Queue Implementations

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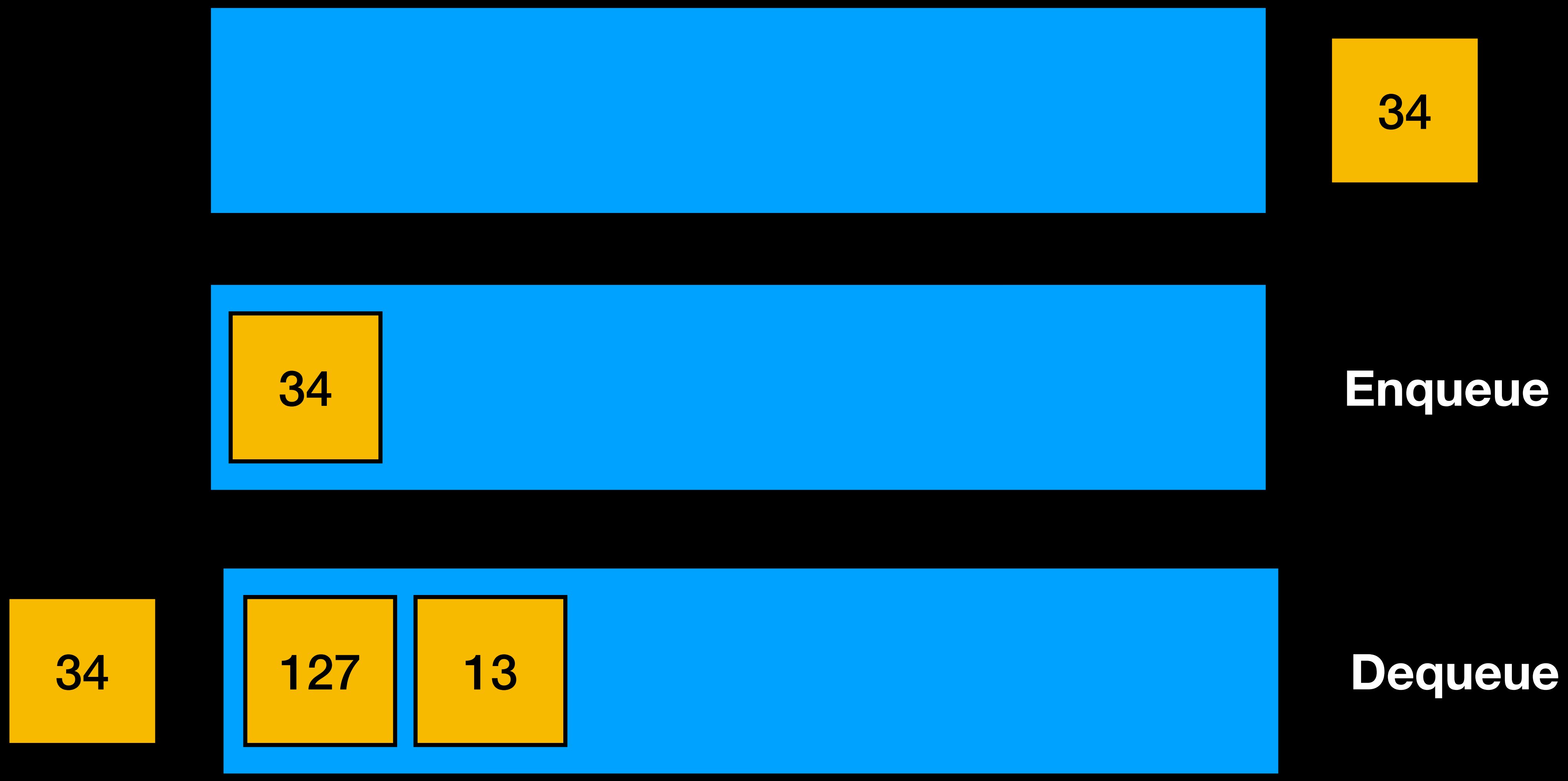
Today's Plan

Queue Implementations

Recap

FIFO structure: First In First Out



Queue ADT

```
#ifndef QUEUE_H_
#define QUEUE_H_

template<typename ItemType>
class Queue
{
public:
   Queue();
   void enqueue(const ItemType& new_entry); //adds an element to back
   void dequeue(); // removes element from front of queue
   ItemType front() const; // returns a copy of the front element
   int size() const; // returns the number of elements in the queue
   bool isEmpty() const; // returns true if no elements in queue

private:
   //implementation details here
}; //end Queue

#include "Queue.cpp"
#endif // QUEUE_H_ `
```

Choose a Data Structure

Array?

Vector?

Linked Chain?

We are looking to enqueue and dequeue in $O(1)$ time

Recall Analysis for Stack

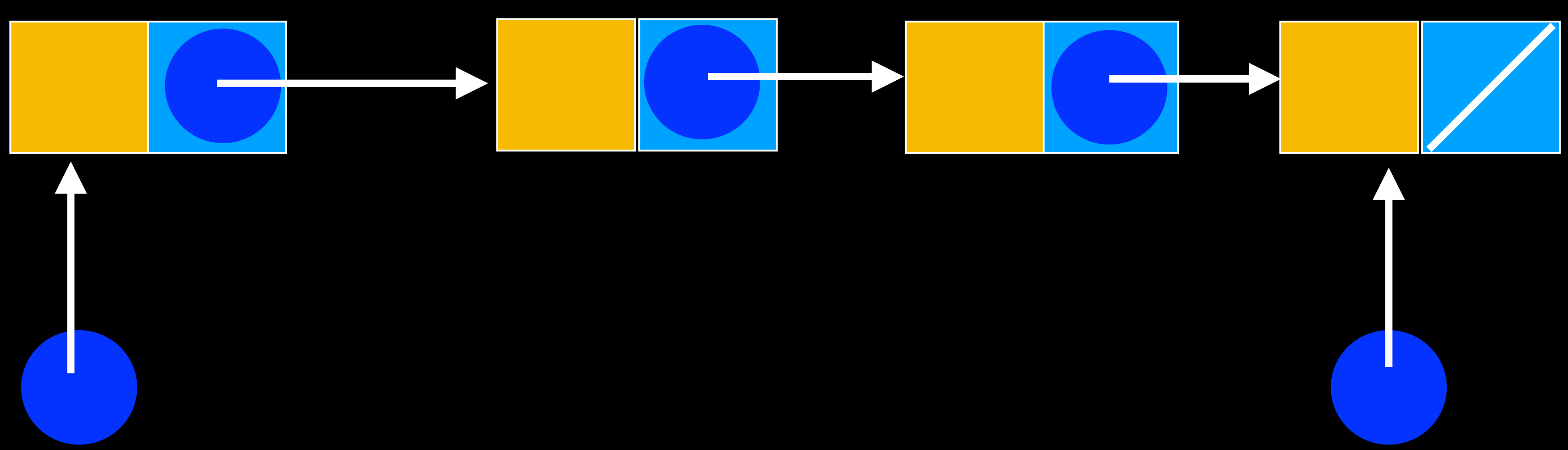
Amortized Analysis

	Big-O	Size unbounded
Array	O(1)	✗
Vector	O(1)+	✓
Linked Chain	O(1)	✓

What is the main difference btw stack and queue?

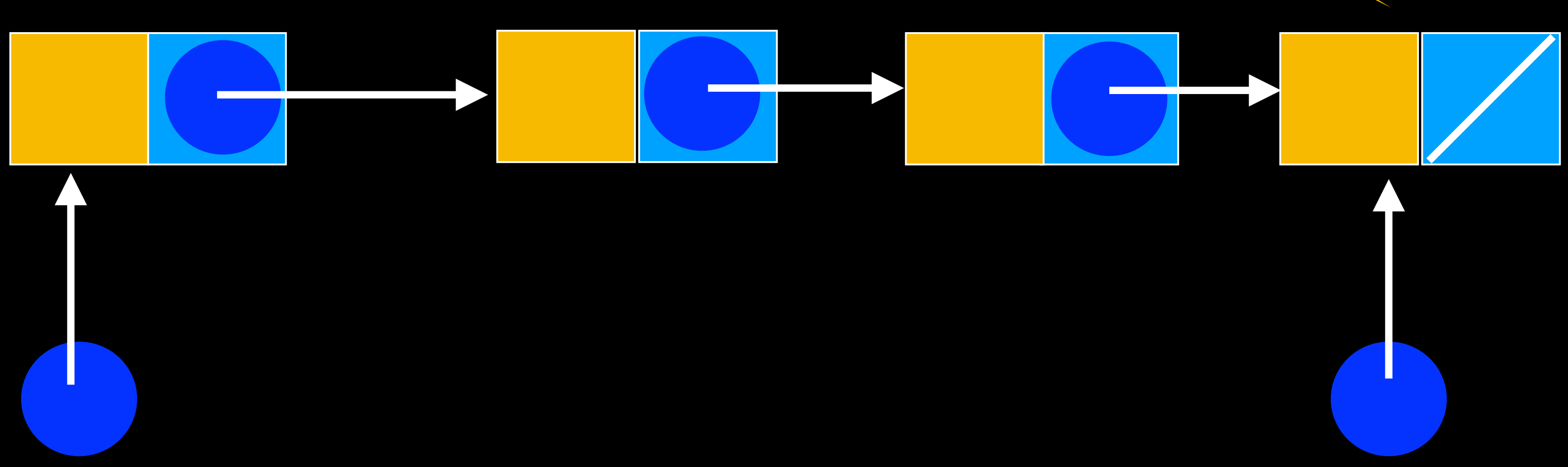
Singly Linked Chain

Where is front?
Where is back?

