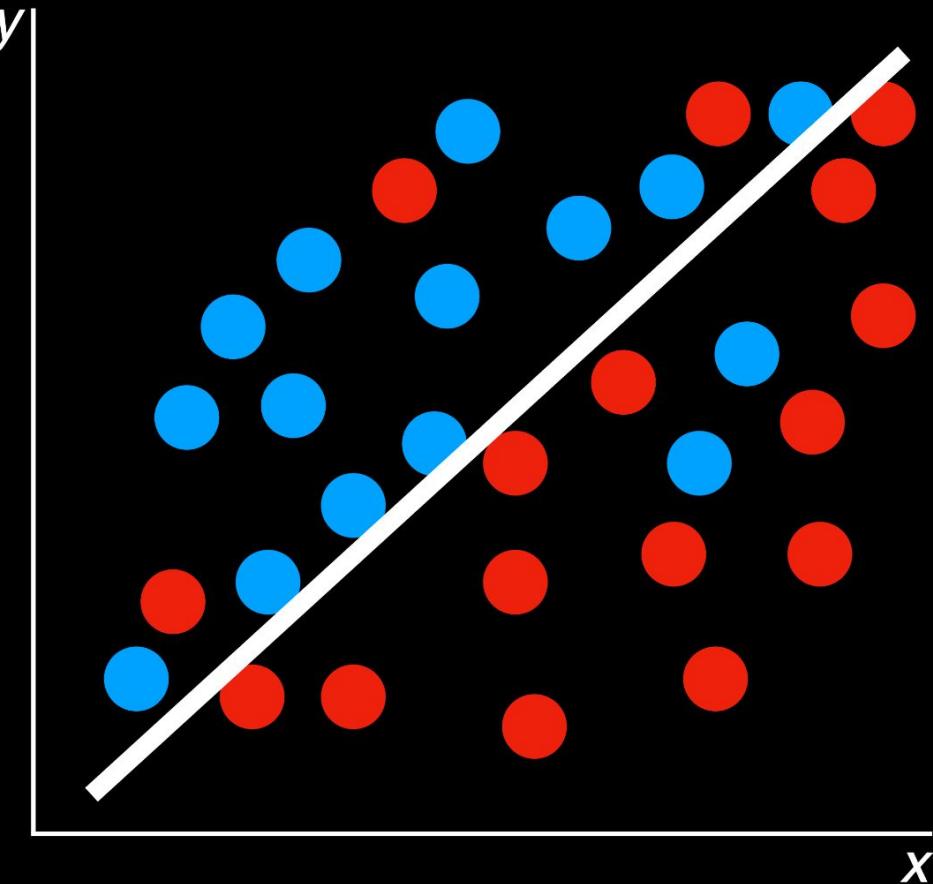
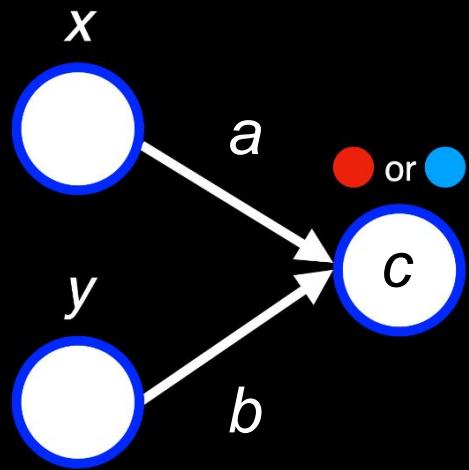




