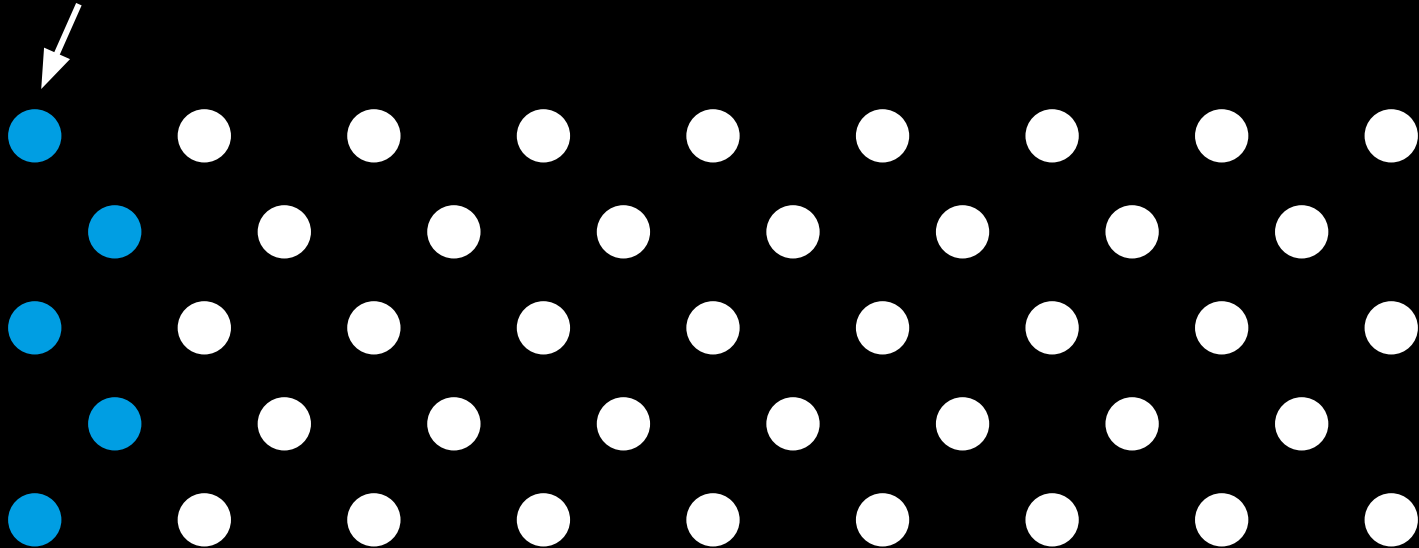


- 0. MOTIVATION
- 1. PROBLEM SOLVING
- 2. INFORMATION
- 3. COUNTING
- 4. BITS
- 5. CODES
- 6. ALGORITHMS
- 7. LOGIC
- 8. ARITHMETIC
- 9. ANALOG VS. DIGITAL

# MOTIVATION

a few  
experts

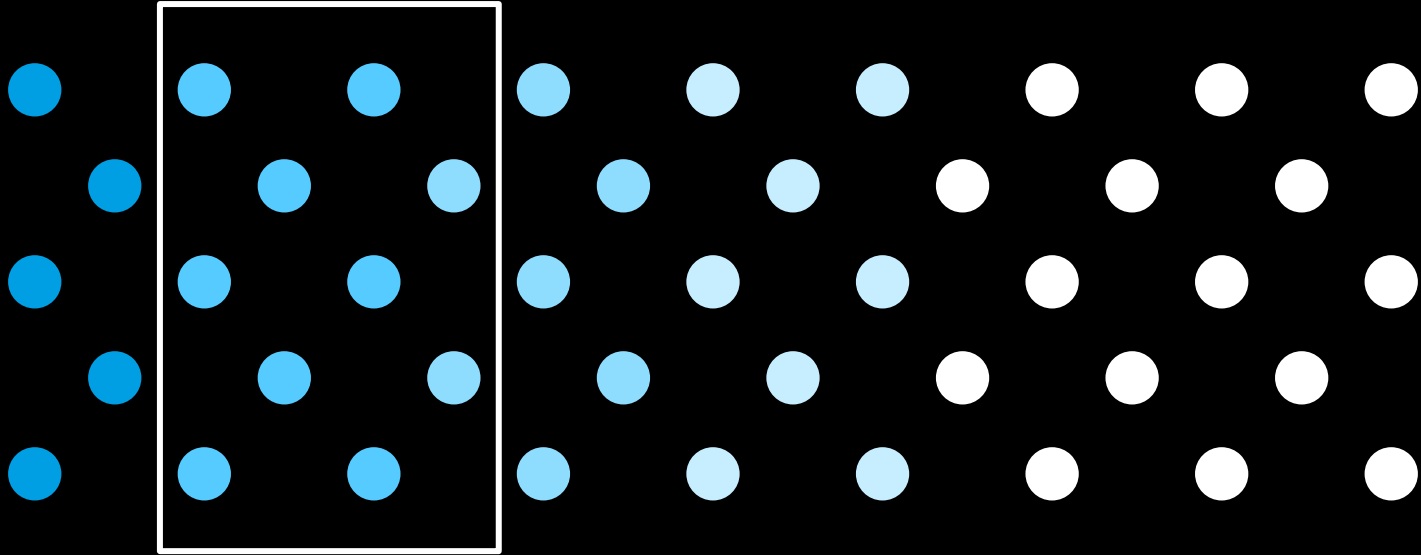
digitally uneducated  
society



digitally illiterate society with a few experts

# collective understanding

You?



society with a distributed and high degree of digital education

Artificial  
Intelligence

Data Analysis

Representation

Processing

Programming

Artificial  
Intelligence

Data Analysis

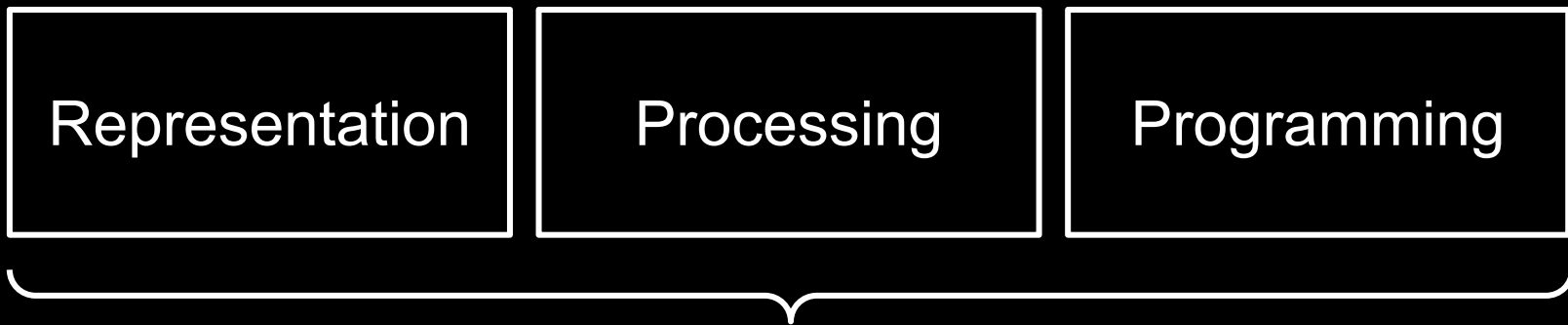
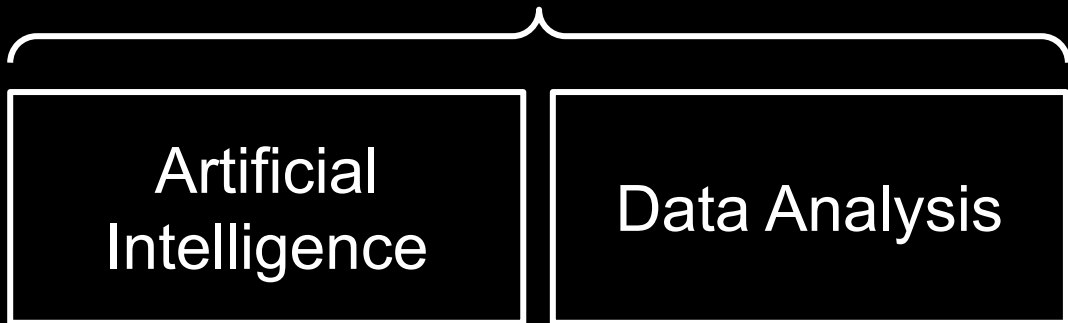
Representation

Processing

Programming

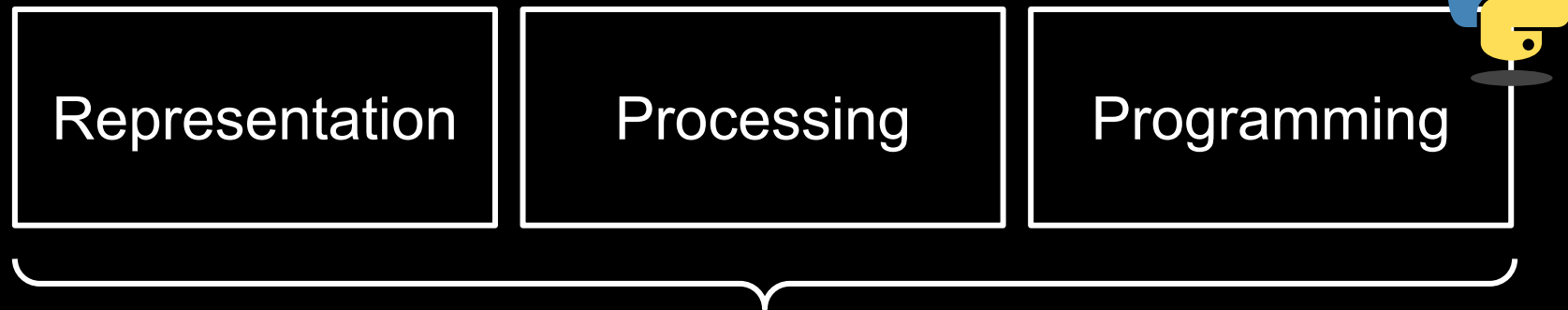
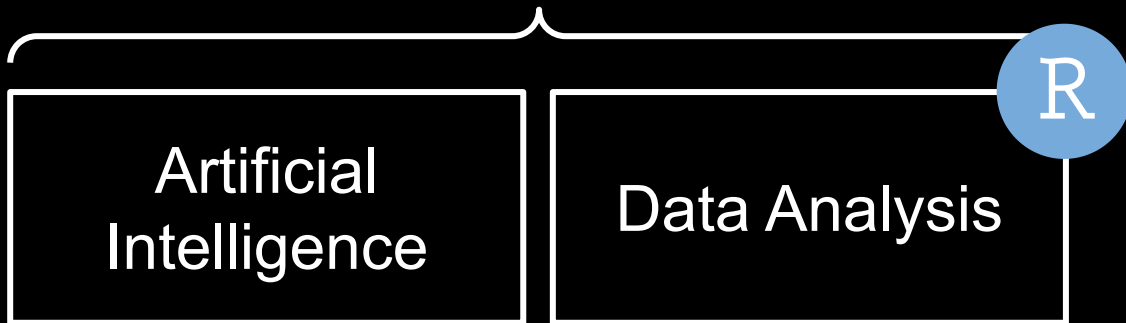
Digital Fundamentals

## Digital Applications



## Digital Fundamentals

## Digital Applications



## Digital Fundamentals

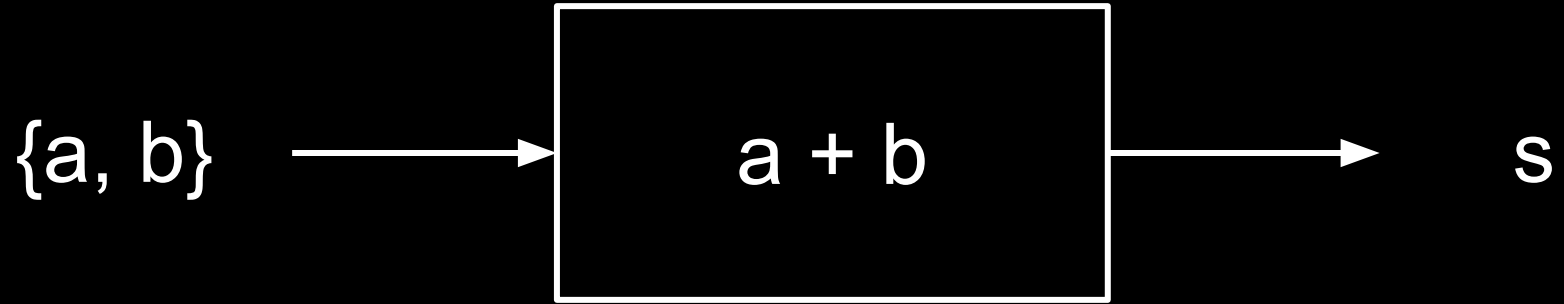


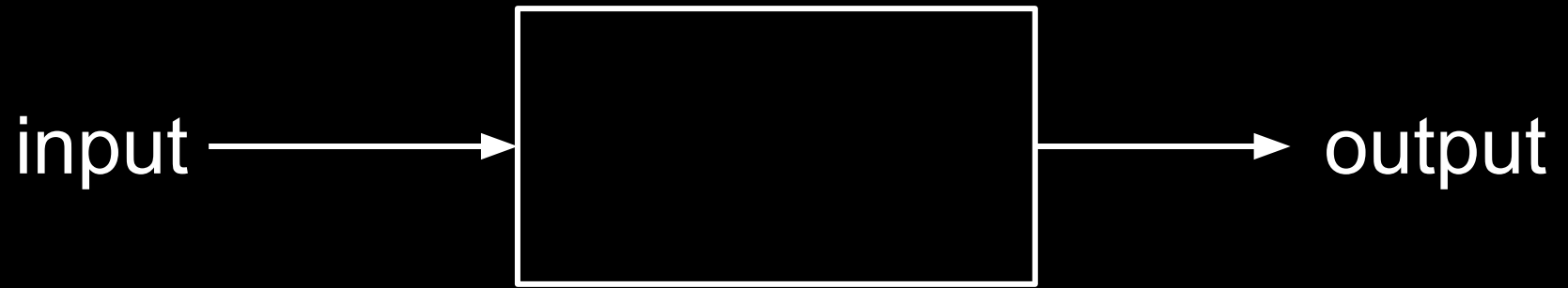
# PROBLEM SOLVING

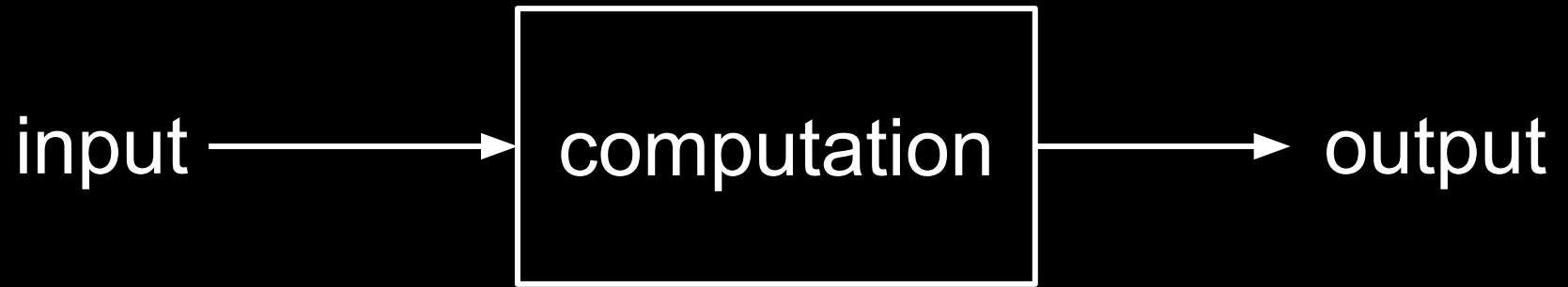
# a model for solving problems



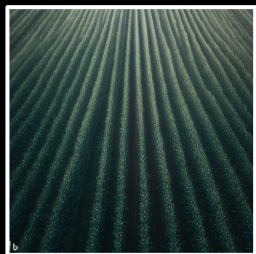
# a model for solving problems





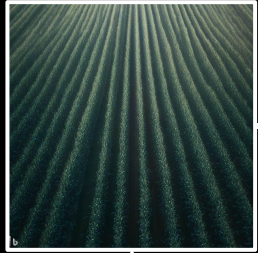






42

processing of  
information



`count_plants()`

42

representation of  
information







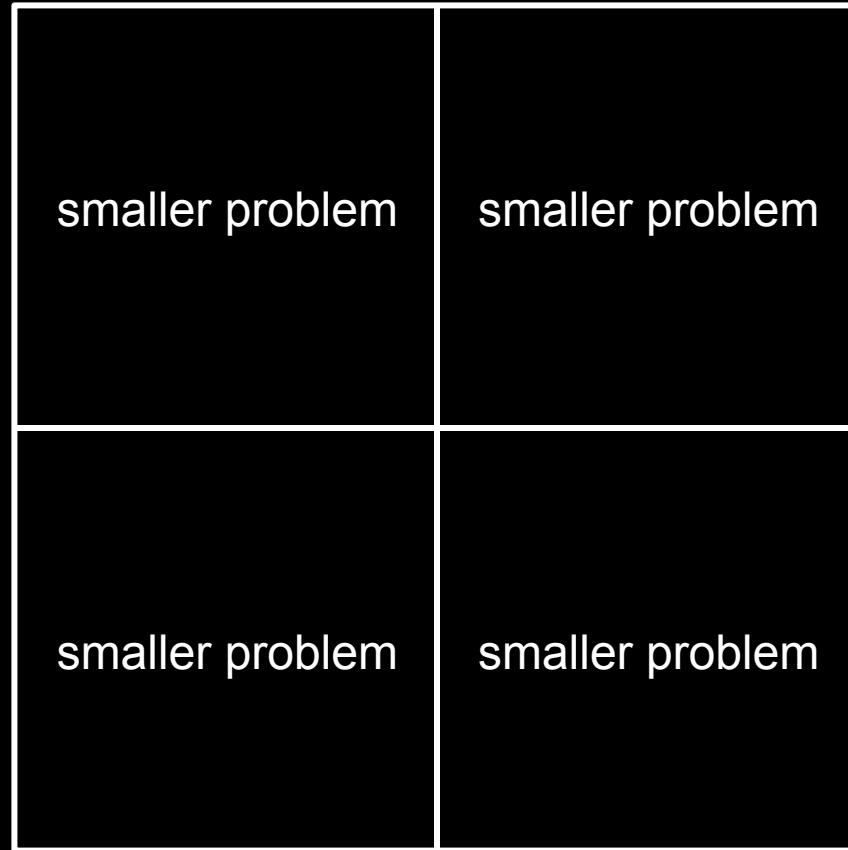
next\_move()

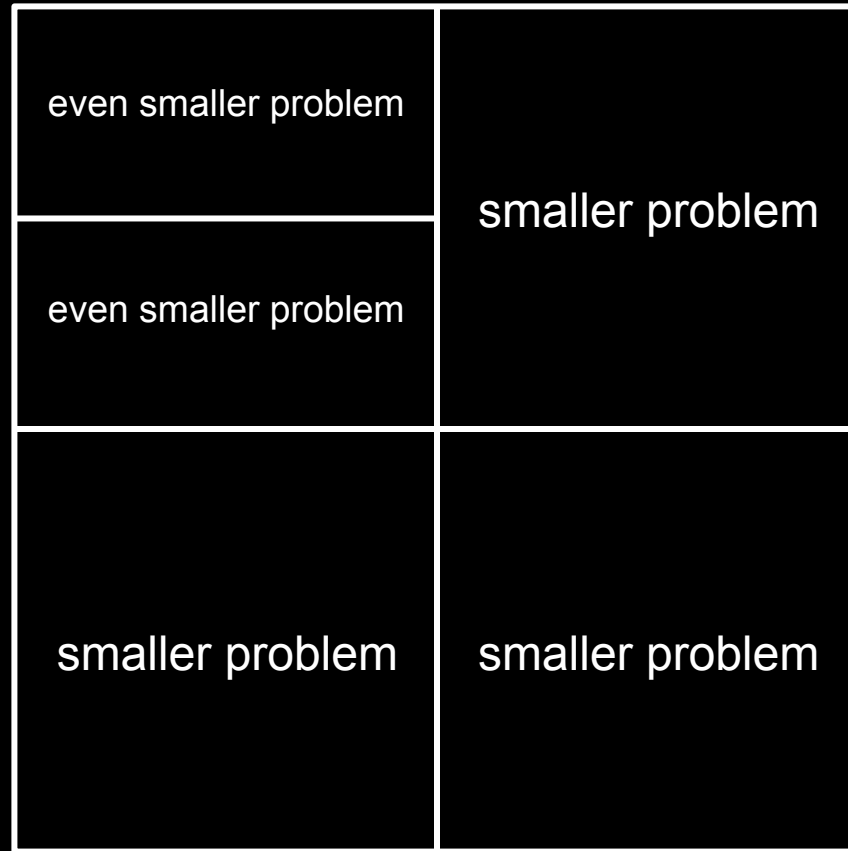
E2 → E4

problem solving strategies

divide and conquer

large and complex problem





sorted list +  
element



search()



yes / no



is 67 a prime number?