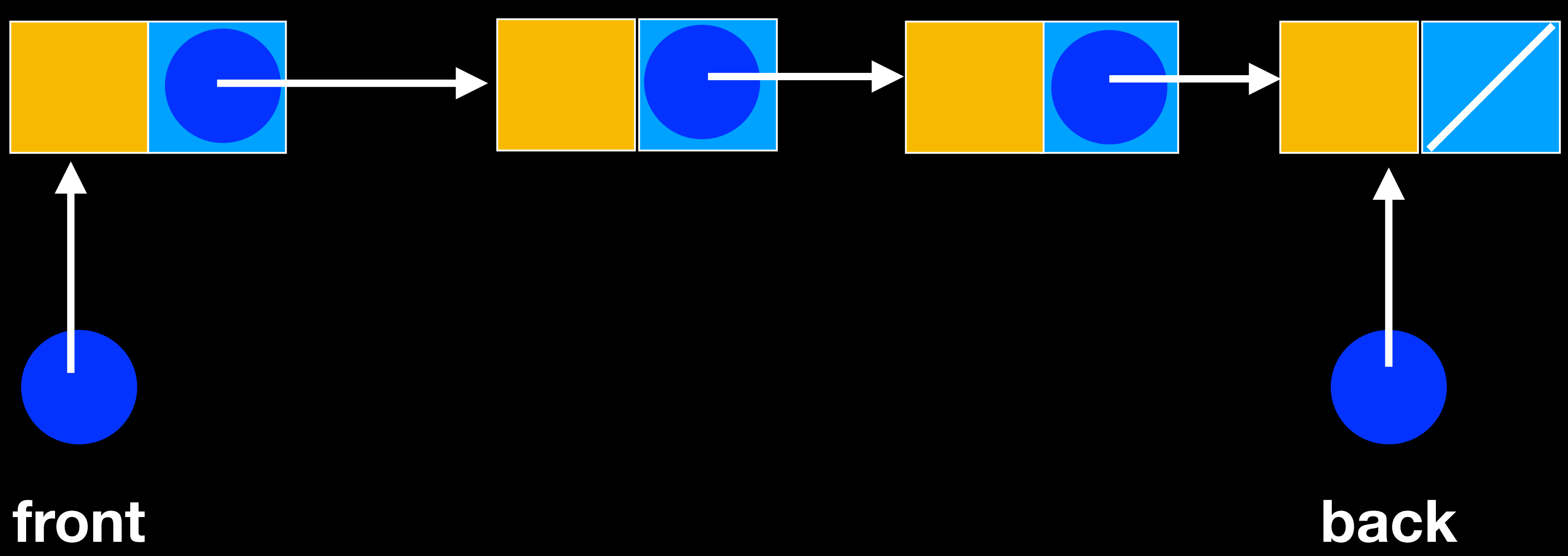


Singly Linked Chain

Deleting here is not O(1)
Because we don't have
pointer to previous node

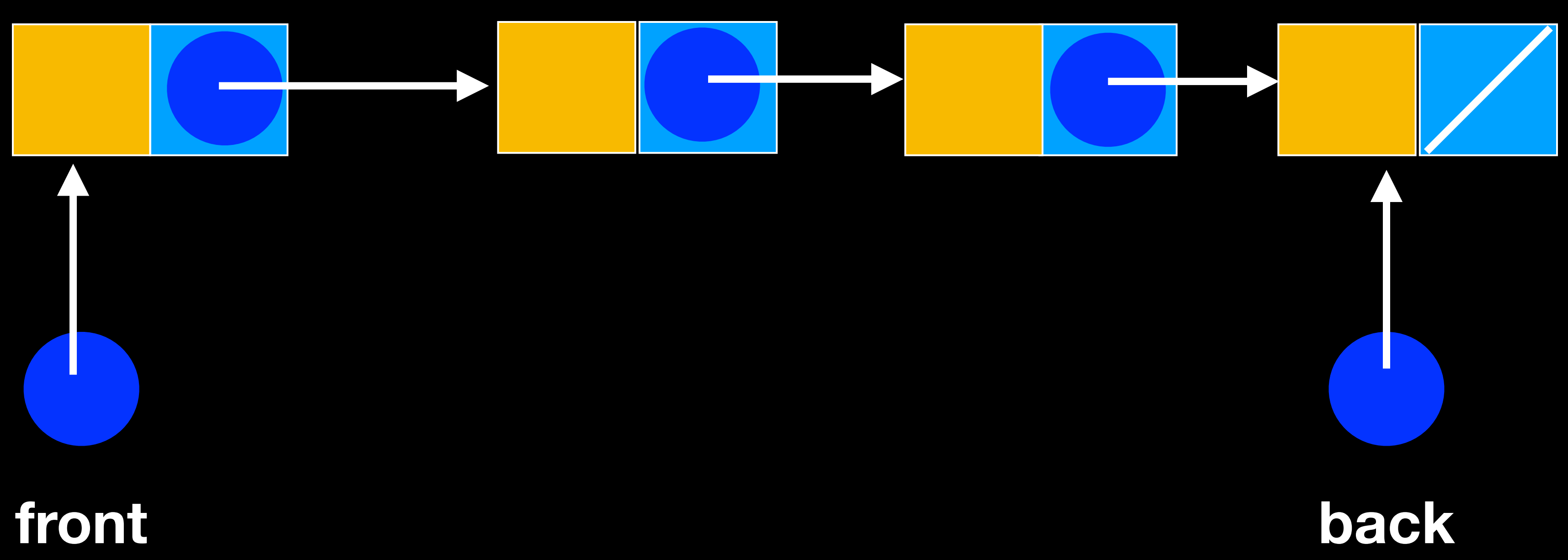


Singly Linked Chain



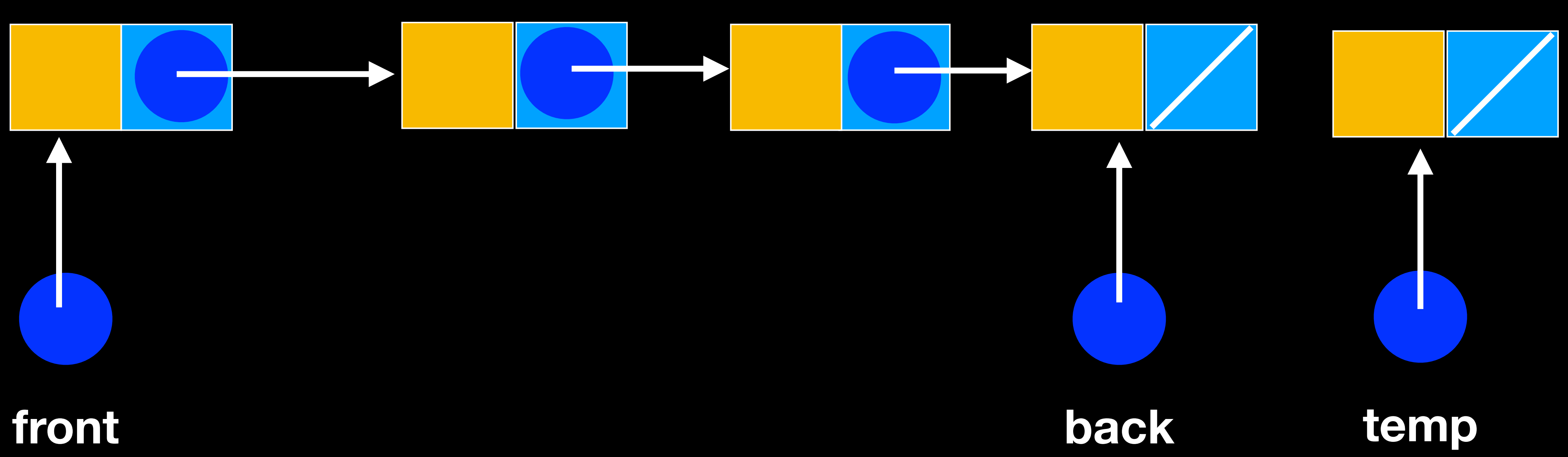
Singly Linked Chain