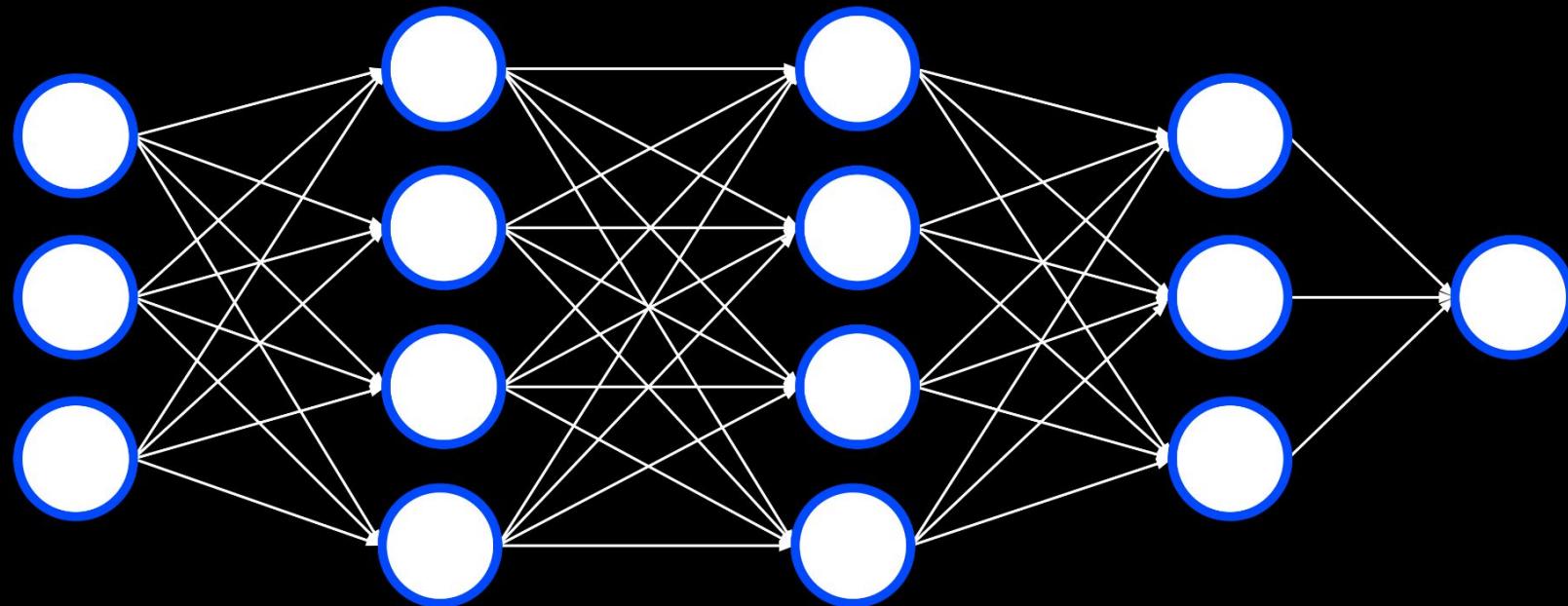




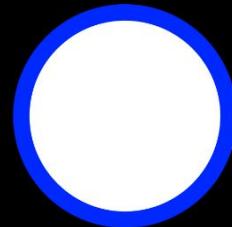




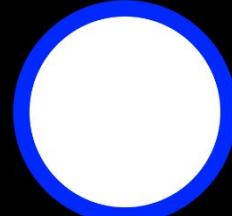
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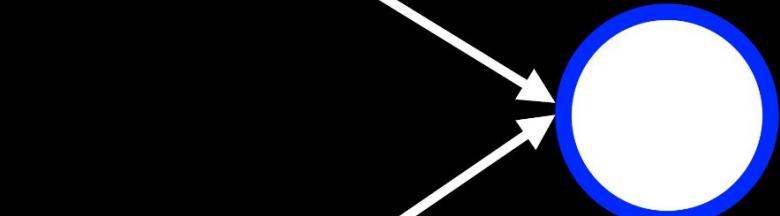
Humidity



