Why parallel programming is hard

Excerpt from a slide deck by Charlie Curtsinger
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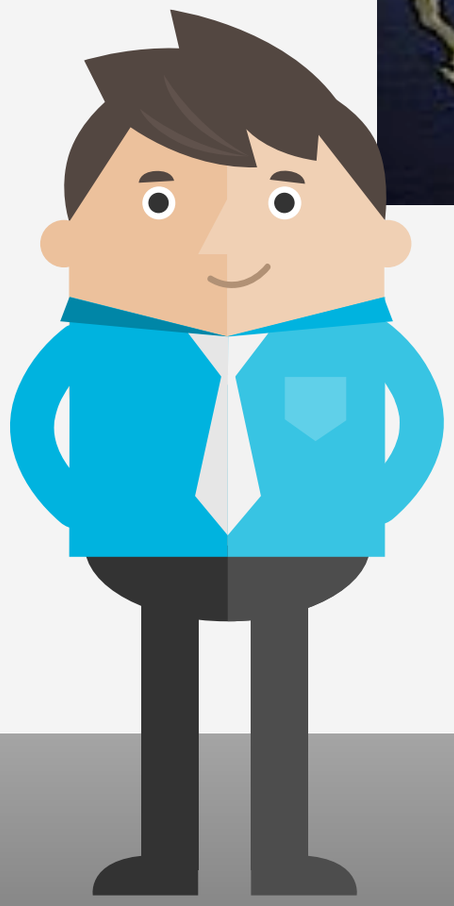
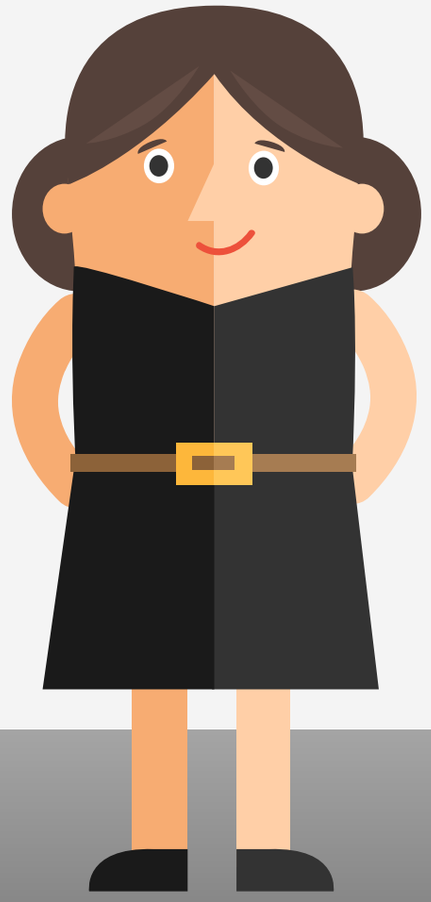
Race Conditions

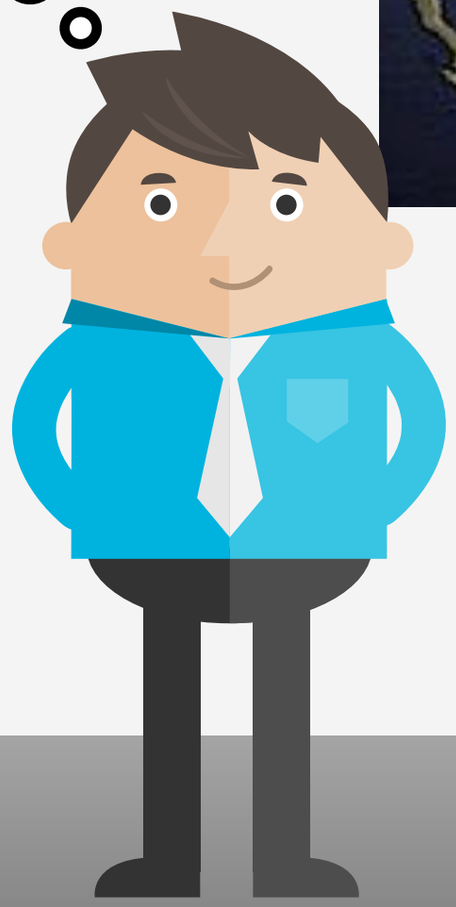
Race Conditions





Race Conditions

I'll make sure we have bread and milk



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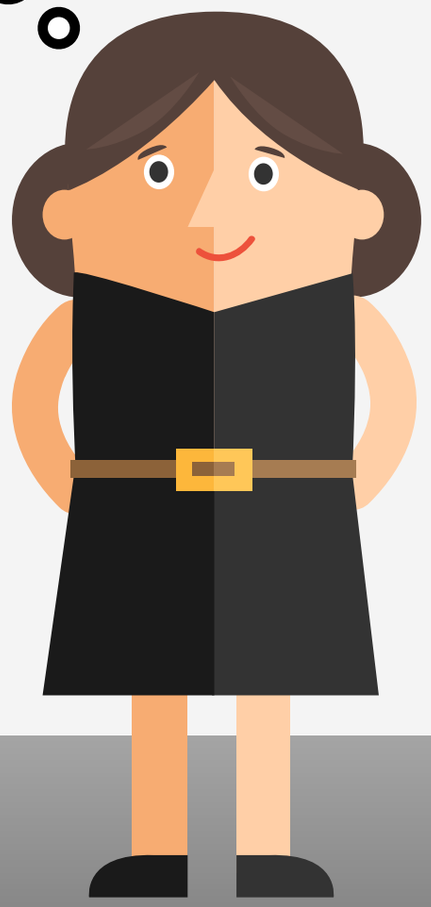


Race Conditions


Oh no! Better go to the store.


Oh no! Better go to the store.

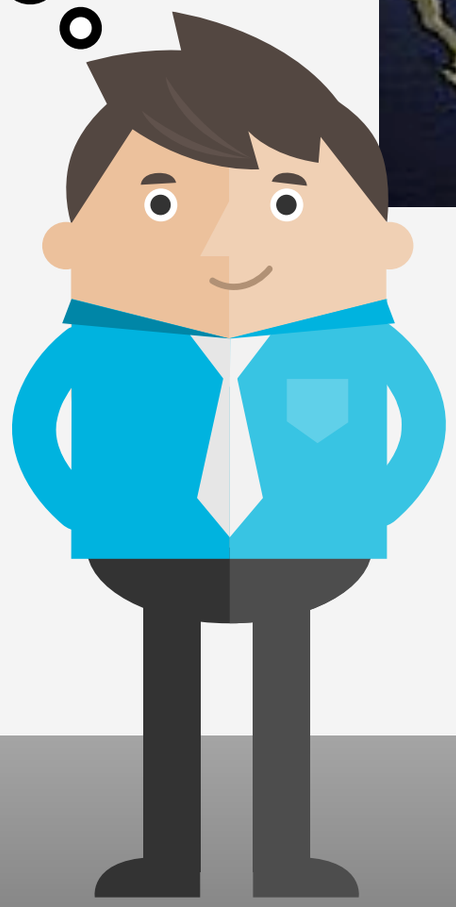

Great Value
2%
Nutrition Facts


I hate race conditions!

Try again with a lock

Try again with a lock

I'll make sure we have bread and milk



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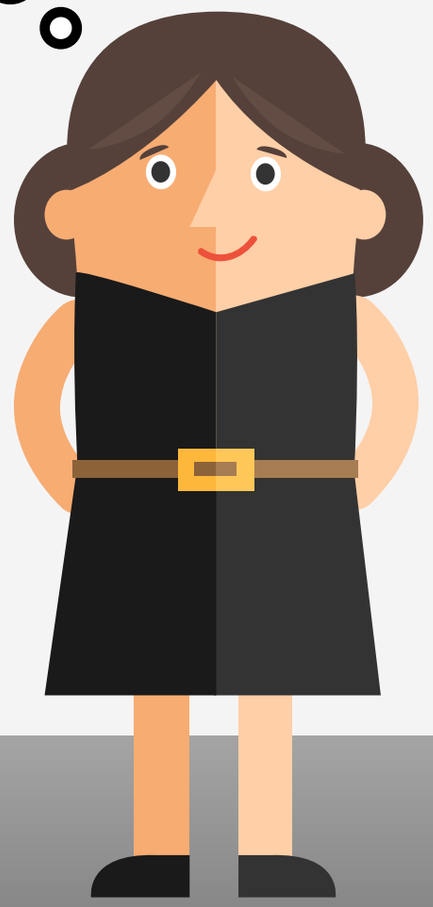
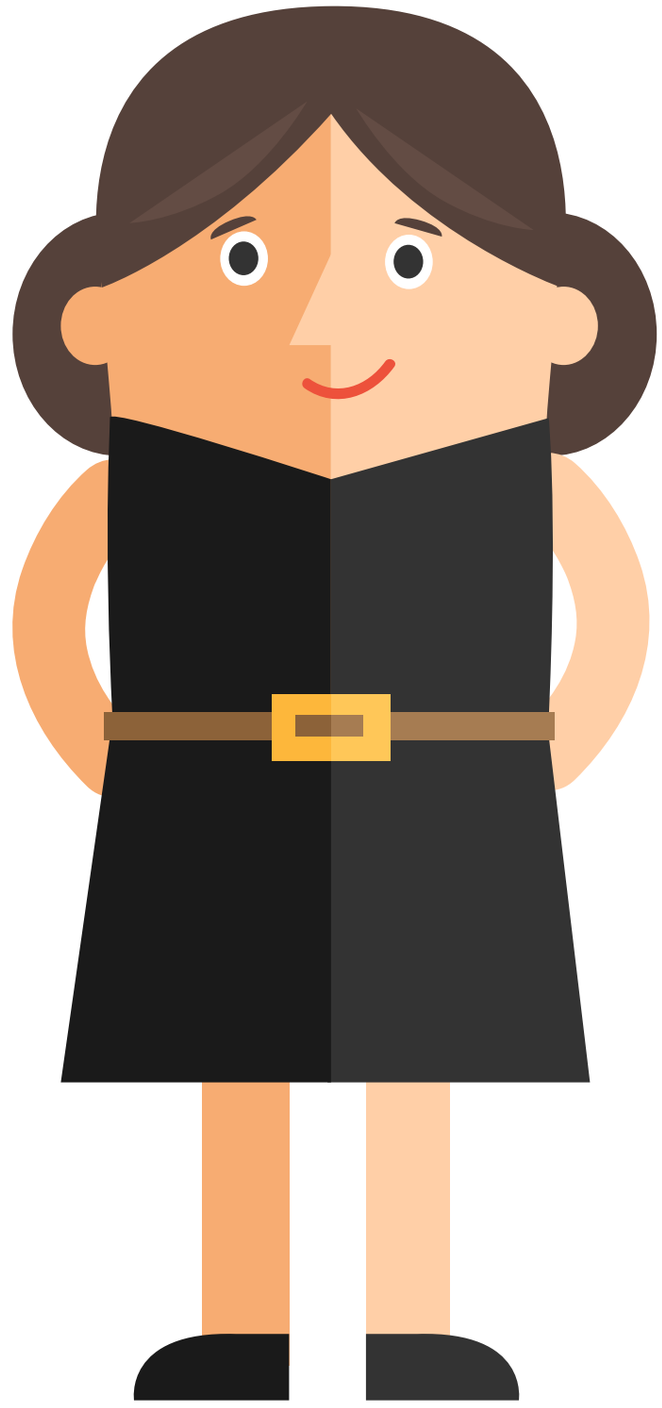
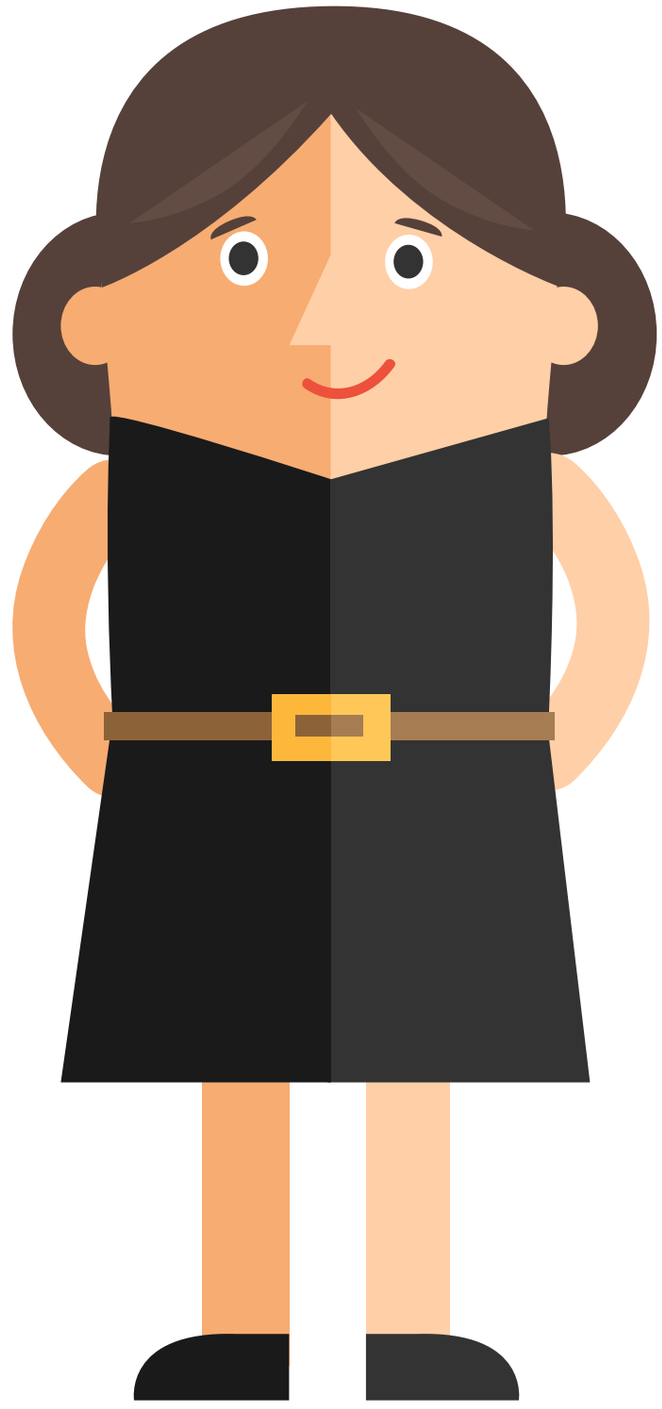



Oh no! Better go to the store.

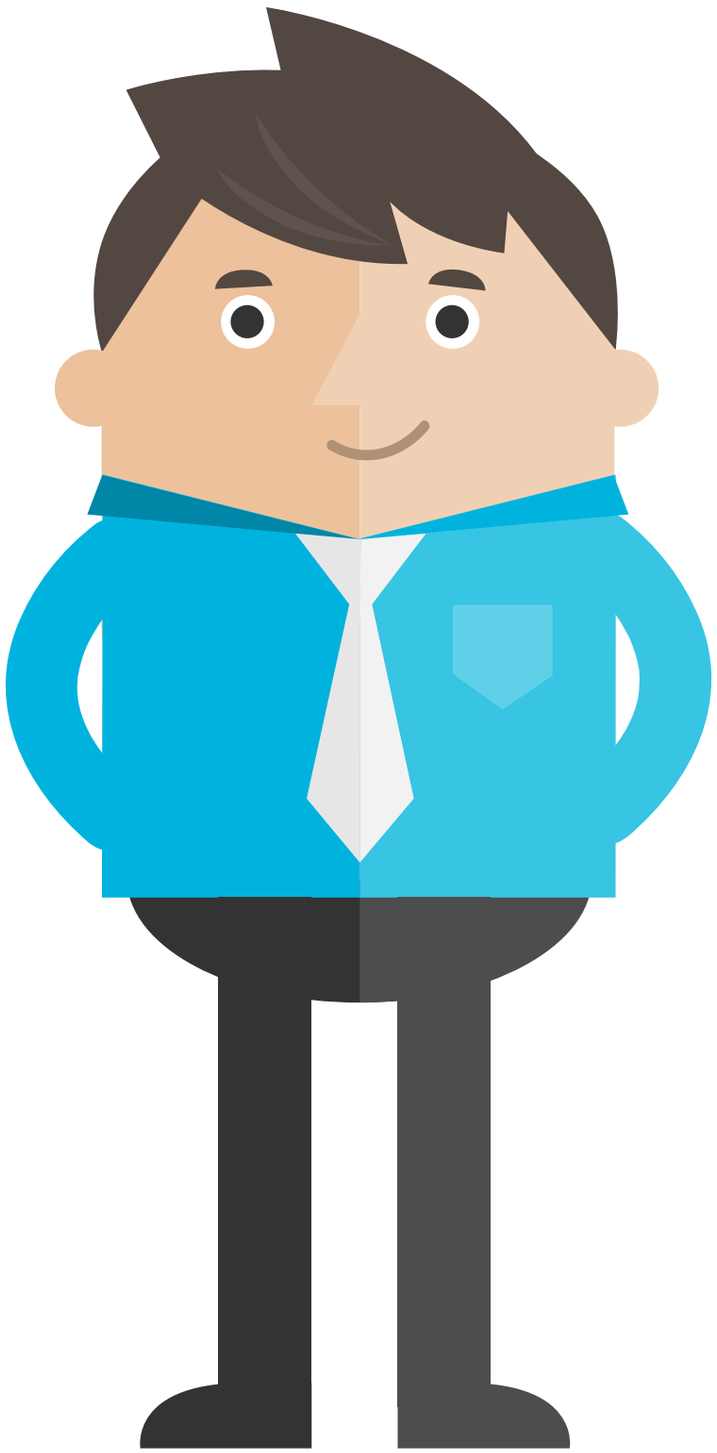

JENN-AIR




JENN-AIR




JENN-AIR




JENN-AIR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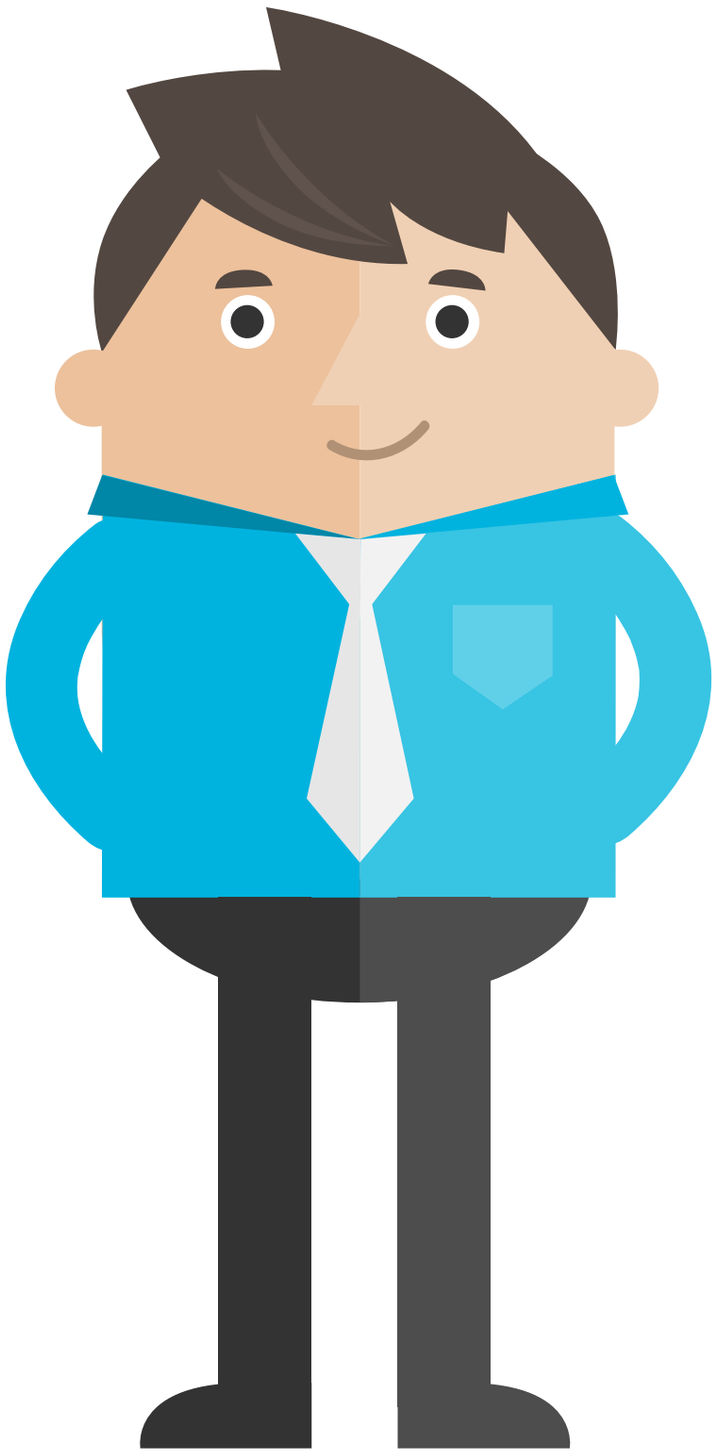



JENN-AIR


JENN-AIR


JENN-AIR

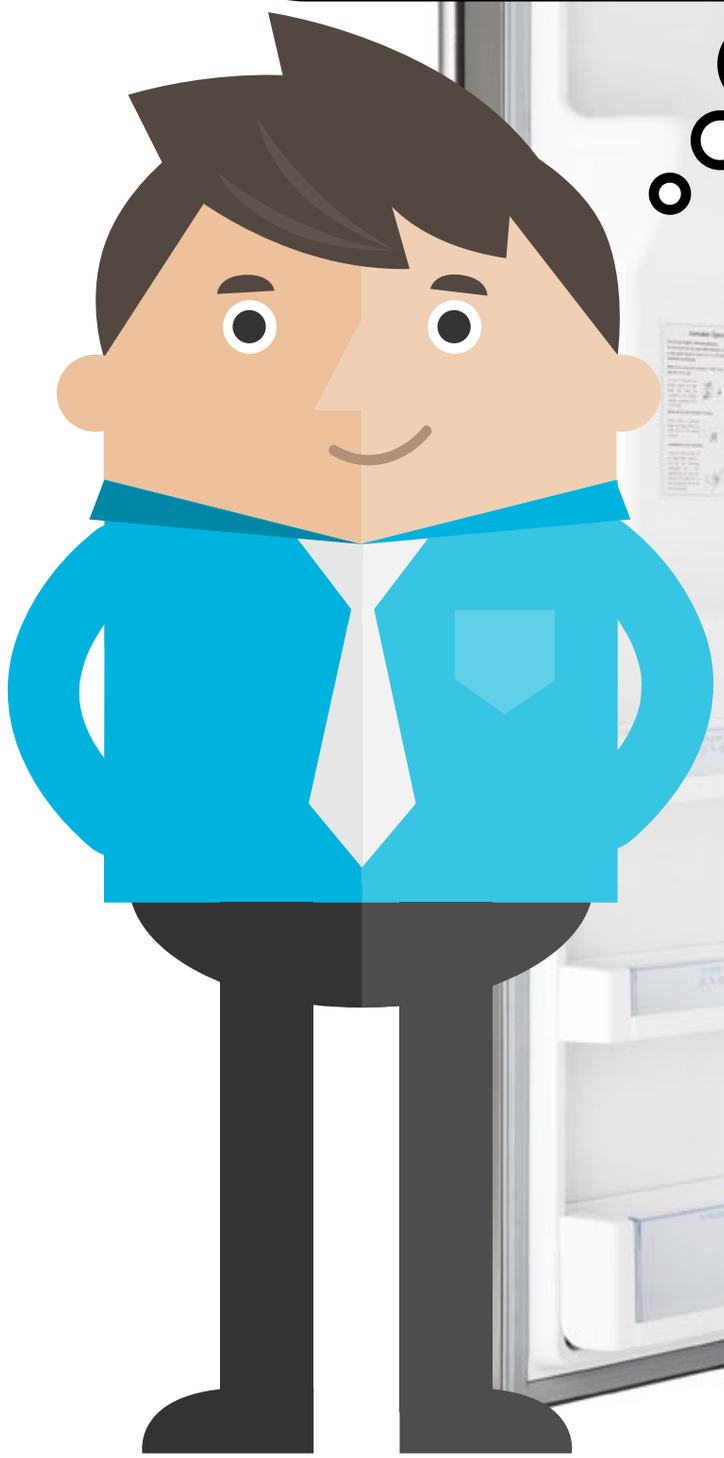

JENN-AIR


Great Value
2%


JENN-AIR


Great Value
2%
Nutrition Facts

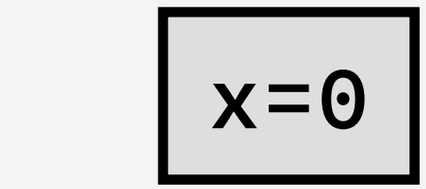
Oh good, we have bread and milk.