enqueue



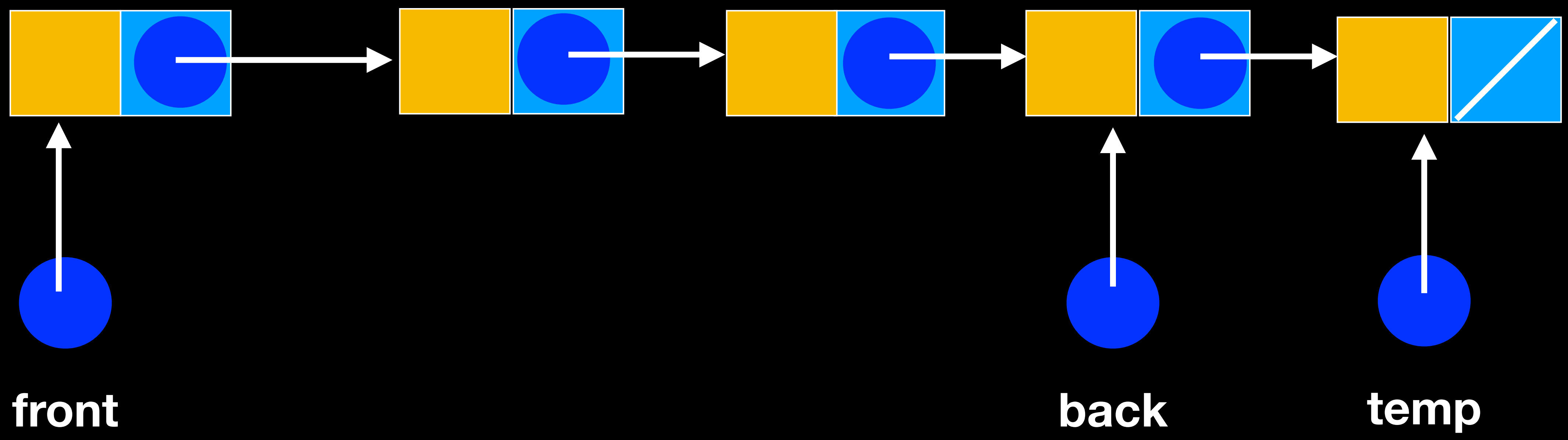
Singly Linked Chain

enqueue



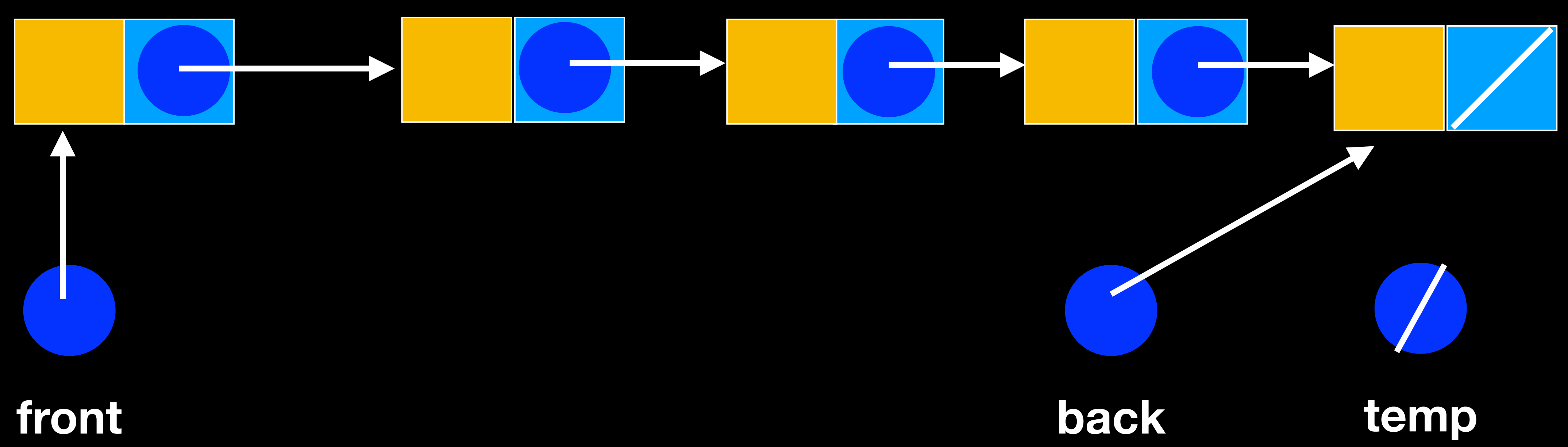
Singly Linked Chain

enqueue



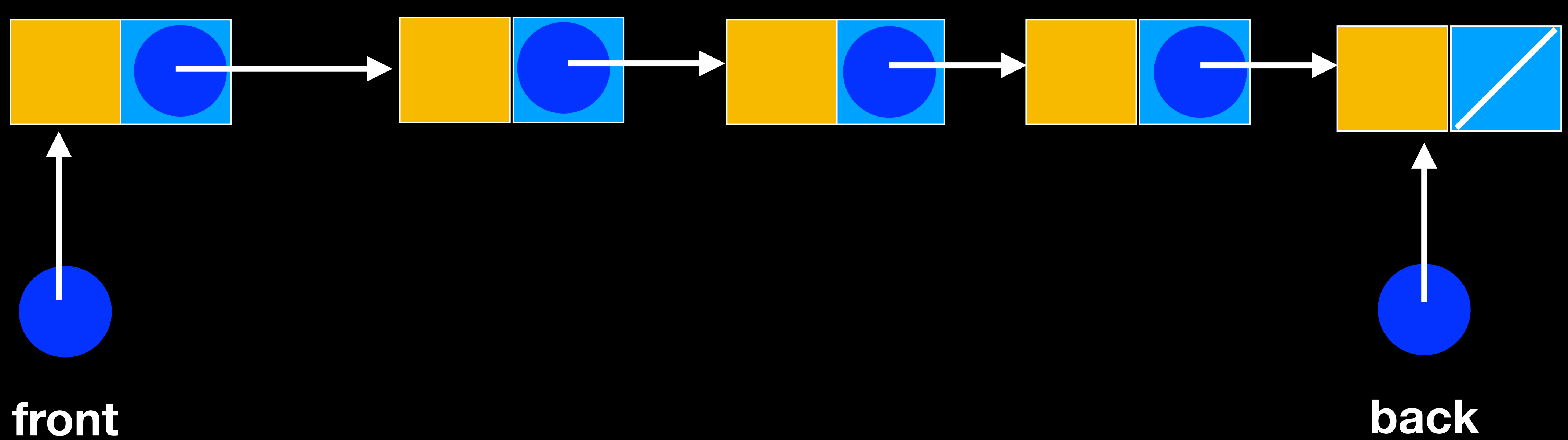
Singly Linked Chain

enqueue



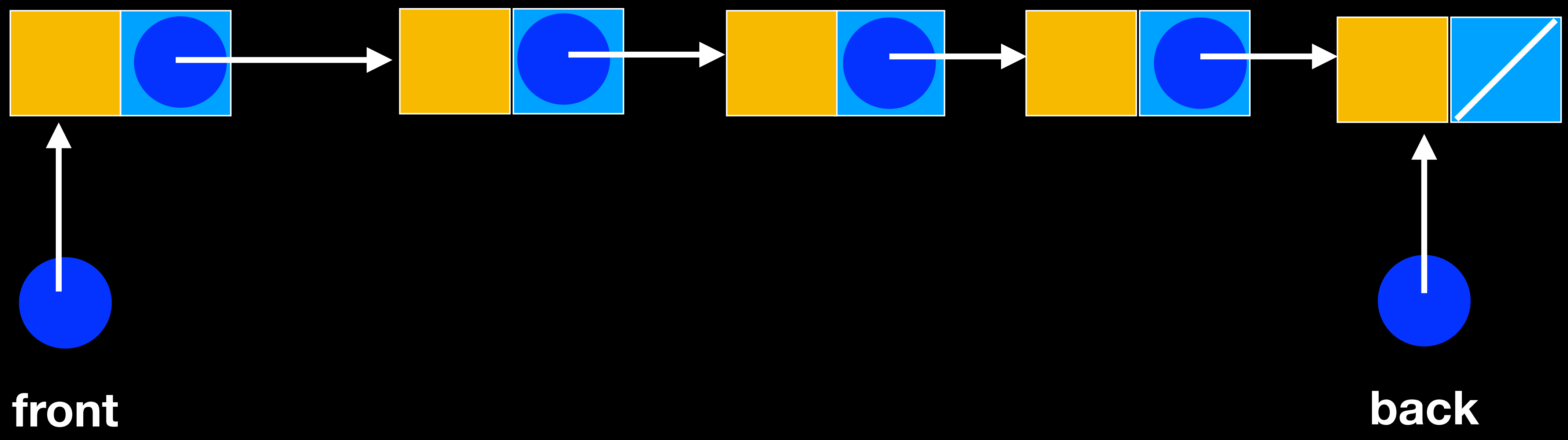