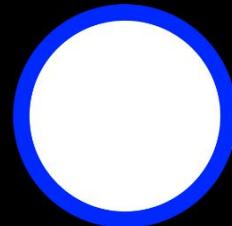
Pressure



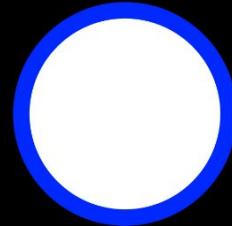
Rainfall



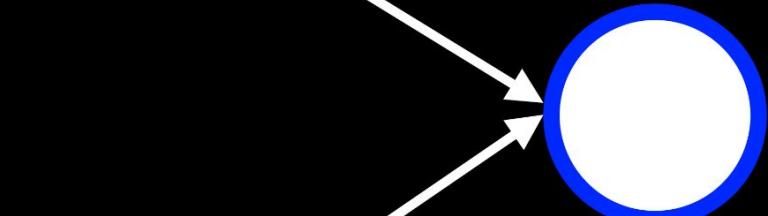
Advertising



Month



Sales



generative artificial intelligence





## Essay 1

... I like to bring a yummy sandwich and a cold juice box for lunch, and sometimes I'll even pack a tasty piece of fruit or a bag of crunchy chips. As we eat, we chat and laugh and catch up on each other's day. ...

## Essay 2

... My mother packs me a sandwich, a drink, fruit, and a treat. When I get in the lunchroom I find an empty table and sit there, and eat my lunch. My friends come and sit down with me. ...

large language models

# Attention Is All You Need

---

**Ashish Vaswani\***  
Google Brain  
[avaswani@google.com](mailto:avaswani@google.com)

**Noam Shazeer\***  
Google Brain  
[noam@google.com](mailto:noam@google.com)

**Niki Parmar\***  
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**Jakob Uszkoreit\***  
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**Łukasz Kaiser\***  
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**Illia Polosukhin\* ‡**  
[illia.polosukhin@gmail.com](mailto:illia.polosukhin@gmail.com)

# transformer architecture

"Massachusetts is a state in the New England region of the Northeastern United States. It borders on the Atlantic Ocean to the east.  
The state's capital is..."

**"Massachusetts** is a state in the New England region of the Northeastern United States. It borders on the Atlantic Ocean to the east.  
The **state's** capital is..."

Massachusetts

is

a

state

...

the

state's

capital

is

Massachusetts 1  
is 2  
a 3  
state 4

...

...

the 24  
state's 25  
capital 26  
is 27

Massachusetts 1 →

is 2 →

a 3 →

state 4 →

...

...