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97

## linear search



2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97

## linear search



~~2,~~ 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97

## linear search

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97

↑

19 steps... can we do better?

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97  
↑

binary search

67 != 41



2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, ~~41~~,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97

binary search

67 > 41



2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, ~~41~~,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97

binary search

67 > 41



2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97



## binary search

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97



67 != 71

## binary search

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97



67 != 71

## binary search

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97



$67 < 71$

## binary search

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97



67 != 59

## binary search

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41,  
~~43~~, 47, ~~53~~, 59, 61, 67, ~~71~~, ~~73~~, 79, ~~83~~, ~~89~~, 97



67 > 59

## binary search

2, 3, 5, 7, 11, ~~13~~, 17, 19, ~~23~~, ~~29~~, 31, 37, 41,  
~~43~~, 47, ~~53~~, ~~59~~, 61, 67, ~~71~~, ~~73~~, ~~79~~, ~~83~~, ~~89~~, 97



67 = 67

## binary search

2, 3, 5, 7, 11, ~~13~~, 17, 19, ~~23~~, ~~29~~, 31, 37, 41,  
~~43~~, 47, ~~53~~, 59, ~~61~~, 67, ~~71~~, ~~73~~, 79, ~~83~~, ~~89~~, 97



67 = 67

3 splits → much better

2, 3, 5, 7, 11, ~~13~~, 17, 19, ~~23~~, ~~29~~, 31, 37, 41,  
~~43~~, 47, ~~53~~, 59, ~~61~~, 67, ~~71~~, ~~73~~, 79, ~~83~~, ~~89~~, 97

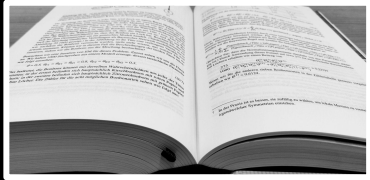


67 = 67





how efficient are linear and  
binary search in general?

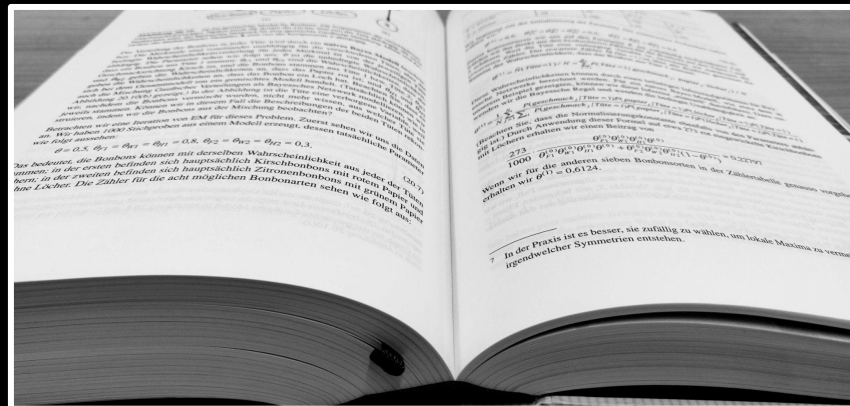


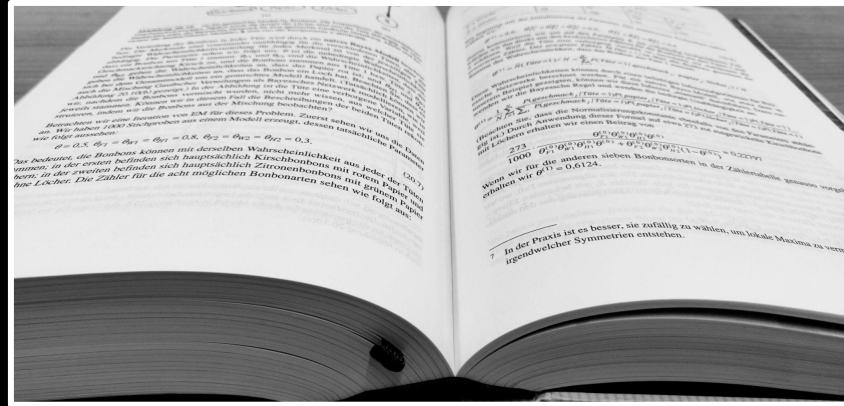
`count_words()`

word count

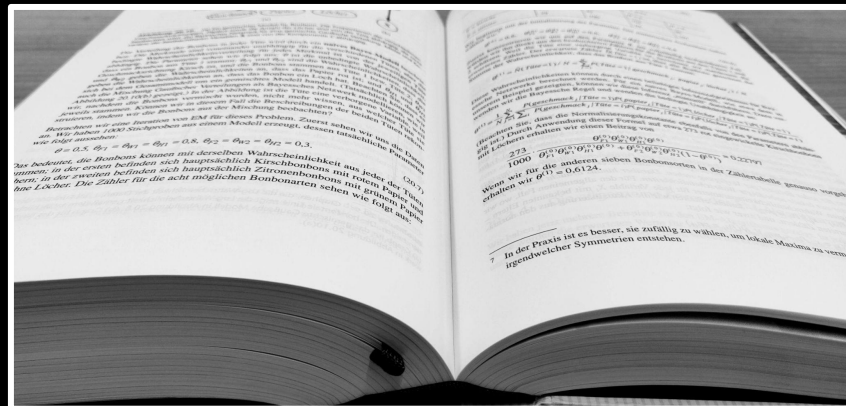
[illegible]

strategies, anyone?





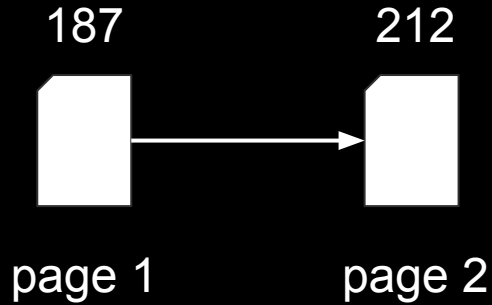
page 1



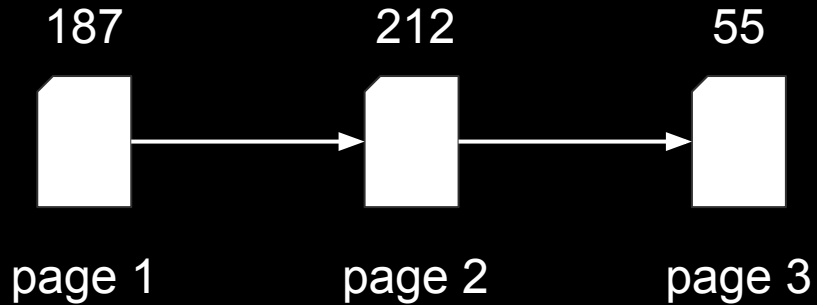
187

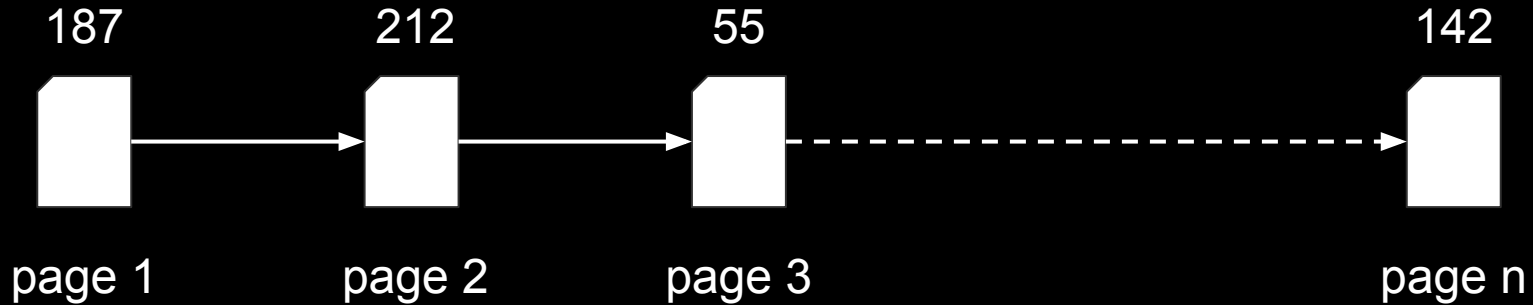
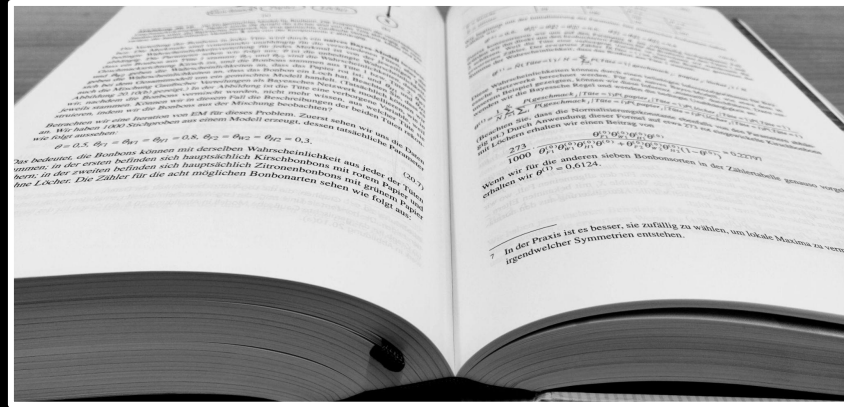


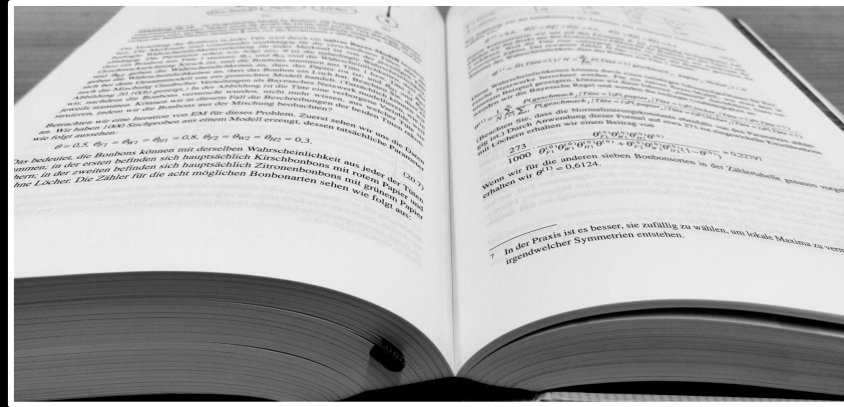
page 1











$n = 1327$  pages

$\varnothing$  2:23 minutes per page

$\sim 52.34$  hours

divide and conquer

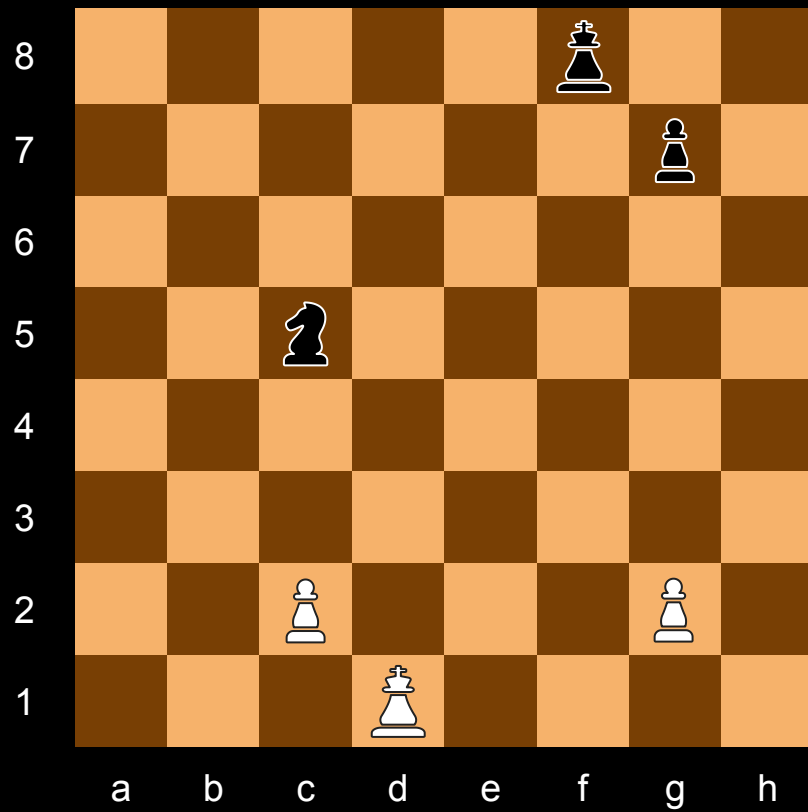
+

?

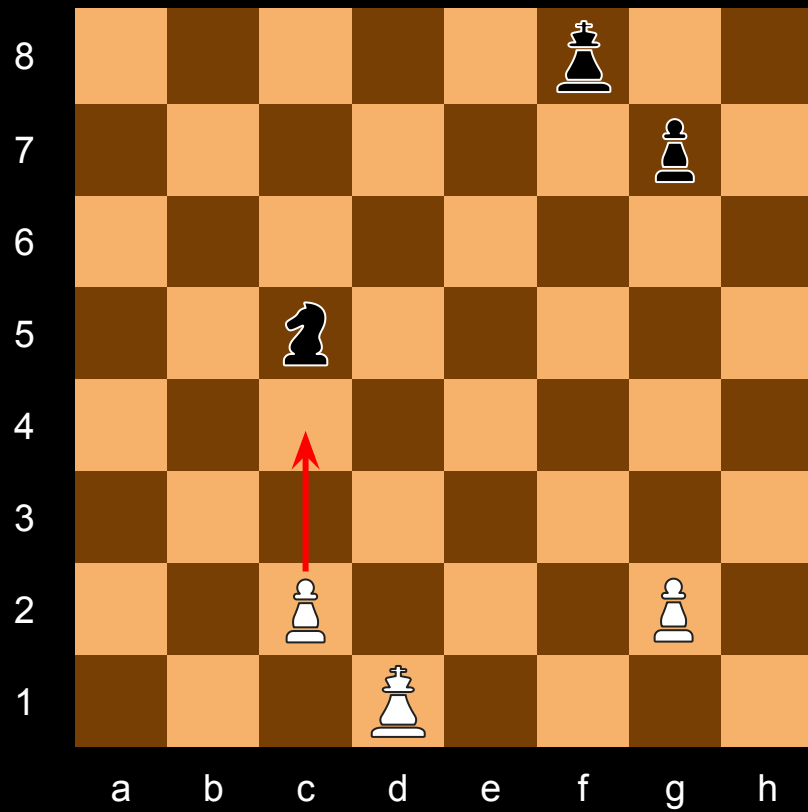
divide and conquer  
+  
distribution and parallelization