Not so different for programs

Race Conditions

Race Conditions

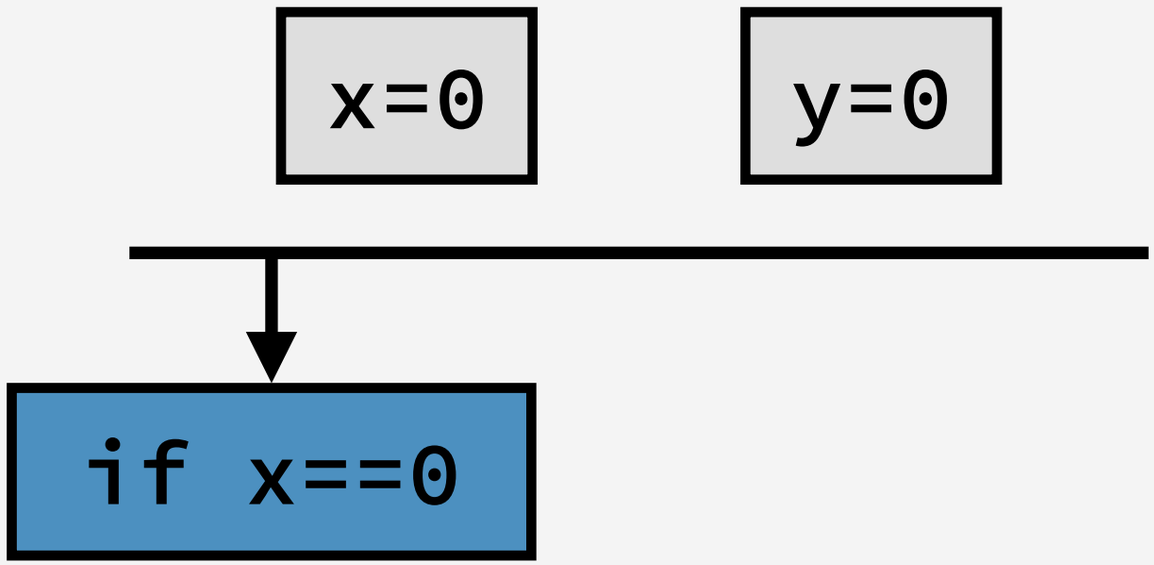


Race Conditions

`x=0`

`y=0`

Race Conditions



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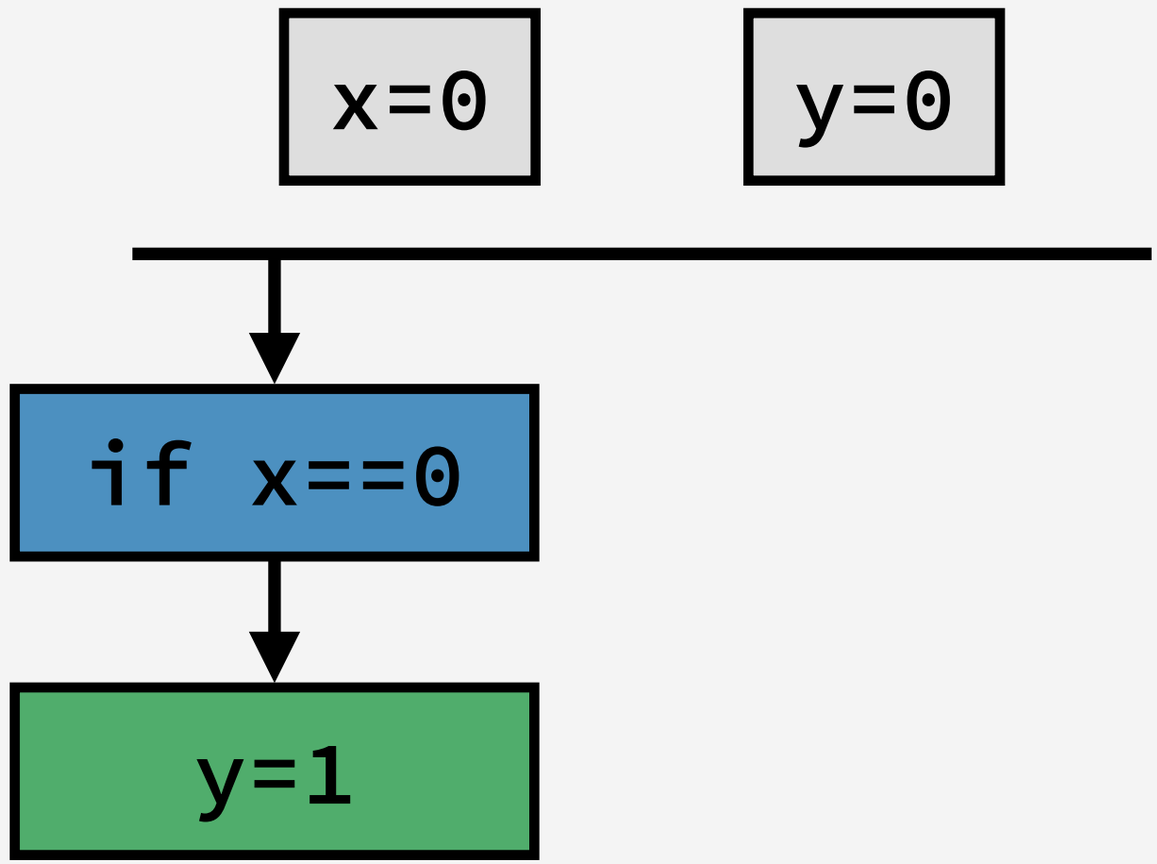

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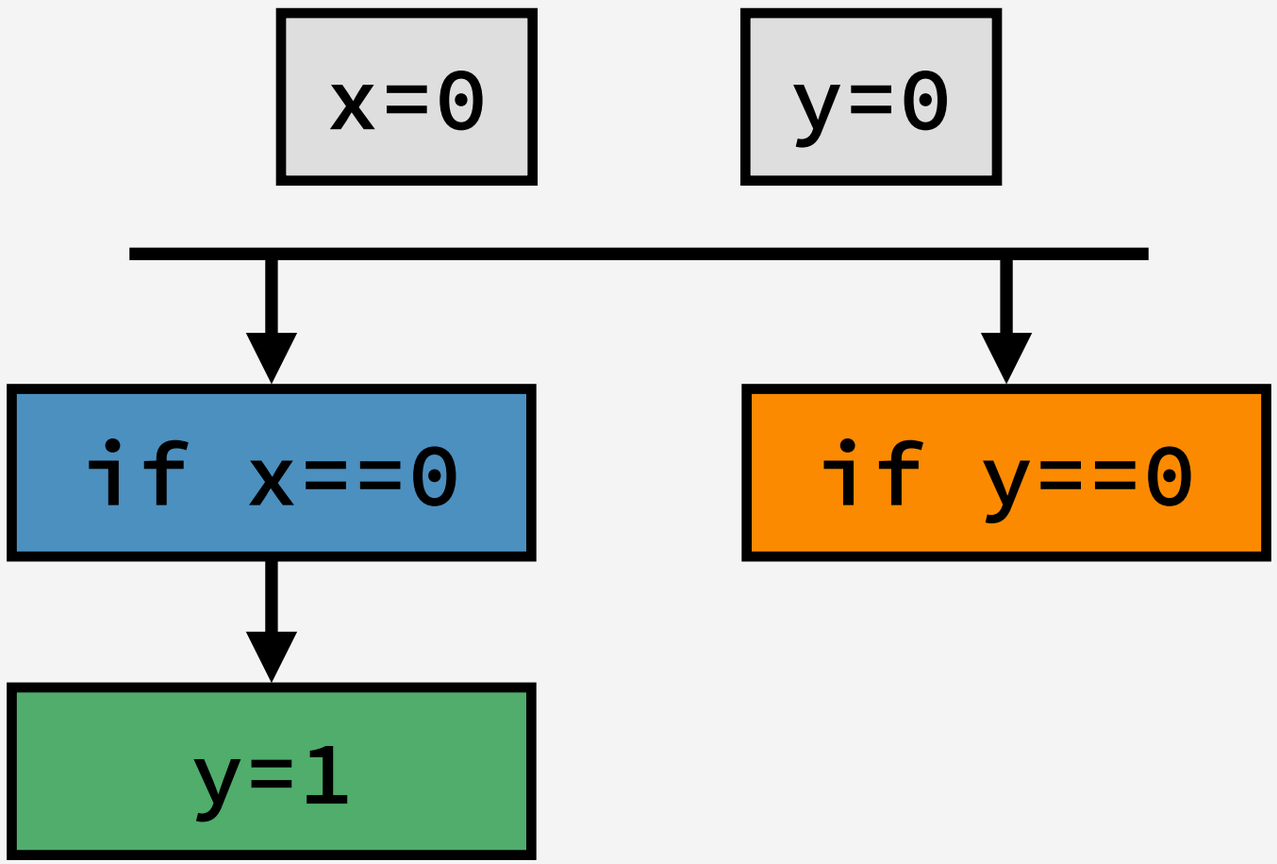
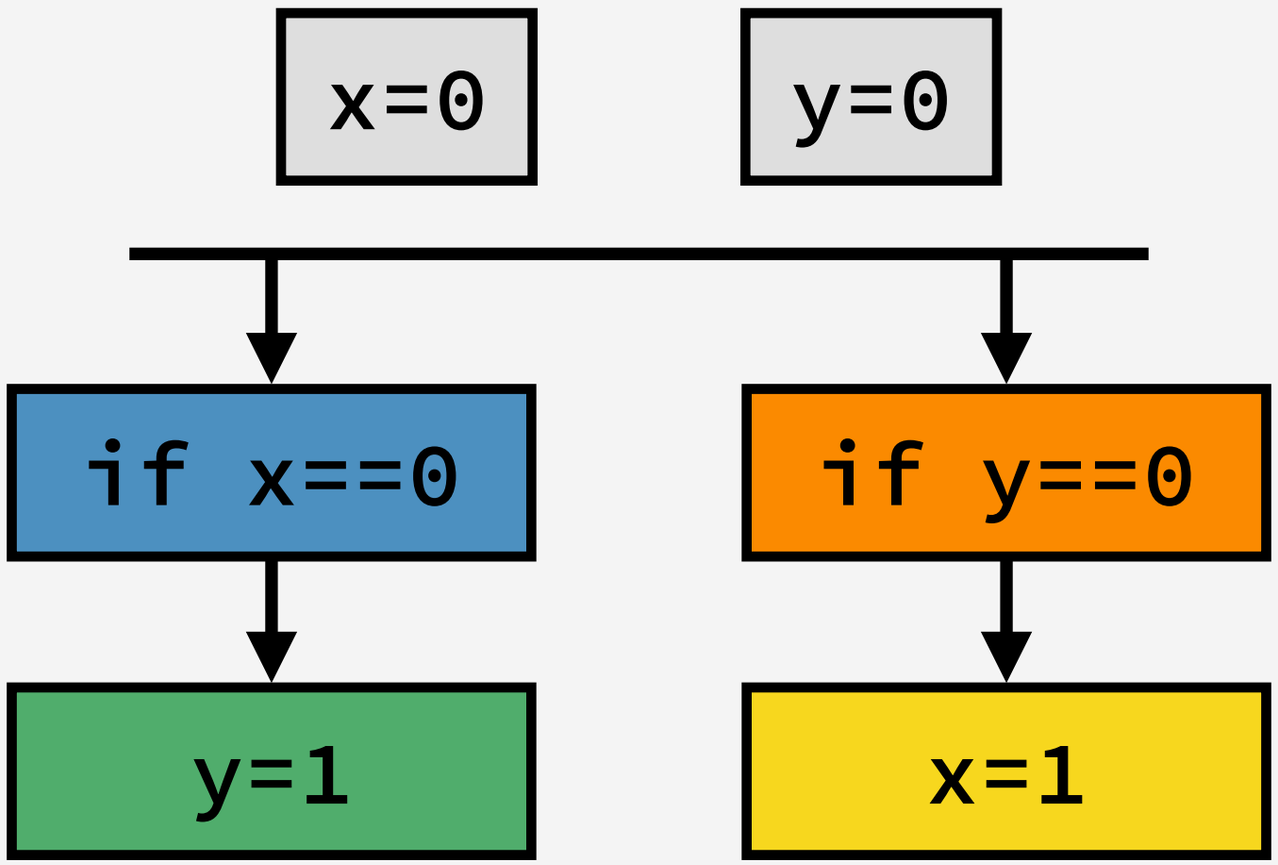
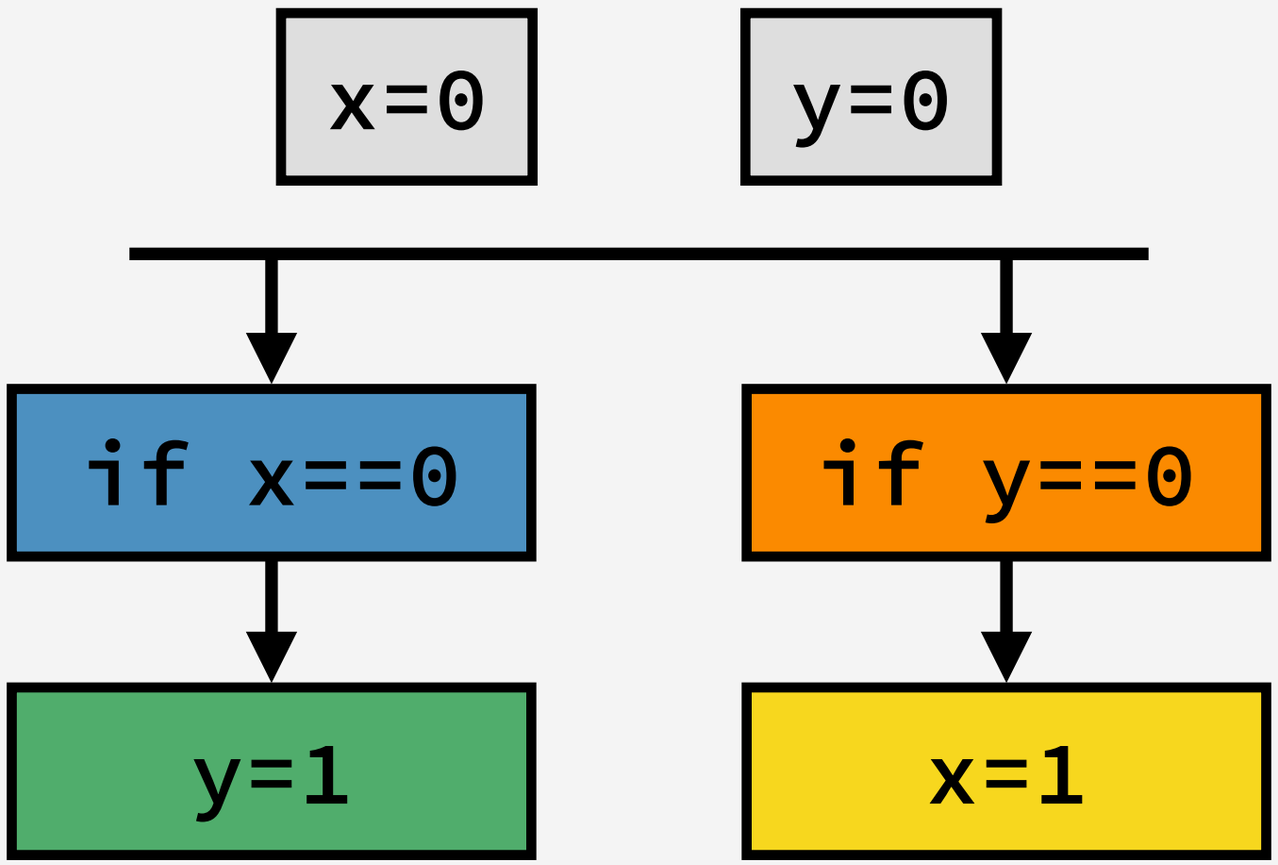


Race Conditions

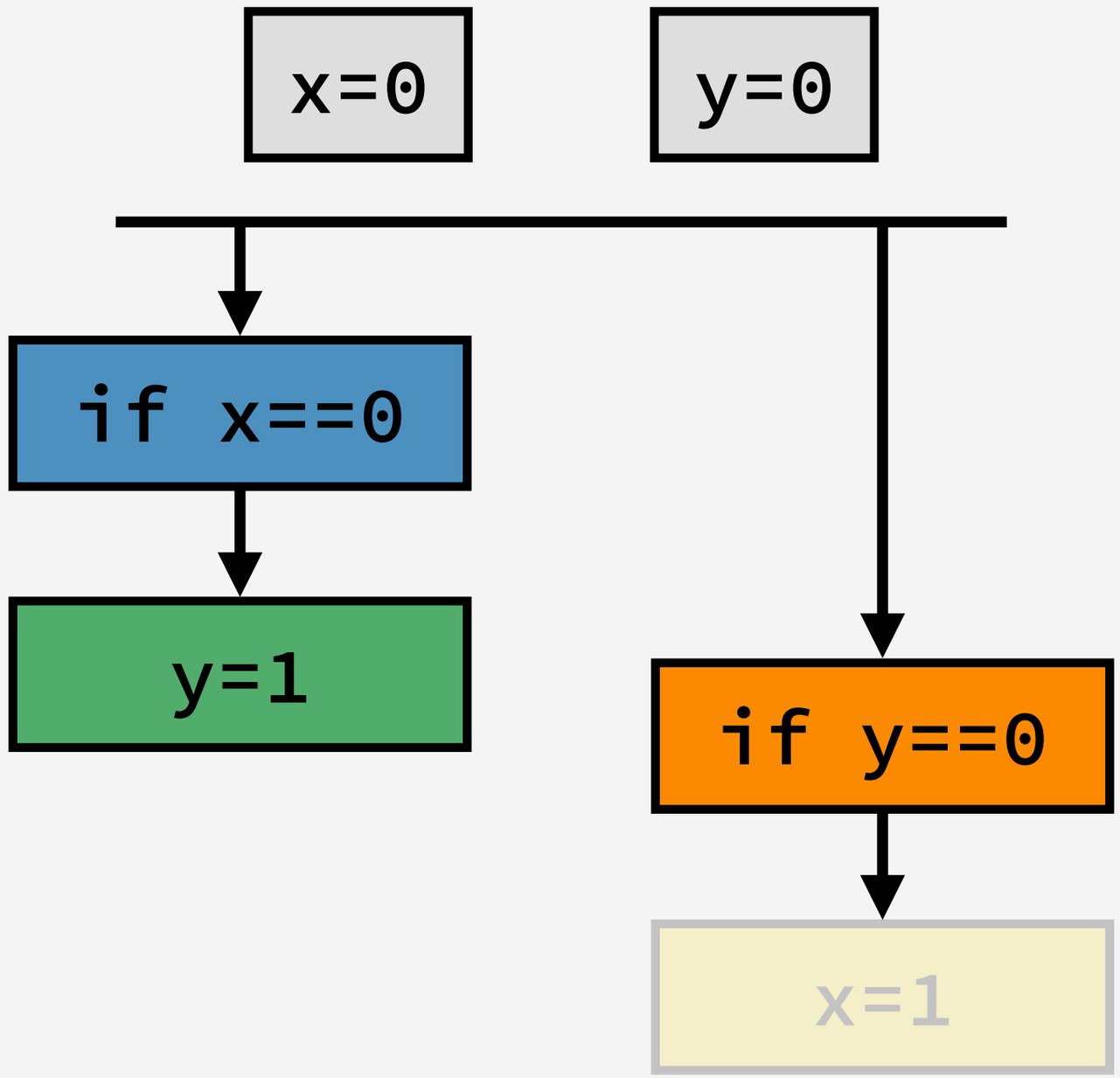


Race Conditions

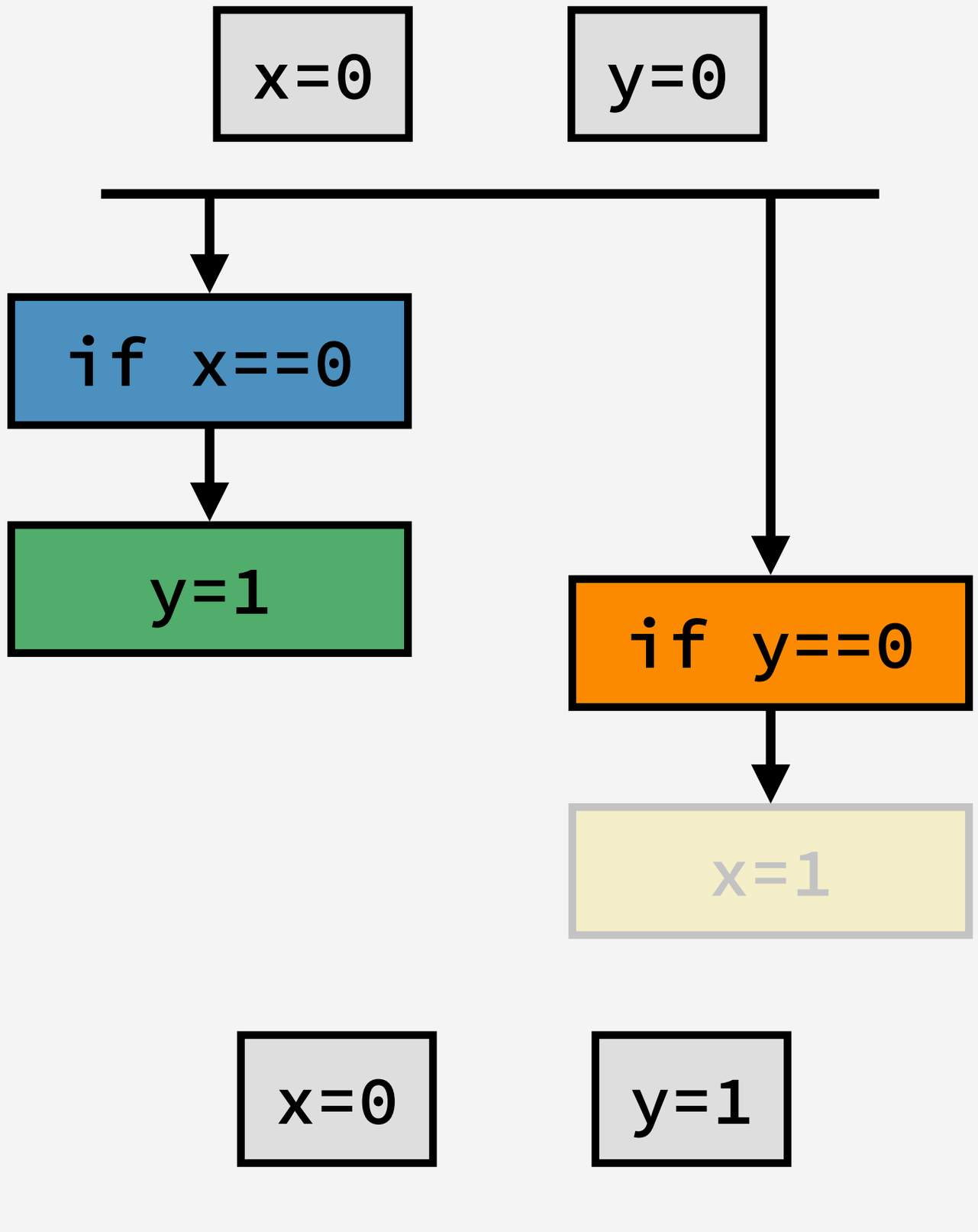


What are the values of x and y?