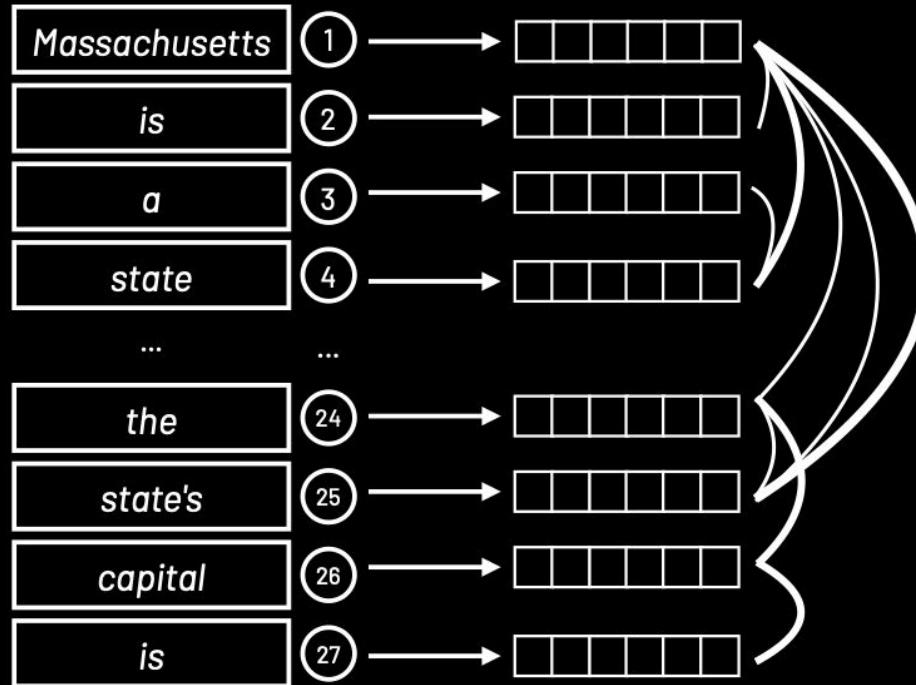
the 24 →

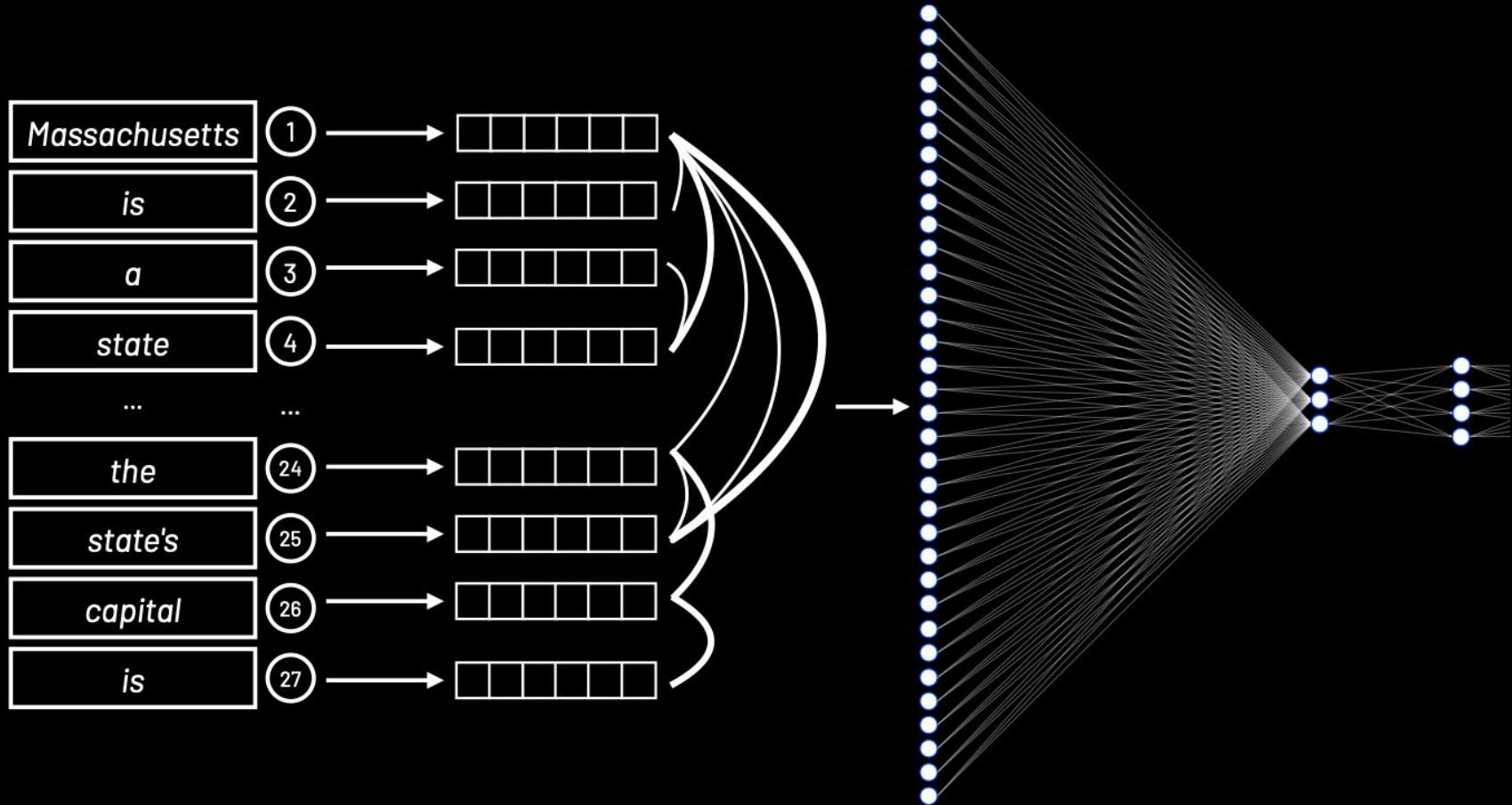
state's 25 →

capital 26 →

is 27 →