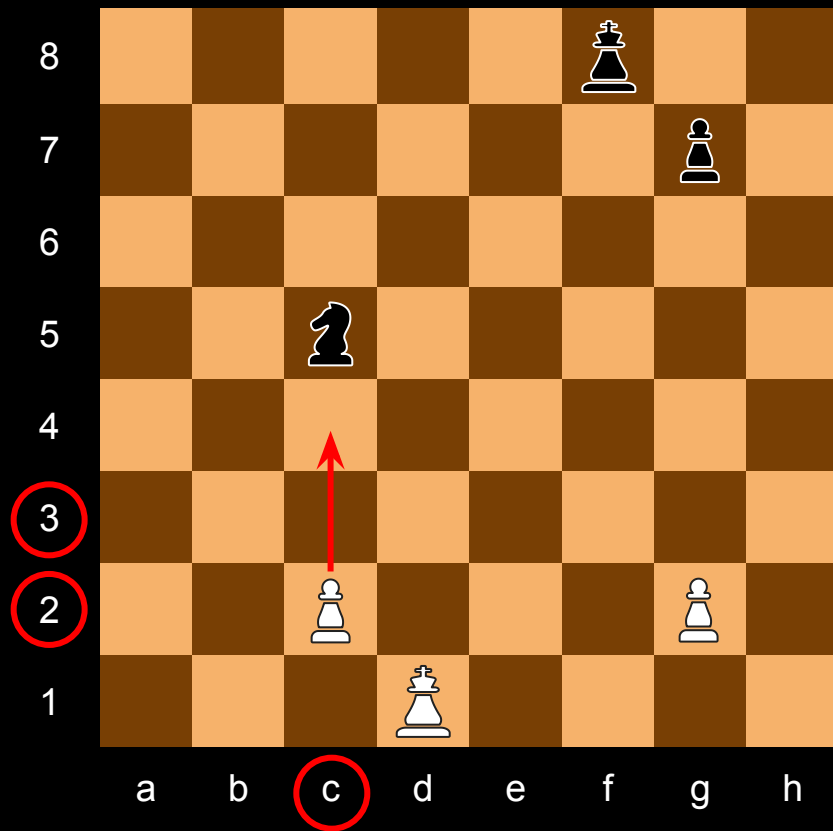
# INFORMATION



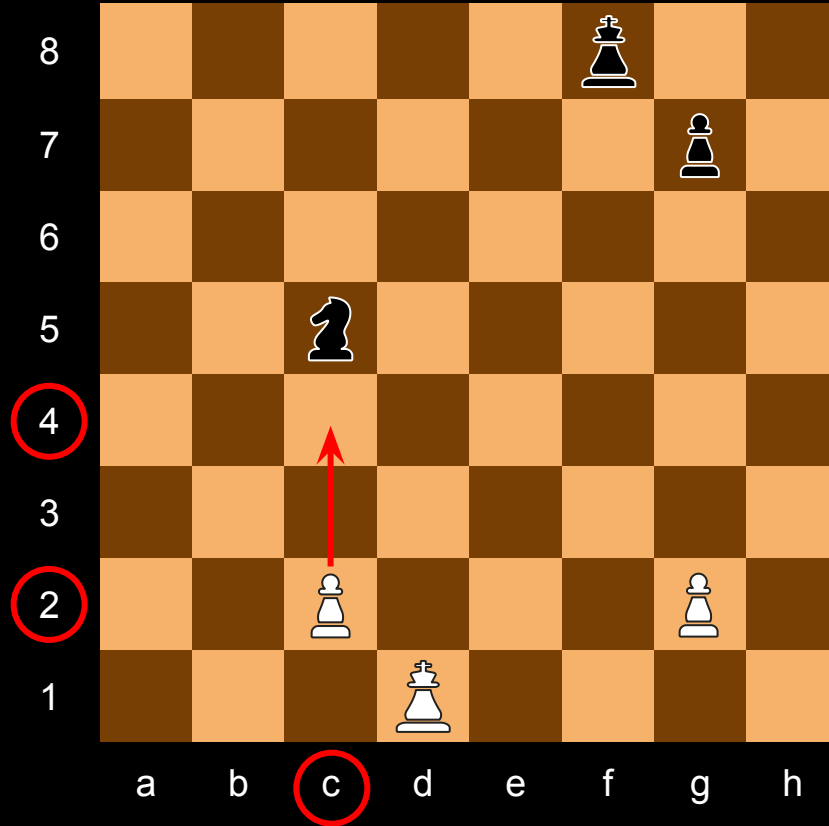




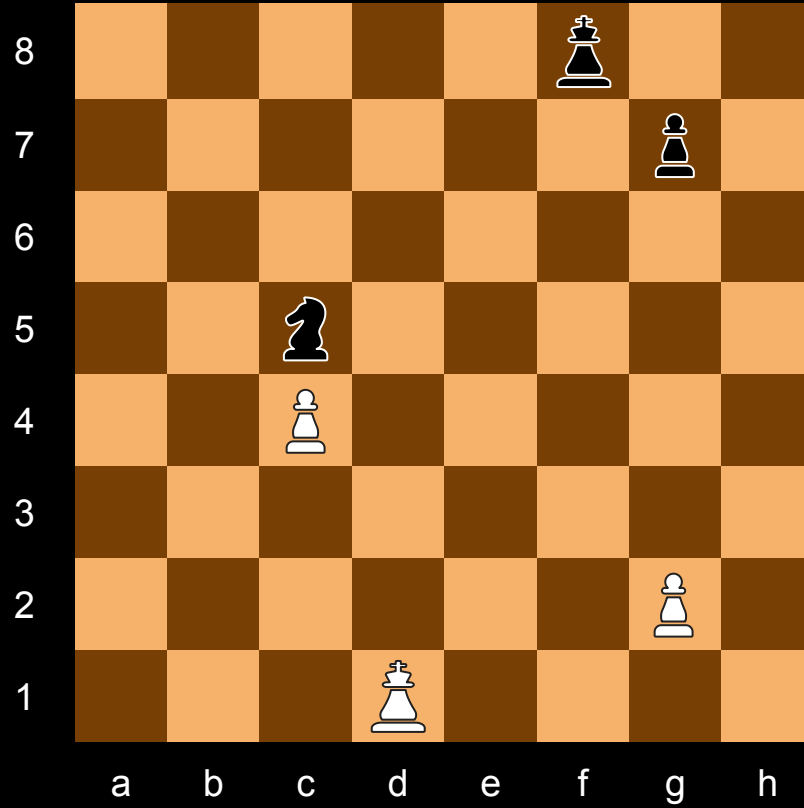




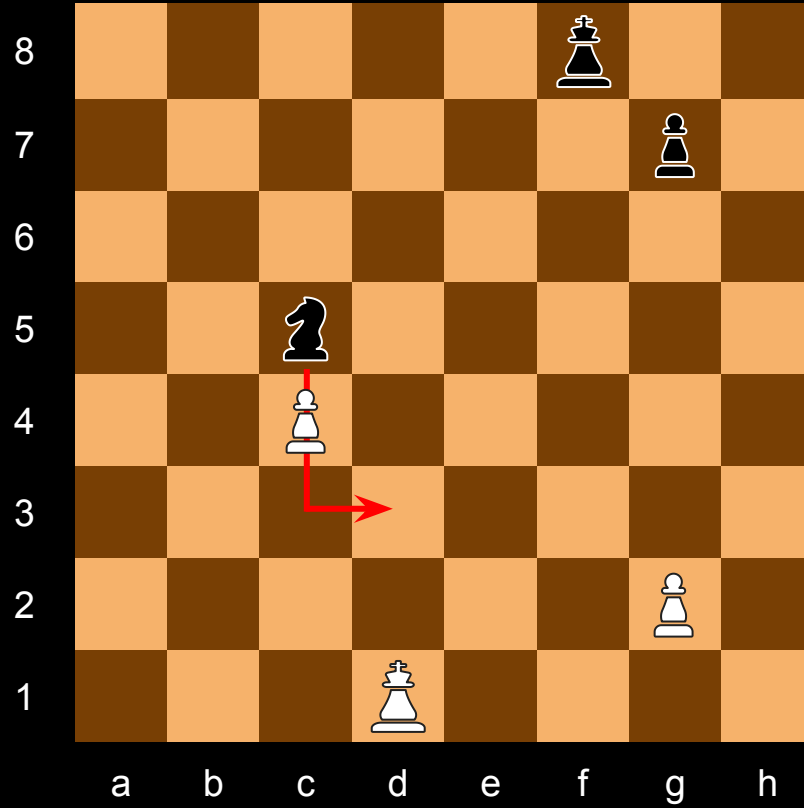
c2 → c4



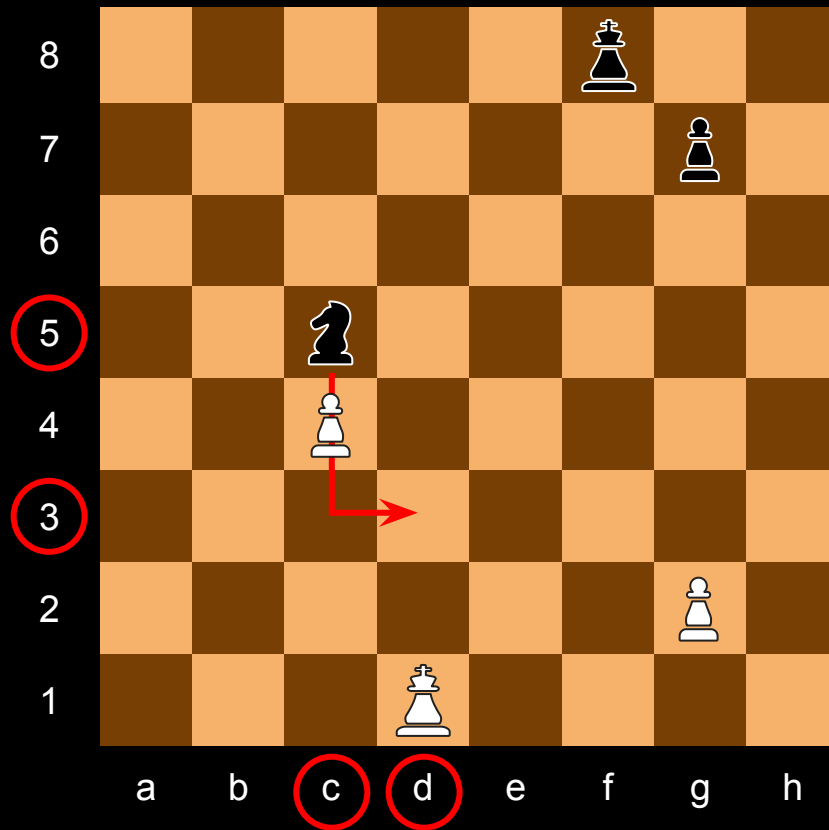
c2 → c4



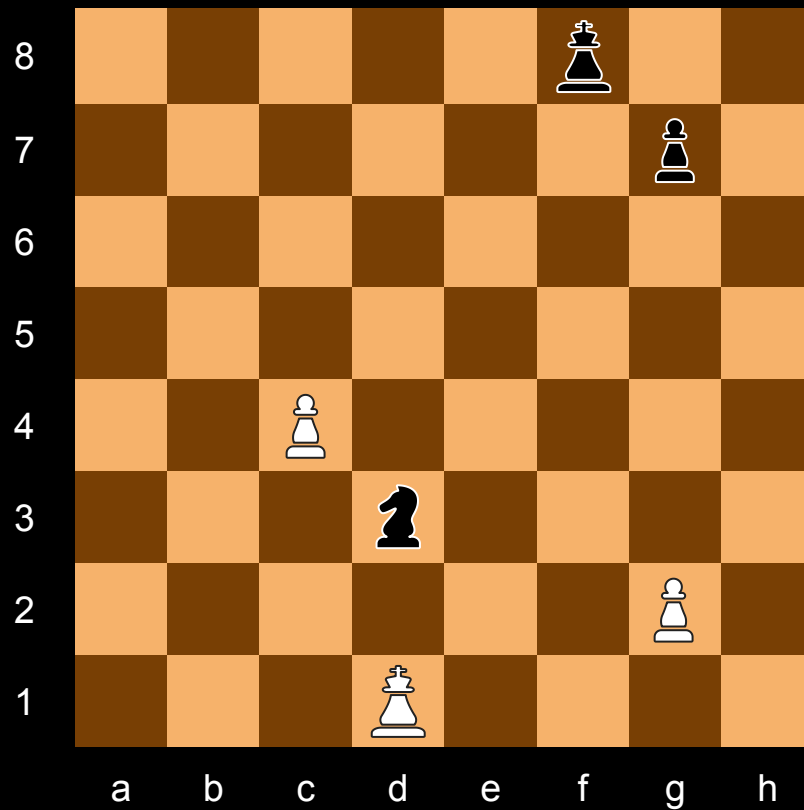
c2 → c4



c2 → c4  
c5 → d3



c2 → c4  
c5 → d3  
...



$\{A\}$

— —



$\{A\}$

A A

$\{A, B\}$

— —

$\{A, B\}$

A A

$\{A, B\}$

A B

$\{A, B\}$

B A

$\{A, B\}$

B B

$\{A, B, C\}$

— — —

$\{A, B, C\}$

— —



$\{A, B, C\}$

AA, AB, BA, BB,  
AC, BC, CA, CB, CC

$\{A, B, C, D\}$

— —

$\{A, B, C, D\}$

AA, AB, BA, BB, AC, BC, CA, CB,  
CC, AD, DA, BD, DB, CD, DC, DD

{A, B, C, D, E}

— —

$\{A, B, C, D, E\}$

AA, AB, BA, BB, AC, BC, CA, CB, CC,  
AD, DA, BD, DB, CD, DC, DD, AE, EA,  
BE, EB, CE, EC, DE, ED, EE

with length  $n = 2$

# symbols

# messages

1

1

2

4

3

9

4

16

5

25

with length  $n = 2$

# symbols

# messages

1

1

2

4

3

9

4

16

5

25

$f(x)$



# COUNTING



1

2

3

1

2

3

---

$10^2$

$10^1$

$10^0$

1 2 3

---

$10^2$

$10^1$

$10^0$

$$= 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

$$= 1 \times 100 + 2 \times 10 + 3 \times 1$$

$$= 123$$

4

1

2

3

---

?

$10^2$

$10^1$

$10^0$

4 1 2 3

---

?

$10^2$

$10^1$

$10^0$

$$= 4 \times 10^3 + 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

4 1 2 3

---

?

$10^2$

$10^1$

$10^0$

$$= 4 \times 10^3 + 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

$$= 4 \times 1000 + 1 \times 100 + 2 \times 10 + 3 \times 1$$

4 1 2 3

---

?

$10^2$

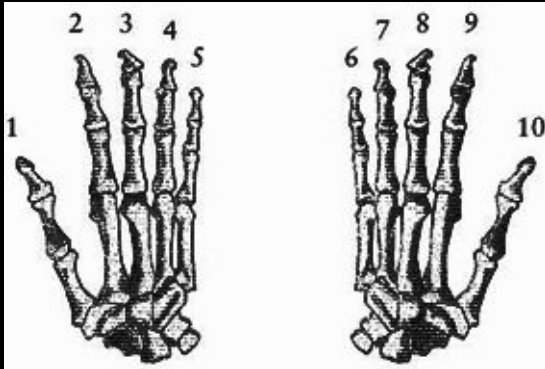
$10^1$

$10^0$

$$= 4 \times 10^3 + 1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

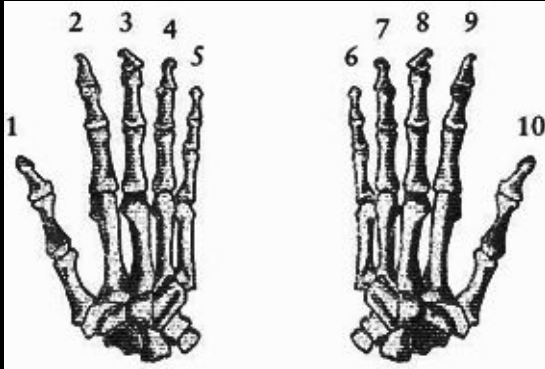
$$= 4 \times 1000 + 1 \times 100 + 2 \times 10 + 3 \times 1$$

$$= 4123$$

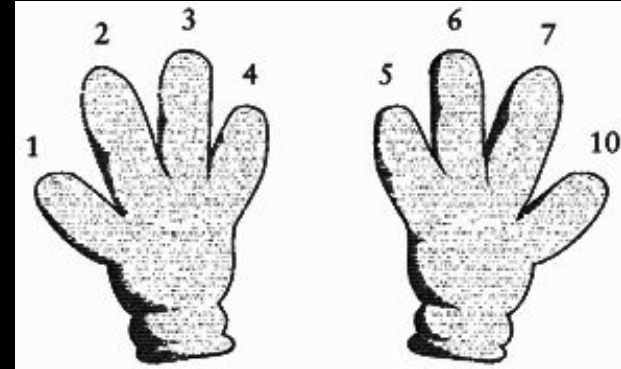


Human Hand





Human Hand



Cartoon Character's Hand

1

2

3

(octal)

1

2

3

(octal)

---

$8^2$

$8^1$

$8^0$

1

2

3

(octal)

---

$8^2$

$8^1$

$8^0$

$$= 1 \times 8^2 + 2 \times 8^1 + 3 \times 8^0$$

1

2

3

(octal)

---

$8^2$

$8^1$

$8^0$

$$= 1 \times 8^2 + 2 \times 8^1 + 3 \times 8^0$$

$$= 1 \times 64 + 2 \times 8 + 3 \times 1$$

1

2

3

(octal)

---

$8^2$

$8^1$

$8^0$

$$= 1 \times 8^2 + 2 \times 8^1 + 3 \times 8^0$$

$$= 1 \times 64 + 2 \times 8 + 3 \times 1$$

$$= 83 \text{ (decimal)}$$

decimal

octal

8



?

decimal

octal

?



7



decimal

octal

16



?

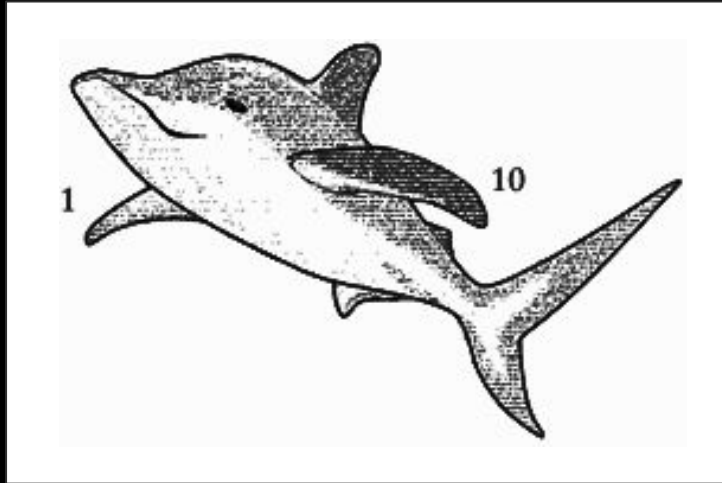
decimal

octal

?



100



What now?

0, 1, ...

0, 1, 10, ...

0, 1, 10, 11, ...

0, 1, 10, 11, 100, ...

0, 1, 10, 11, 100, 101, ...



0, 1, 10, 11, 100, 101, 110

1

1

0

(binary)

1

1

0

(binary)

---

$2^2$

$2^1$

$2^0$

1

1

0

(binary)

---

$2^2$

$2^1$

$2^0$

$$= 1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$$

1 1 0

---

(binary)

$2^2$

$2^1$

$2^0$

$$= 1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$$

$$= 1 \times 4 + 1 \times 2 + 0 \times 1$$

1 1 0

---

(binary)

$2^2$

$2^1$

$2^0$

$$= 1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$$

$$= 1 \times 4 + 1 \times 2 + 0 \times 1$$

$$= 6 \text{ (decimal)}$$

2 3 4 5 6

0, 1, 10, 11, 100, 101, 110

# Place Value Systems

$$N = d_n * R^{n-1} + \dots + d_1 * R^1 + d_0 * R^0$$

$$d \in \{ 0, 1, \dots R-1 \}$$

$n$  = Number of digits

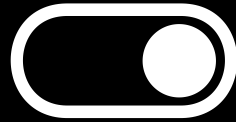


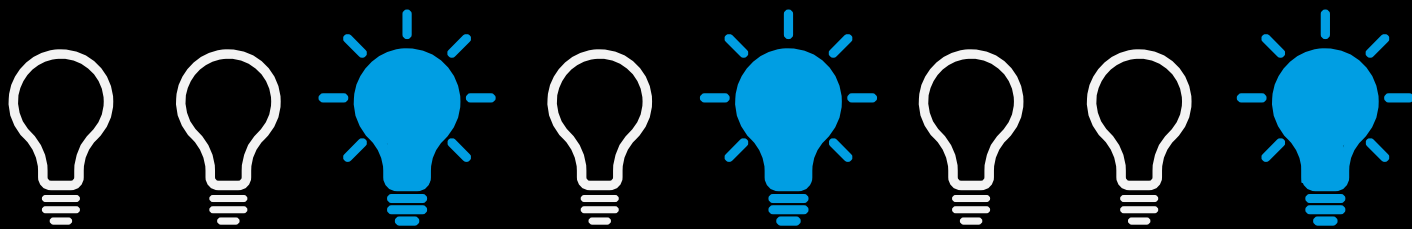
# Place Value Systems

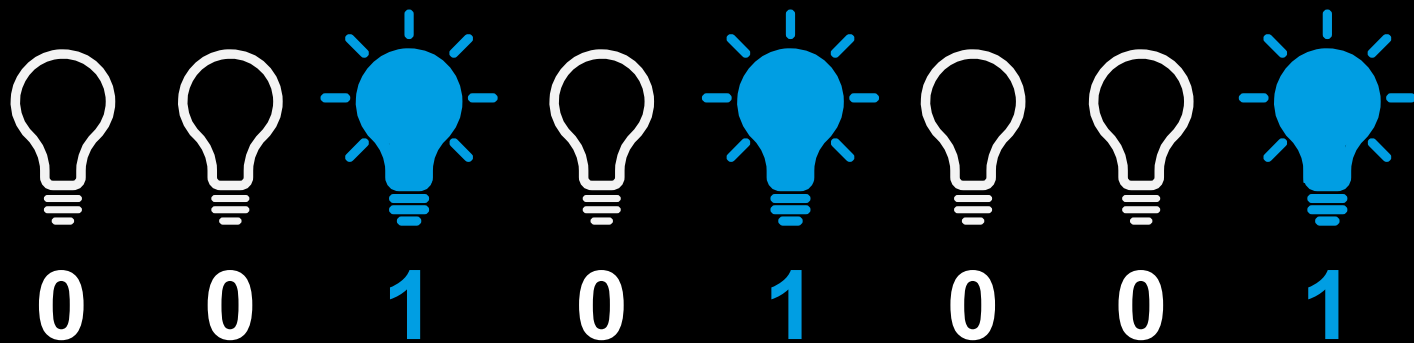
$$R \geq 2$$

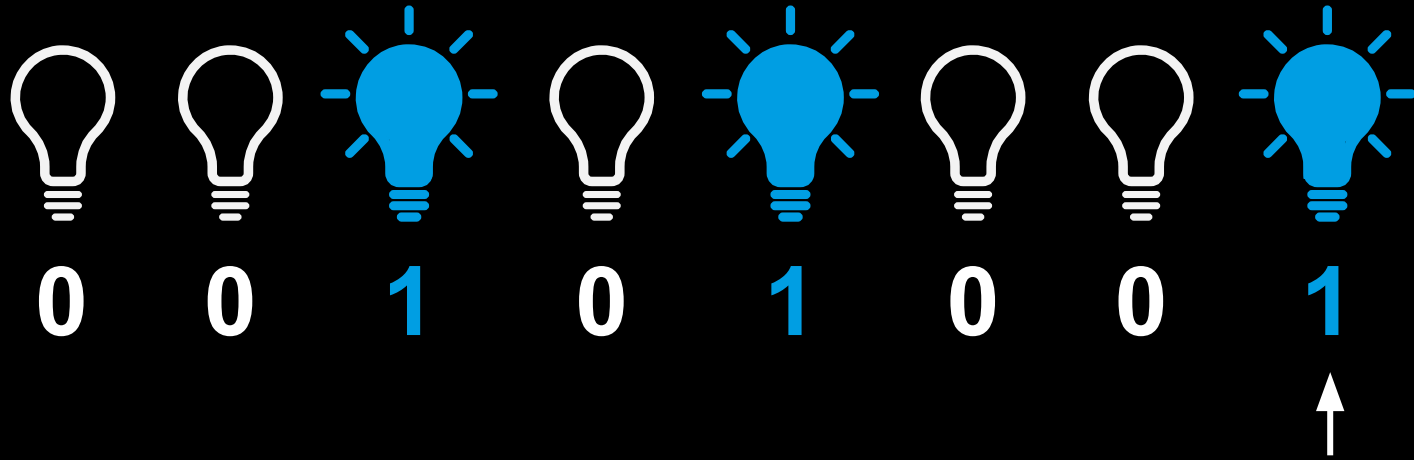
# BITS

Why do computers think **binary**?