Race Conditions

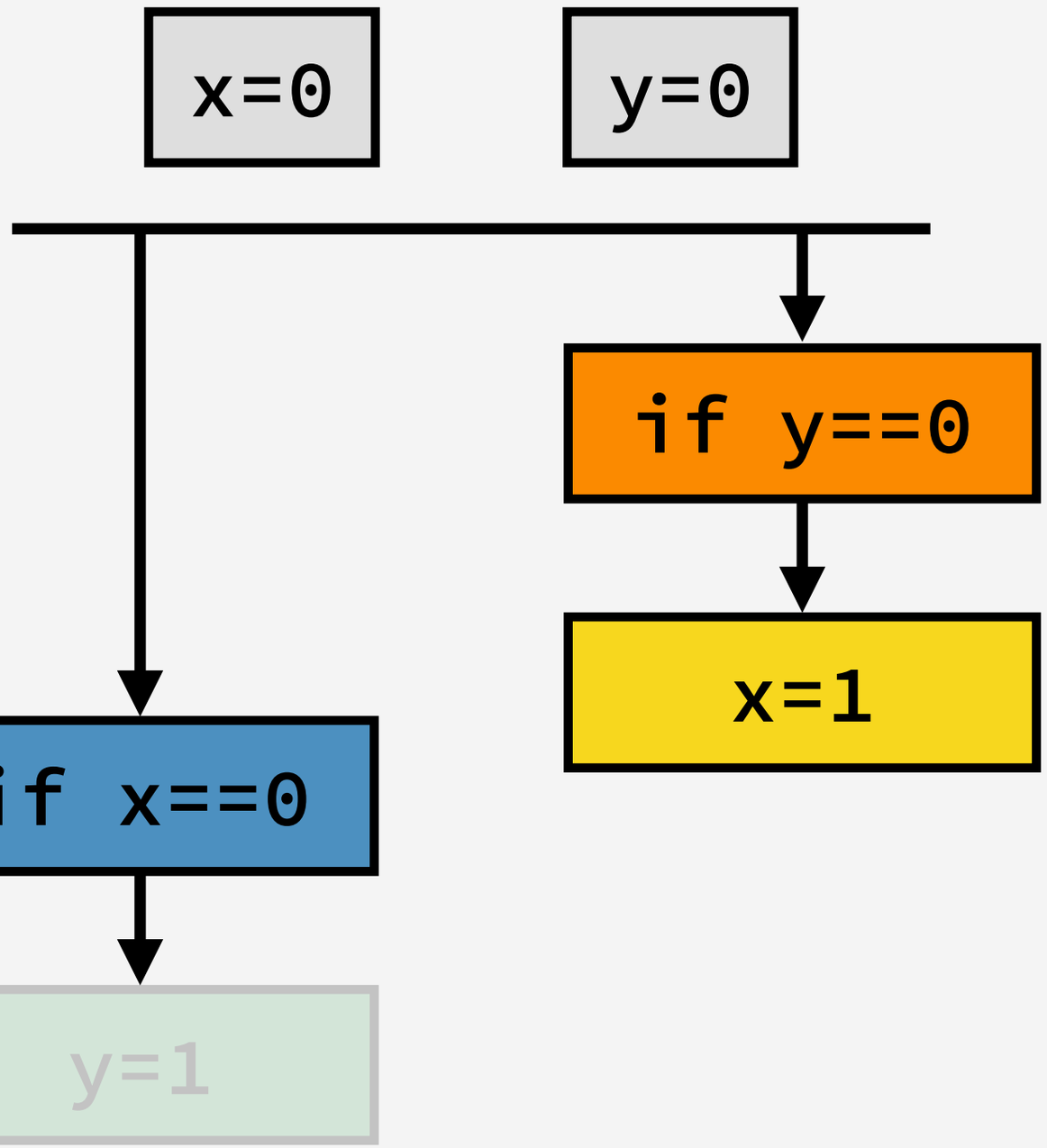


Race Conditions



x=0 y=1

Race Conditions



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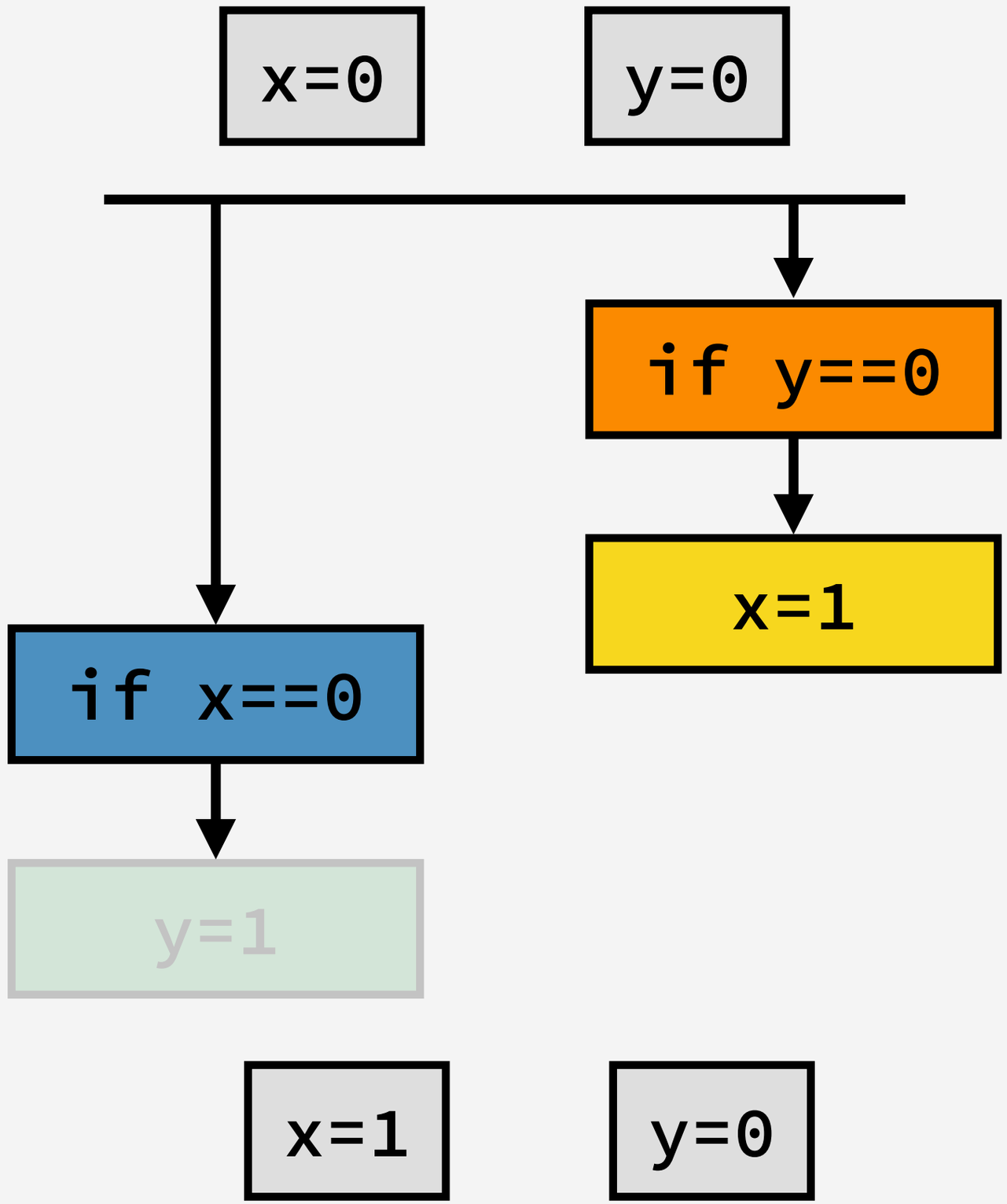

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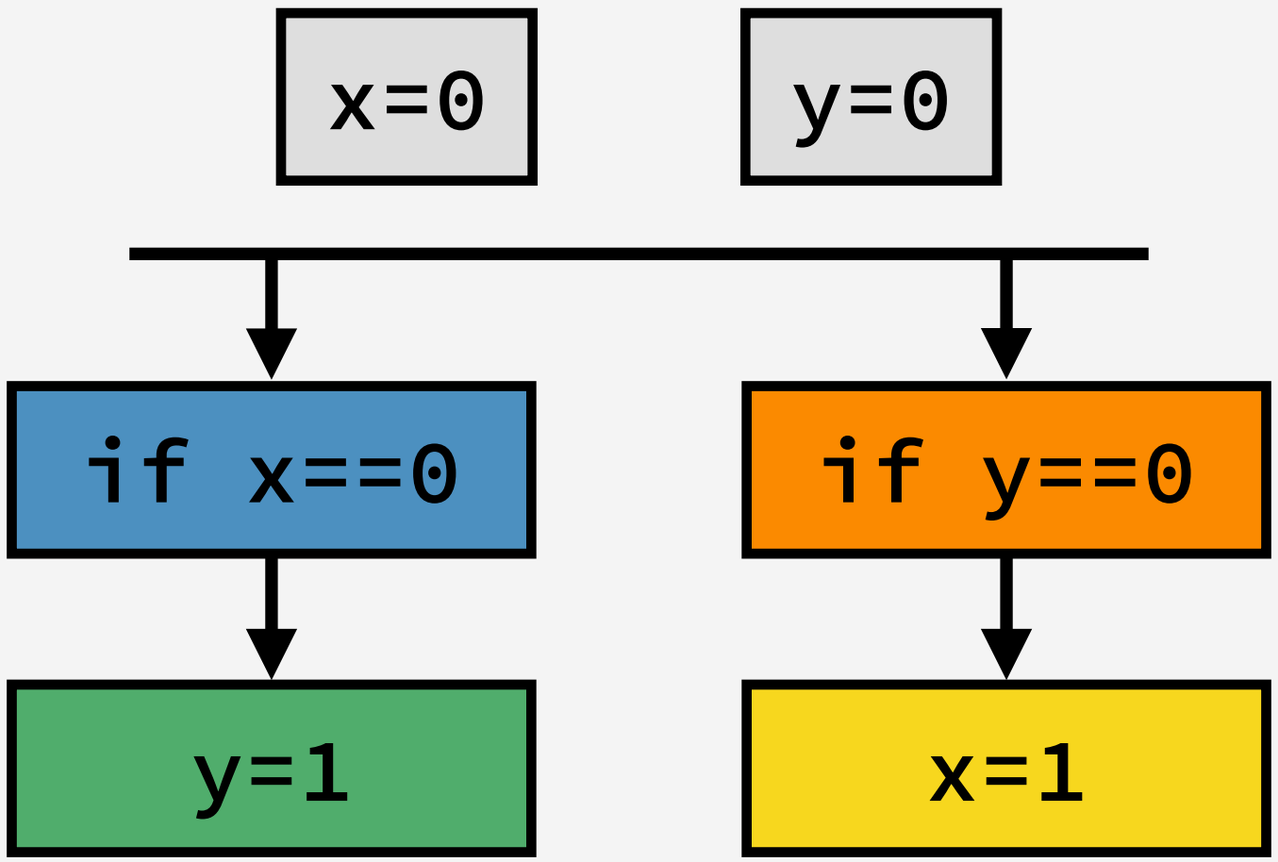

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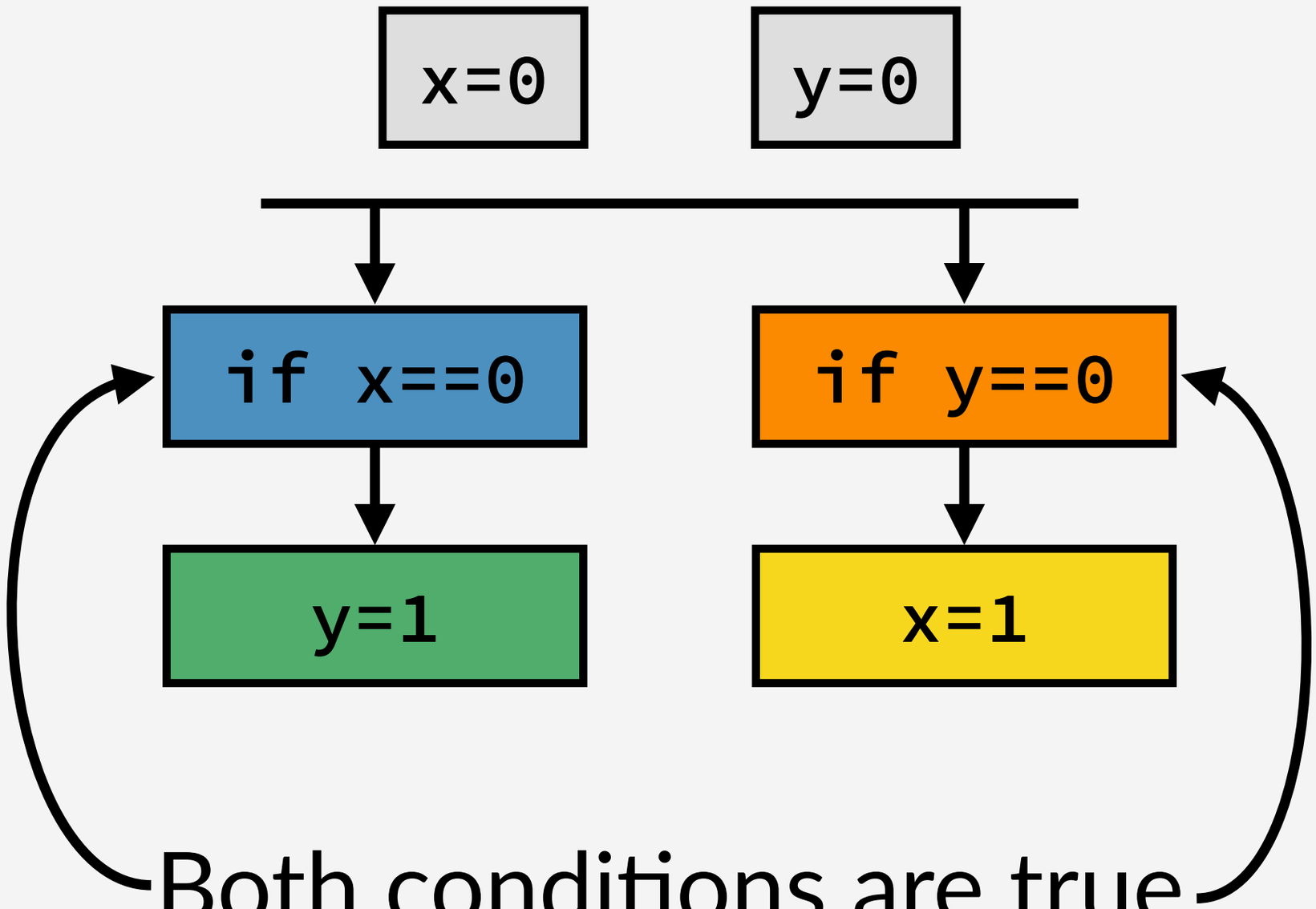

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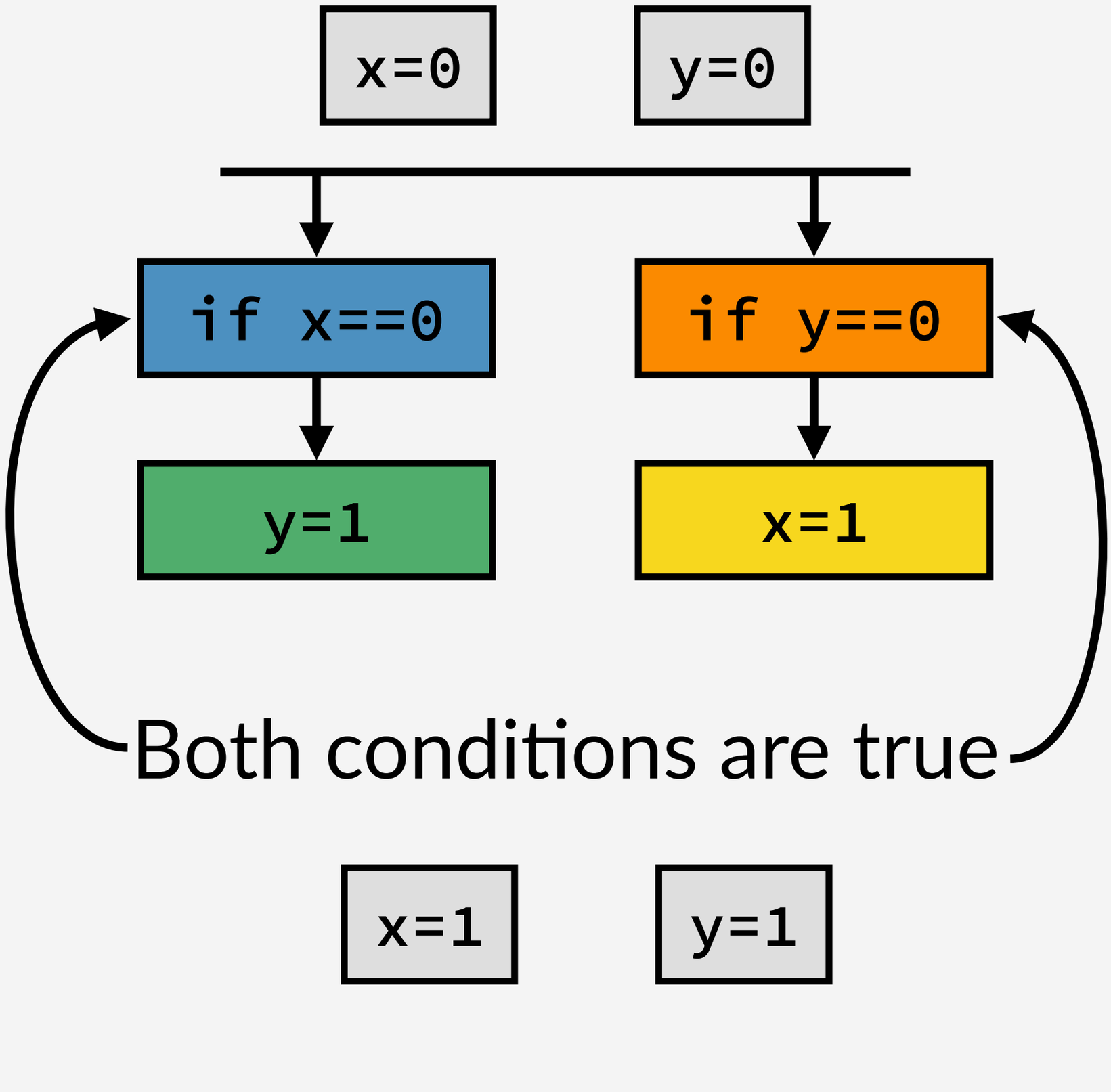

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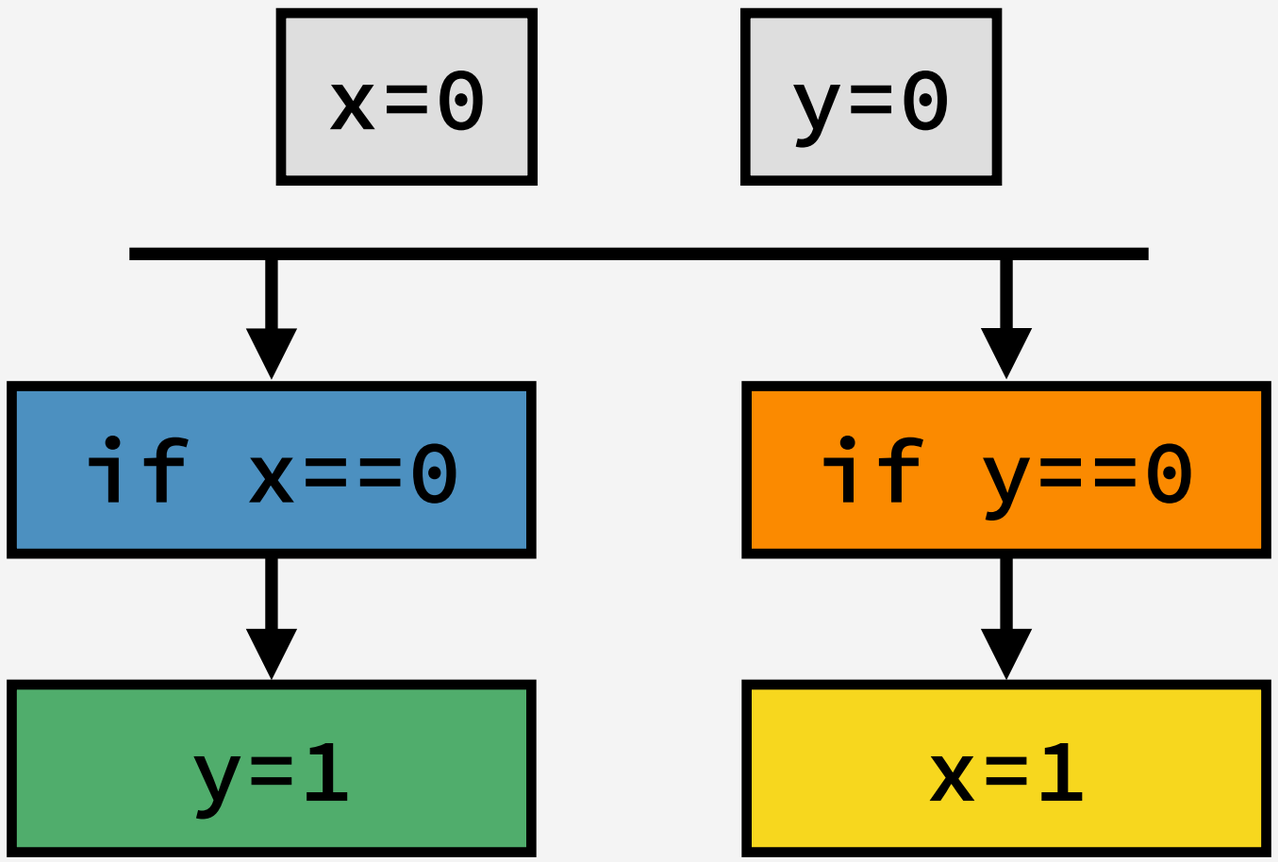