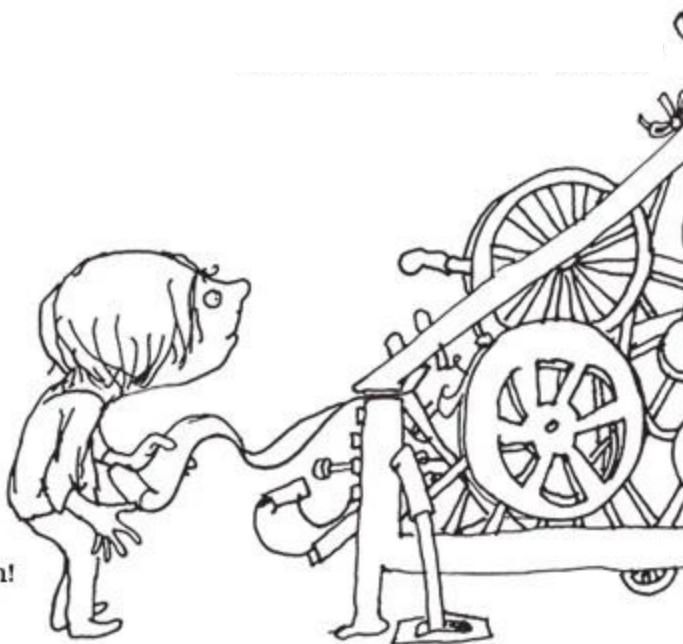




hallucinations

## HOMEWORK MACHINE

Read more  
poems in  
*A Light in  
the Attic*  
by Shel Silverstein!