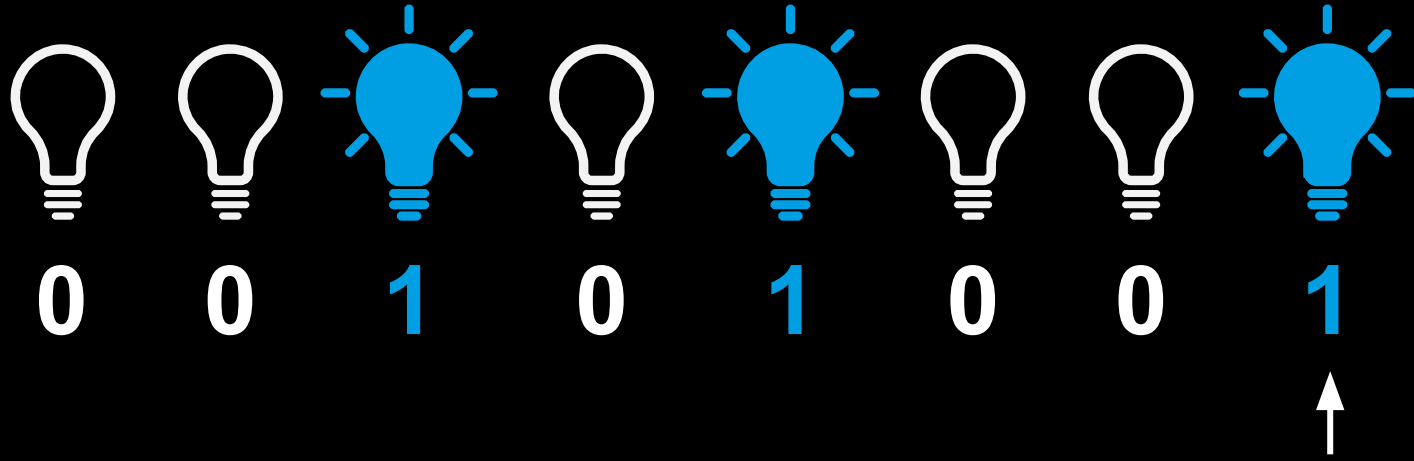






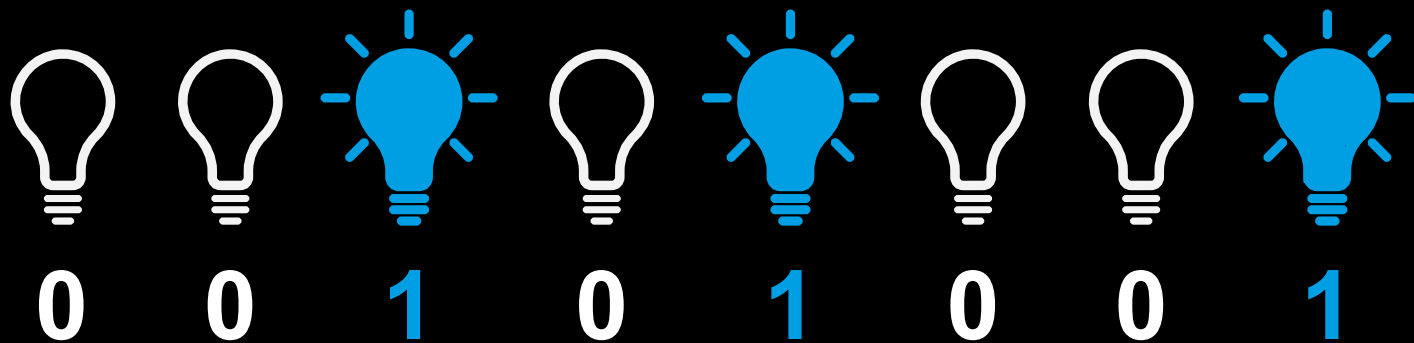


A **Bit** (binary digit)



A **Bit** (binary digit)

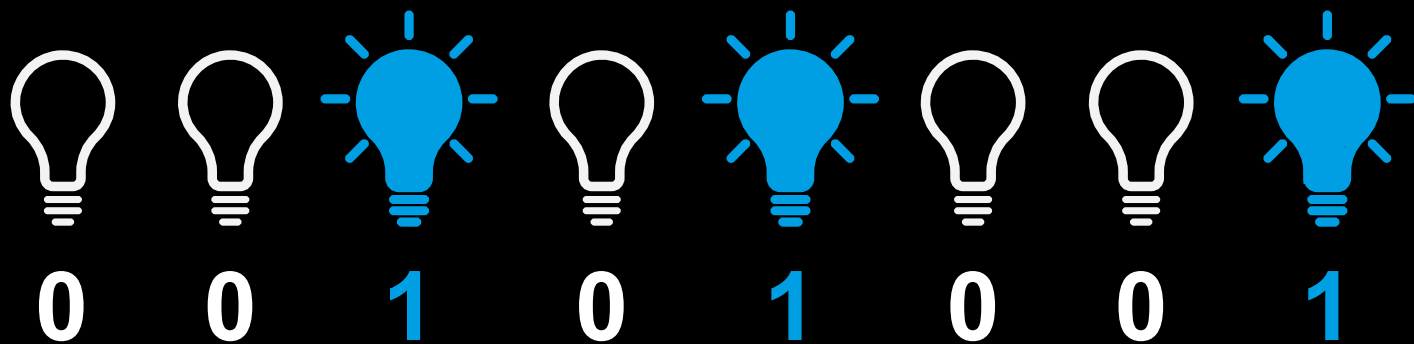
A **byte** (8 bits)



---

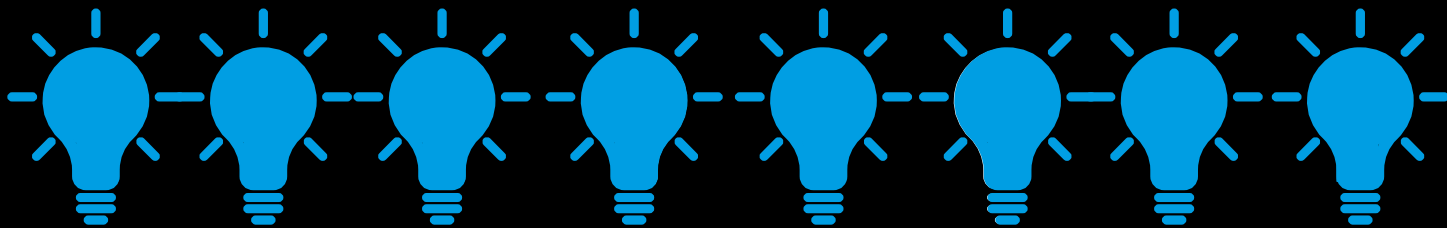
$2^7$   $2^6$   $2^5$   $2^4$   $2^3$   $2^2$   $2^1$   $2^0$





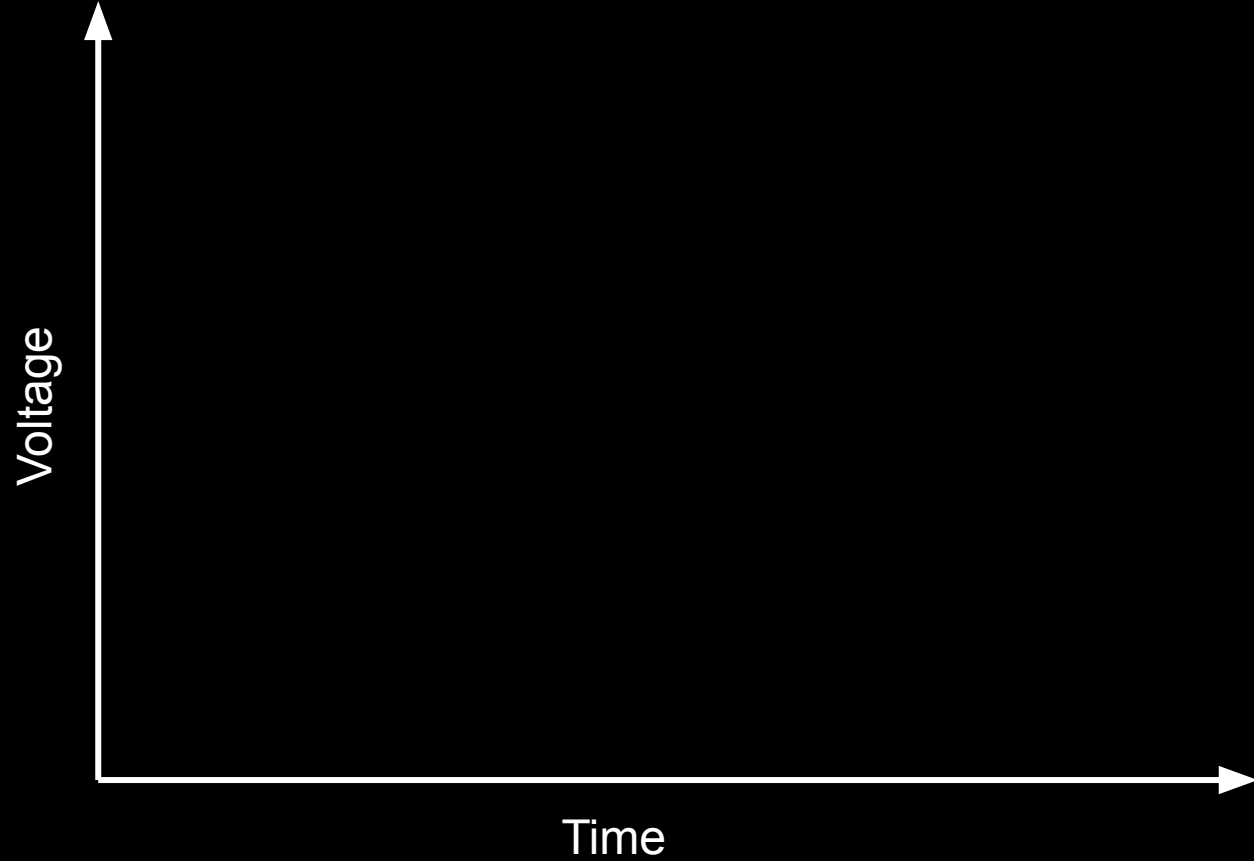
---

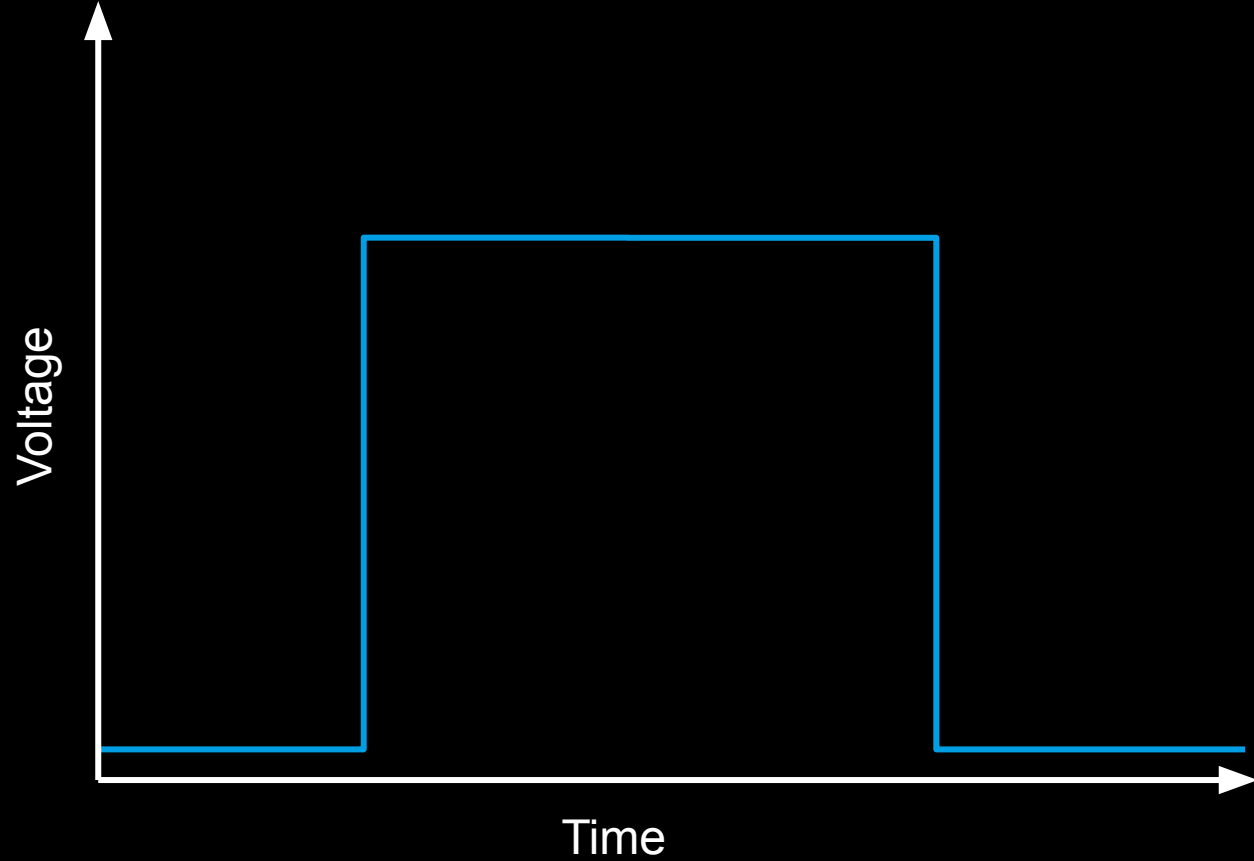
$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
128	64	32	16	8	4	2	1

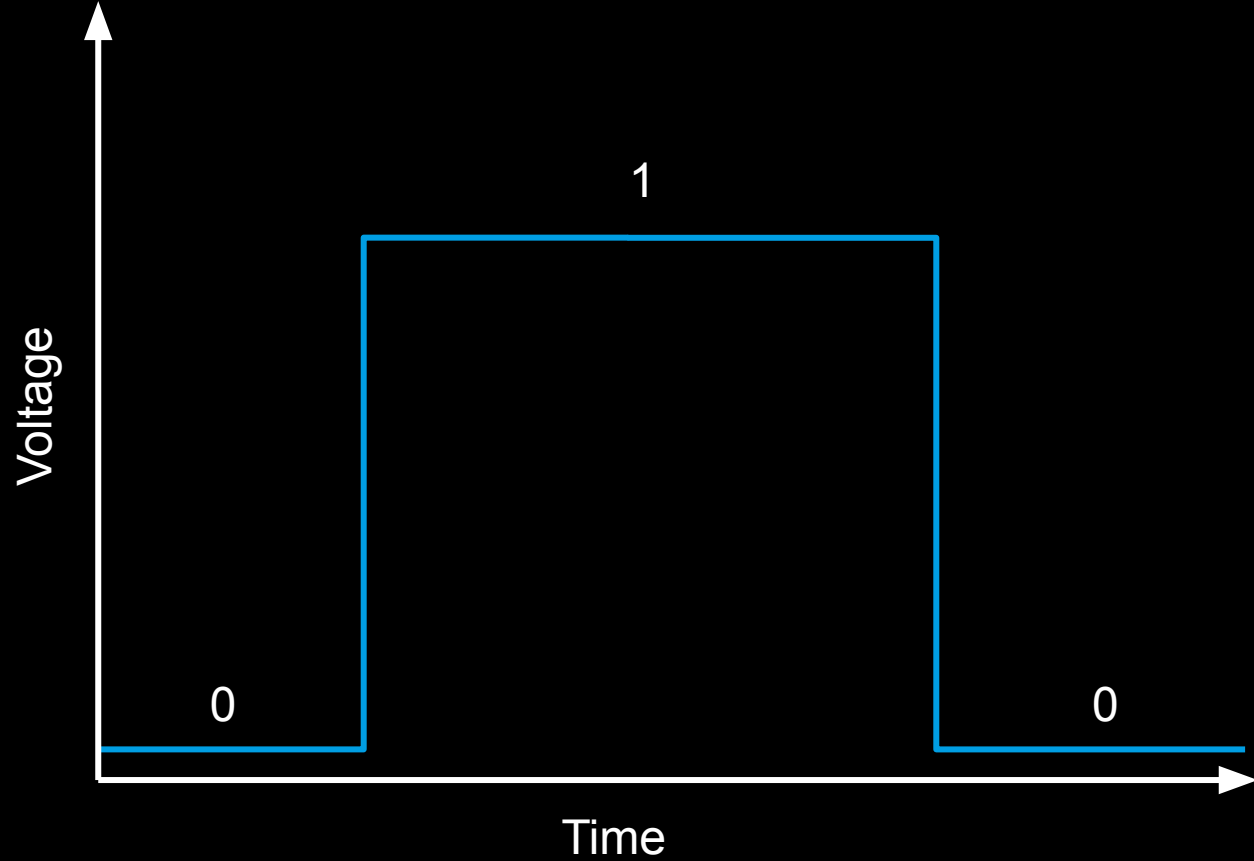


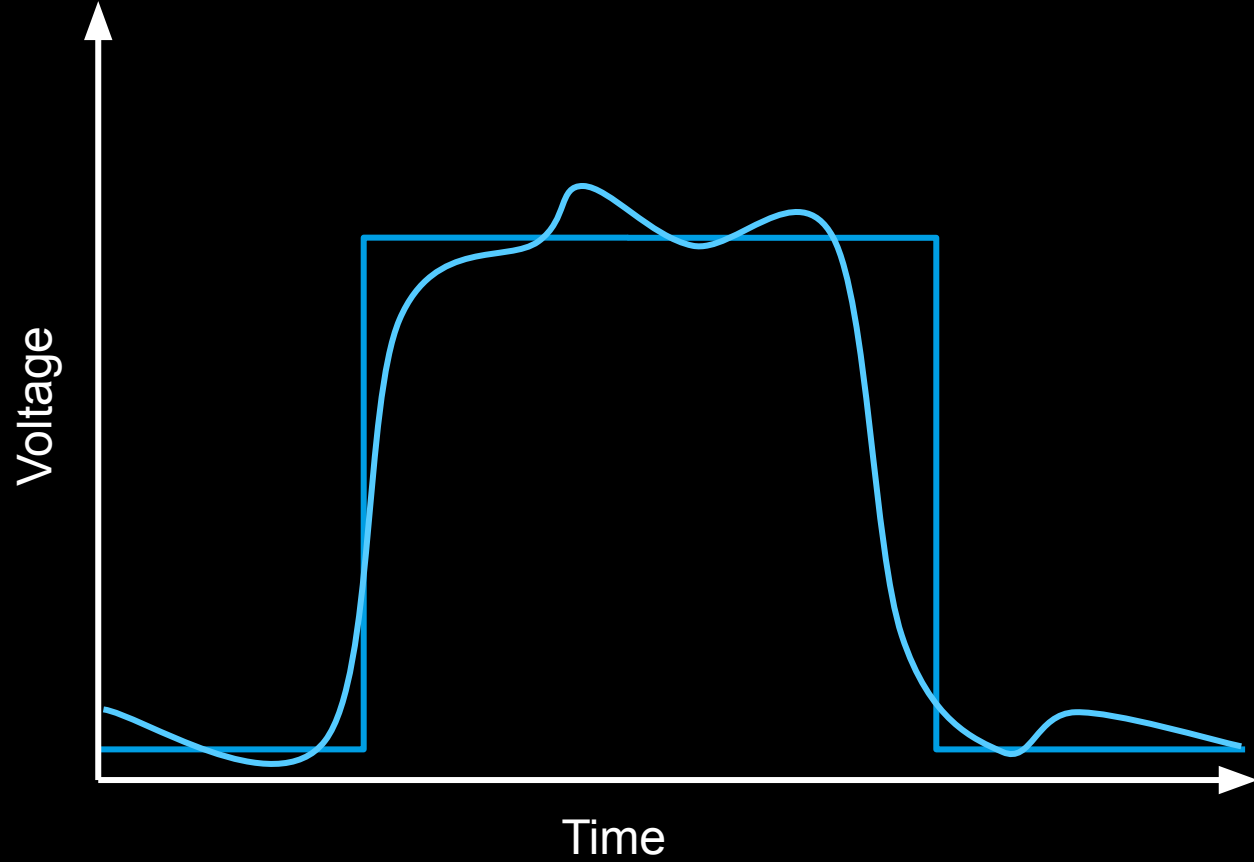
What can we store in one byte?