Singly Linked Chain

enqueue

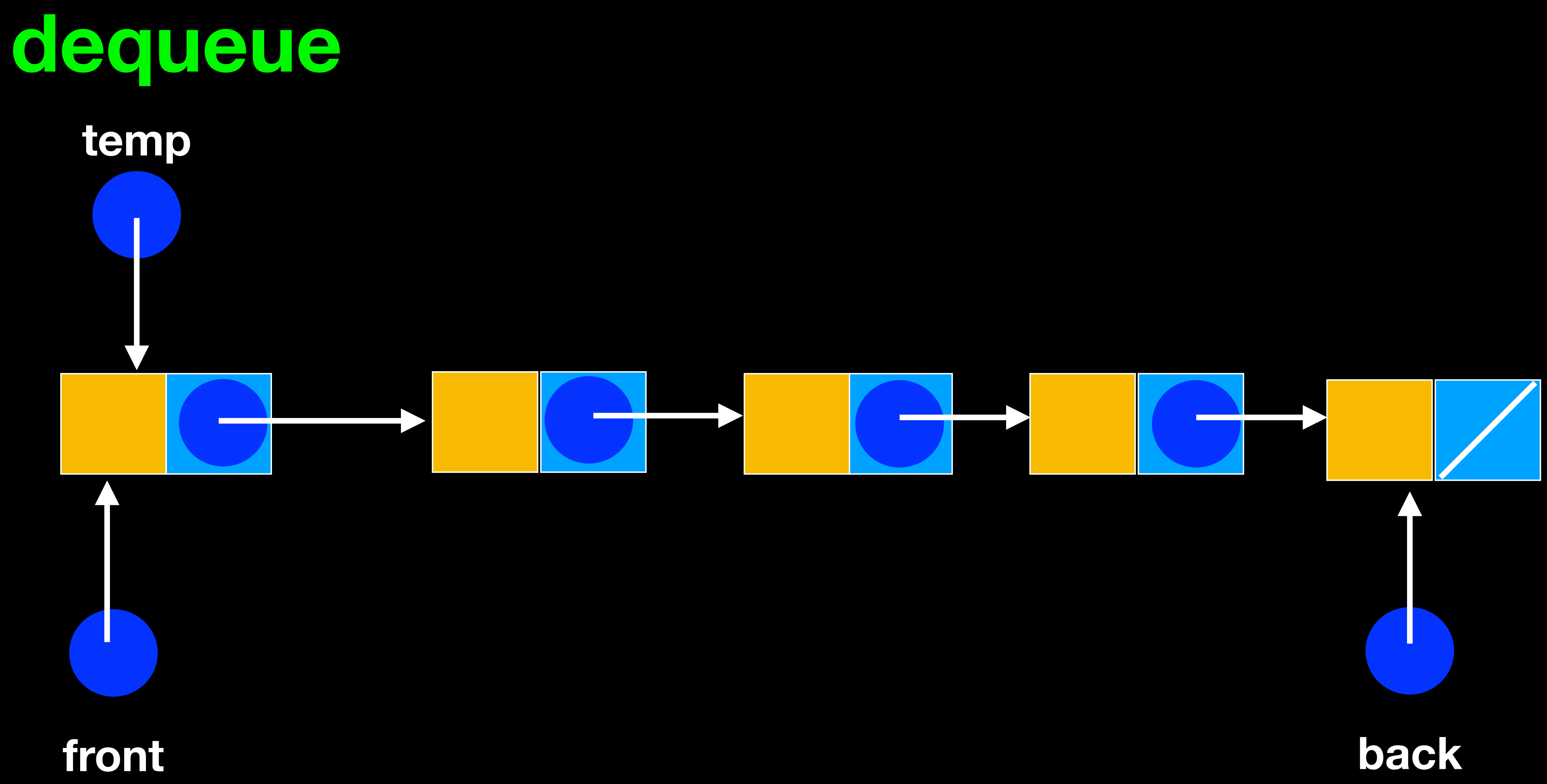


Singly Linked Chain

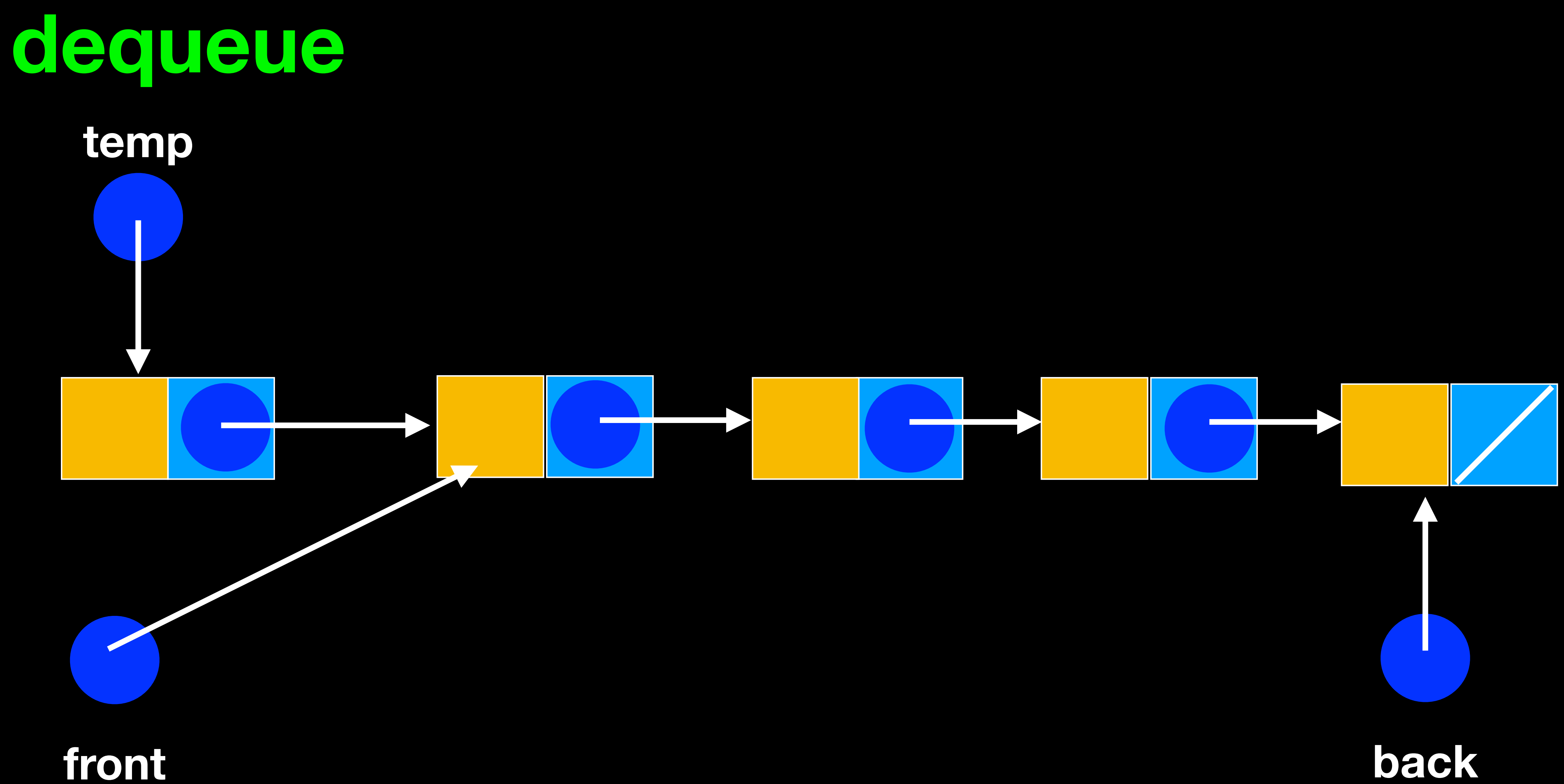
dequeue



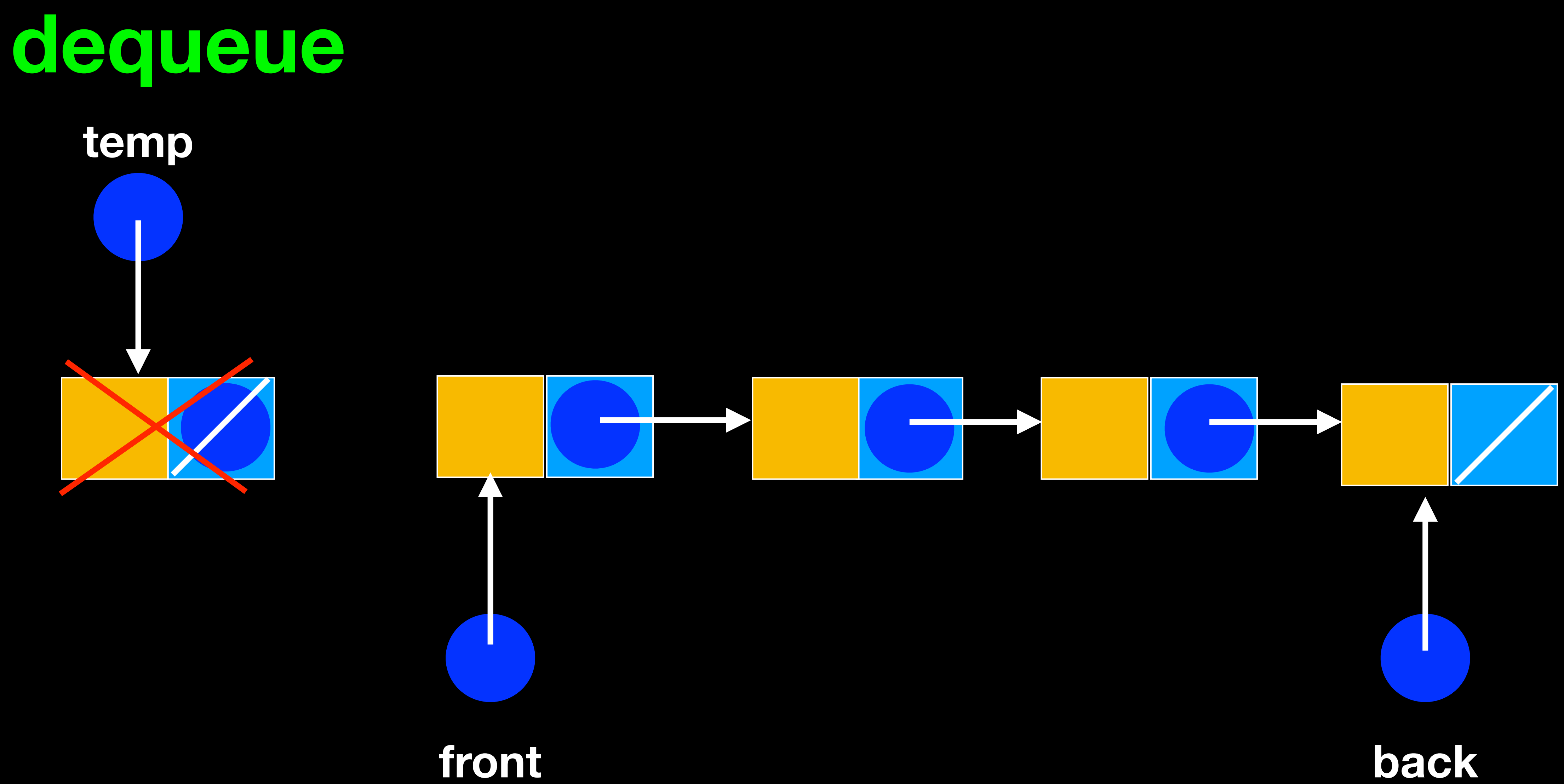
Singly Linked Chain



Singly Linked Chain

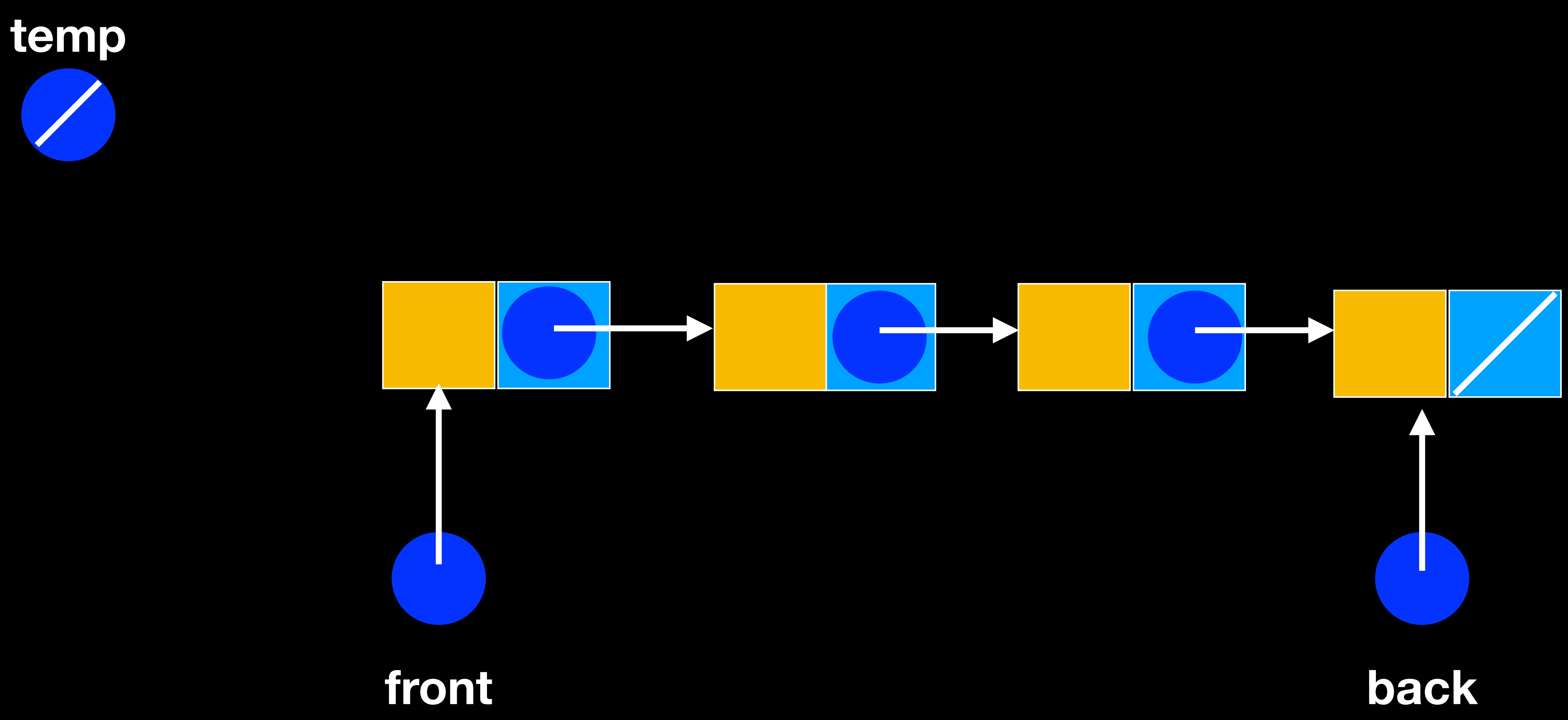