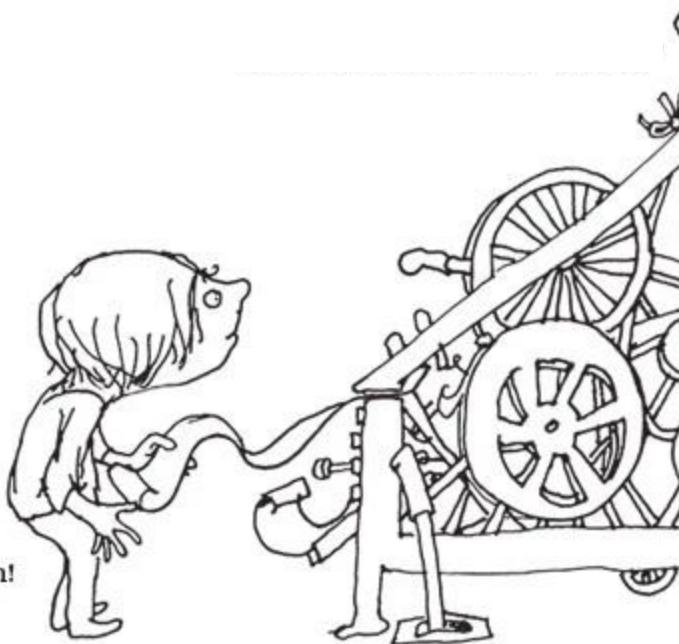


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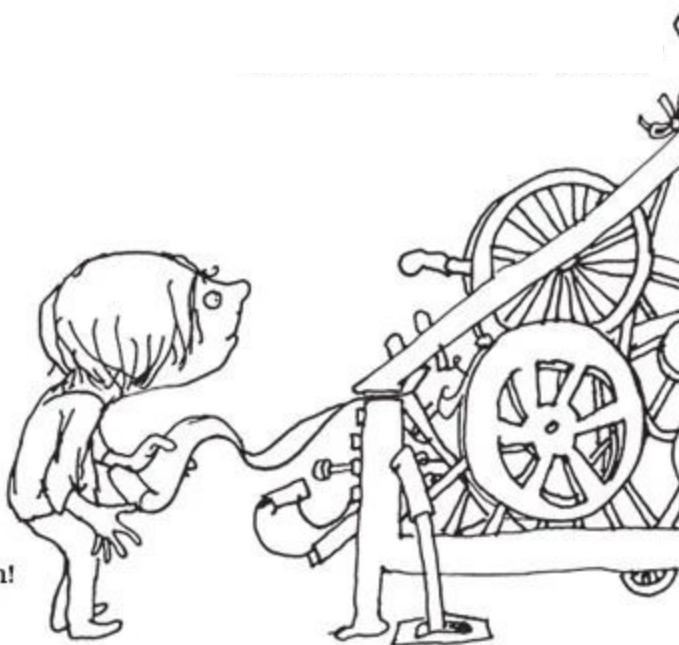


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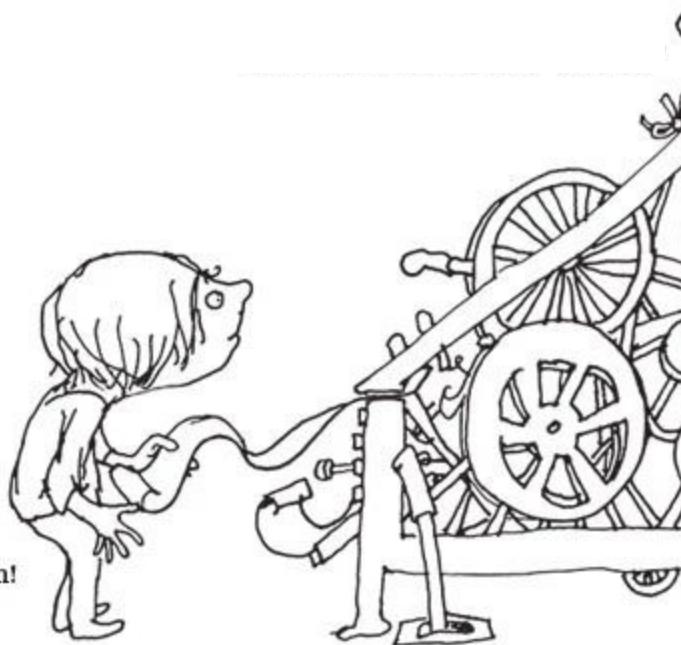
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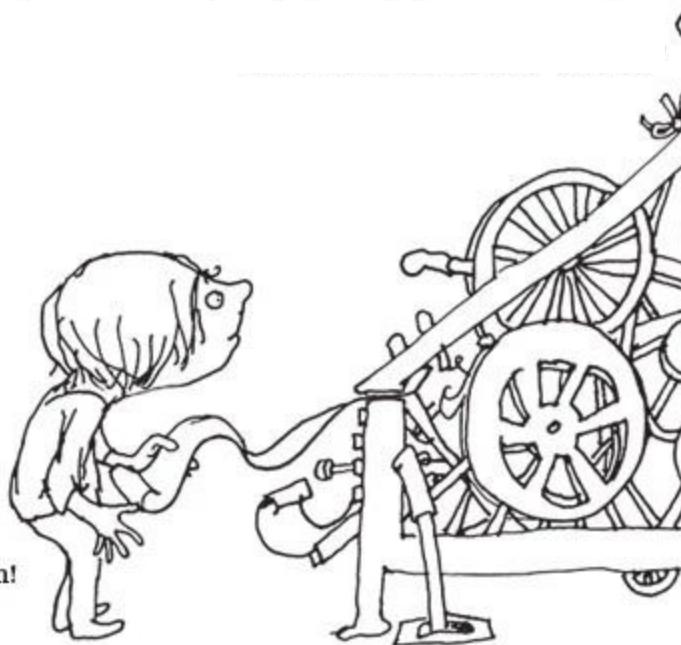