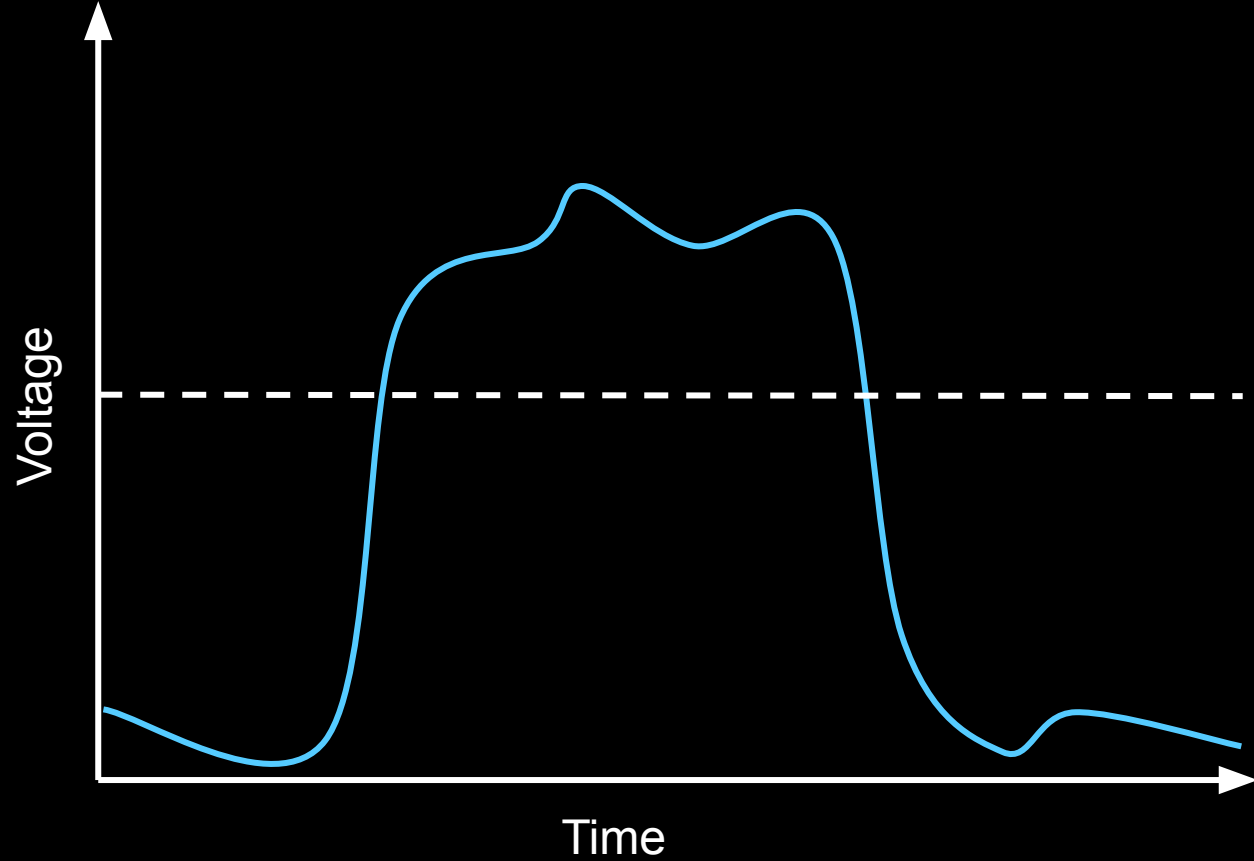
Are we stuck with binary?