Singly Linked Chain



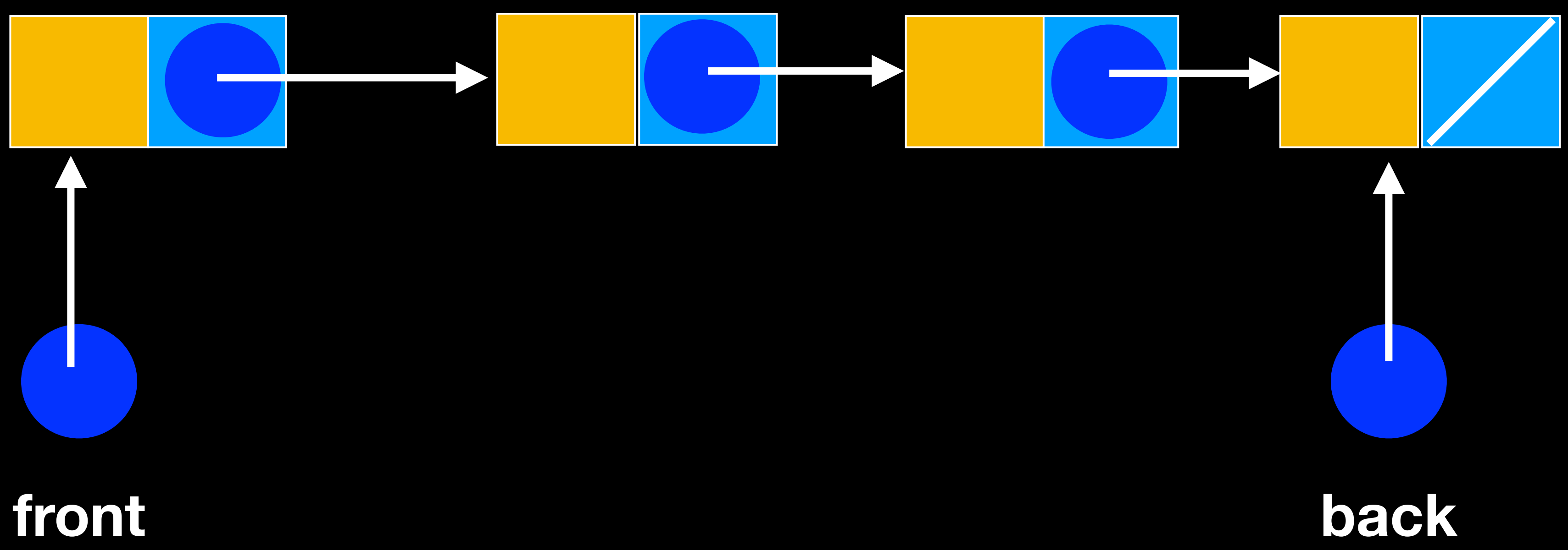
Singly Linked Chain

dequeue

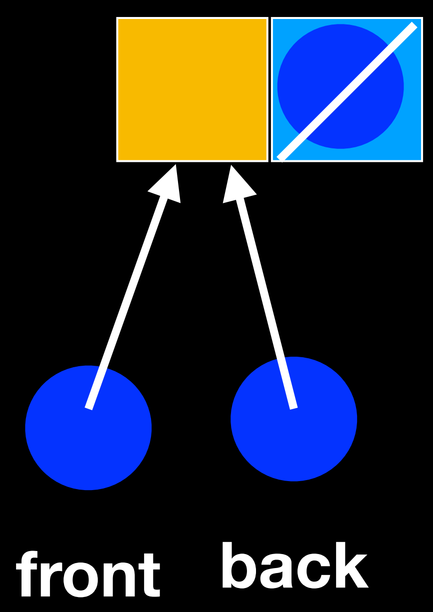


Singly Linked Chain

Front?



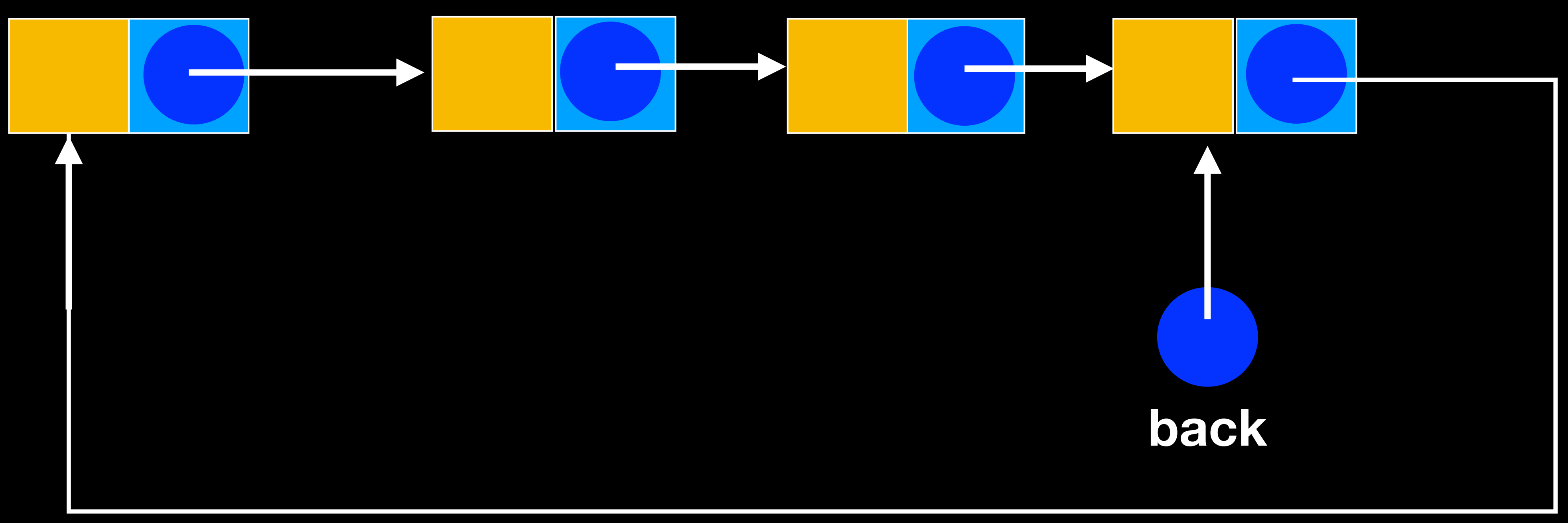
Singly Linked Chain



That’s it!