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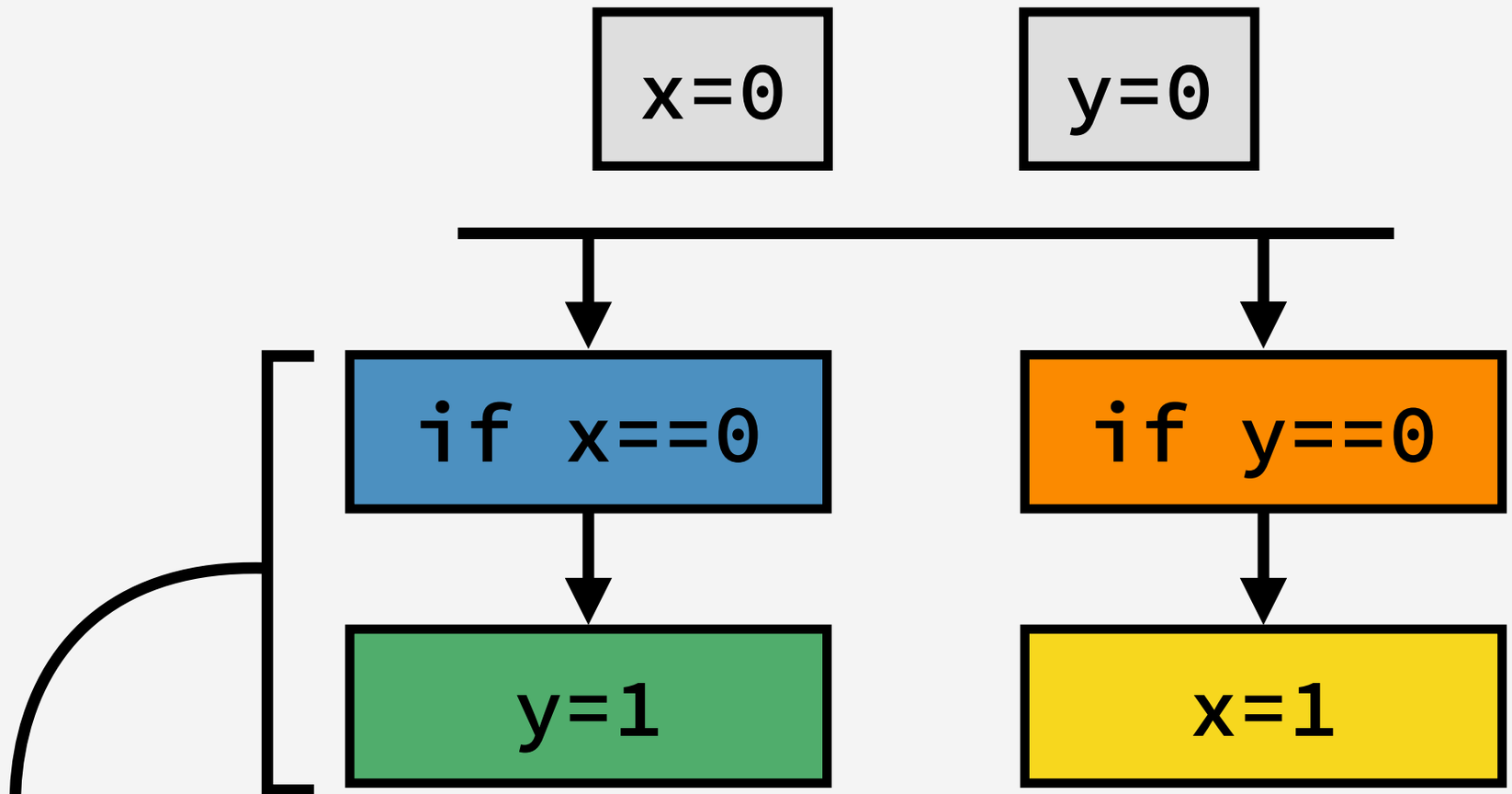
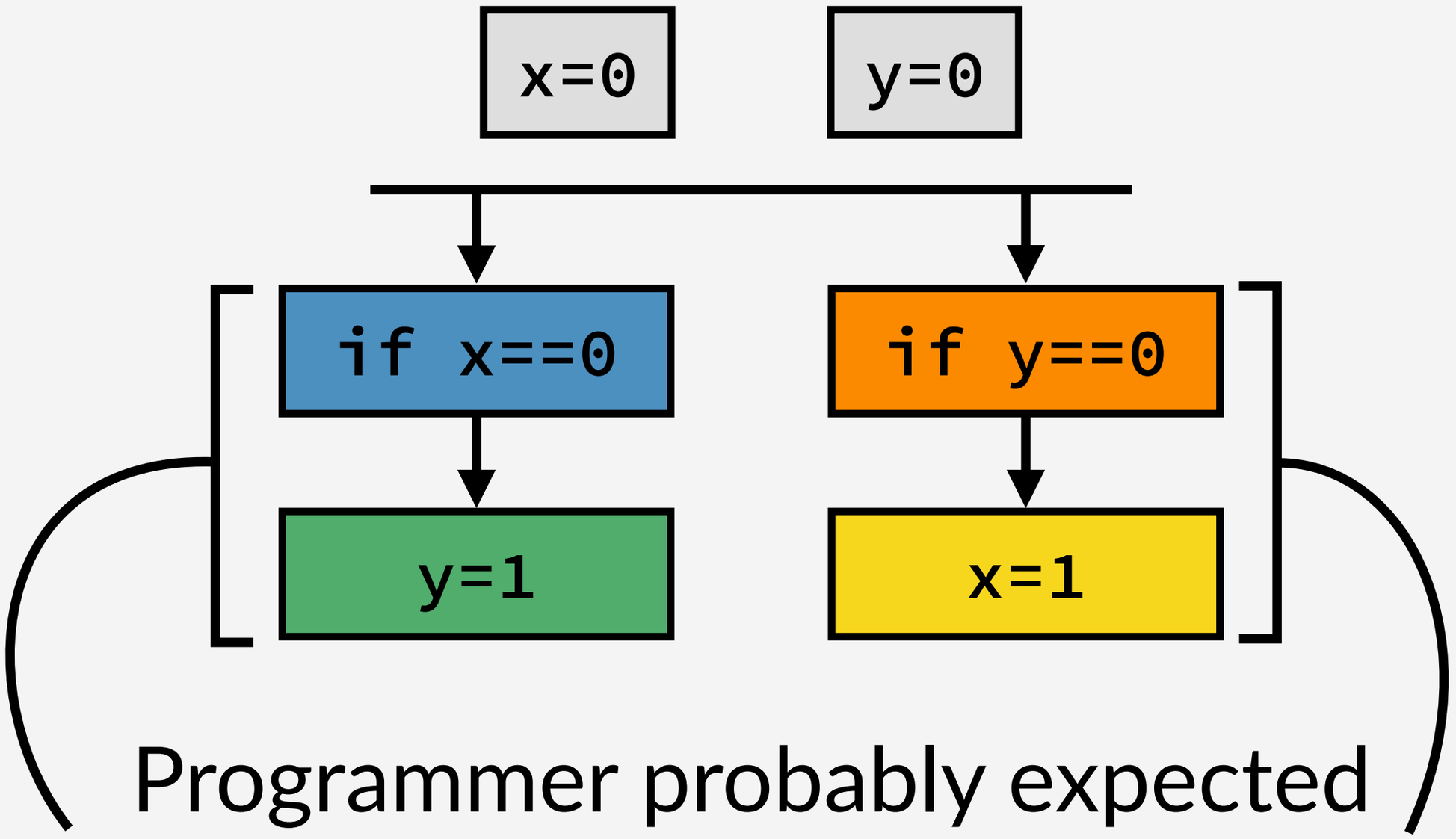


Programmer probably expected these statements to run *atomically*.

Race Conditions



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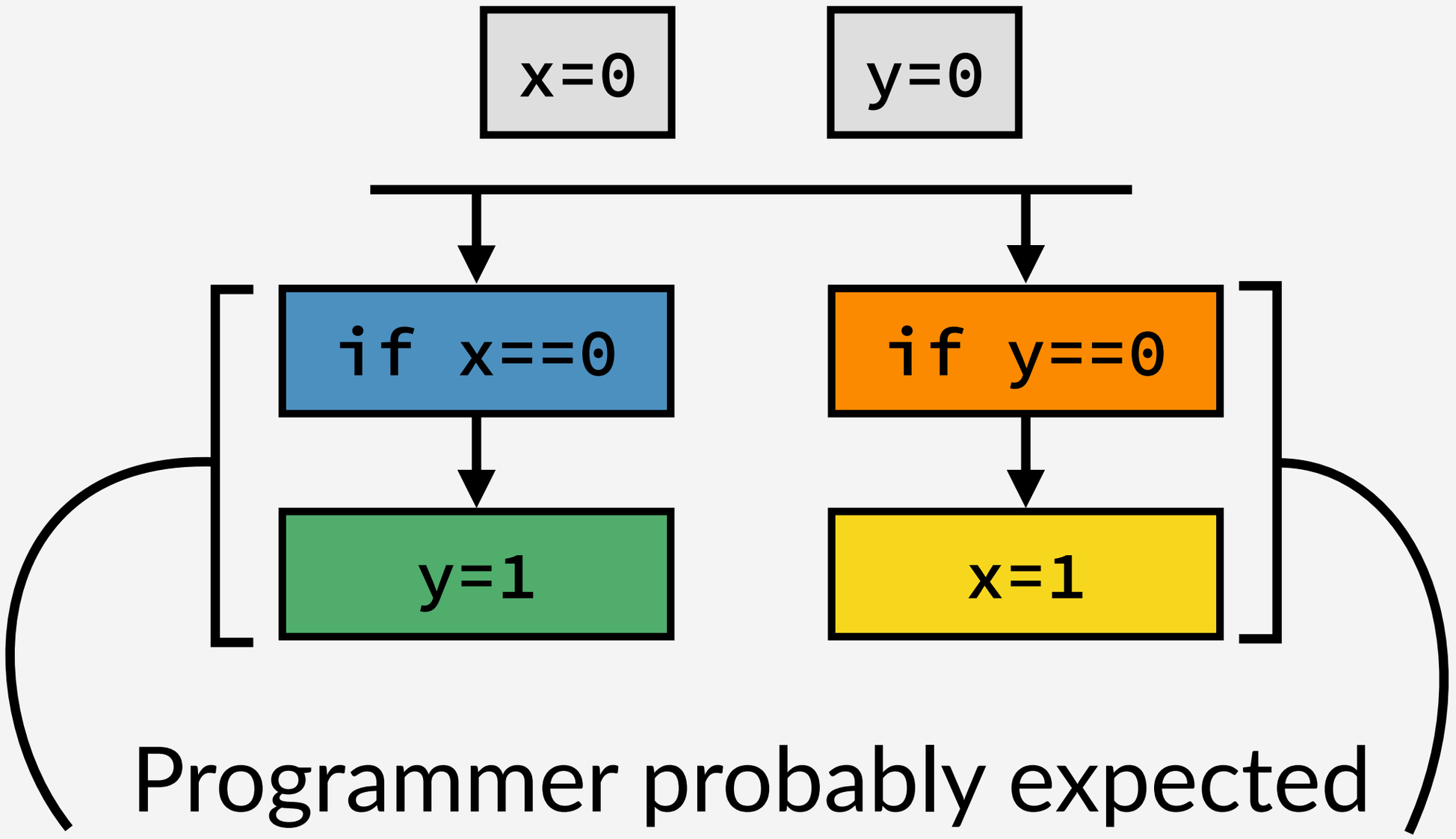
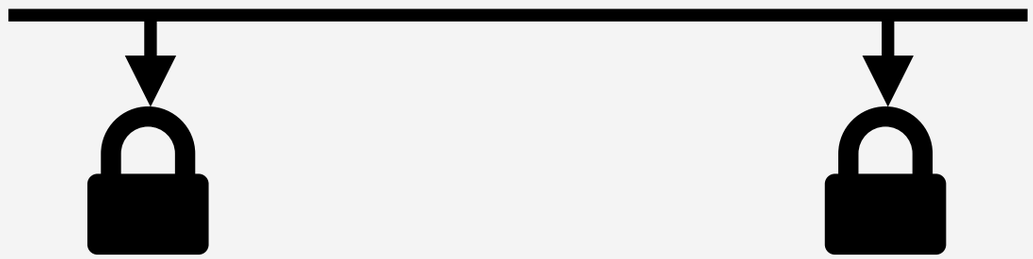


Programmer probably expected these statements to run *atomically*.

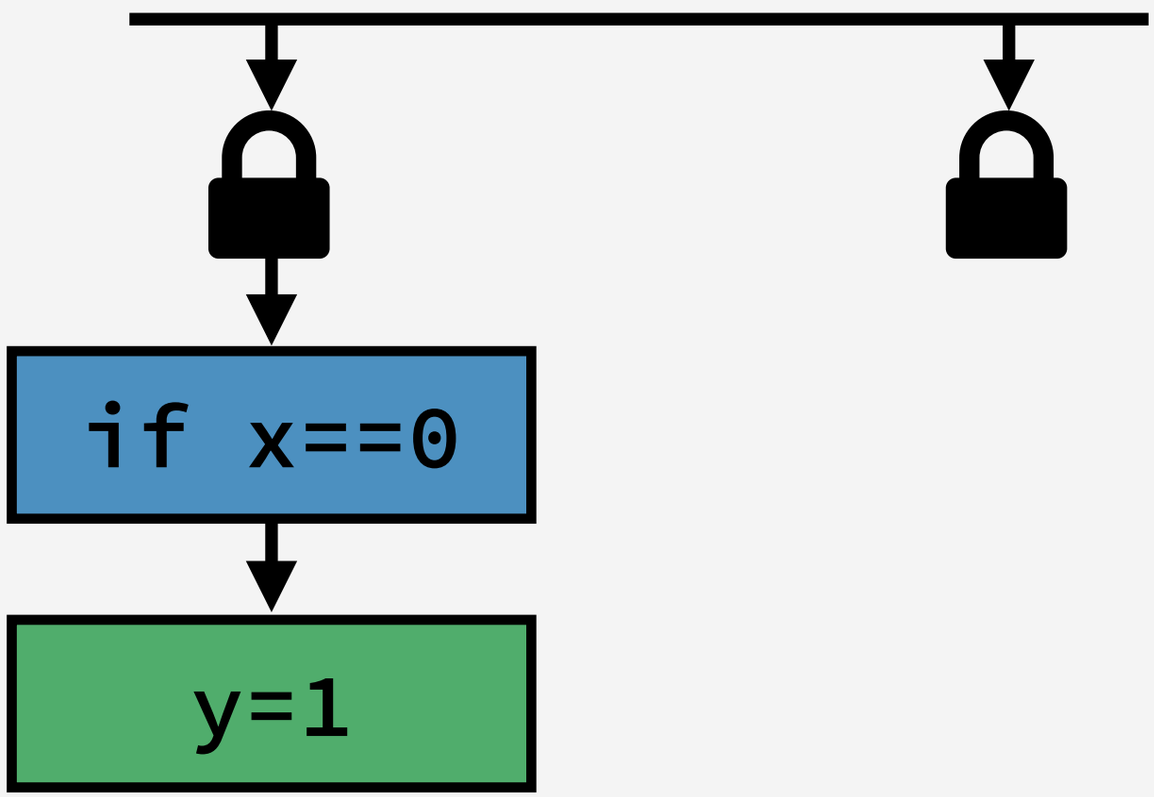
We can fix this program with locks.