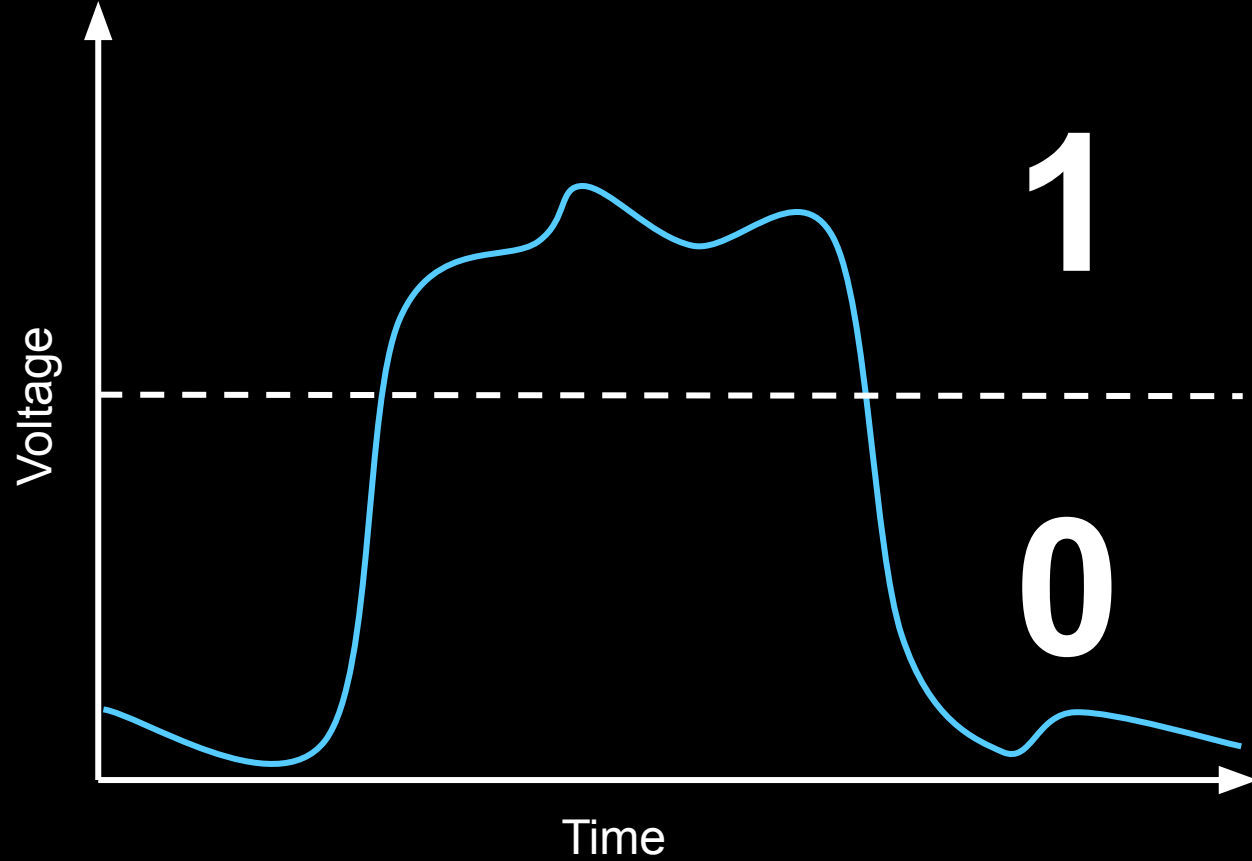


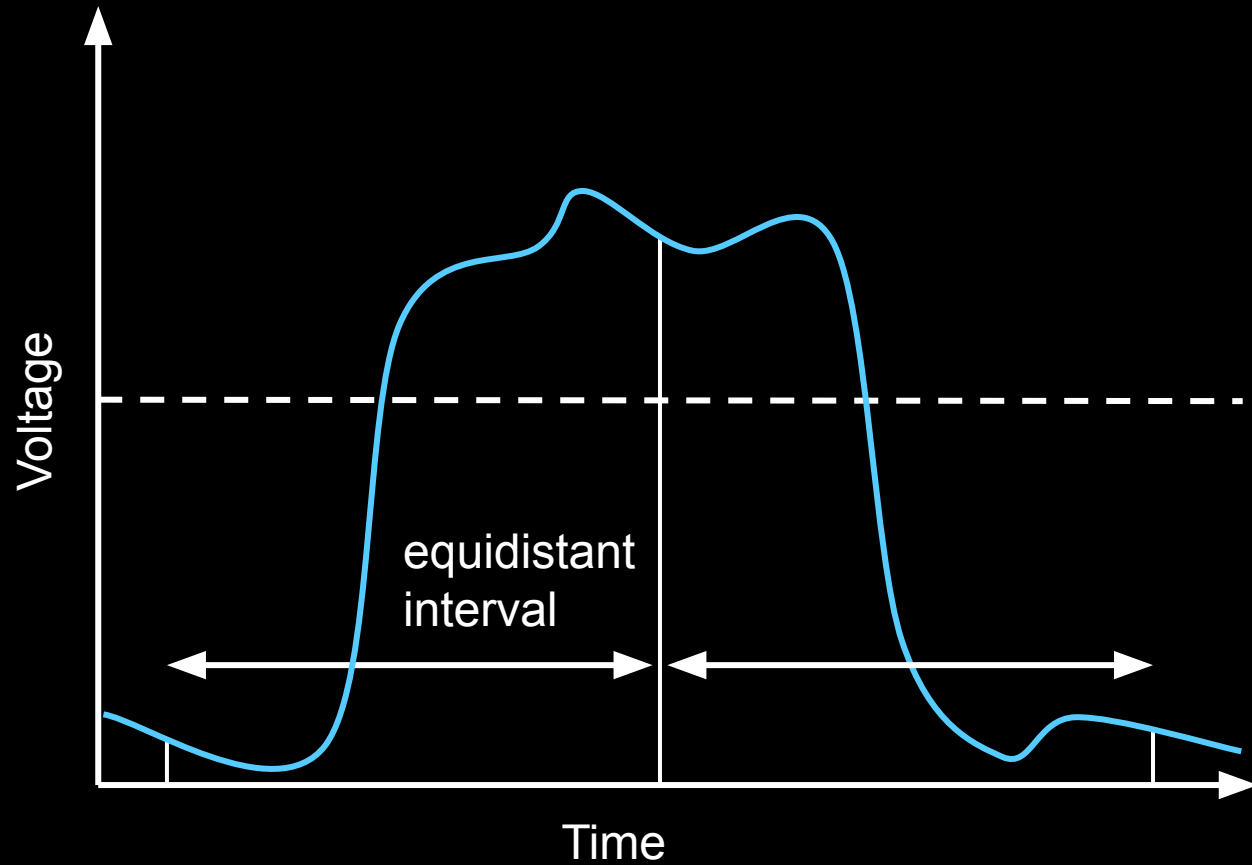


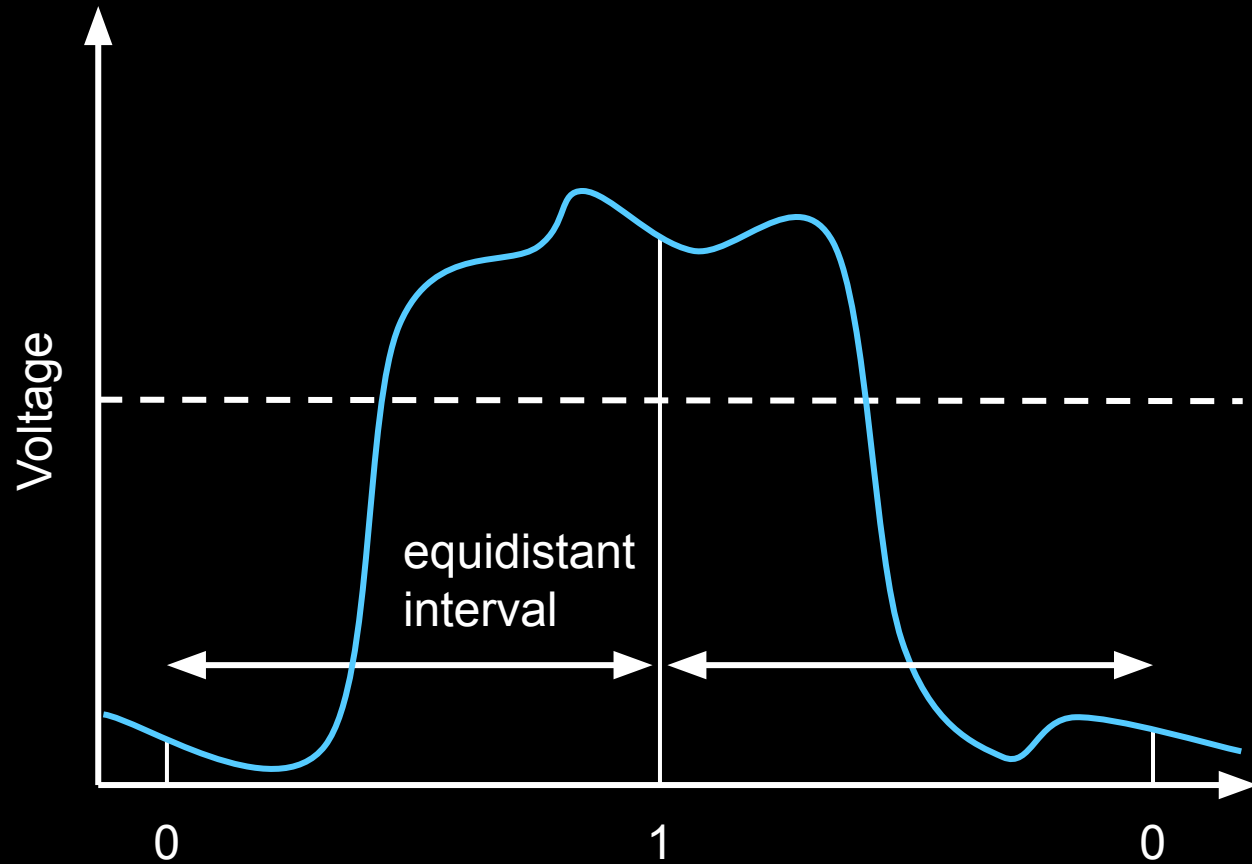




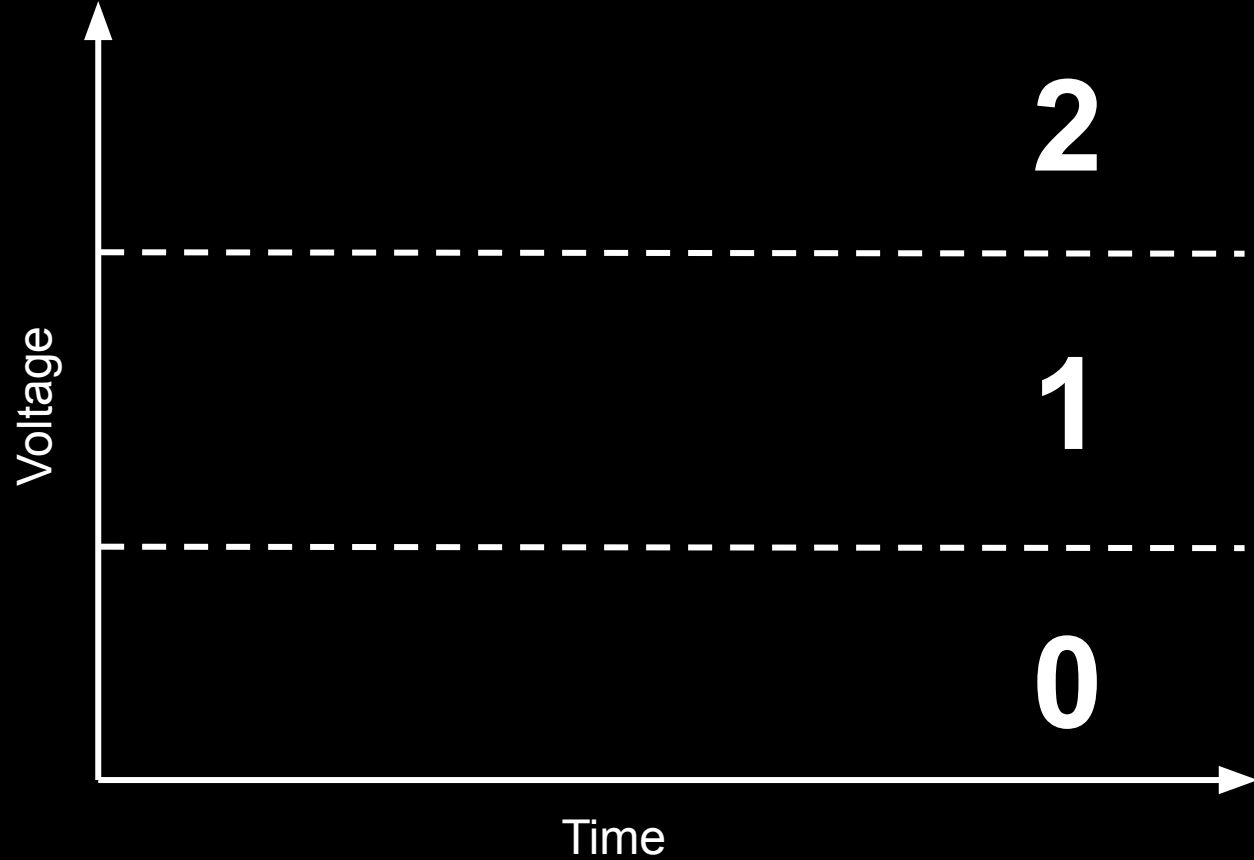


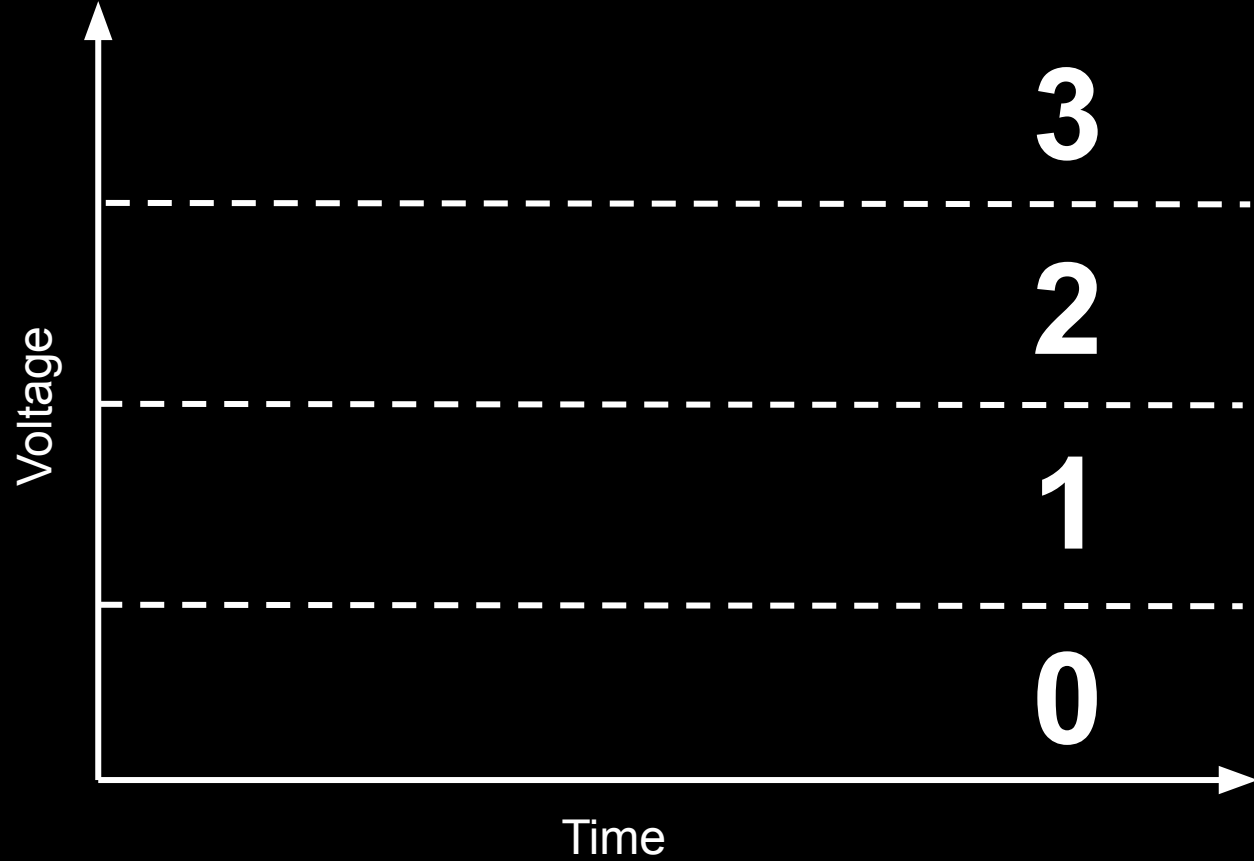


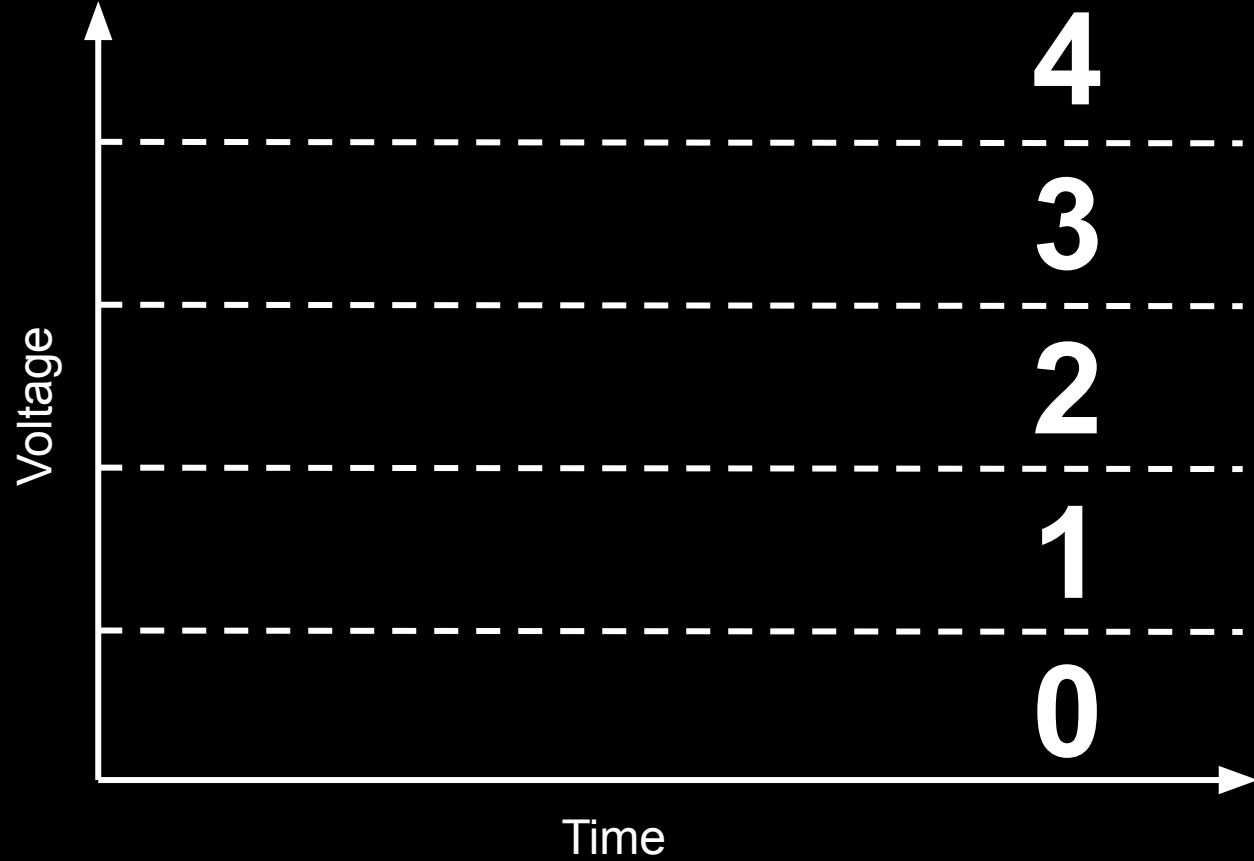


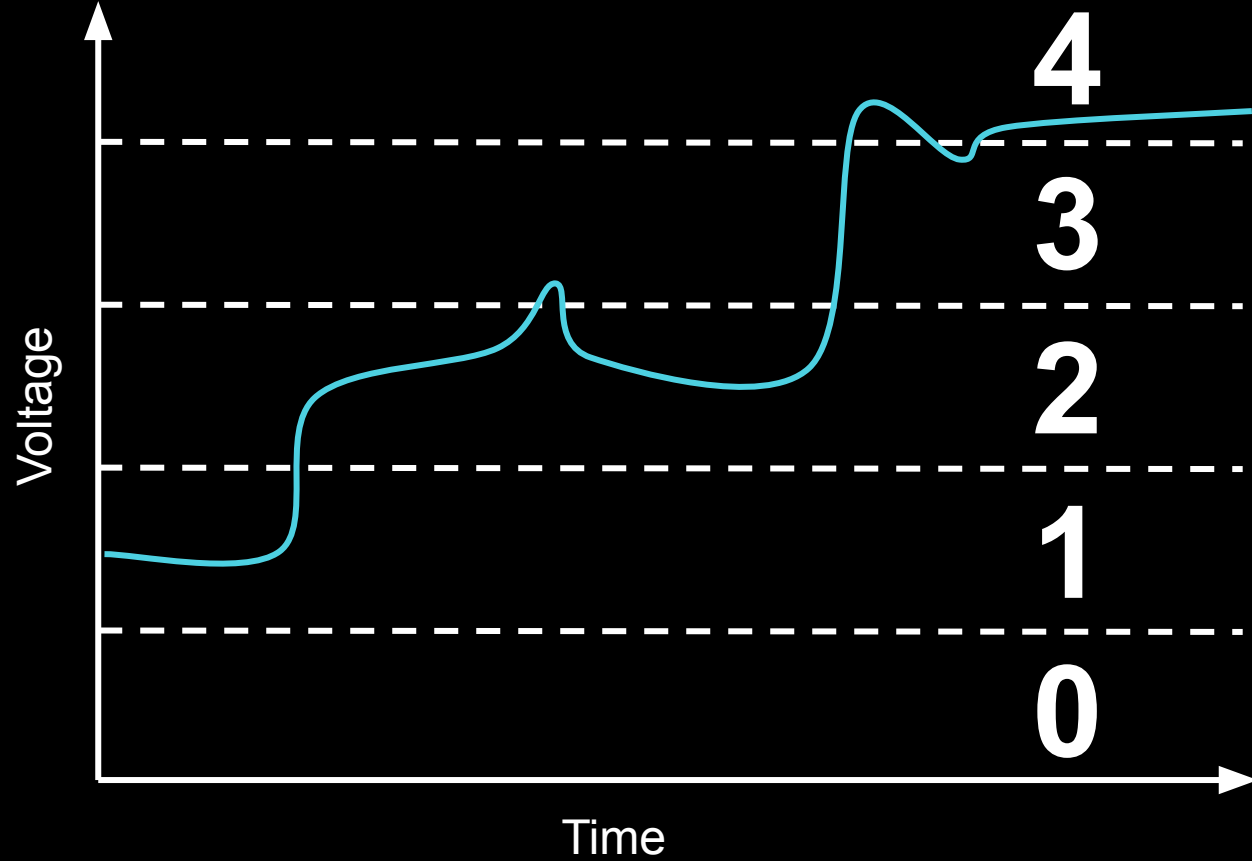


What about ternary?

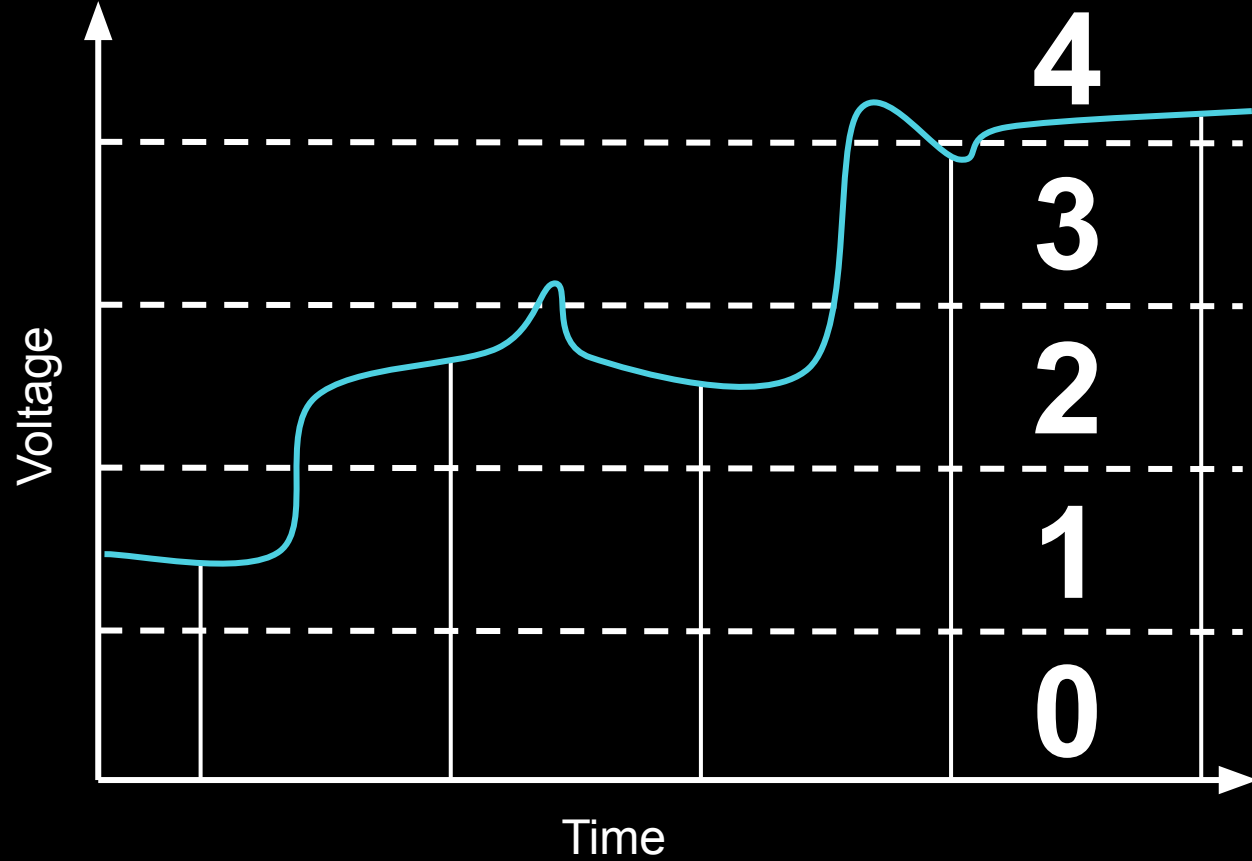


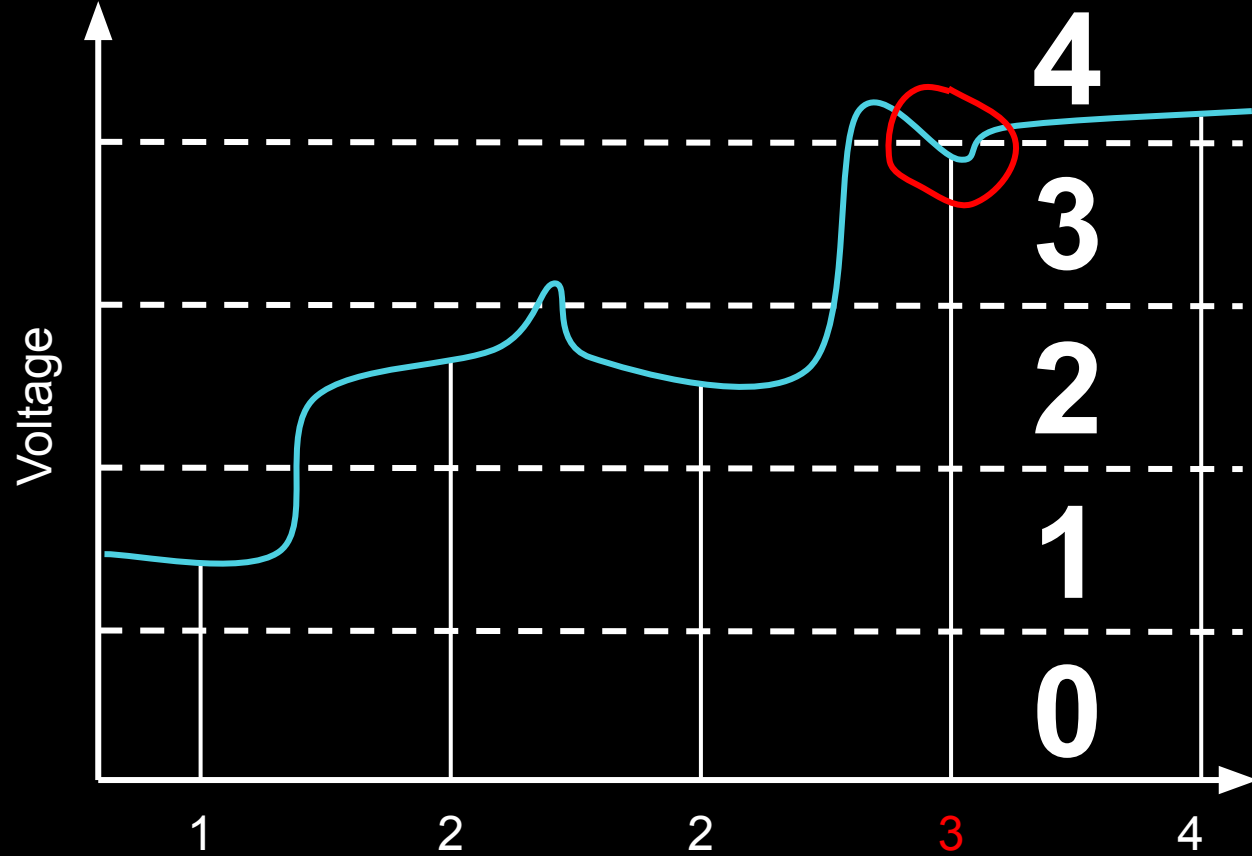






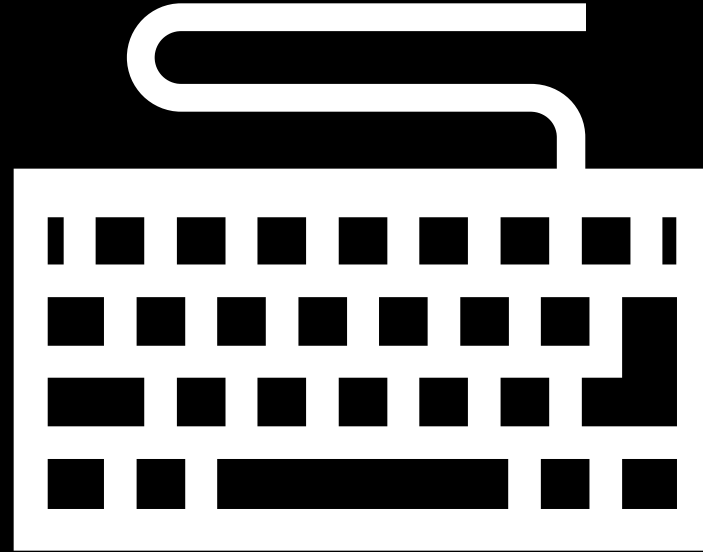






# CODES





A	B	C	D	...	a	b	c	d
65	66	67	68		97	98	99	100

# ASCII Code

A	B	C	D	...	a	b	c	d
65	66	67	68		97	98	99	100



1F600



1F601



1F602



1F603

...



1F648



1F649



1F64A



1F64B



# Unicode



1F600



1F601



1F602



1F603

...



1F648



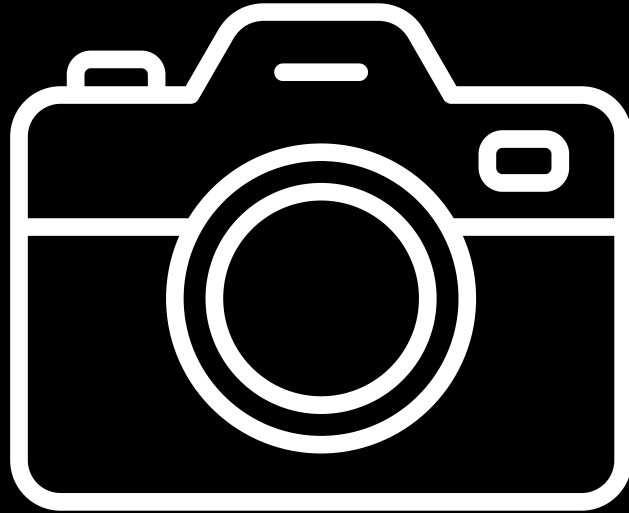
1F649



1F64A



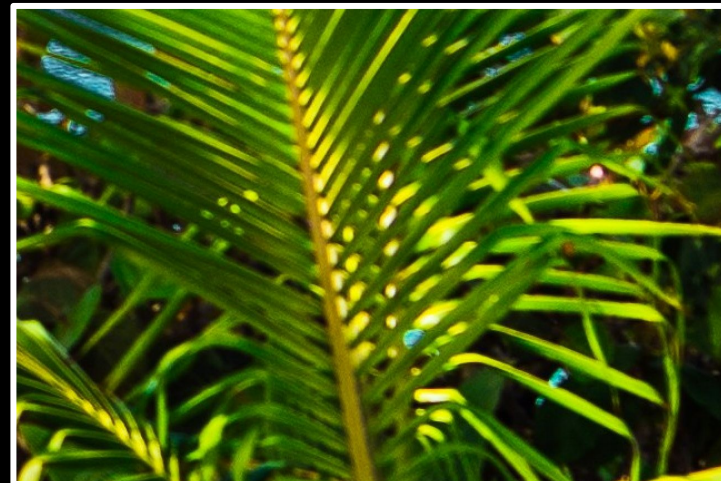
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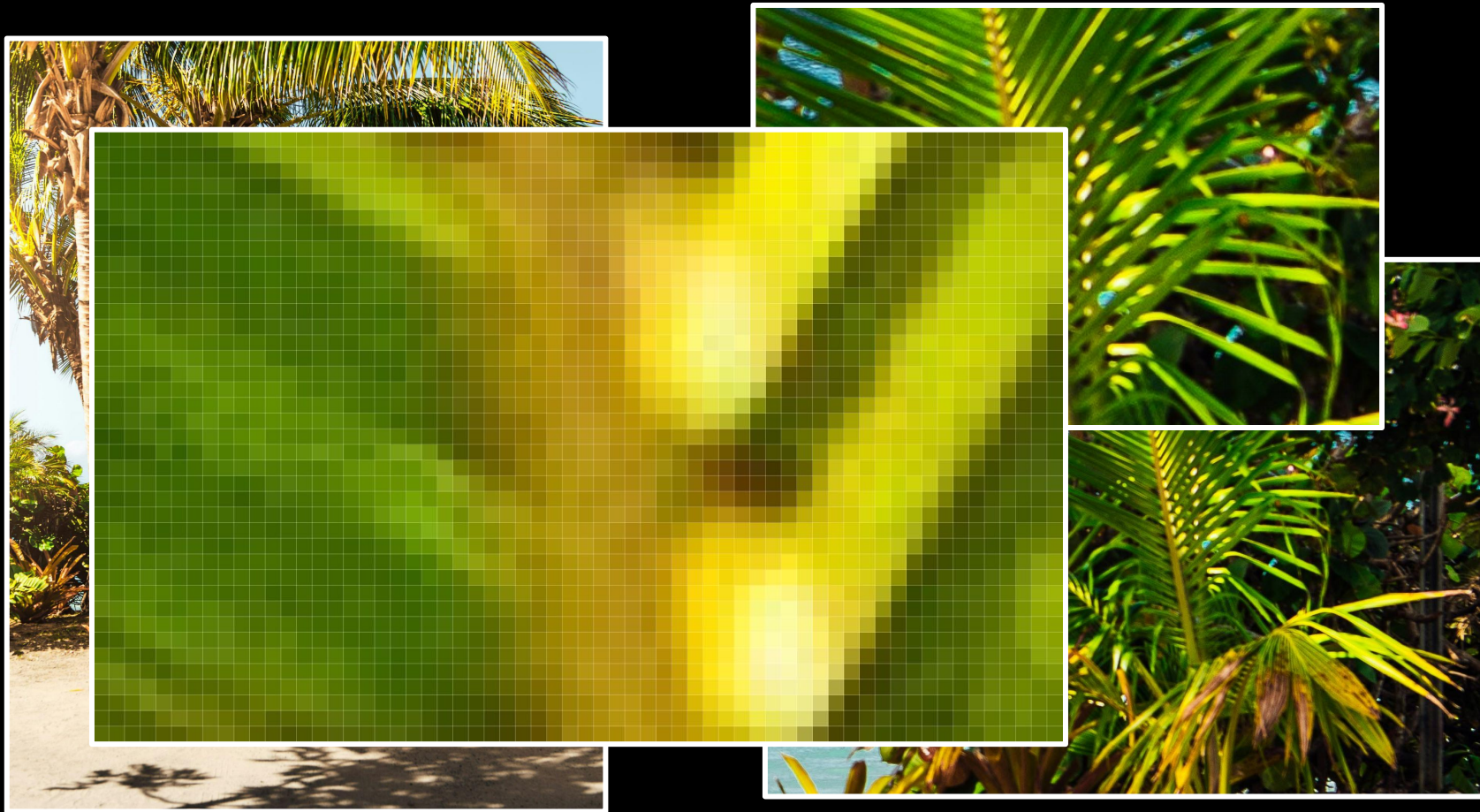