Singly Linked Chain

An Alternative:
A Circular Linked Chain

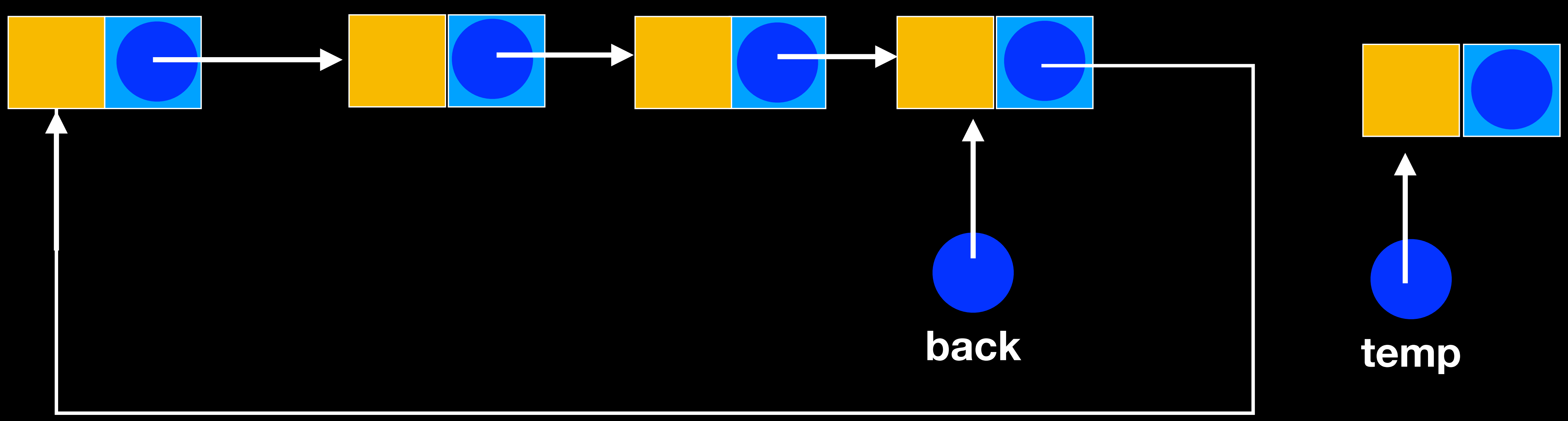


Singly Linked Chain

enqueue

An Alternative:
A Circular Linked Chain

Instantiate new node

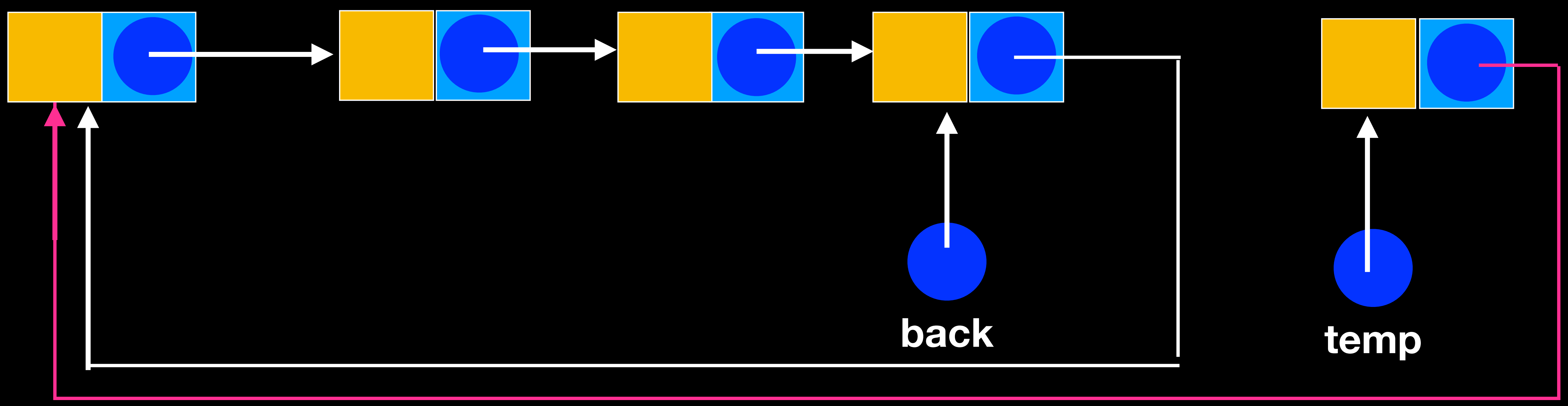


Singly Linked Chain

enqueue

An Alternative:
A Circular Linked Chain

```
temp->setNext(back->getNext());
```

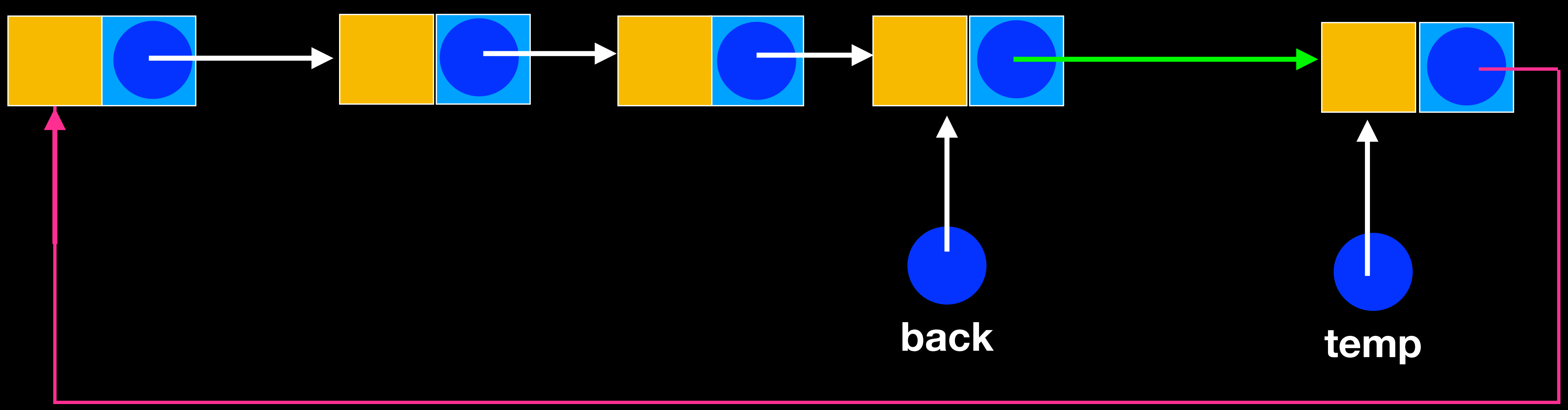


Singly Linked Chain

enqueue

An Alternative:
A Circular Linked Chain

```
back->setNext(temp);
```

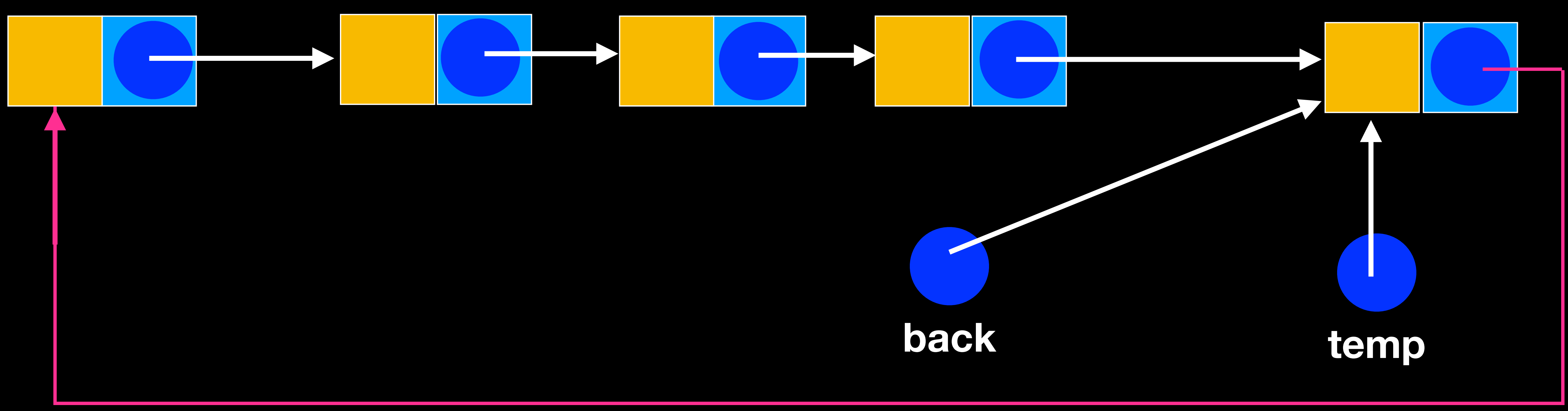


Singly Linked Chain

enqueue

An Alternative:
A Circular Linked Chain

```
back = temp;
```

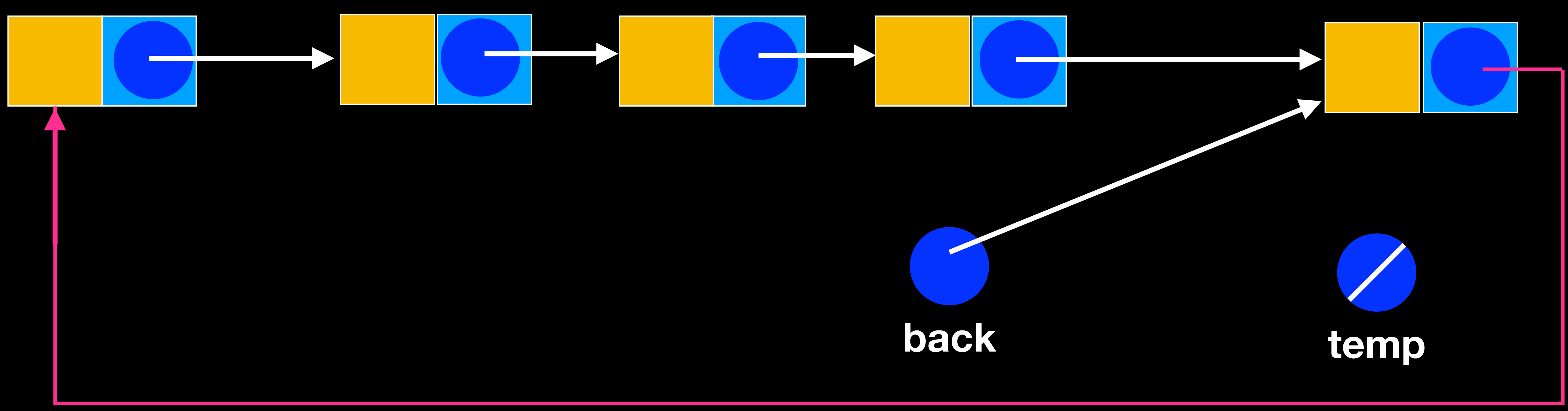


Singly Linked Chain

enqueue

An Alternative:
A Circular Linked Chain