Locks

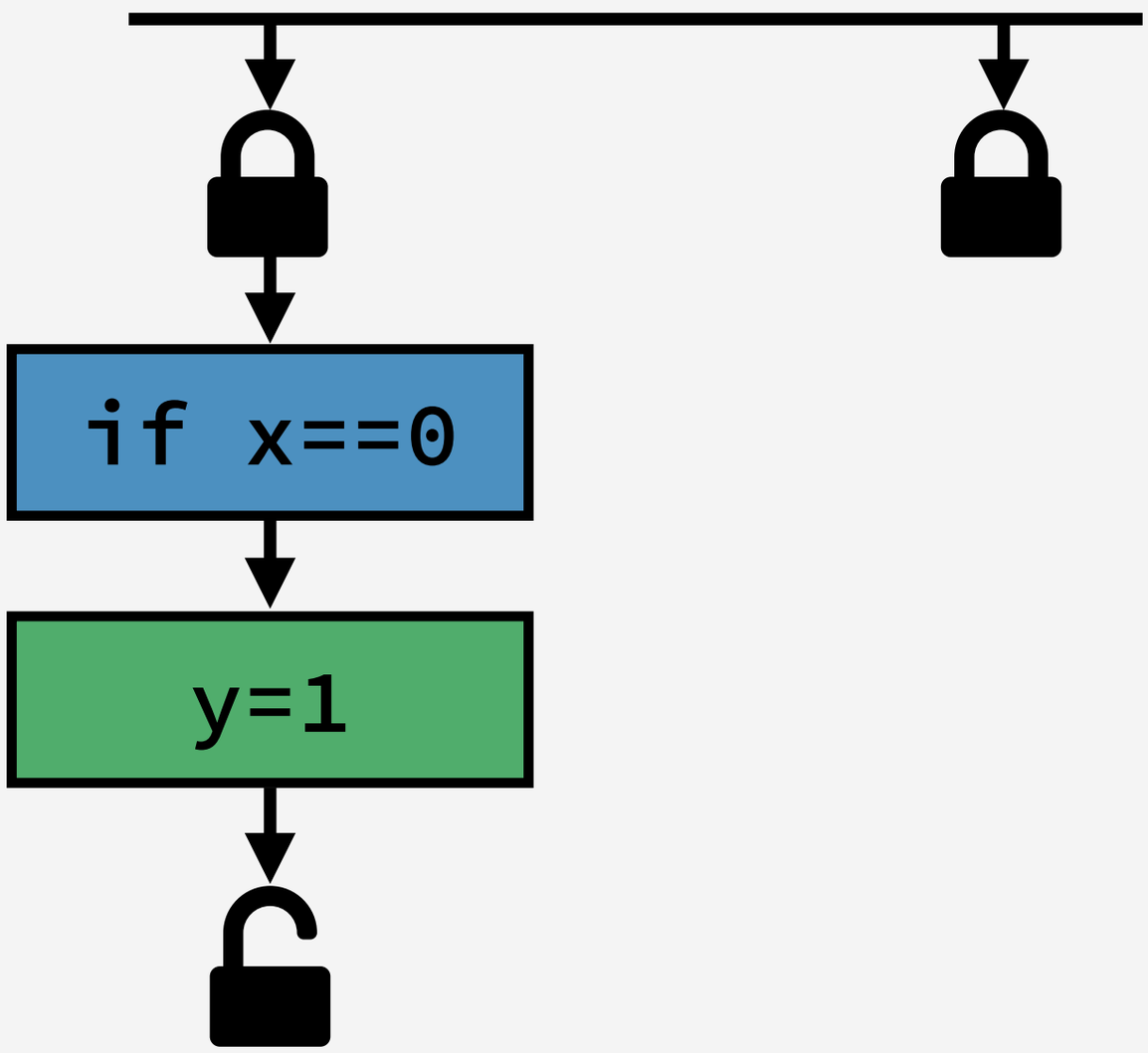
Locks



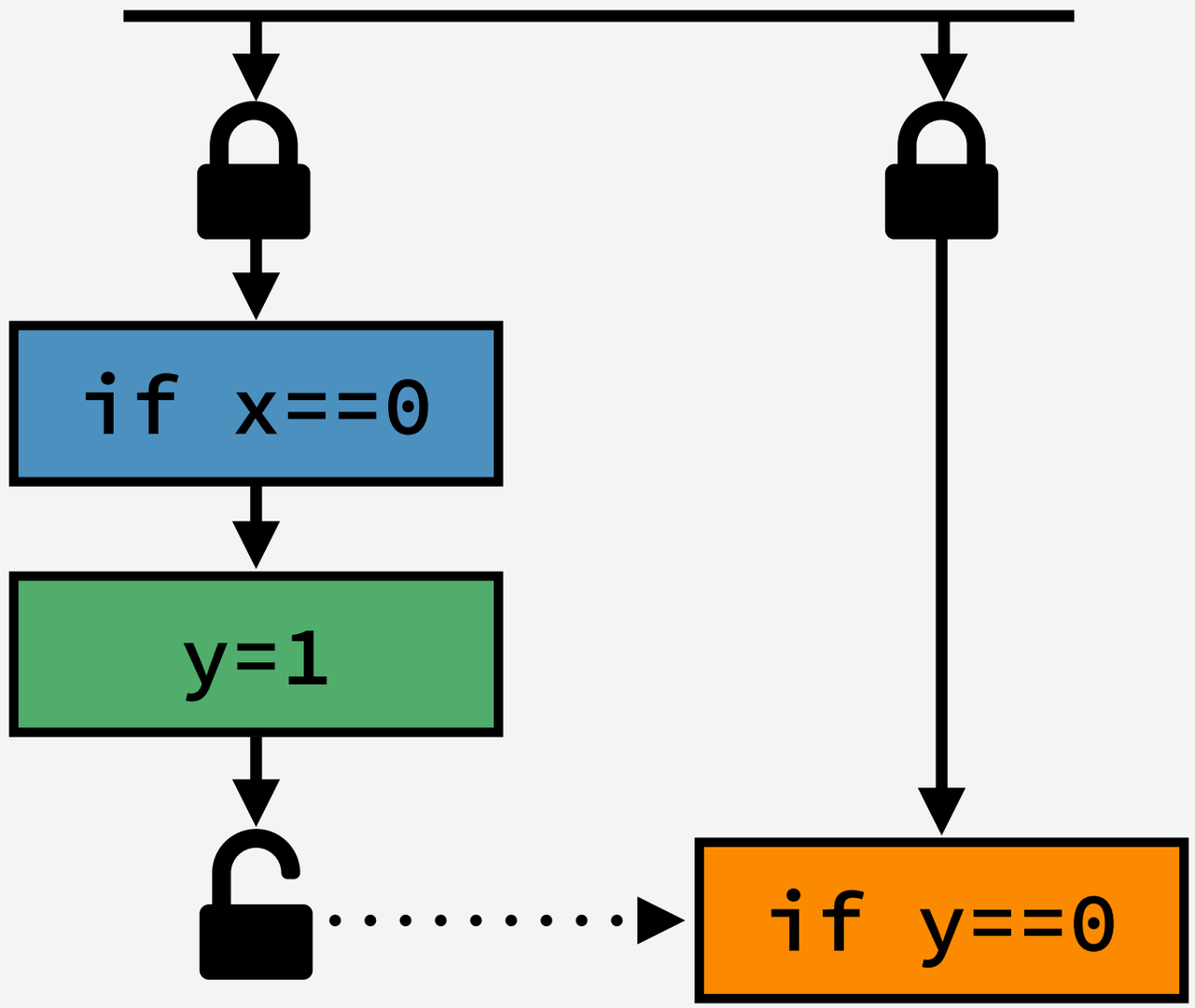
Locks



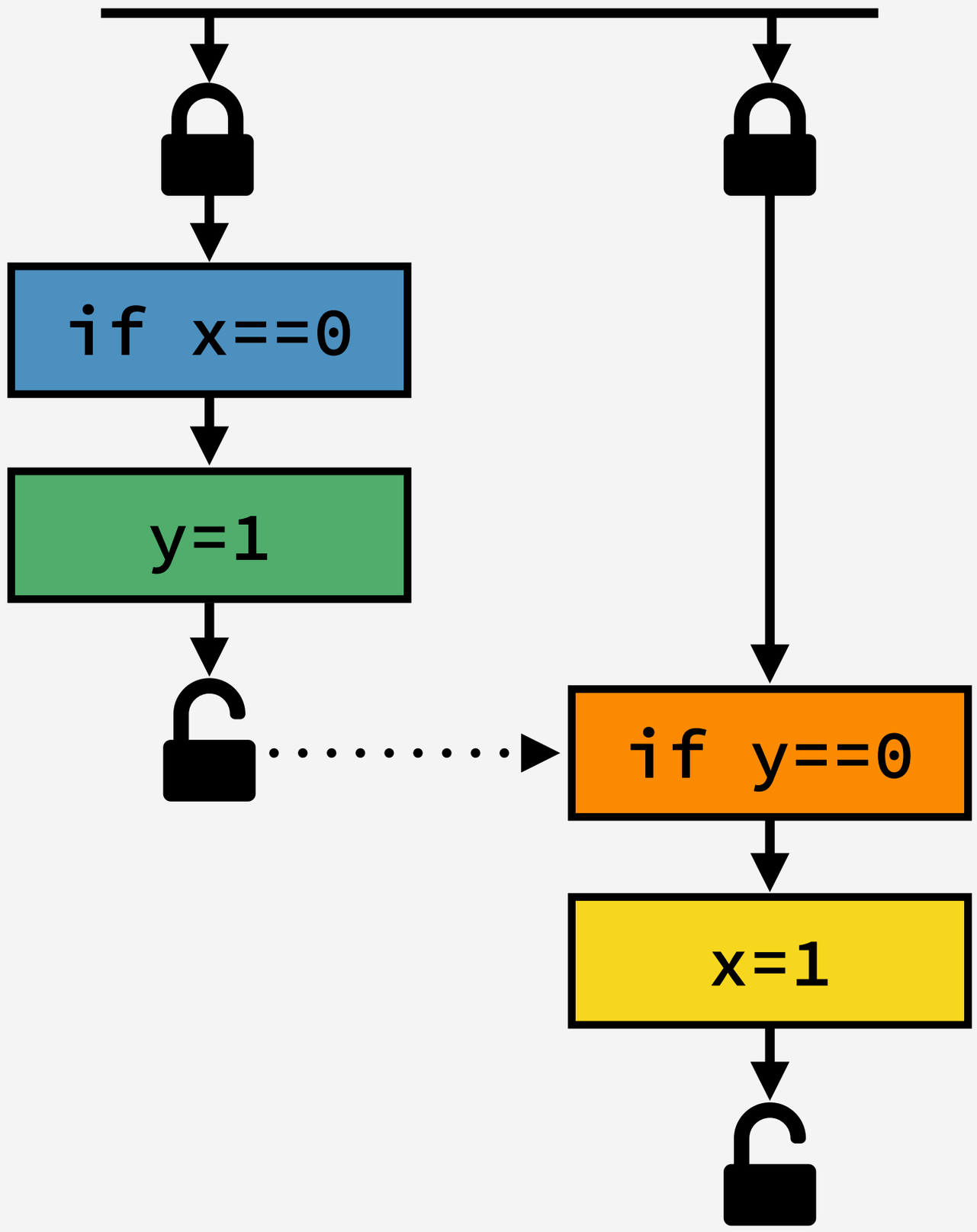
Locks



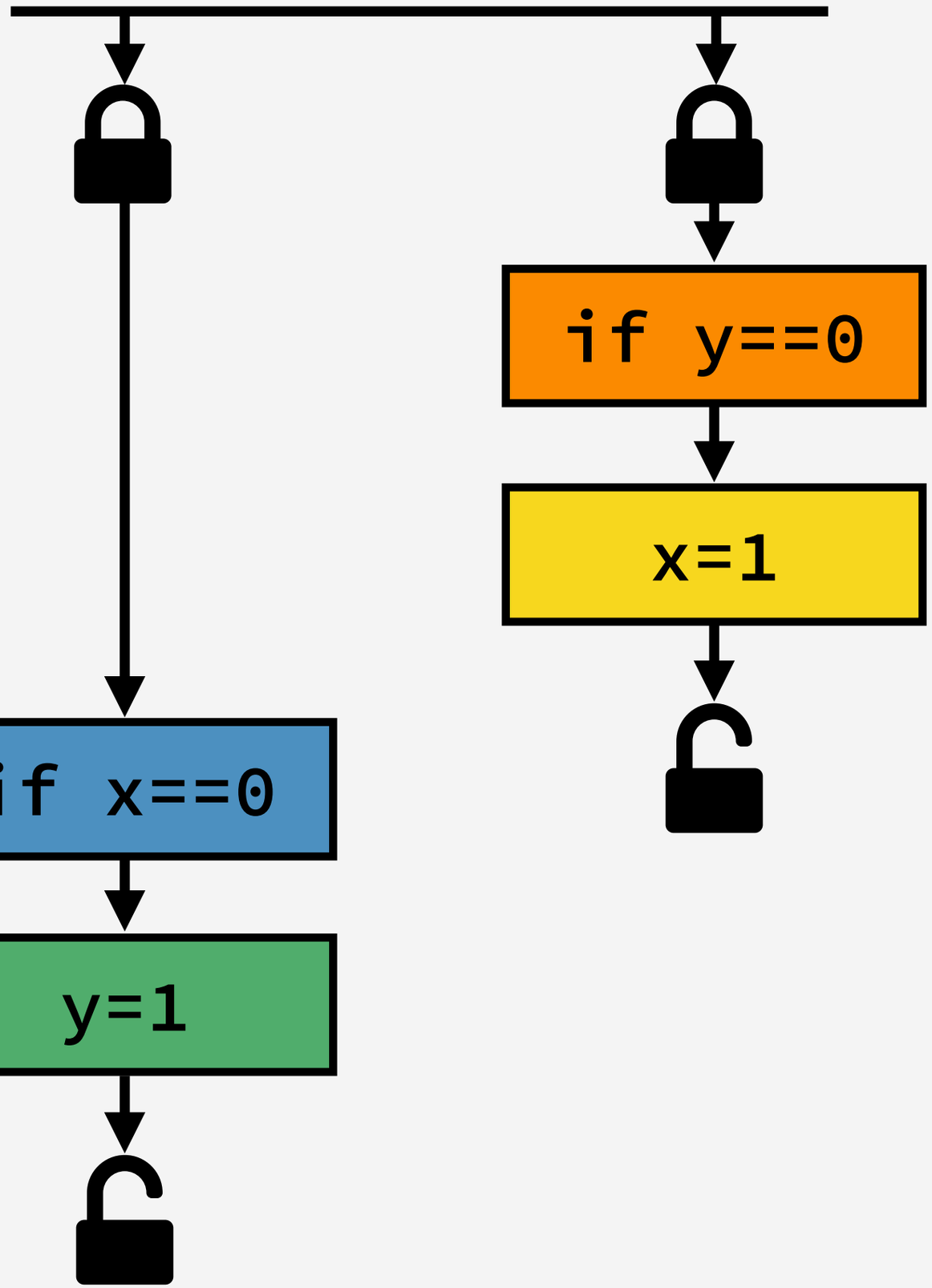
Locks



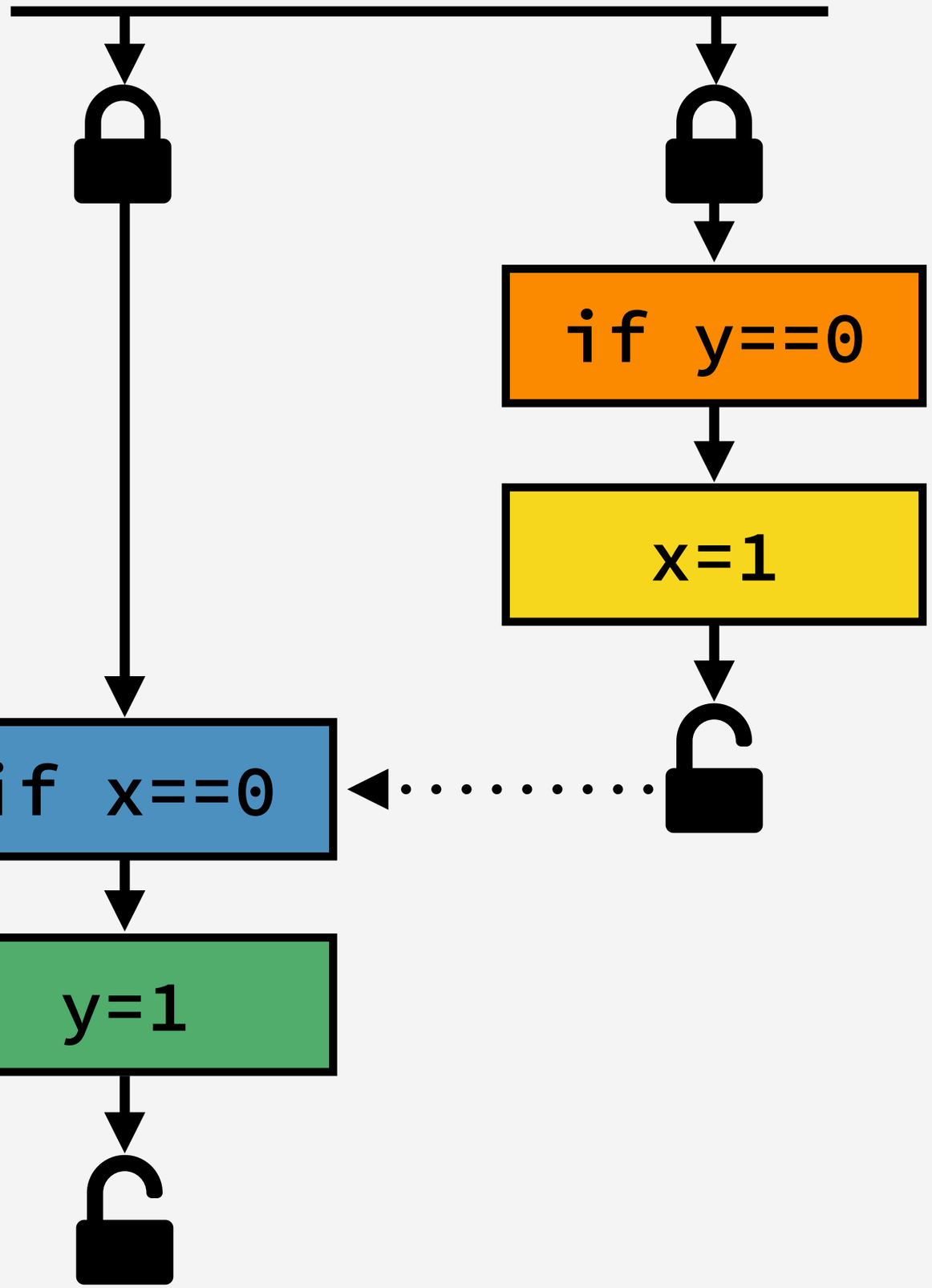
Locks



Locks



Locks



Locks

Locks

Atomicity comes at a performance cost

Locks

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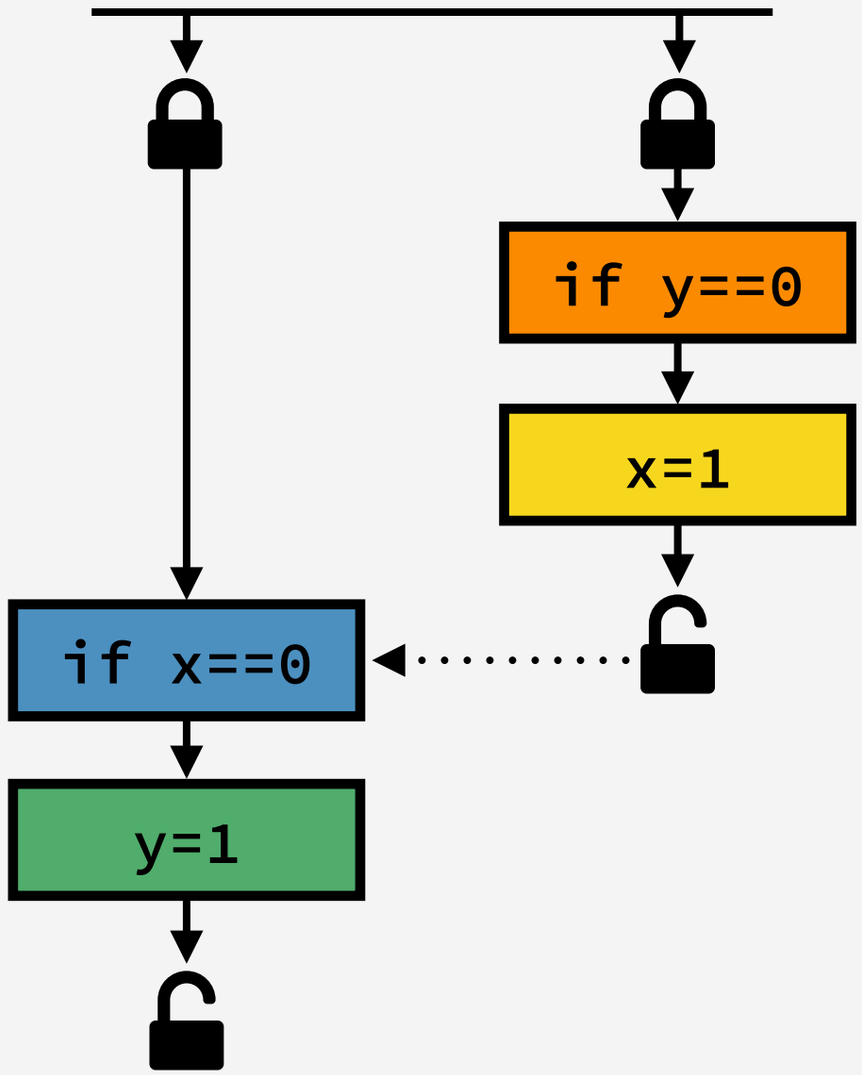

Locks

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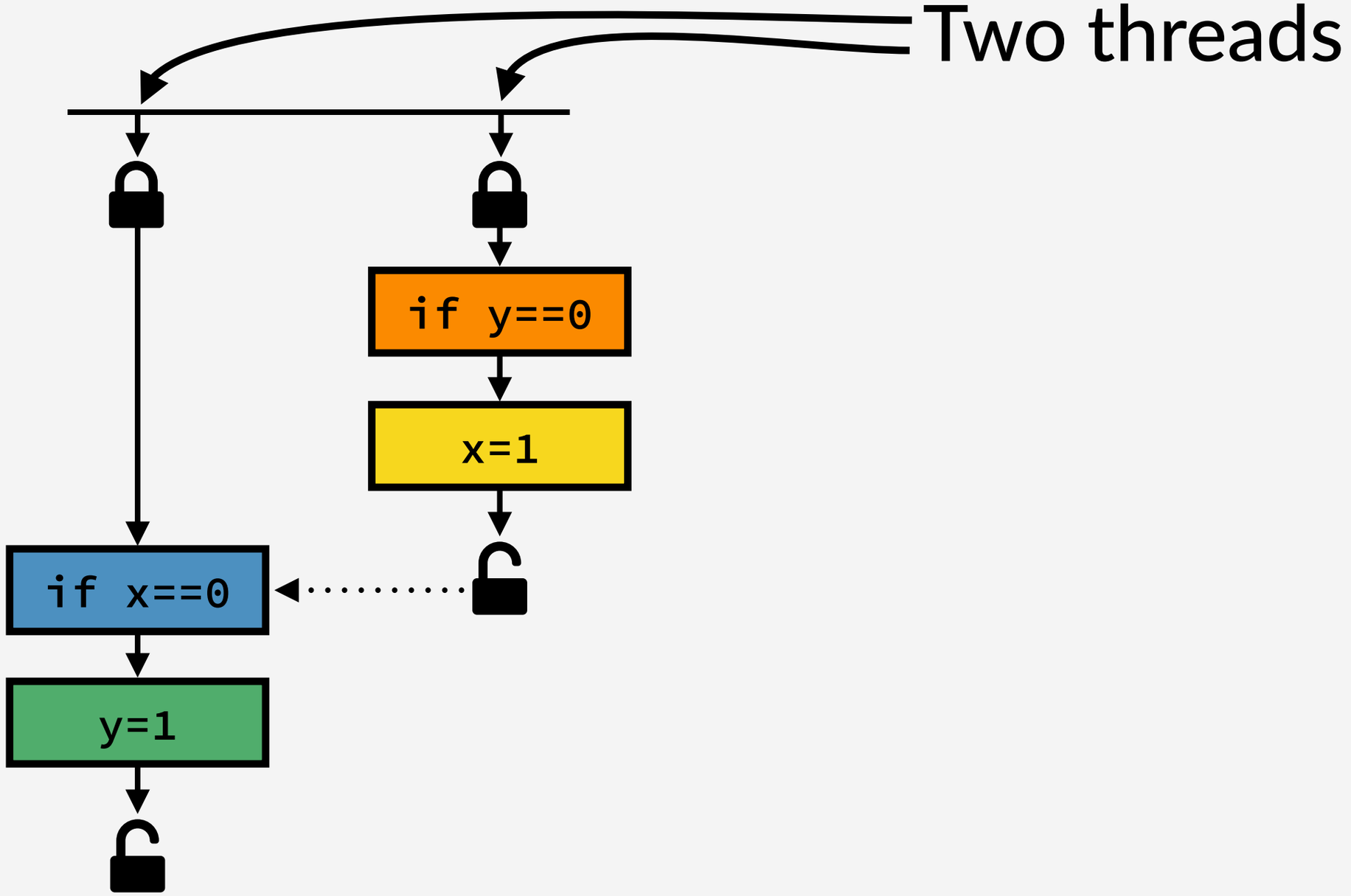

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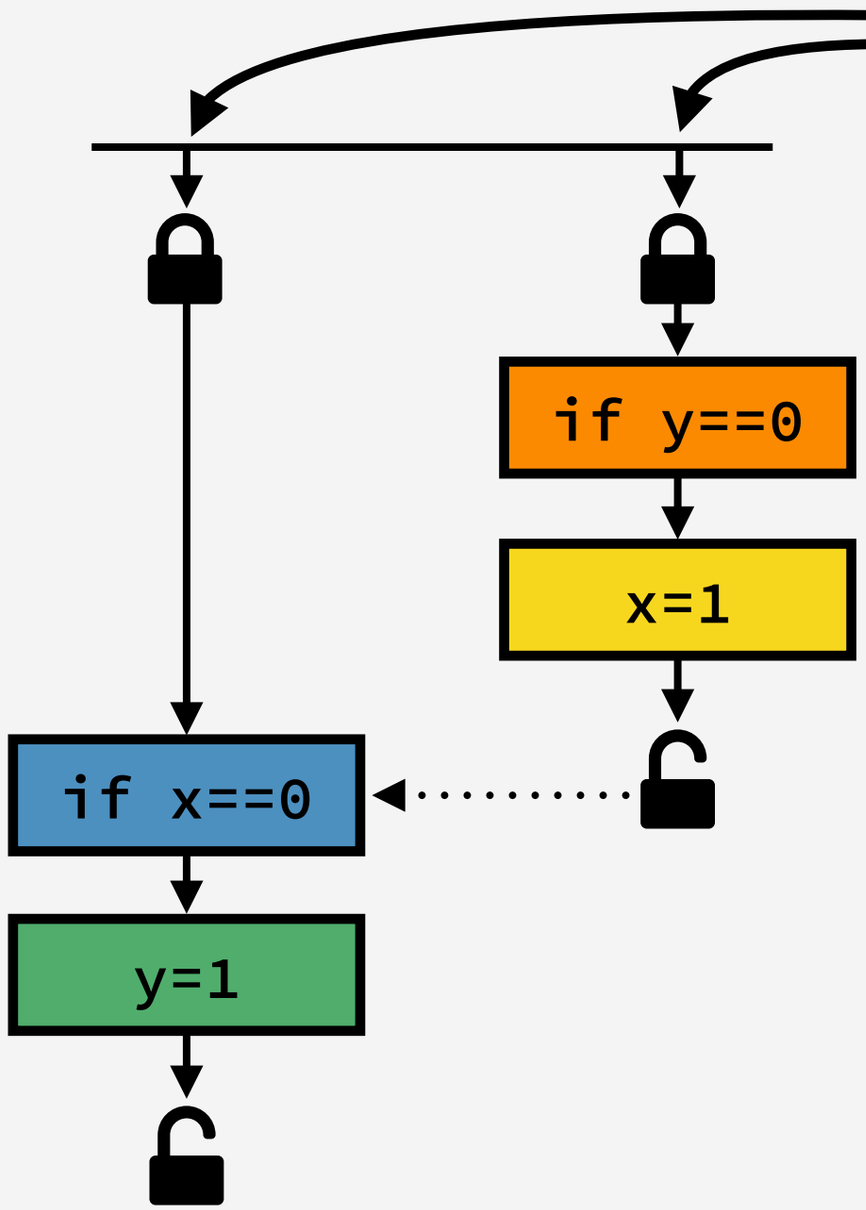
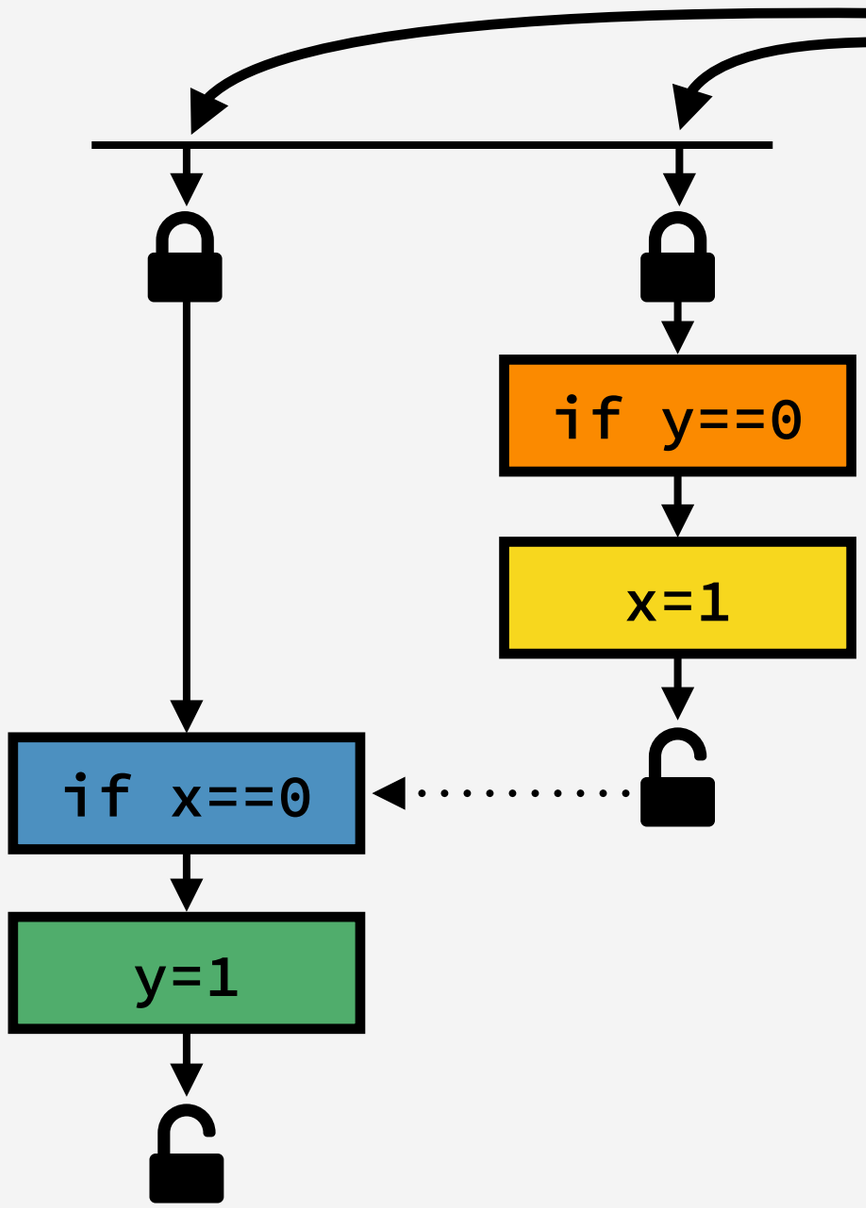