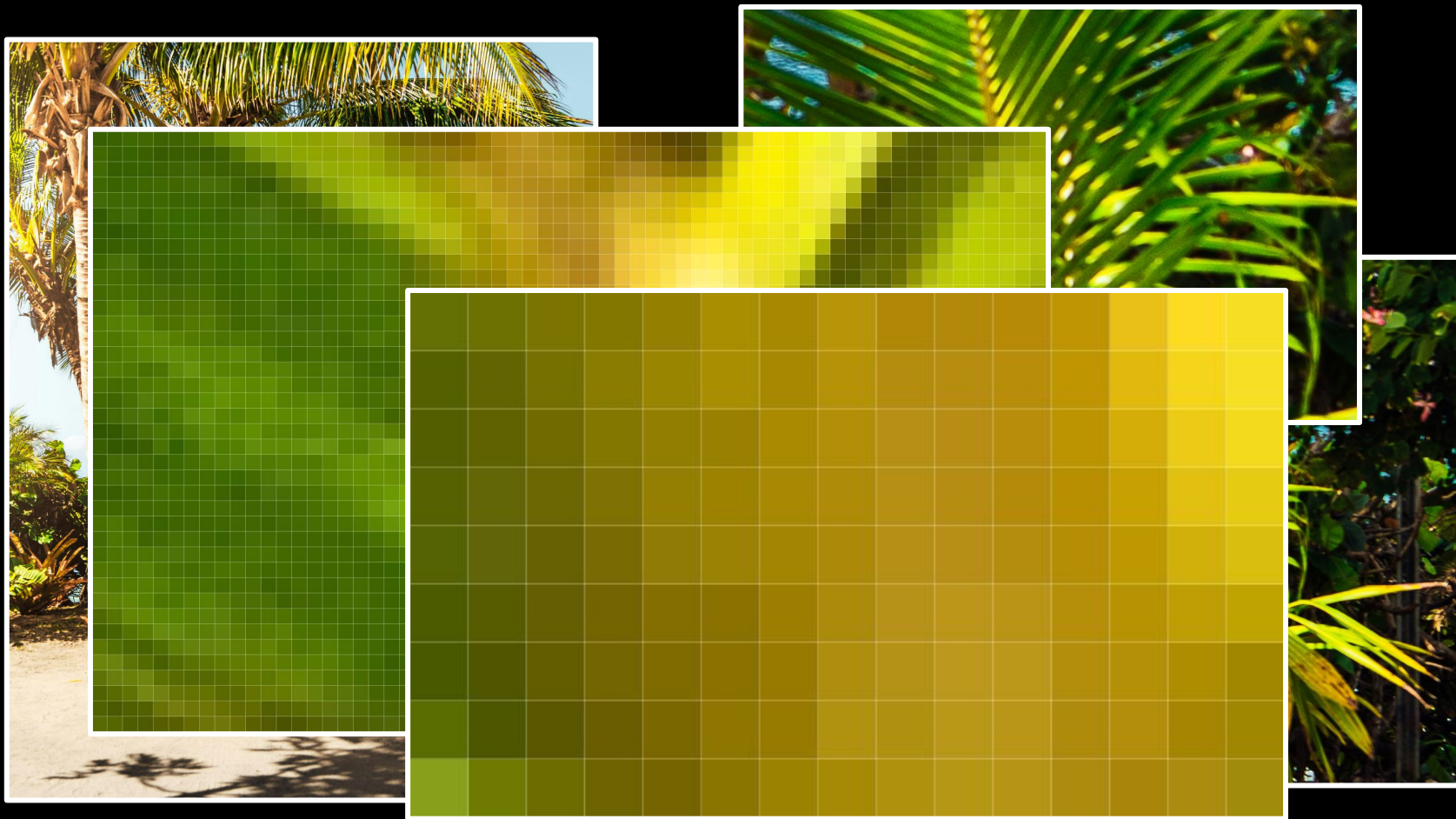


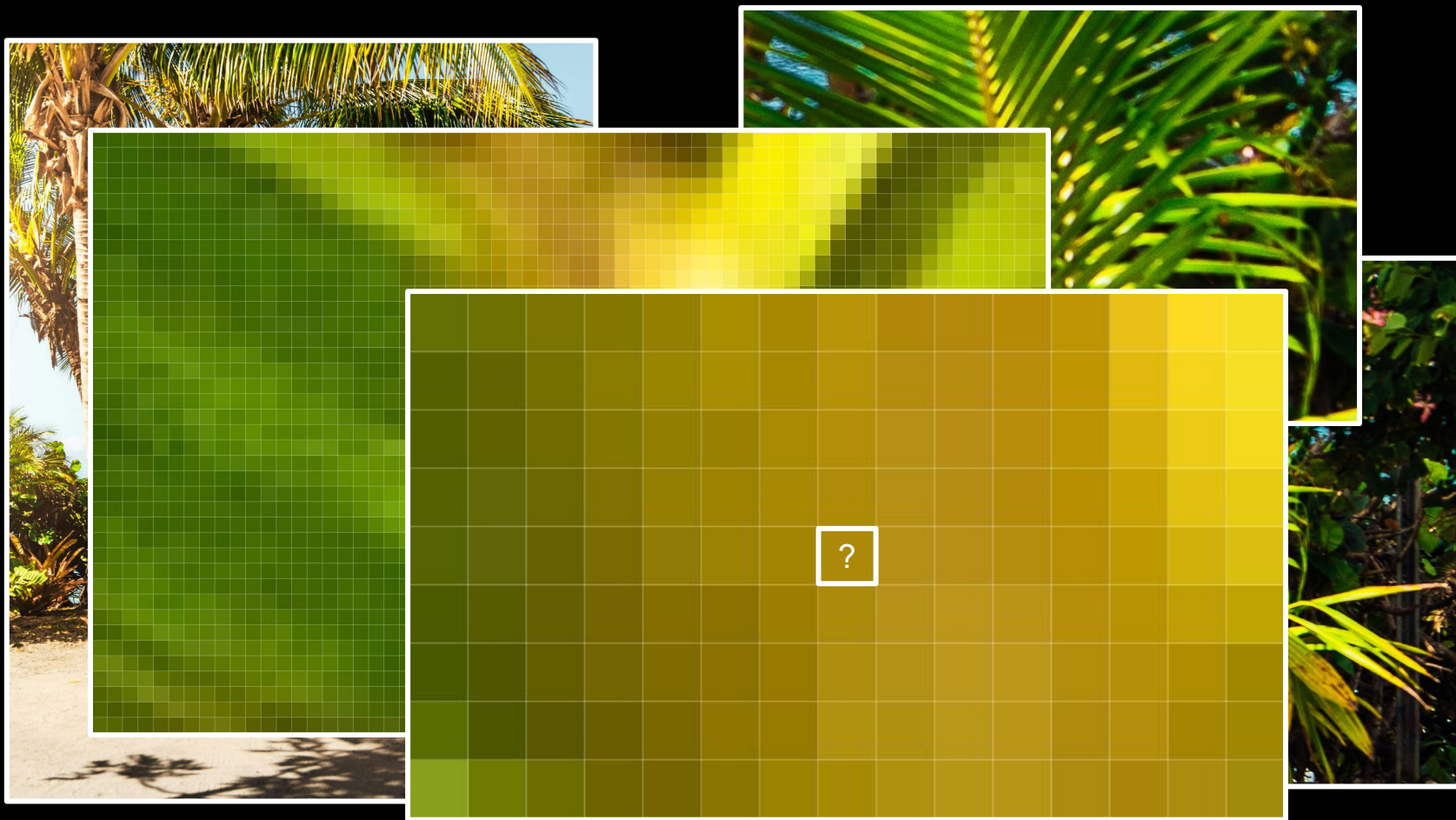




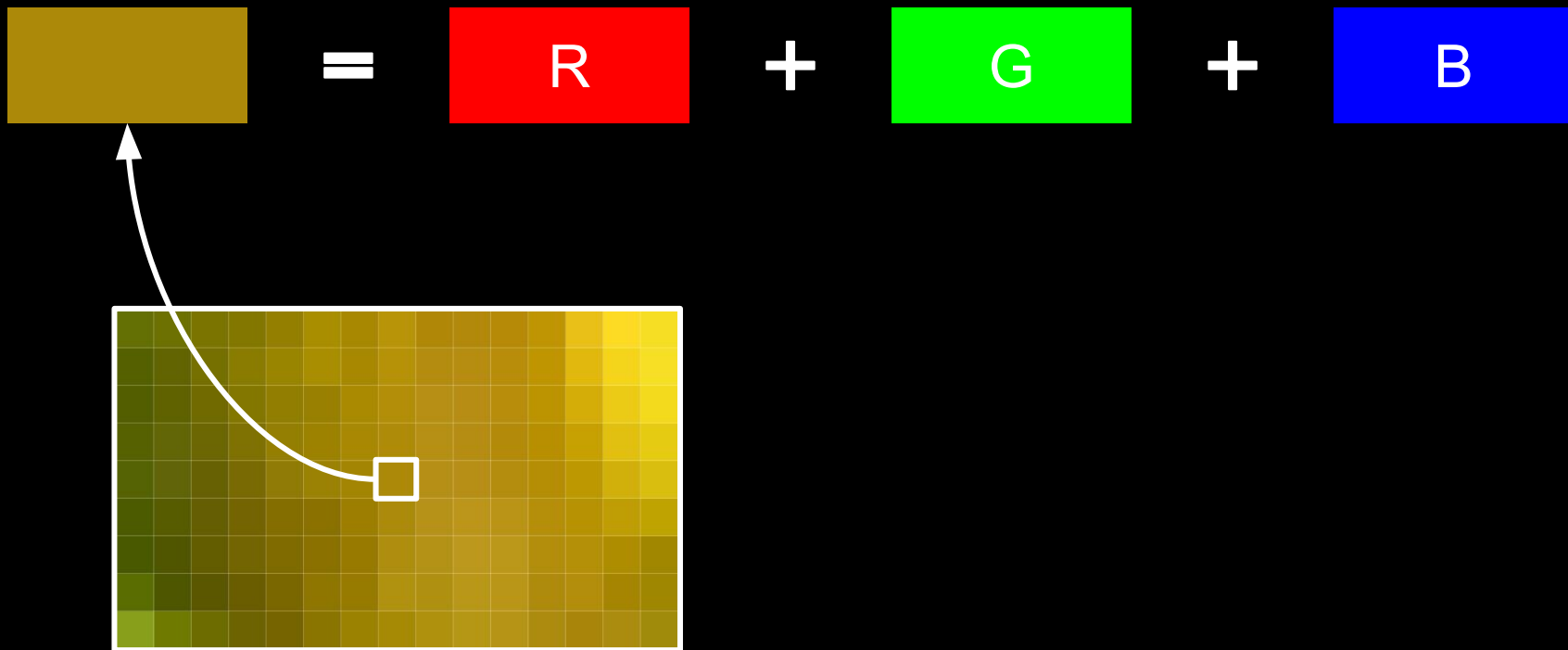


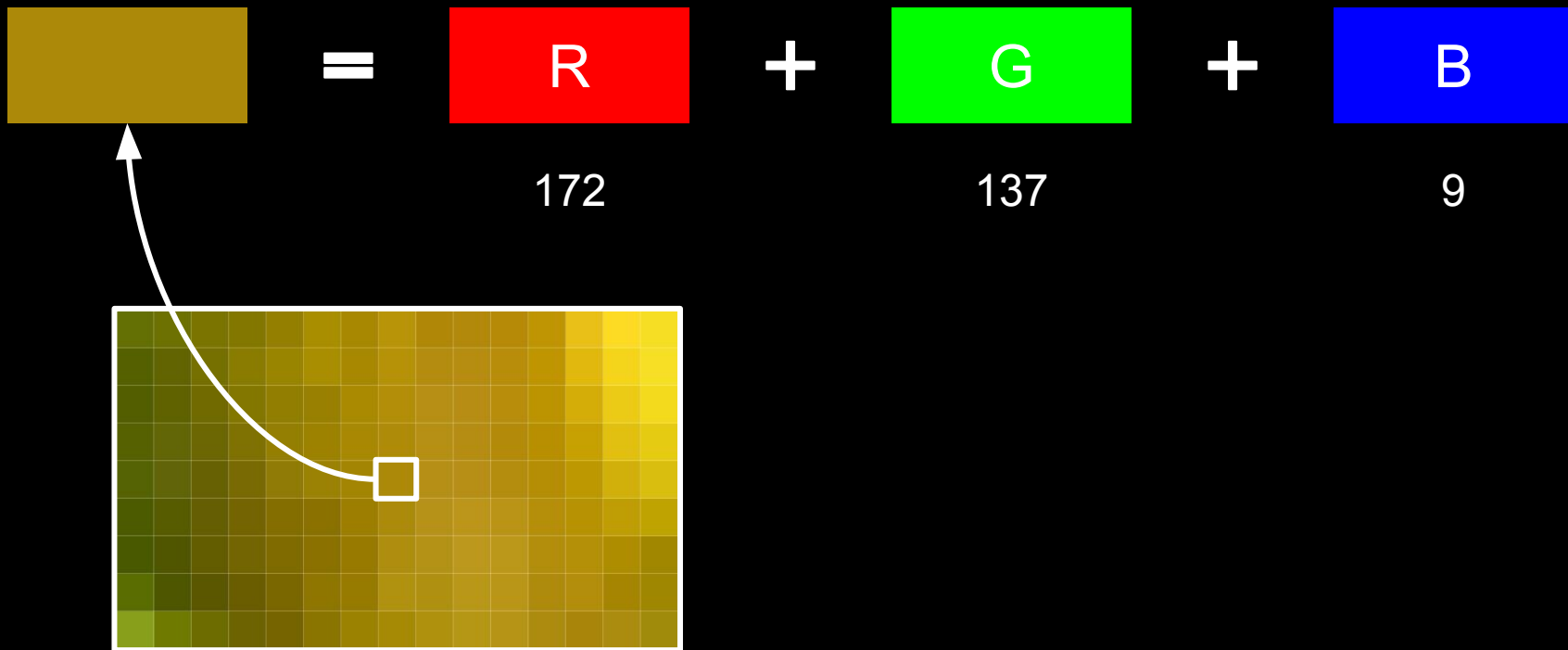


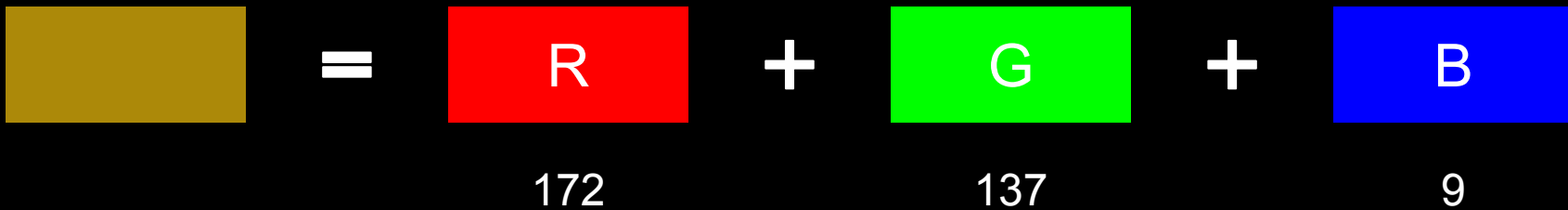








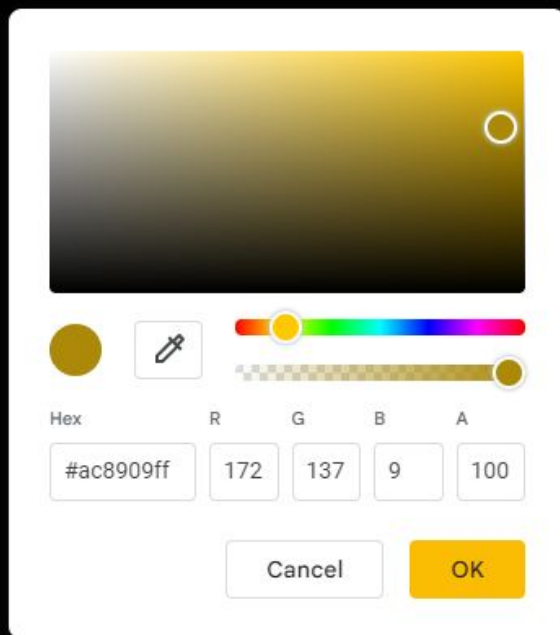


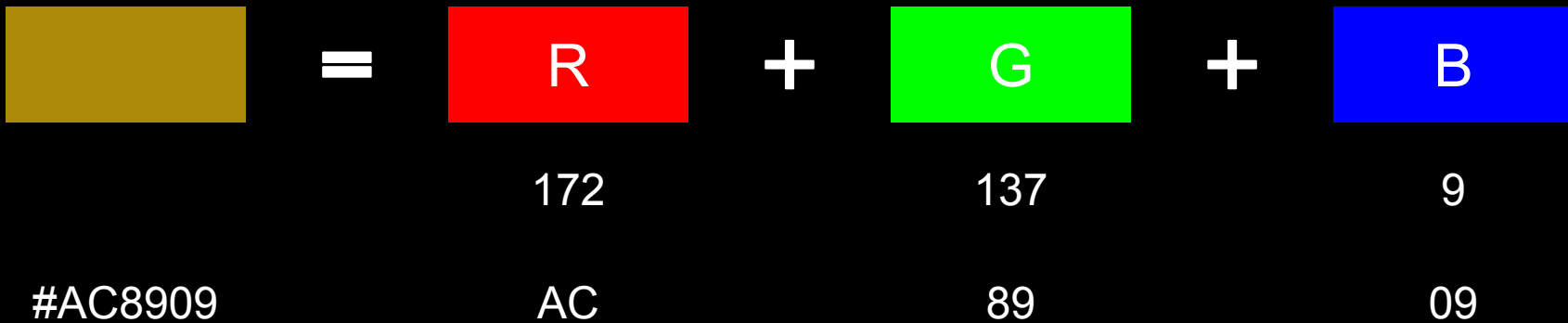


A diagram illustrating the RGB color model. On the left is a gold-colored rectangle. To its right is an equals sign. Further right are three colored rectangles: red, green, and blue. The red rectangle is labeled 'R' and has the value '172' below it. The green rectangle is labeled 'G' and has the value '137' below it. The blue rectangle is labeled 'B' and has the value '9' below it. Plus signs are placed between the red and green rectangles, and between the green and blue rectangles.

$$\text{Gold} = R(172) + G(137) + B(9)$$

#AC8909







# possible colors?

R

$2^7$   $2^6$   $2^5$   $2^4$   $2^3$   $2^2$   $2^1$   $2^0$



A solid red square.