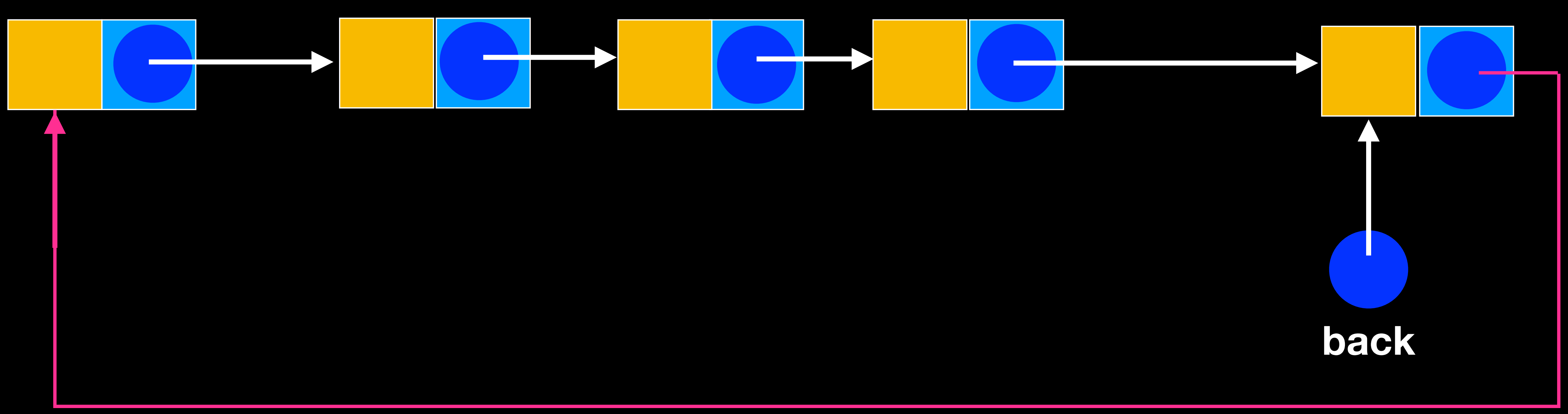
```
temp = nullptr;
```



Singly Linked Chain

enqueue

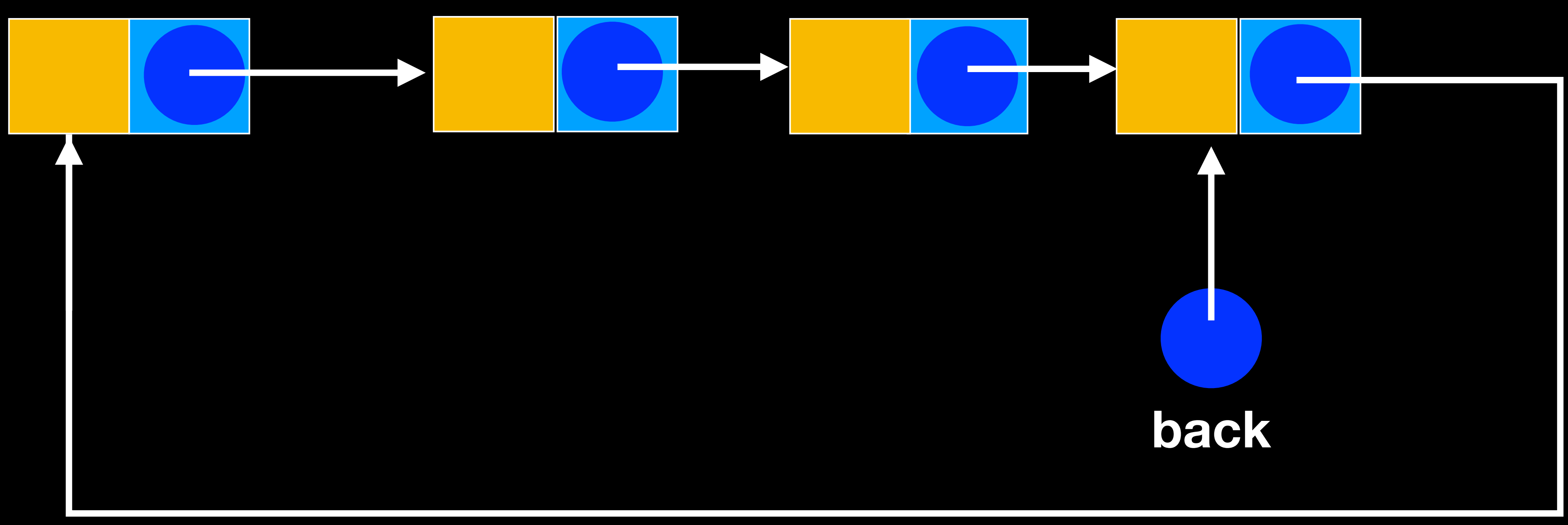
An Alternative:
A Circular Linked Chain



Singly Linked Chain

dequeue

An Alternative:
A Circular Linked Chain

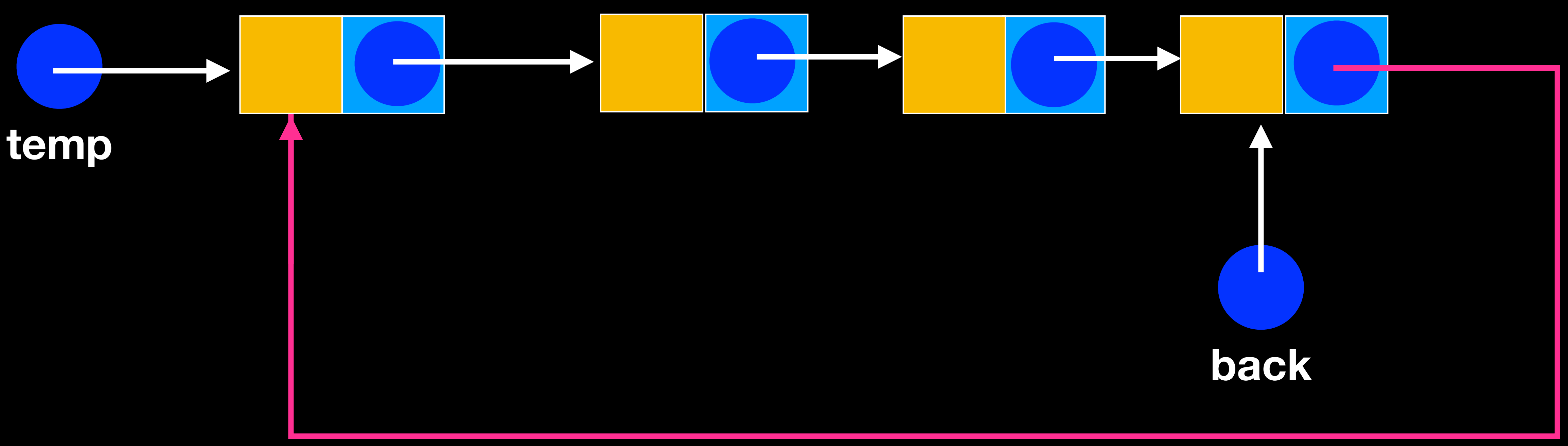


Singly Linked Chain

dequeue

An Alternative:
A Circular Linked Chain

```
temp = back->getNext()
```

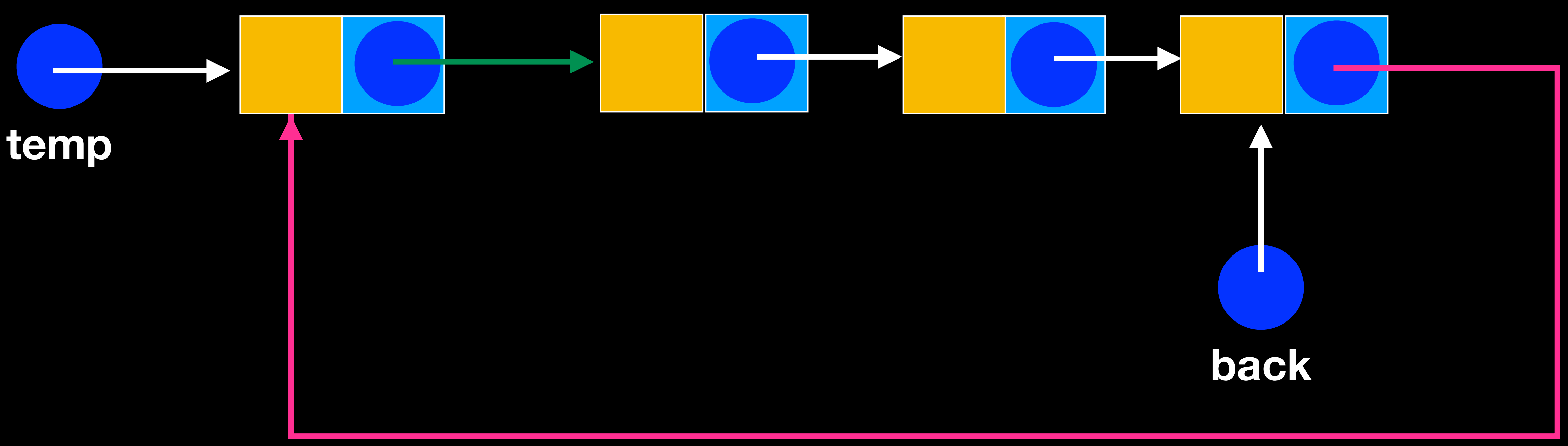


Singly Linked Chain

dequeue

An Alternative:
A Circular Linked Chain

```
back->setNext(back->getNext()->getNext())
```

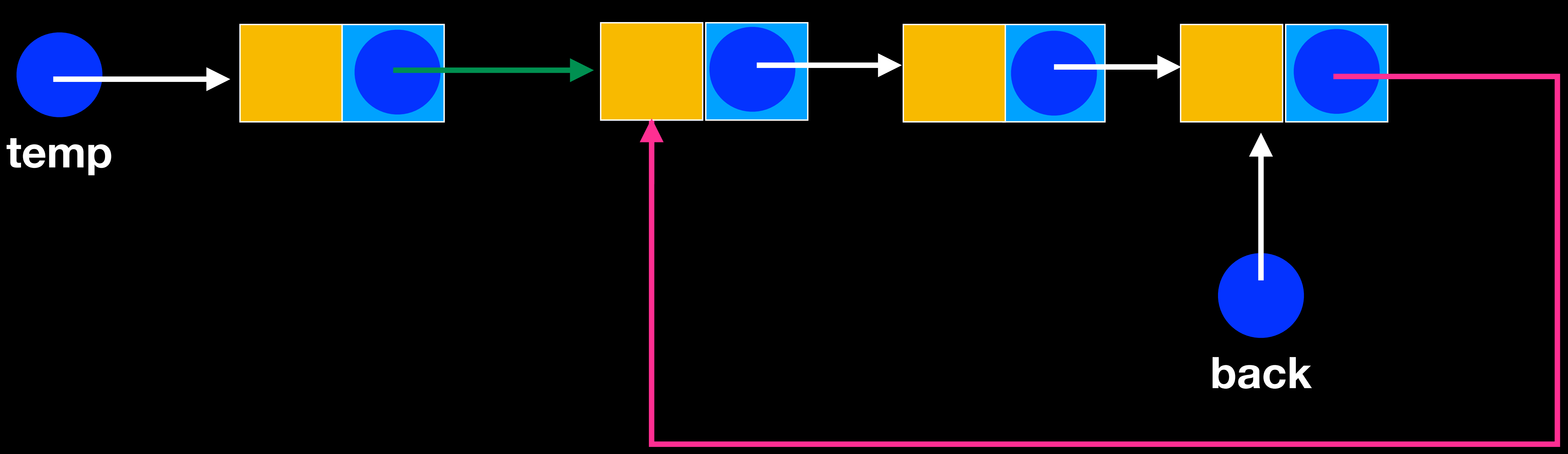


Singly Linked Chain

dequeue

An Alternative:
A Circular Linked Chain

```
back->setNext(back->getNext()->getNext())
```