Two threads

but only one is active at a time

Locks

Atomicity comes at a performance cost



Two threads

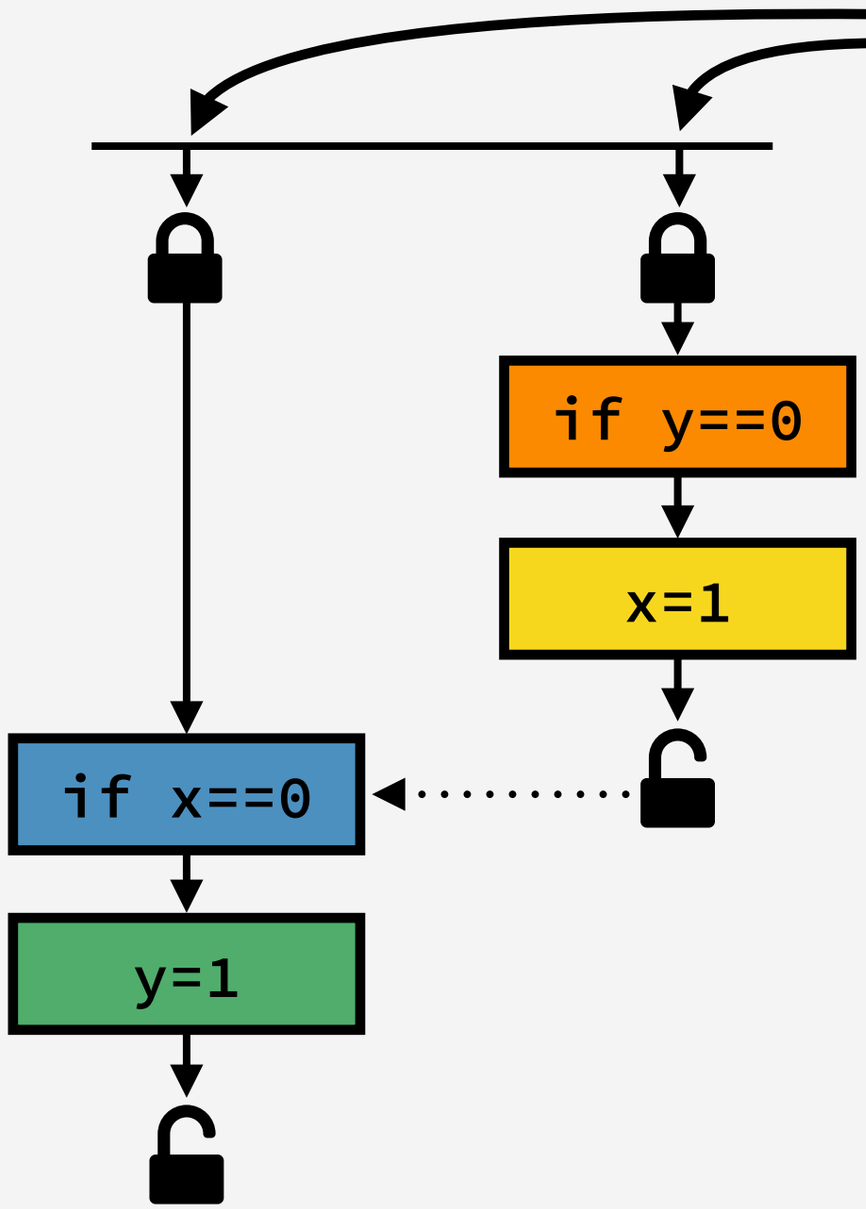
but only one is active at a time

Amdahl's Law

T(n) =

Locks

Atomicity comes at a performance cost



Two threads

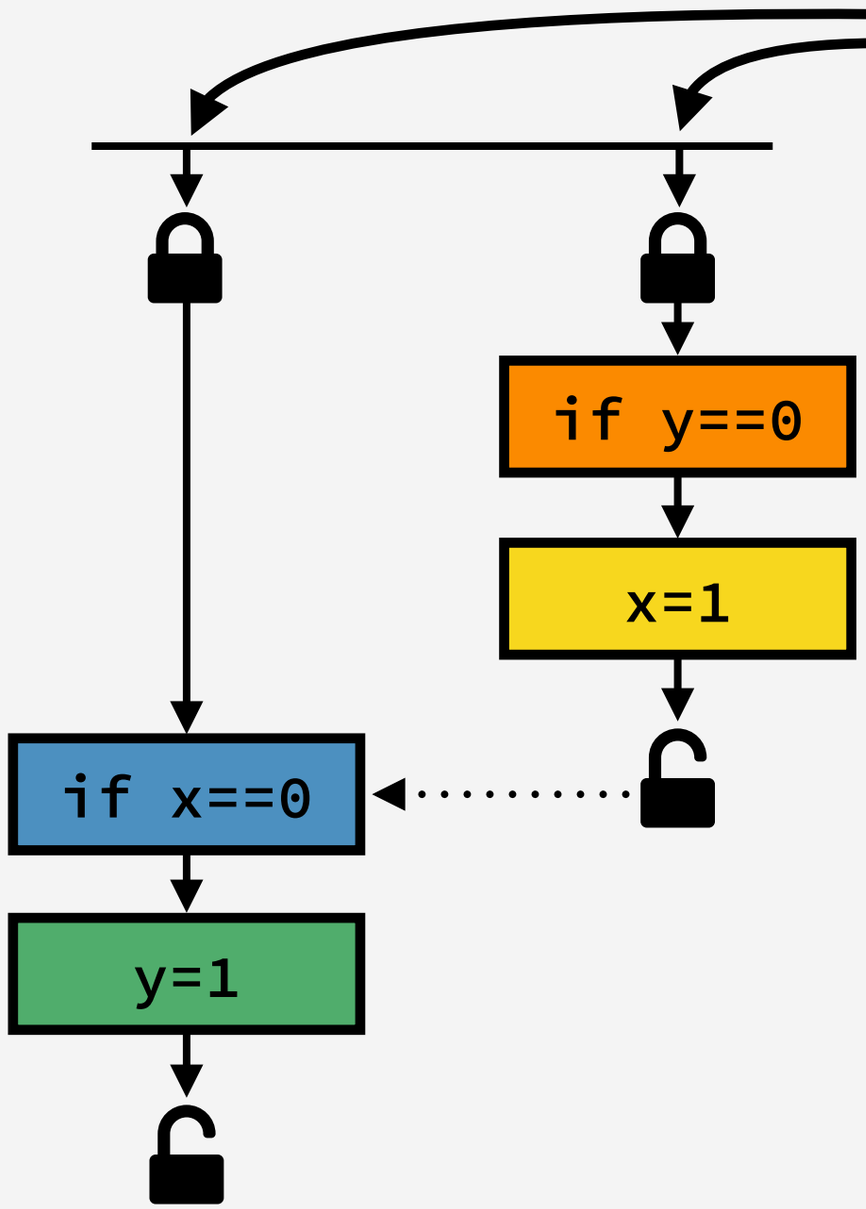
but only one is active at a time

Amdahl's Law

$T(n) = T(1)$

Locks

Atomicity comes at a performance cost



Two threads

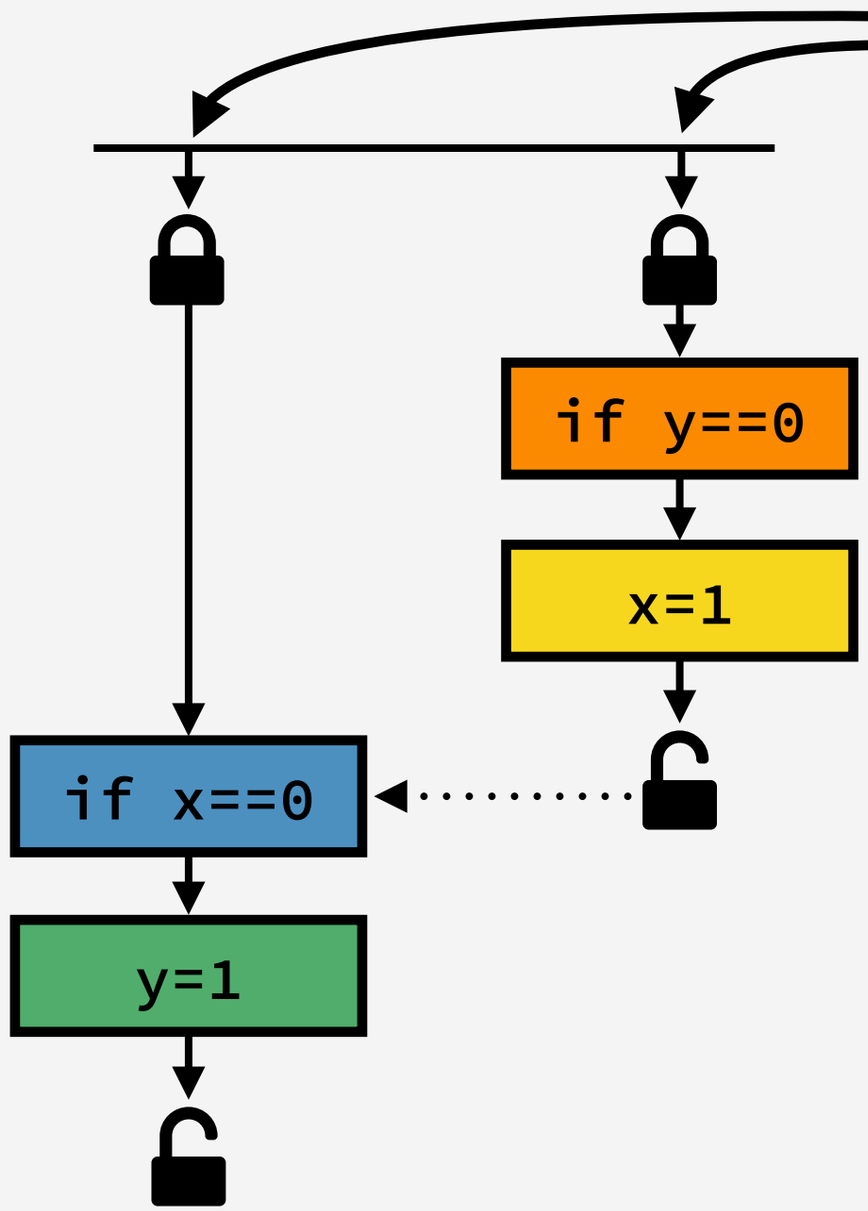
but only one is active at a time

Amdahl's Law

$$T(n) = T(1) \cdot (B + \qquad)$$

Locks

Atomicity comes at a performance cost



Two threads

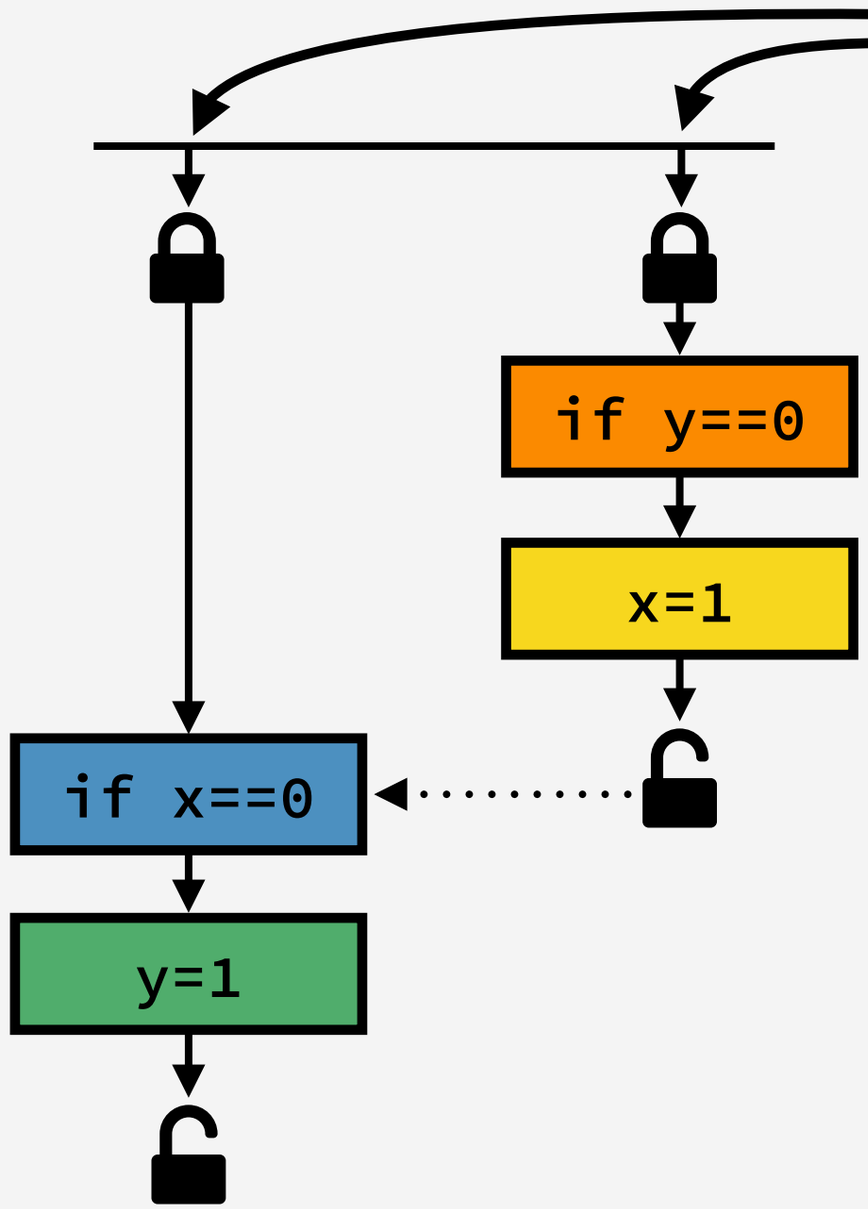
but only one is active at a time

Amdahl's Law

$$T(n) = T(1) \cdot (B + \frac{1 - B}{\ })$$

Locks

Atomicity comes at a performance cost



Two threads

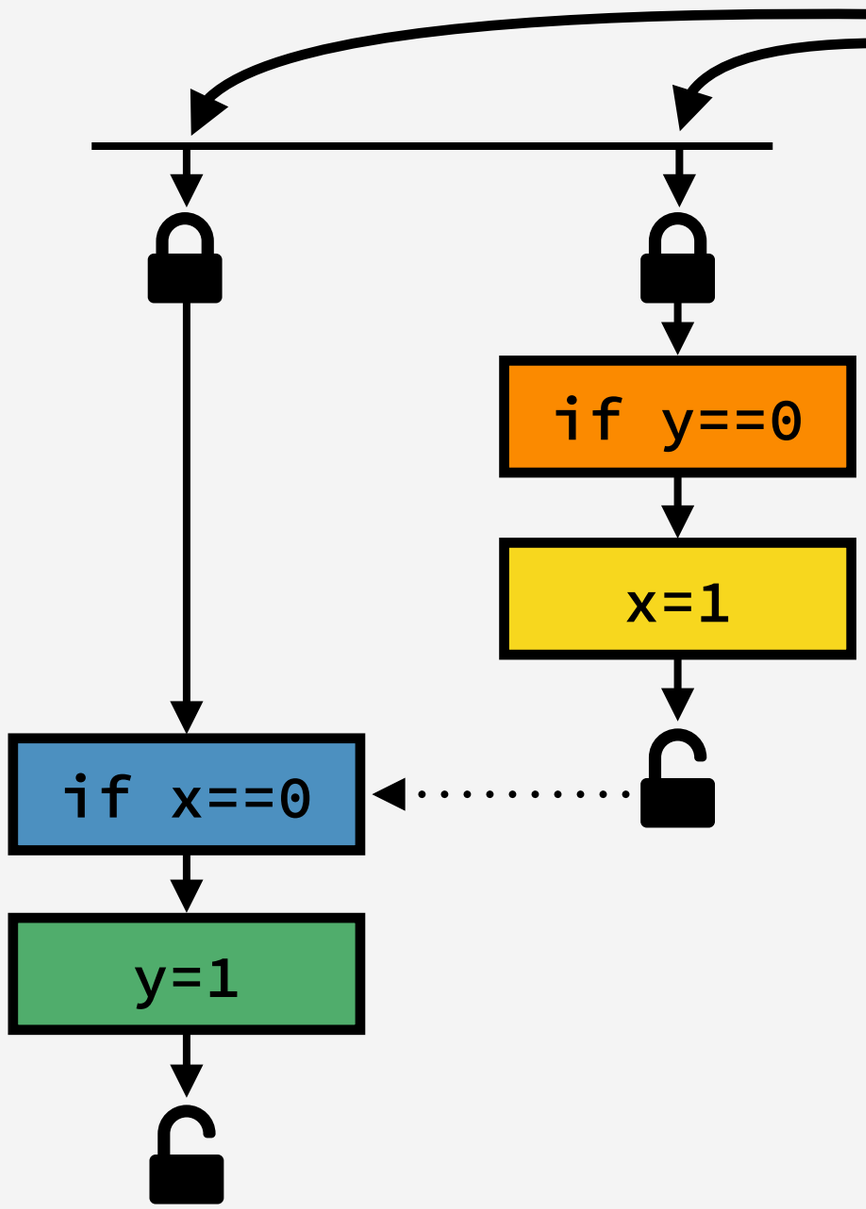
but only one is active at a time

Amdahl's Law

$$T(n) = T(1) \cdot (B + \frac{1 - B}{n})$$

Locks

Atomicity comes at a performance cost



Two threads

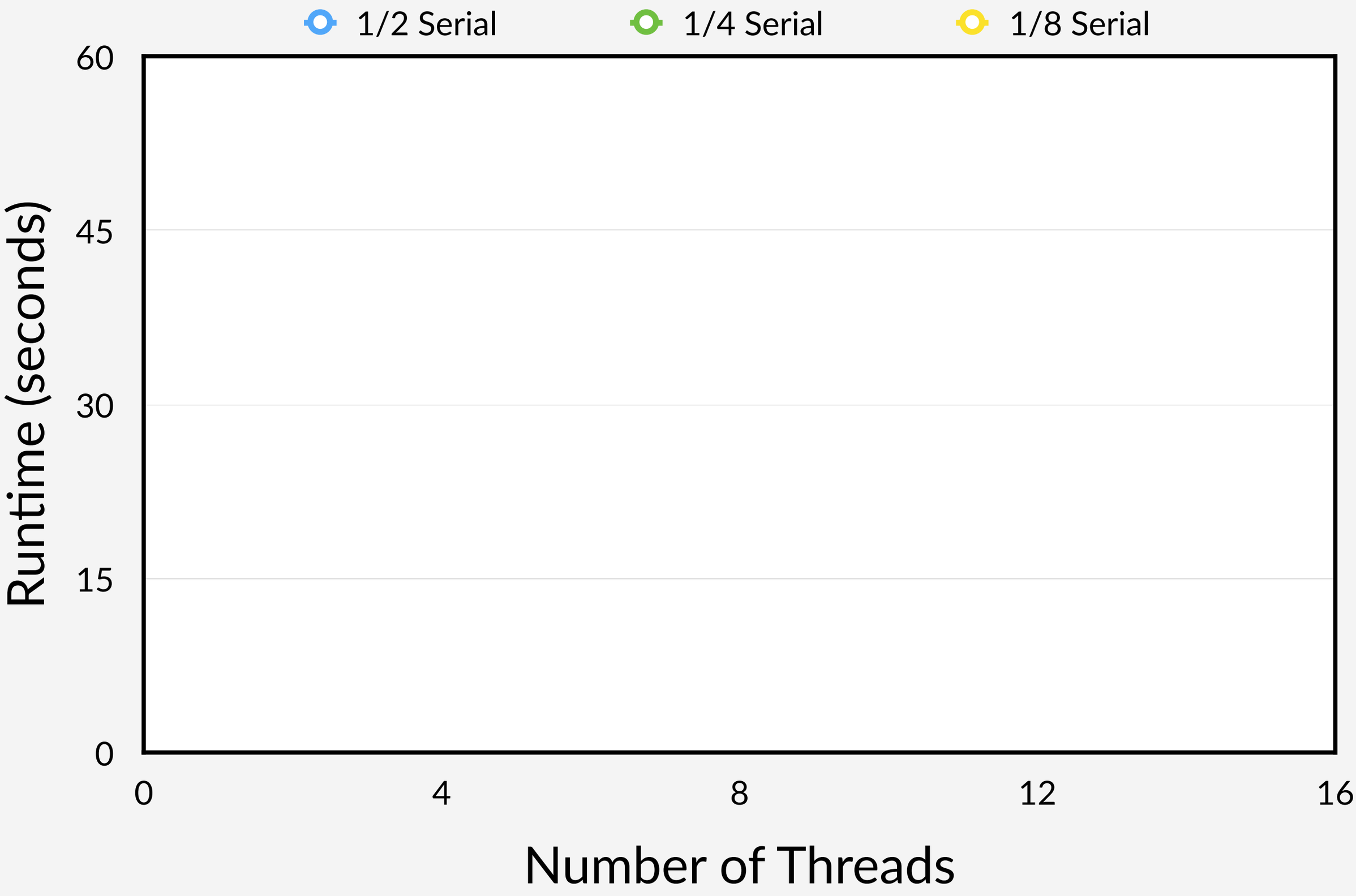