R

A solid green square.

G

A solid blue square.

B

$2^{23}$   $2^{22}$   $2^{21}$   $2^{20}$   $2^{19}$   $2^{18}$   $2^{17}$   $2^{16}$

$2^{15}$   $2^{14}$   $2^{13}$   $2^{12}$   $2^{11}$   $2^{10}$   $2^9$   $2^8$

$2^7$   $2^6$   $2^5$   $2^4$   $2^3$   $2^2$   $2^1$   $2^0$

R

G

B

$2^{23} 2^{22} 2^{21} 2^{20} 2^{19} 2^{18} 2^{17} 2^{16}$      $2^{15} 2^{14} 2^{13} 2^{12} 2^{11} 2^{10} 2^9 2^8$      $2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0$

8.388.608

+

8.388.607

=

16.777.215

R

G

B

$2^{23} 2^{22} 2^{21} 2^{20} 2^{19} 2^{18} 2^{17} 2^{16}$

$2^{15} 2^{14} 2^{13} 2^{12} 2^{11} 2^{10} 2^9 2^8$

$2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0$

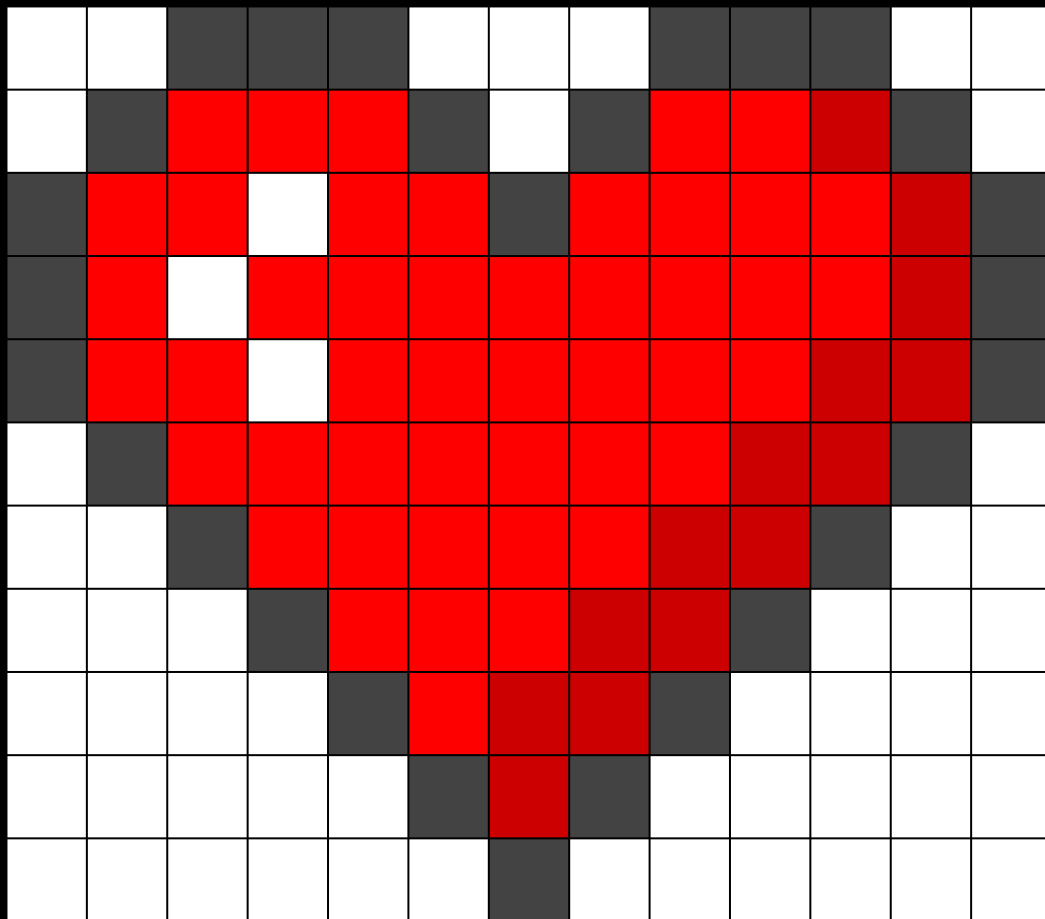
256

×

256

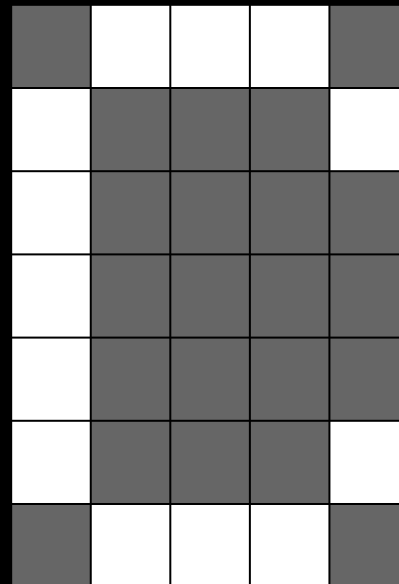
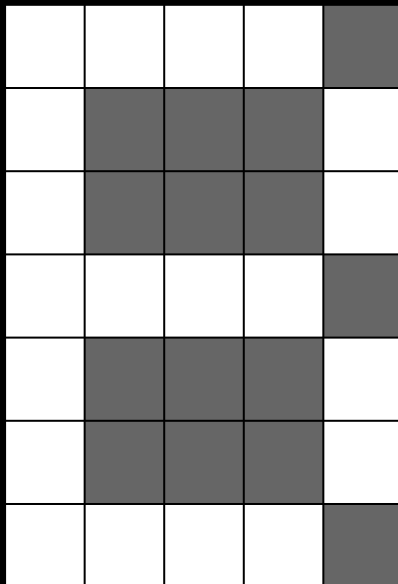
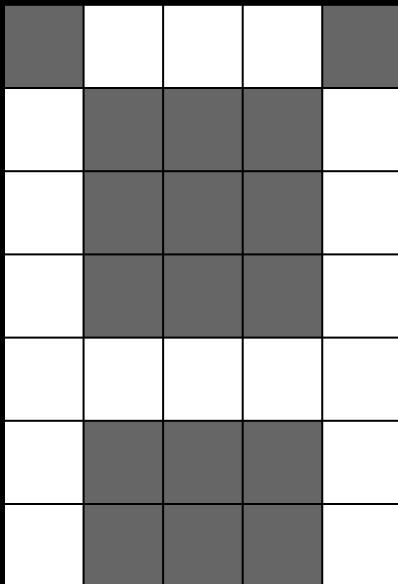
×

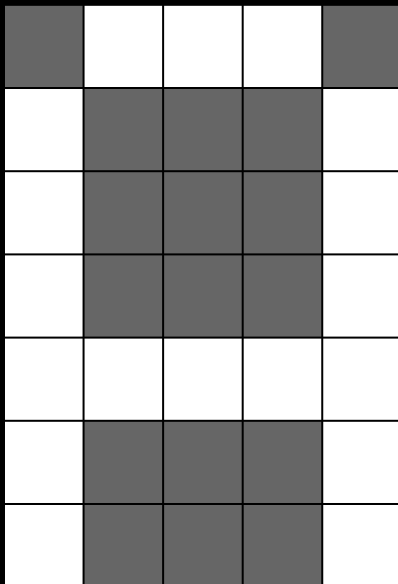
256





compression?





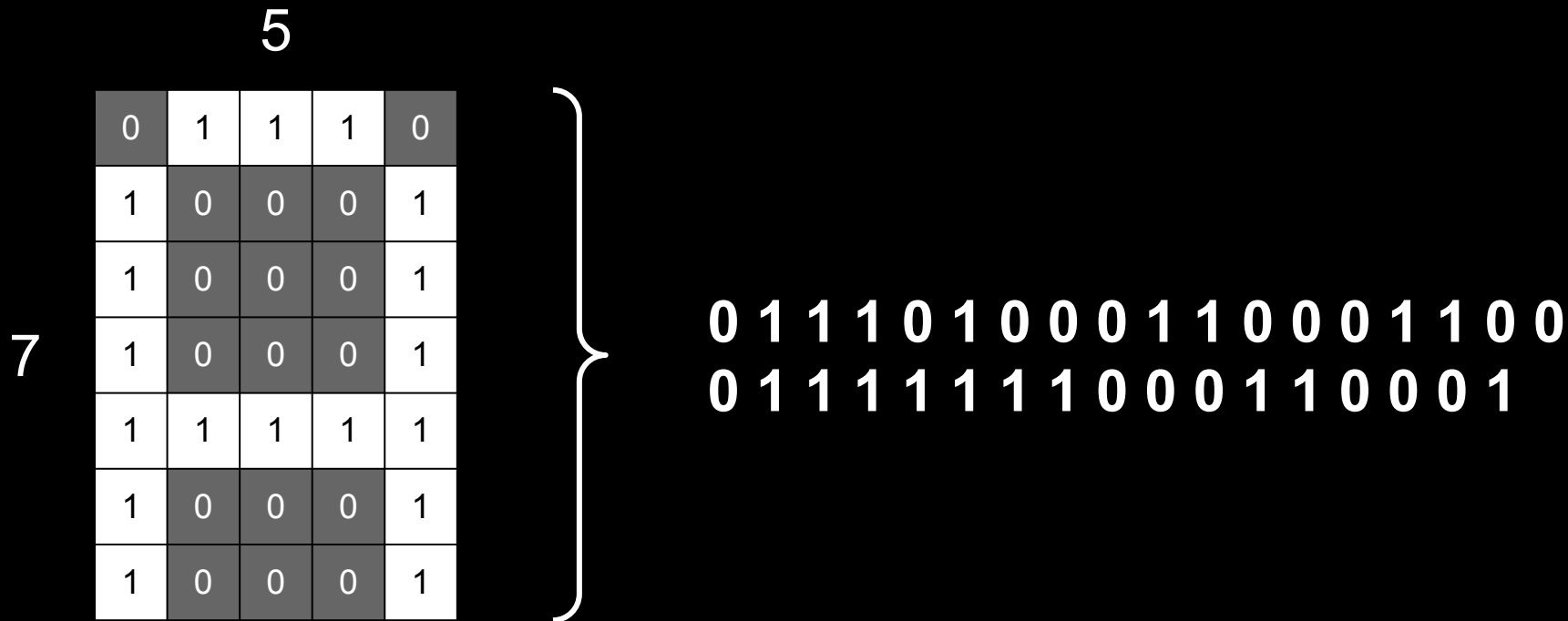
0	1	1	1	0
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	1	1	1	1
1	0	0	0	1
1	0	0	0	1



0	1	1	1	0
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	1	1	1	1
1	0	0	0	1
1	0	0	0	1



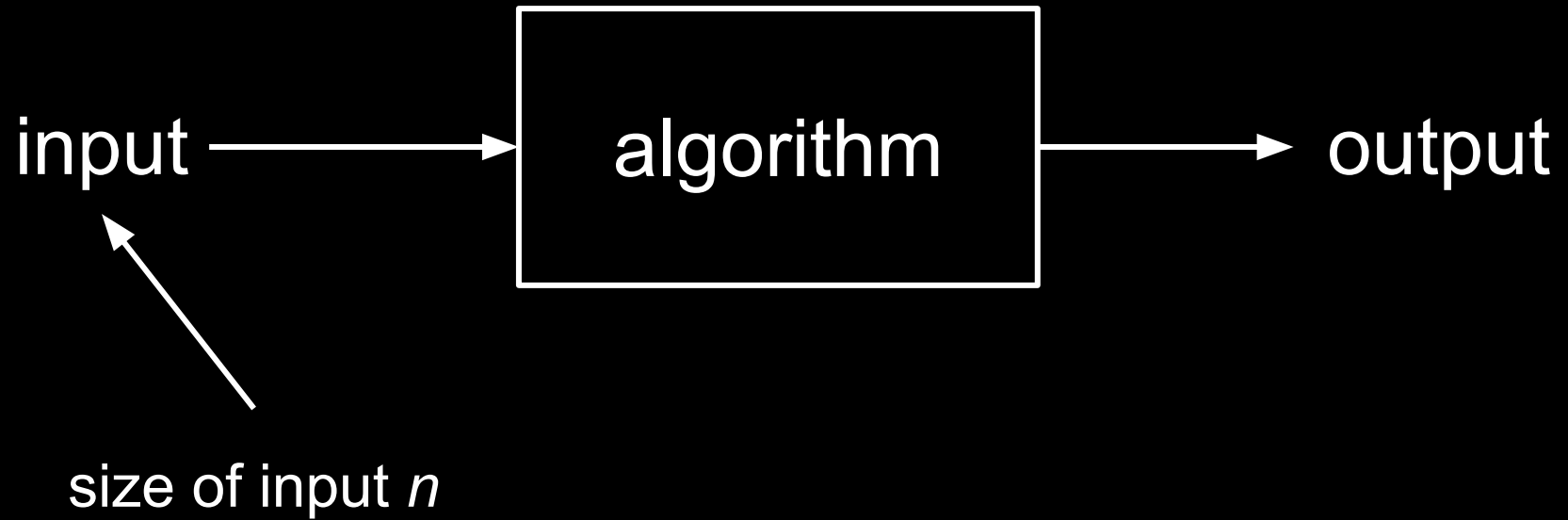
0 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 0 0  
0 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 1

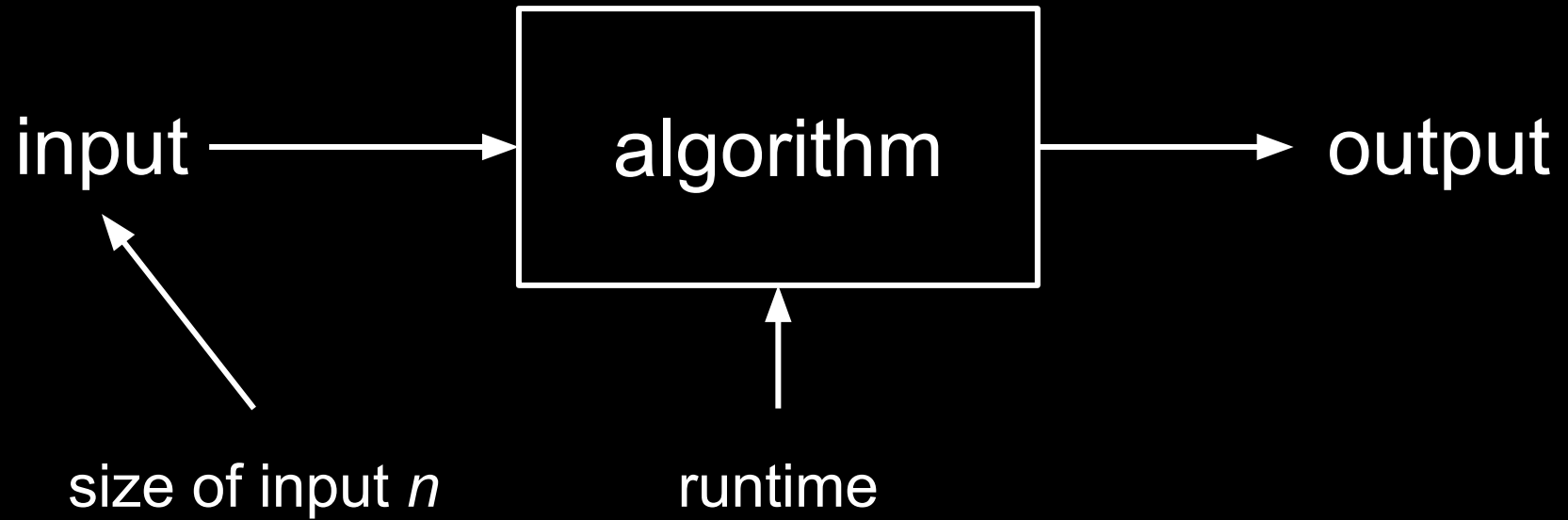


# ALGORITHMS

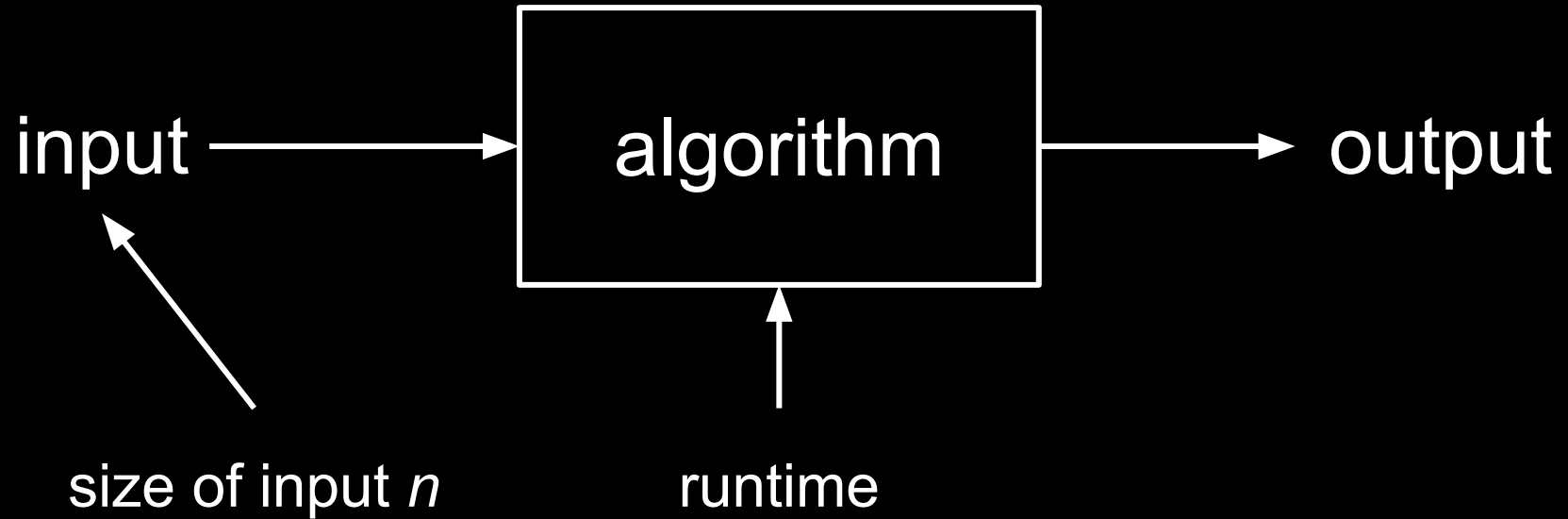
complexity







$O(n)$





# LOGIC

# ARITHMETIC

# ANALOG VS. DIGITAL