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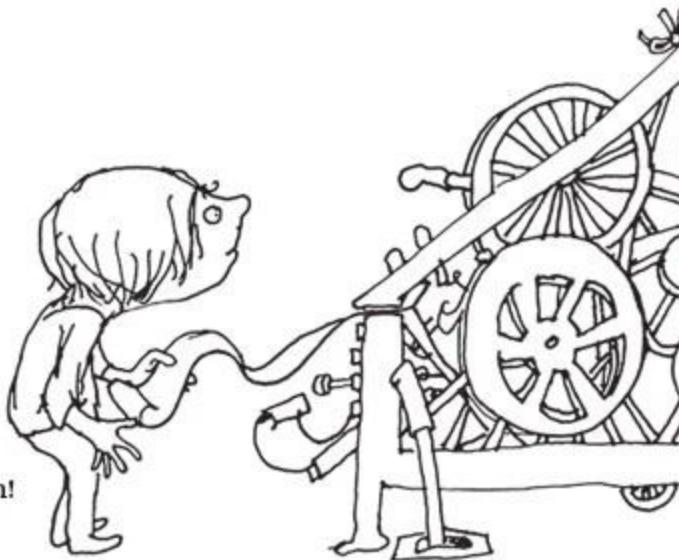


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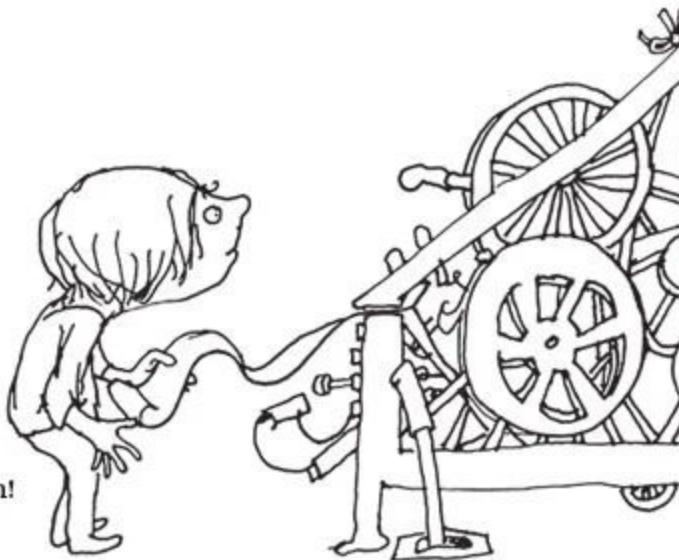


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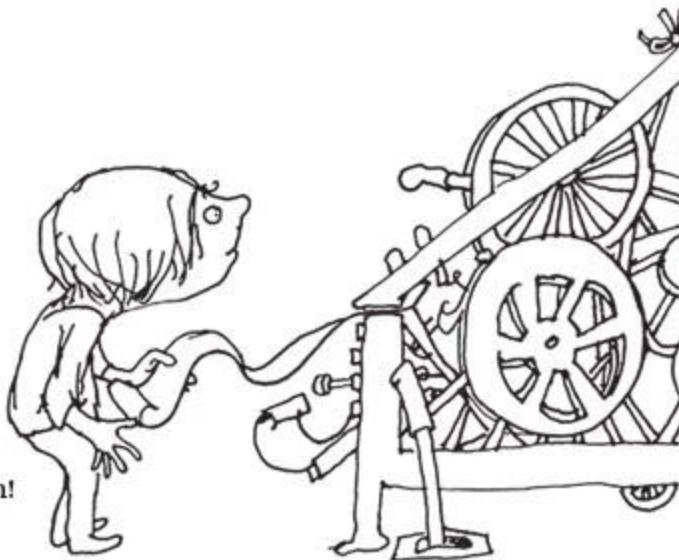