but only one is active at a time

Amdahl's Law

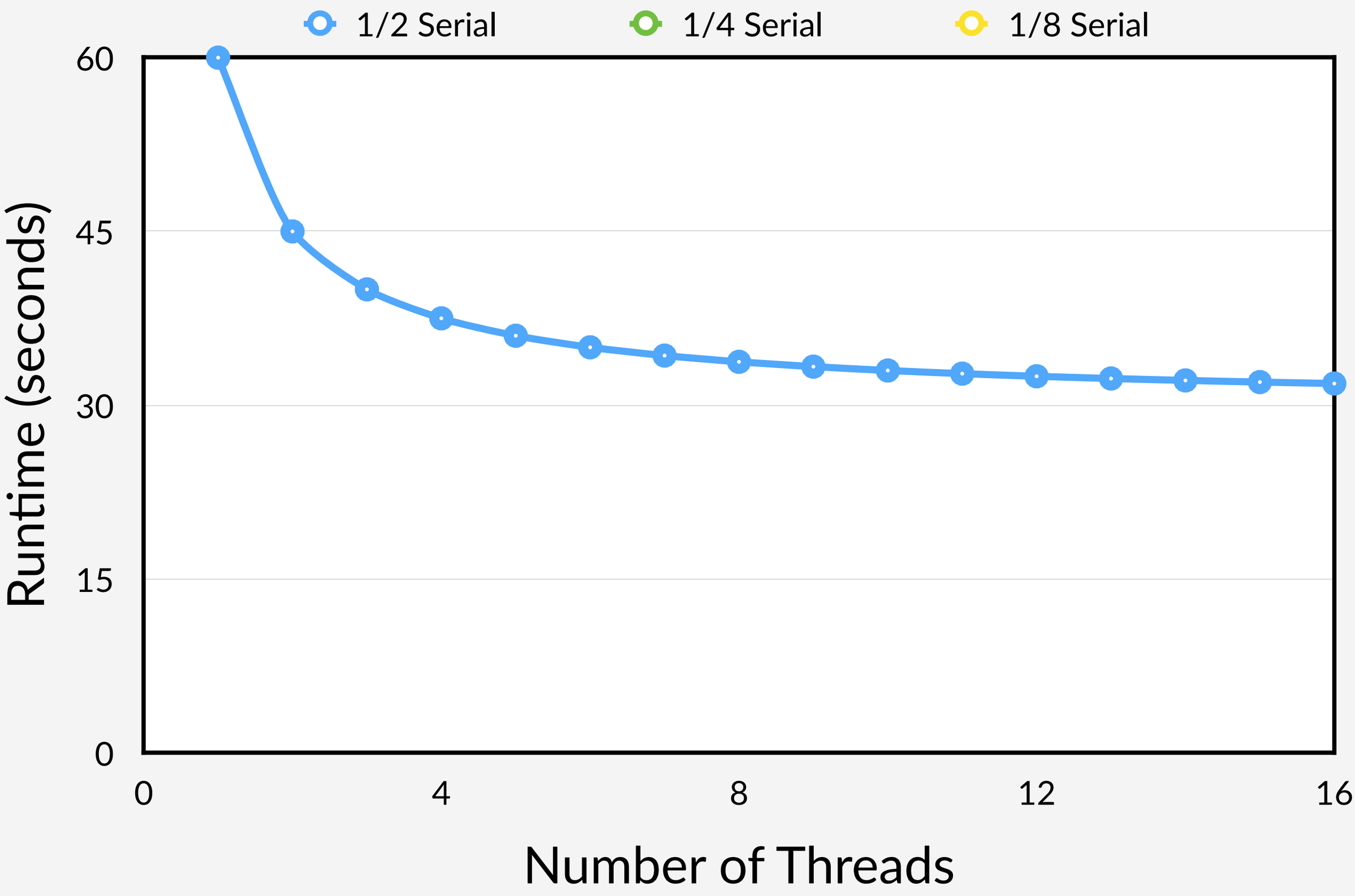
$$T(n) = T(1) \cdot (B + \frac{1 - B}{n})$$

Adding threads only speeds up the parallel part of the program.

Amdahl's Law


1/2 Serial
1/4 Serial
1/8 Serial
60
45
30
15
0
Runtime (seconds)
0
4
8
12
16
Number of Threads

Amdahl's Law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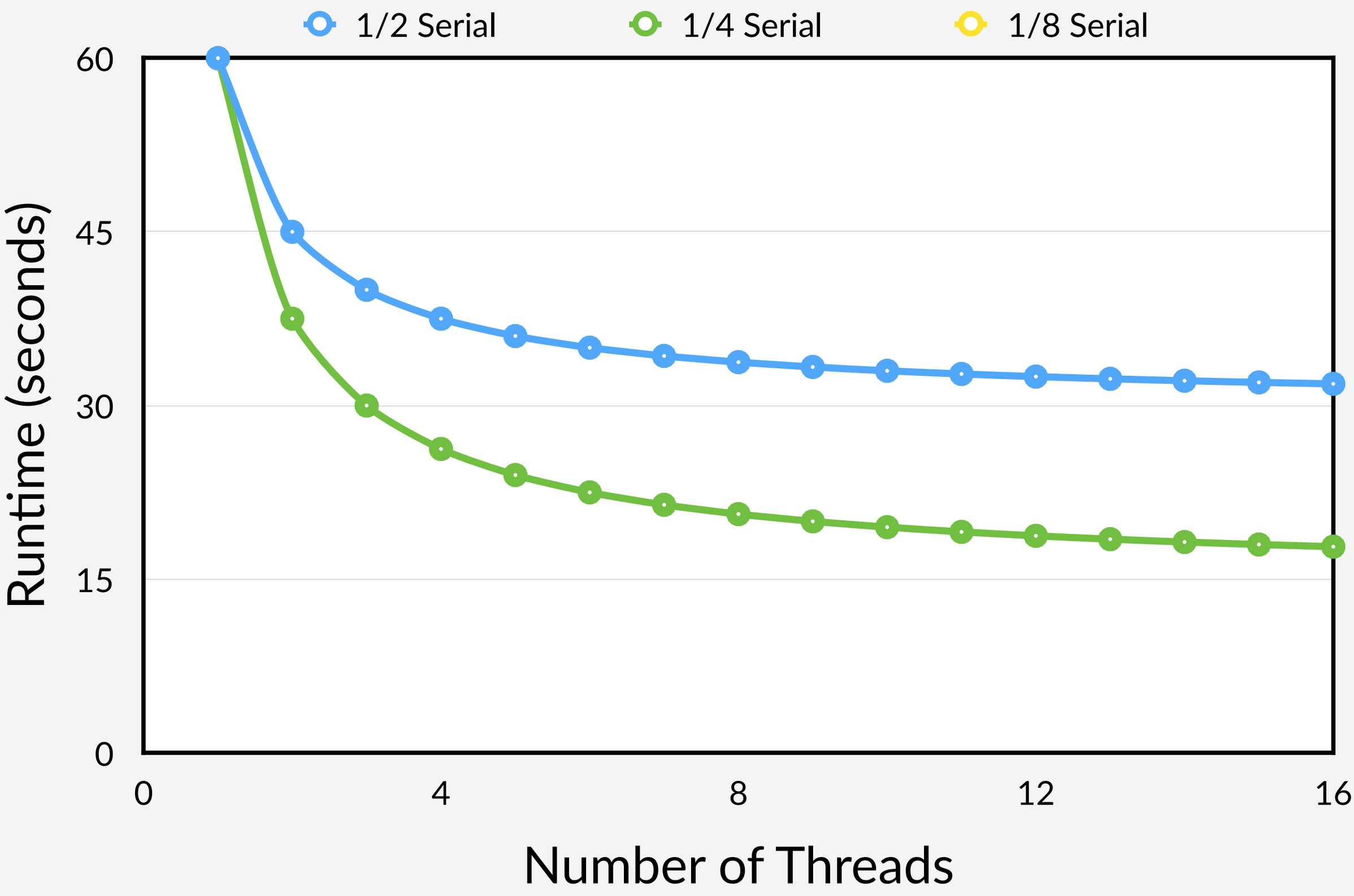
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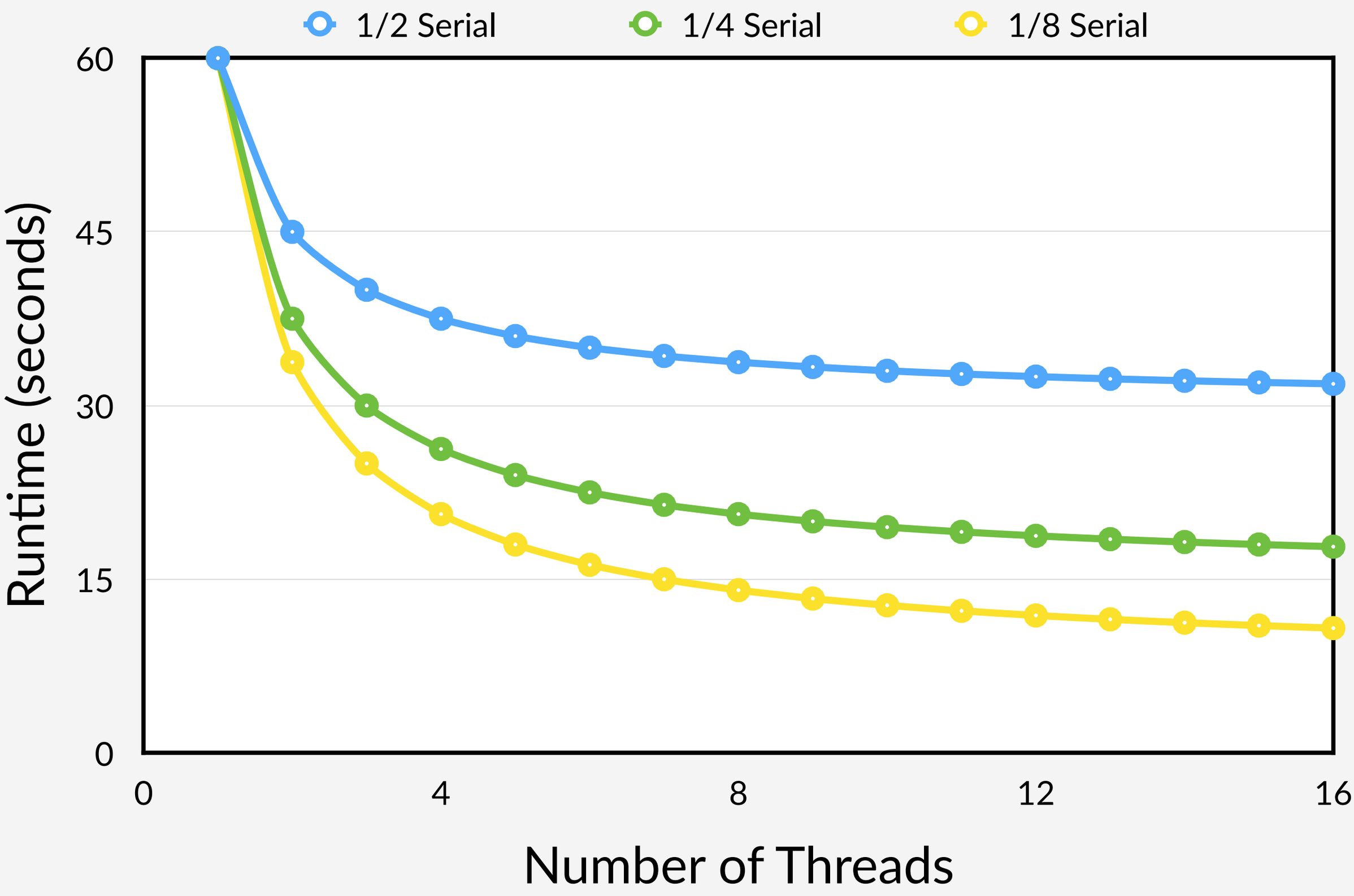
Amdahl's Law


1/2 Serial
1/4 Serial
1/8 Serial
Runtime (seconds)
60
45
30
15
0
0
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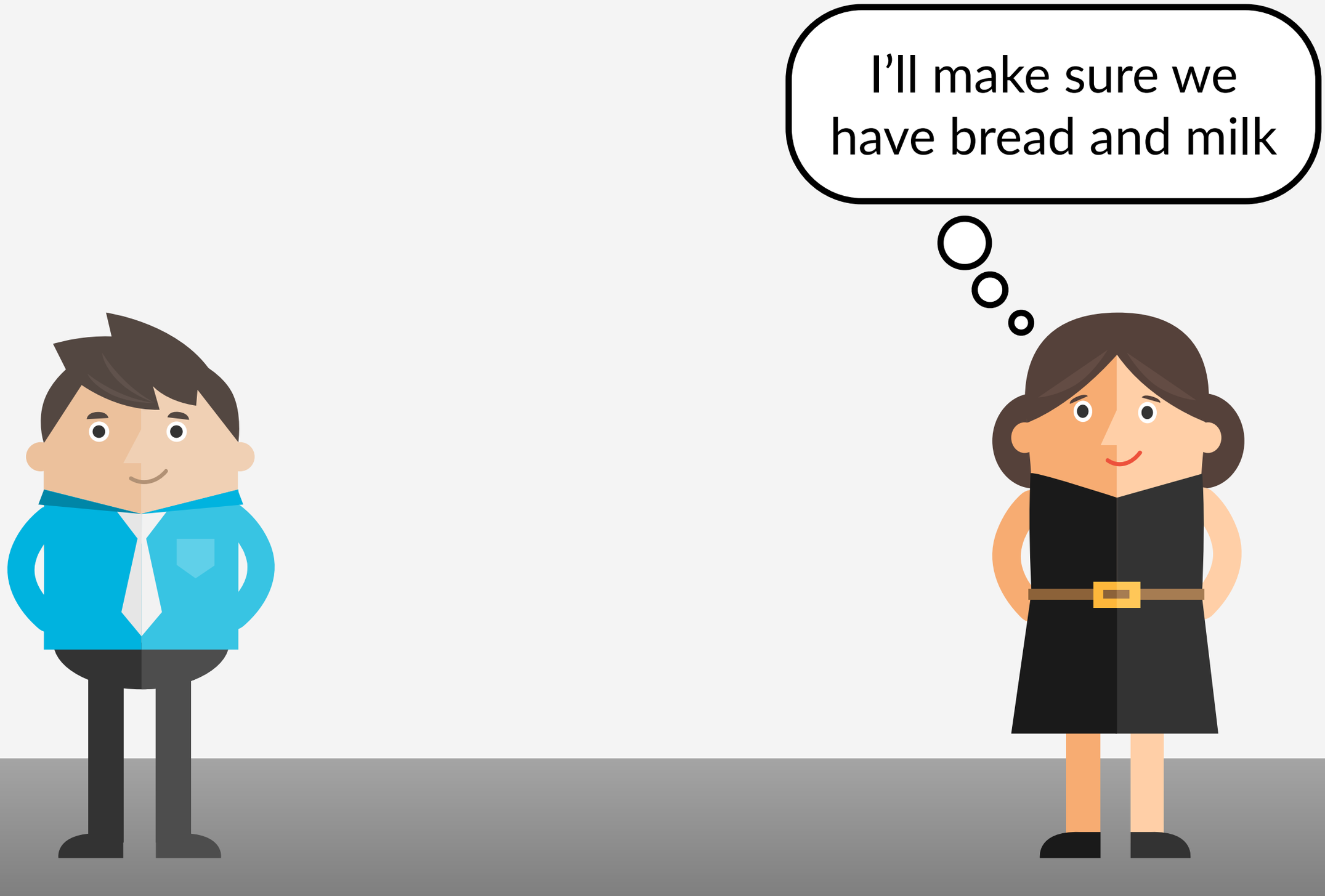
8
12
16
Number of Threads

Contention

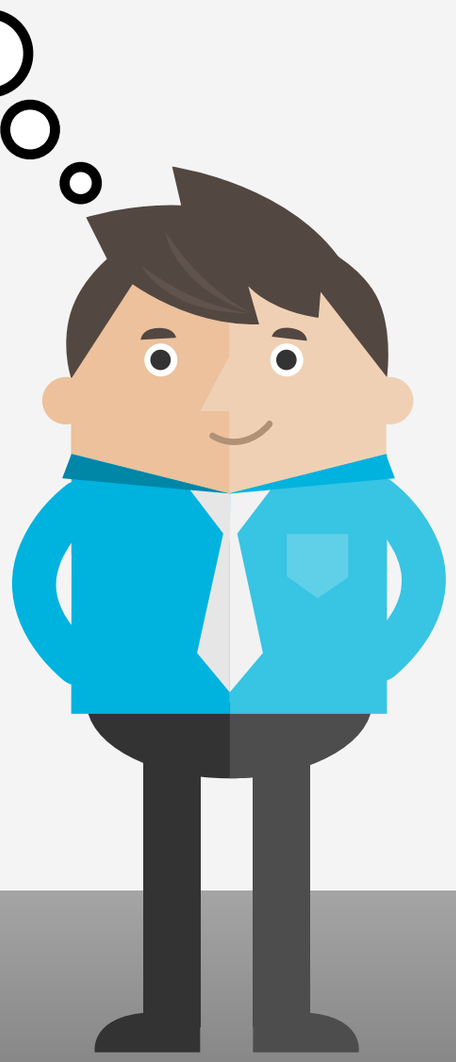
Contention

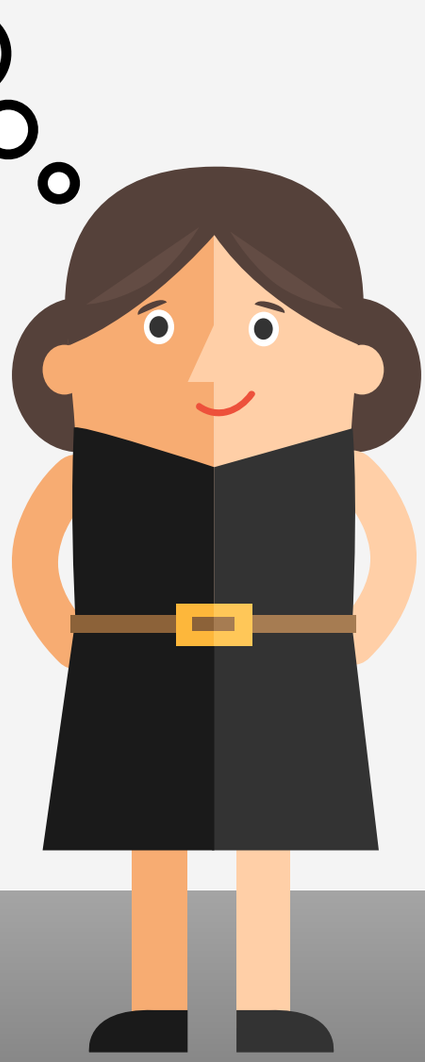


Contention

I wonder if we have any yogurt

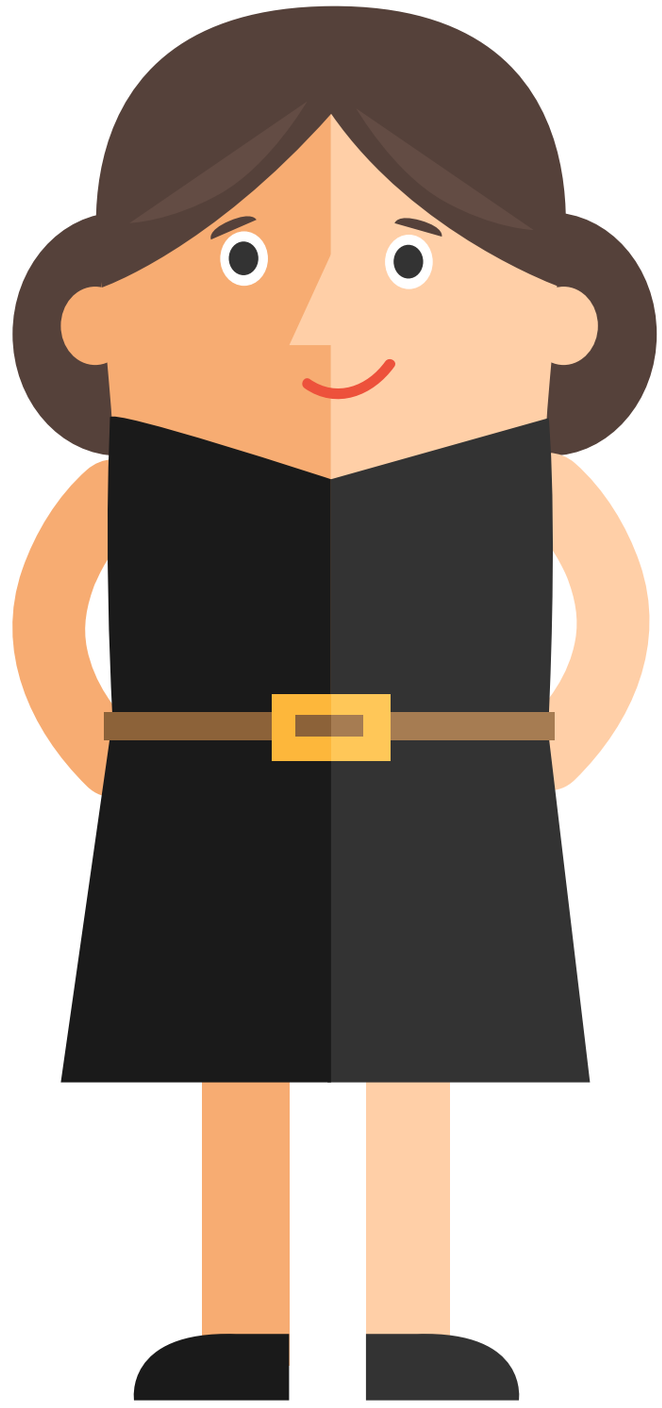
I'll make sure we have bread and milk



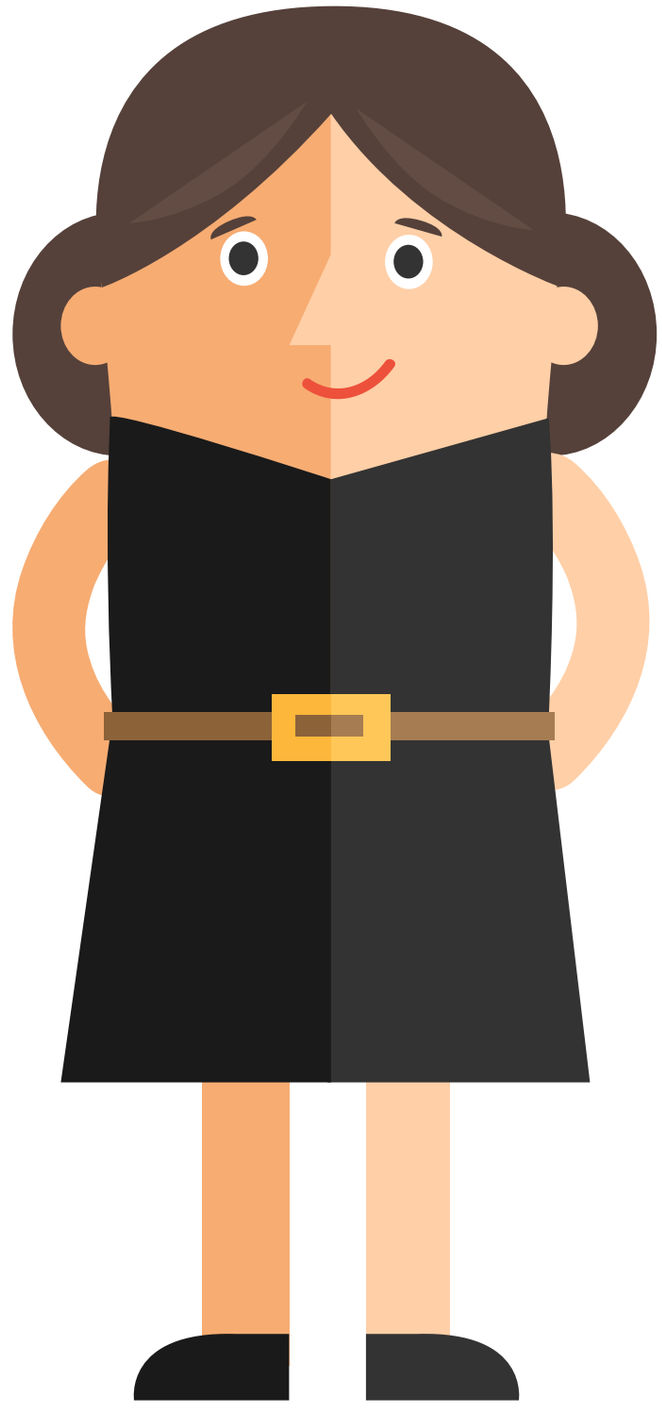



Oh no! Better go to the store.


JENN-AIR




JENN-AIR

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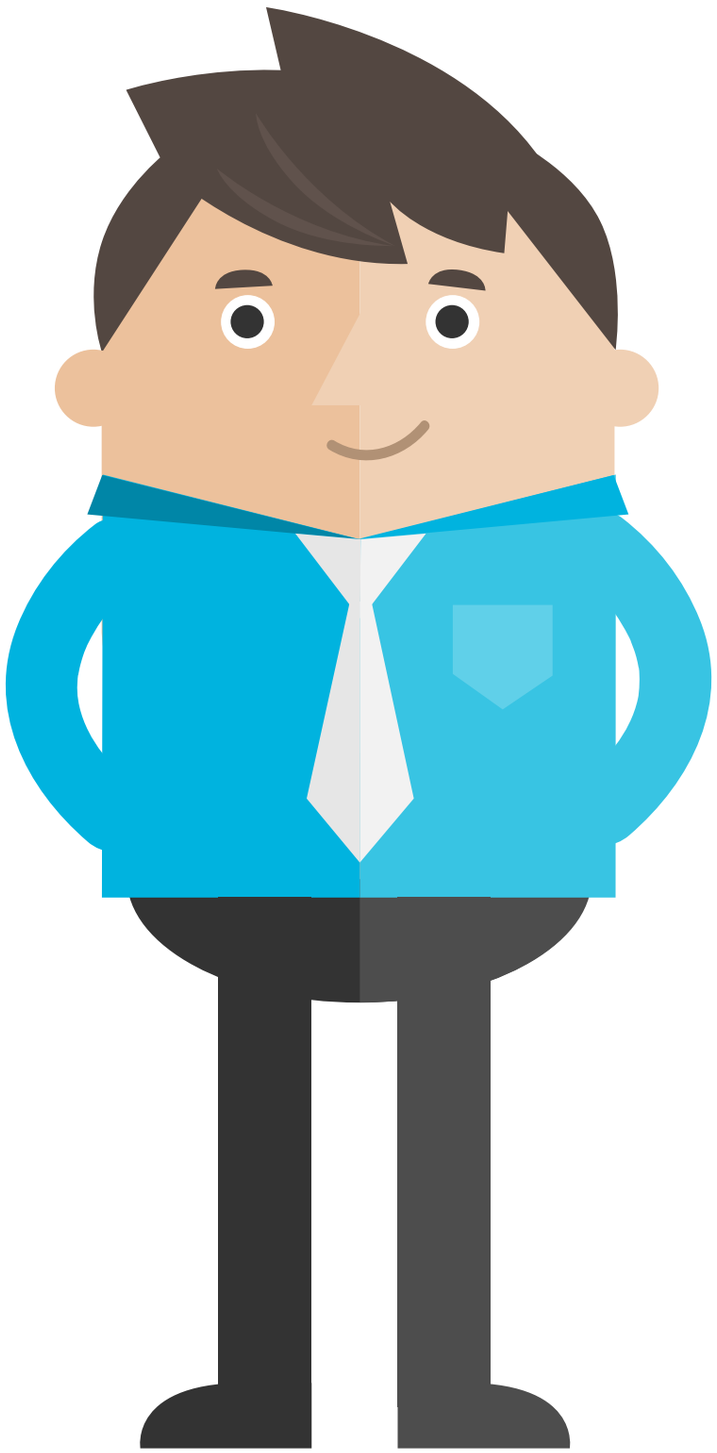



JENN-AIR


JENN-AIR


JENN-AIR

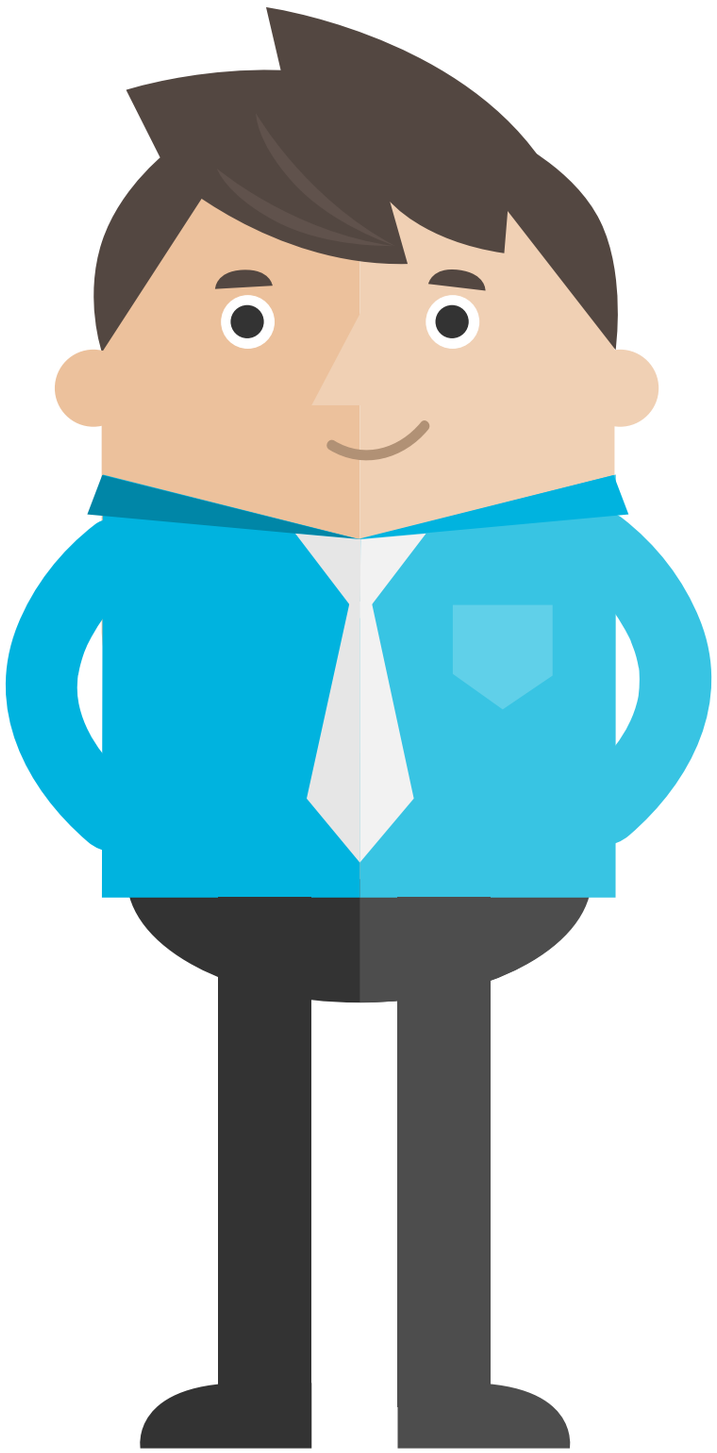

JENN-AIR


Great Value
2%

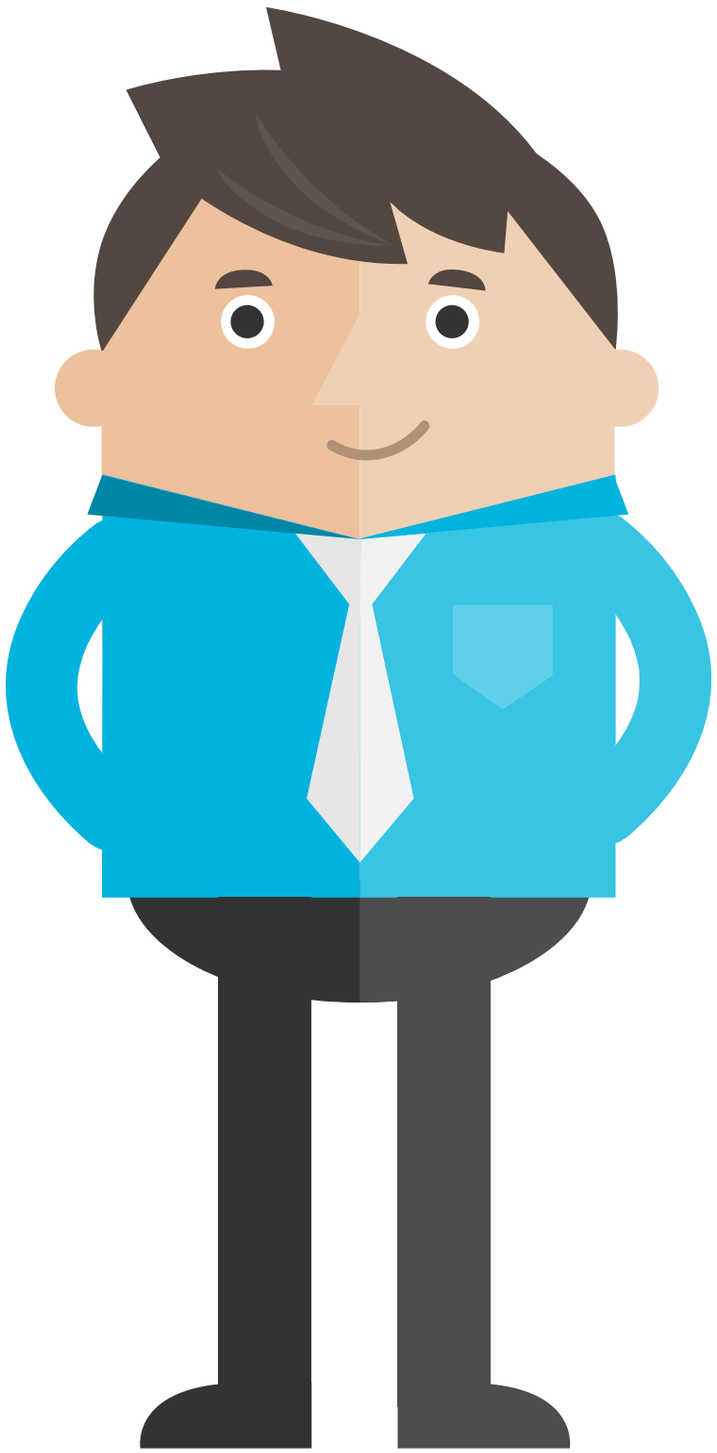

JENN-AIR


Great Value
2%
Nutrition Facts

Darn, no yogurt.
Better go to the store.




JENN-AIR




JENN-AIR


JENN-AIR


JENN-AIR
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OIKOS
VANILLA
GREEK NONFAT YOGURT


JENN-AIR
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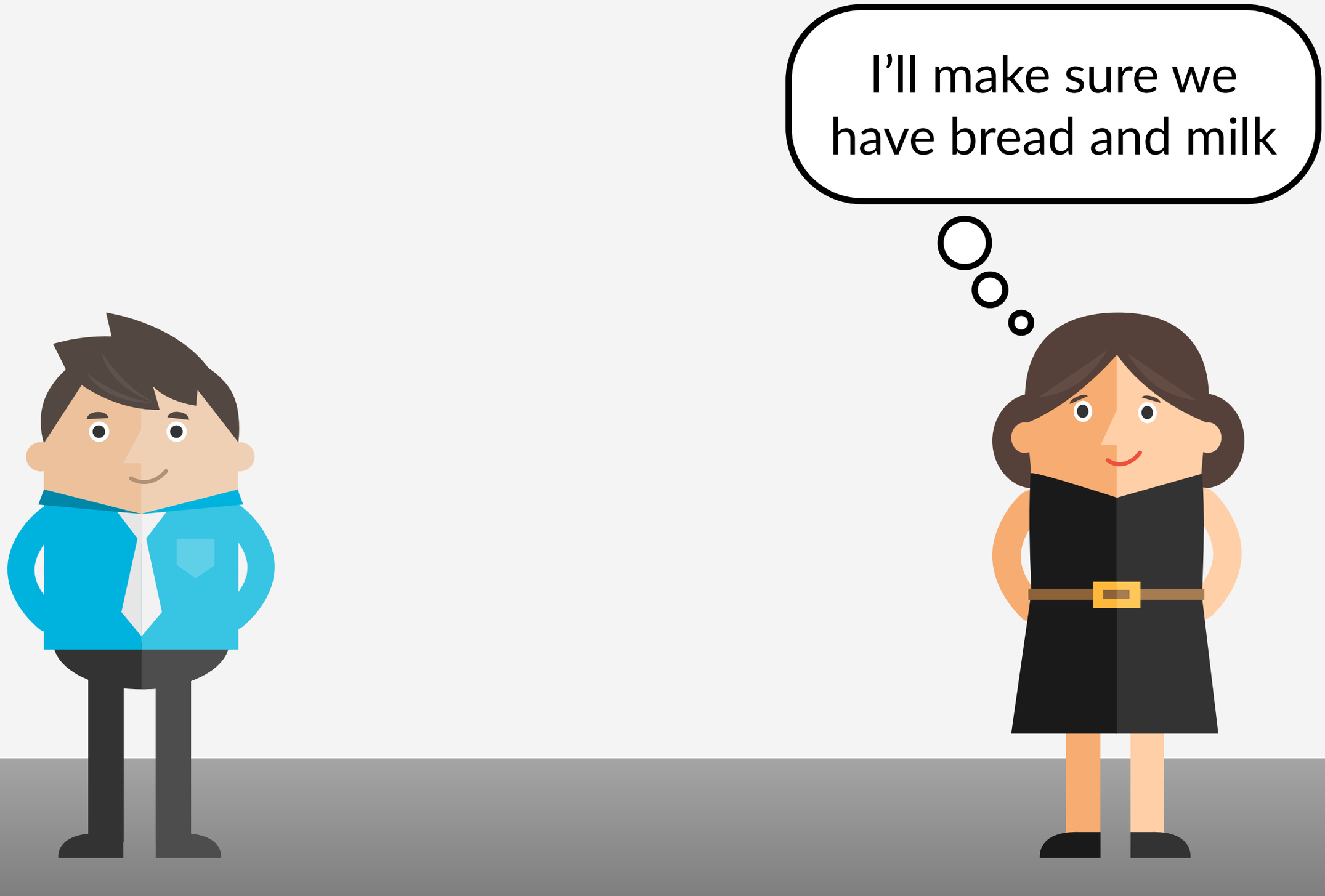
GREEK NONFAT YOGURT

Fine-grained locking

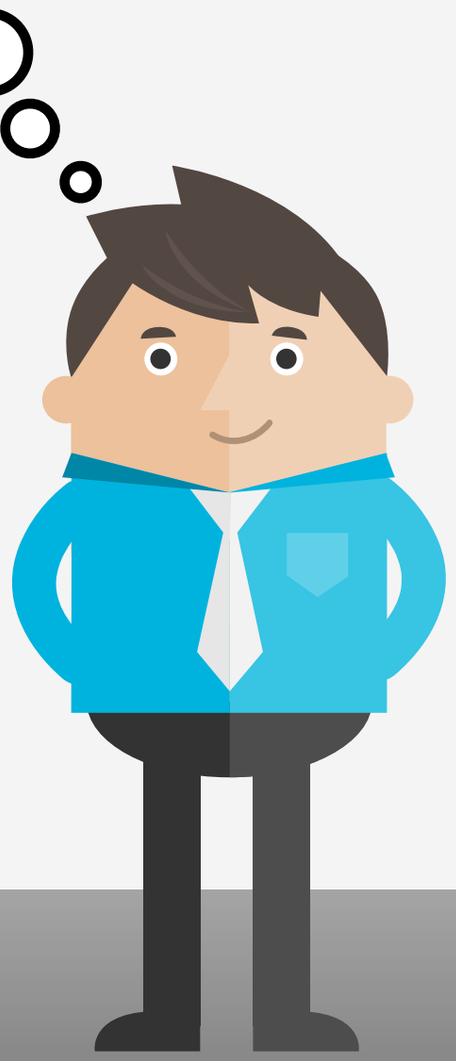
Fine-grained locking

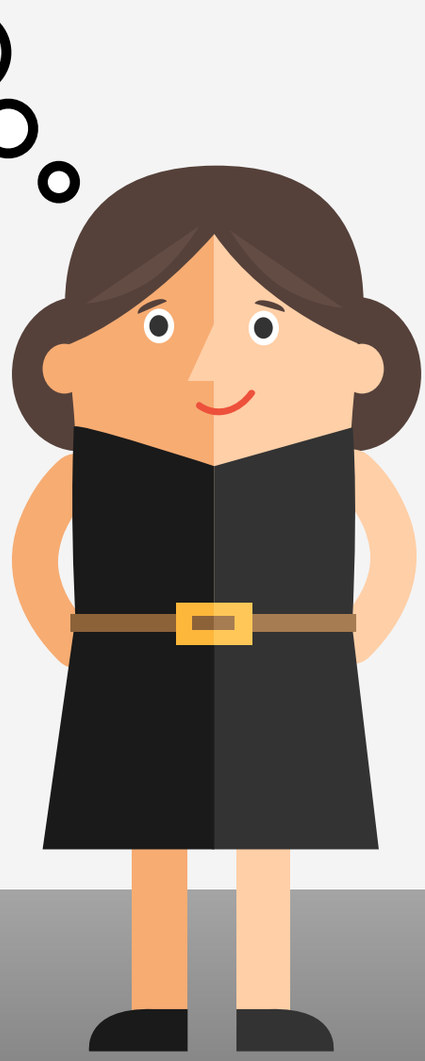


Fine-grained locking

I wonder if we have any yogurt

I'll make sure we have bread and milk






Oh no! Better go to the store.


Oh no! Better go to the store.


Oh no! Better go to the store.


Darn, no yogurt.
Better go to the store.

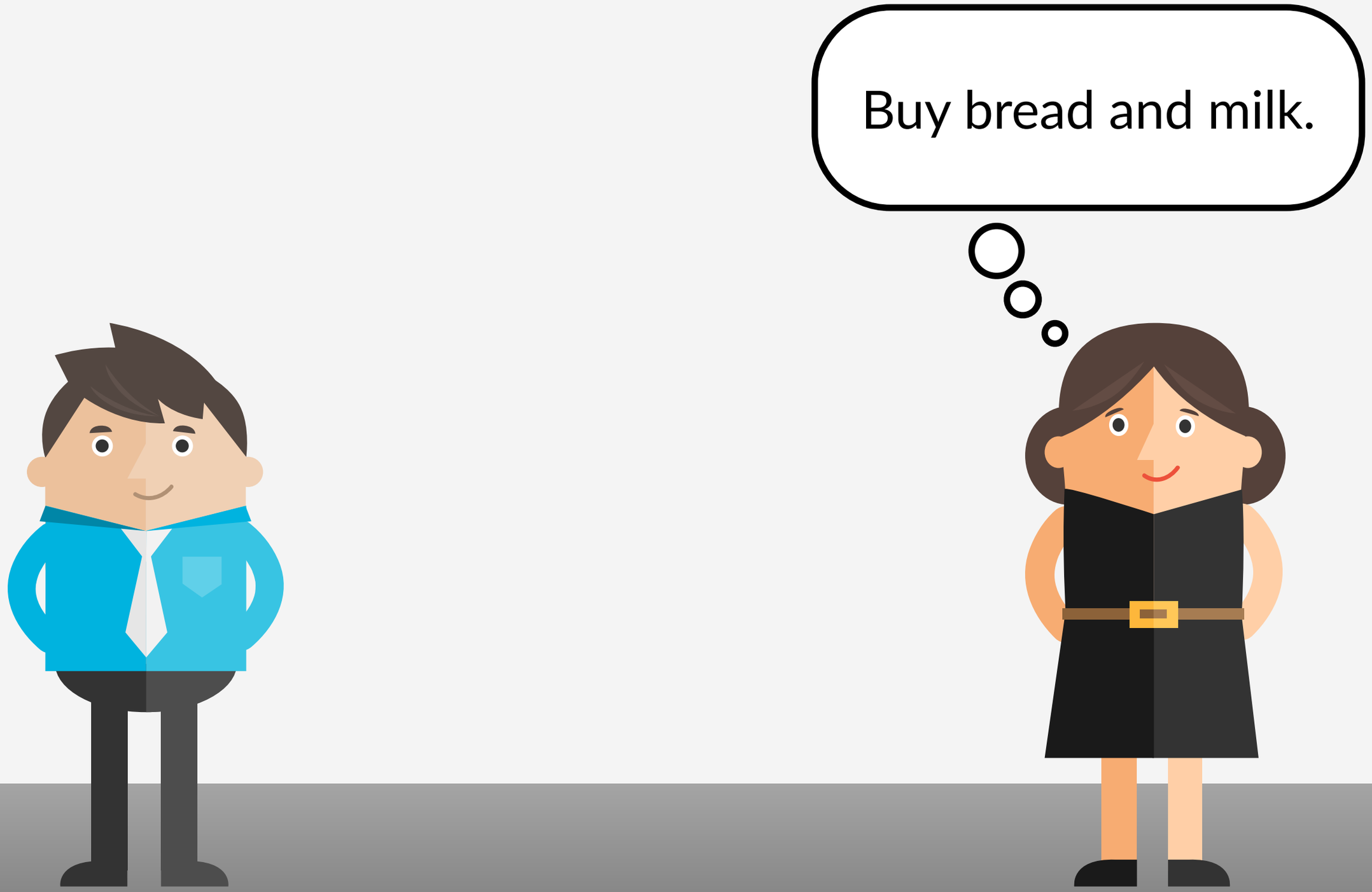

Darn, no yogurt.
Better go to the store.


DANNON
OIKOS
GREEK NONFAT YOGURT
VANILLA
0 G FAT


DANNON
OIKOS
GREEK NONFAT YOGURT

Deadlock

Deadlock



Deadlock

Buy milk and bread.

Buy bread and milk.