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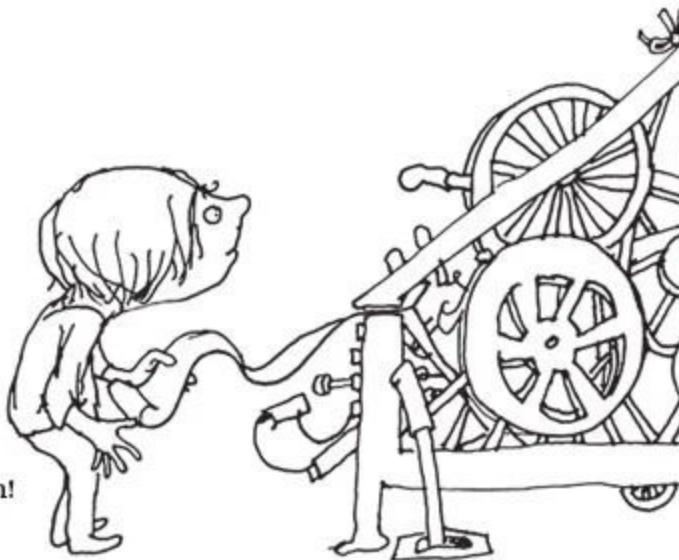
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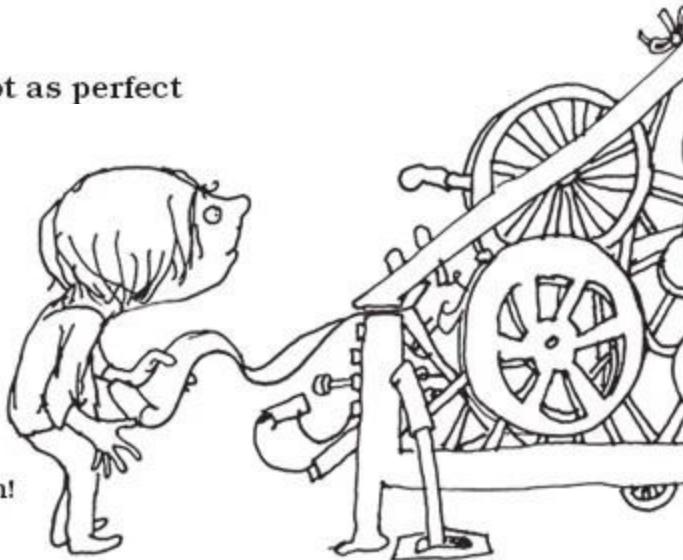
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Oh me . . .  
I guess it's not as perfect

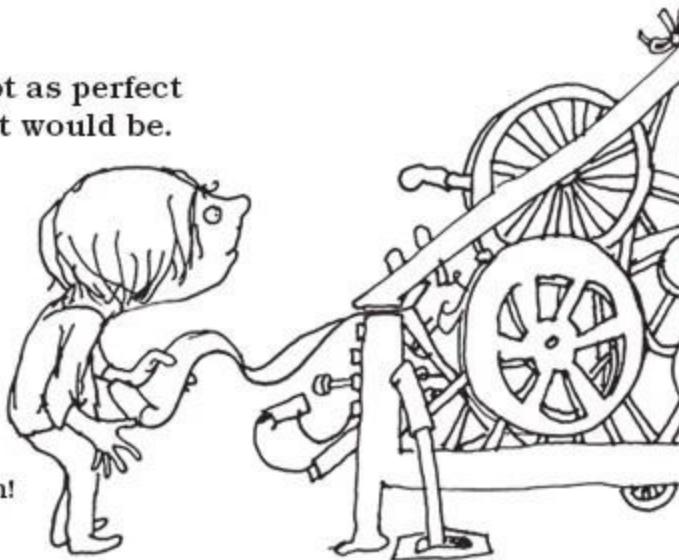
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Three?  
Oh me . . .  
I guess it's not as perfect  
As I thought it would be.

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poems in  
*A Light in  
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by Shel Silverstein!



# CS50x

<https://cs50.edx.org>

thank you

If RSVP'd for CS50 Lunch at Changsho after lecture, look for this yellow duck in the lobby to follow!



This is CS50