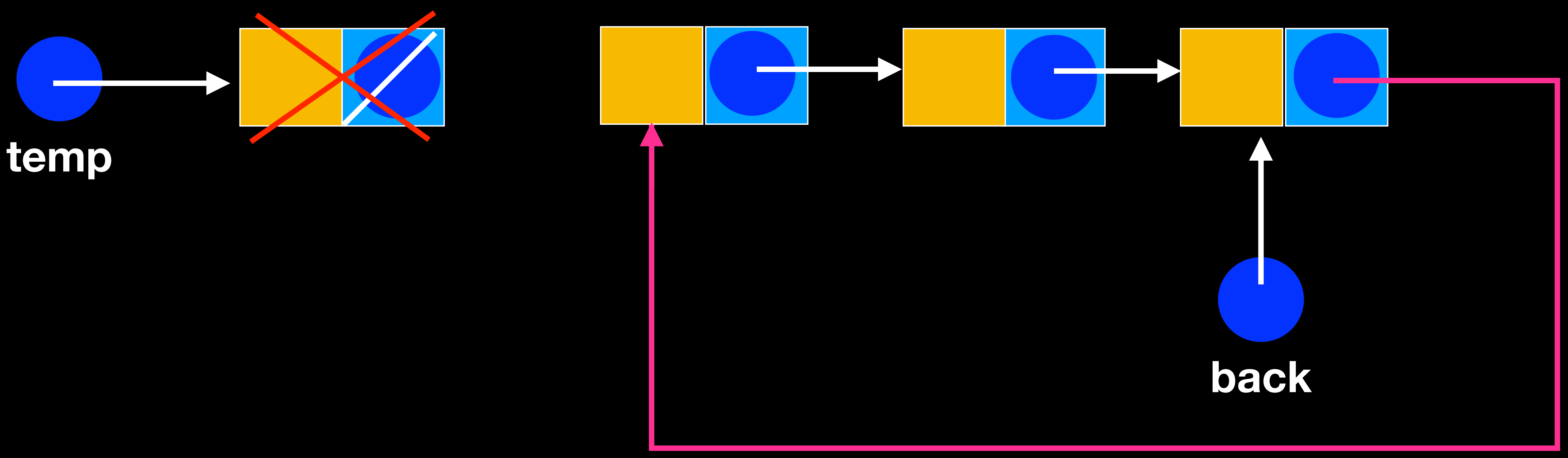


Singly Linked Chain

dequeue

An Alternative:
A Circular Linked Chain

```
temp->setNext(nullptr);
delete temp;
```

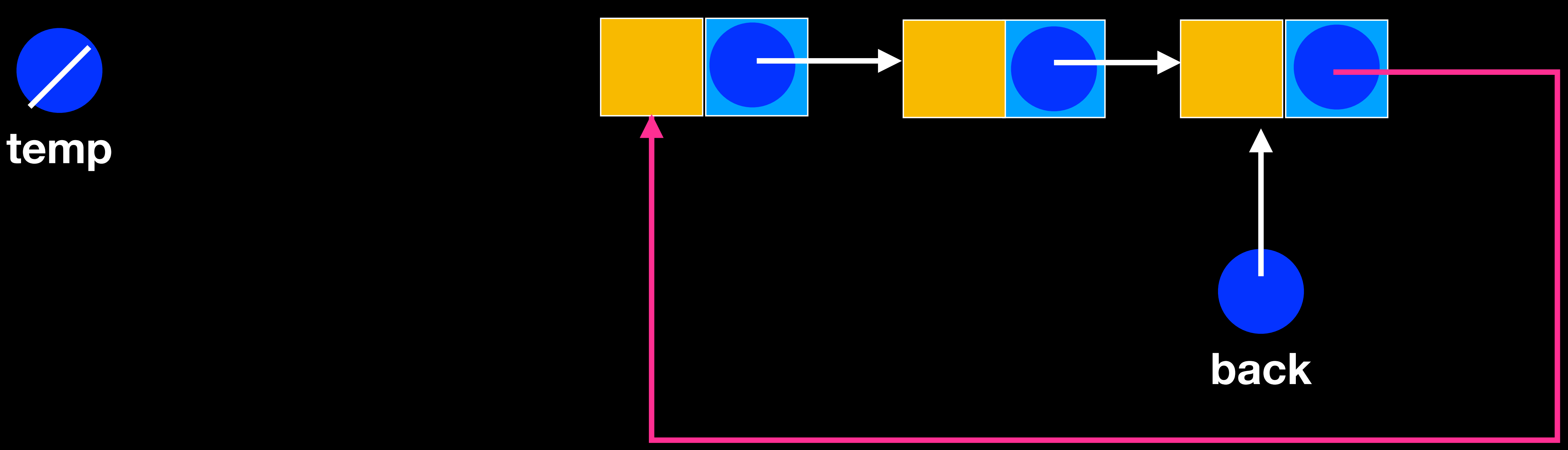


Singly Linked Chain

dequeue

An Alternative:
A Circular Linked Chain

`back->getNext()` **is the** `front` **pointer!**



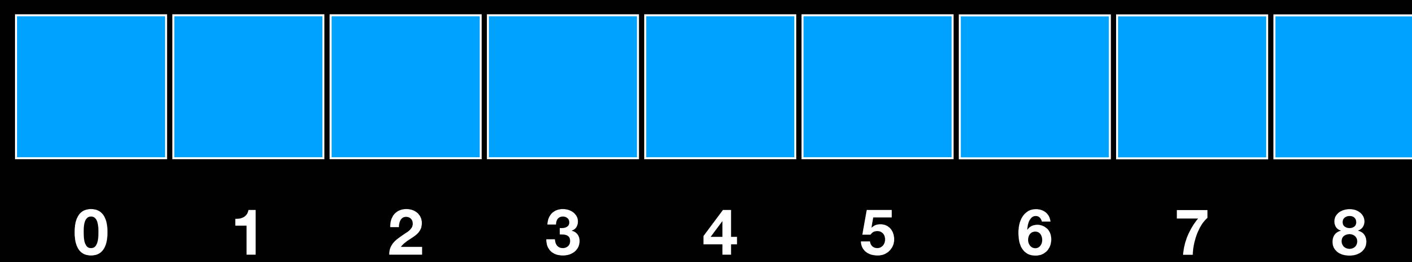
Queue ADT (Circular Linked Chain)

```
#ifndef QUEUE_H_
#define QUEUE_H_

template<typename ItemType>
class Queue
{
public:
    Queue();
    Queue(const Queue<T>& a_queue); // Copy constructor
    ~Queue();
    void enqueue(const ItemType& new_entry); //adds an element to back
    void dequeue(); // removes element from front of queue
    ItemType front() const; // returns a copy of the front element
    int size() const; // returns the number of elements in the queue
    bool isEmpty() const; // returns true if no elements in queue

private:
    Node<ItemType>* back_; // Pointer to back of queue
    int item_count;
}; //end Queue

#include "Queue.cpp"
#endif // QUEUE_H_ `
```

How would you implement it using an array?
enqueue and dequeue in O(1)

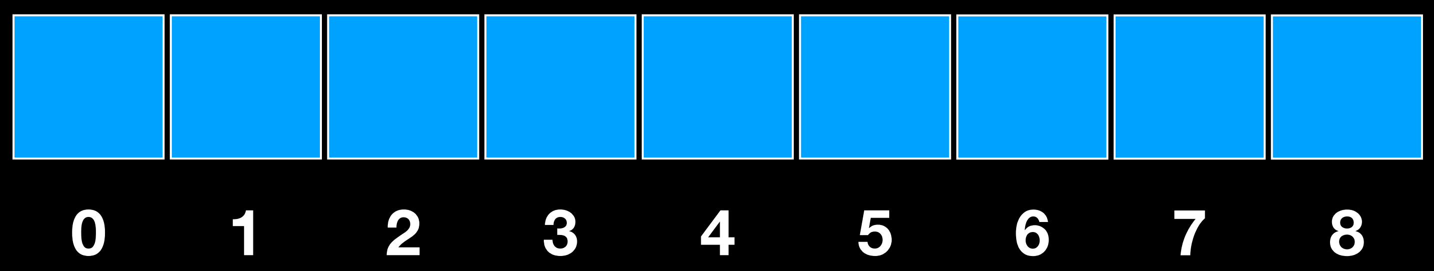
Array Considerations

```
front = ?
back =  ?
```



Array Considerations

```
front = 0
back = -1
```



Array Considerations

enqueue

Increment `back` and add element to `items_[back]`

```
front = 0
back = -1
```

0	1	2	3	4	5	6	7	8

Array Considerations

enqueue

Increment `back` and add element to `items_[back]`

`front = 0`

`back = 0`

15								
0	1	2	3	4	5	6	7	8

Array Considerations

enqueue

Increment `back` and add element to `items_[back]`

```
front = 0
back = 1
```

15	3							
0	1	2	3	4	5	6	7	8

Array Considerations

enqueue

Increment `back` and add element to `items_[back]`

```
front = 0
back = 2
```

15	3	45						
0	1	2	3	4	5	6	7	8

Array Considerations

enqueue

Increment `back` and add element to `items_[back]`

`front = 0`

`back = 5`

0	1	2	3	4	5	6	7	8
15	3	45	13	75	84			

This seems to work, but what happens when we start dequeuing?

Array Considerations

dequeue

Increment `front`

`front = 1`

`back = 5`

15	3	45	13	75	84			
0	1	2	3	4	5	6	7	8

We want $O(1)$ operations, so simply increment front!

Array Considerations

dequeue

Increment `front`

`front = 2`
`back = 5`

15	3	45	13	75	84			
0	1	2	3	4	5	6	7	8

Array Considerations

`front = 6`
`back = 8`

15	3	45	13	75	84	55	38	97
0	1	2	3	4	5	6	7	8

RIGHTWARD DRIFT!!!
At some point queue will be full even if it contains only a few elements

Array Considerations

`front = 3`
`back = 5`

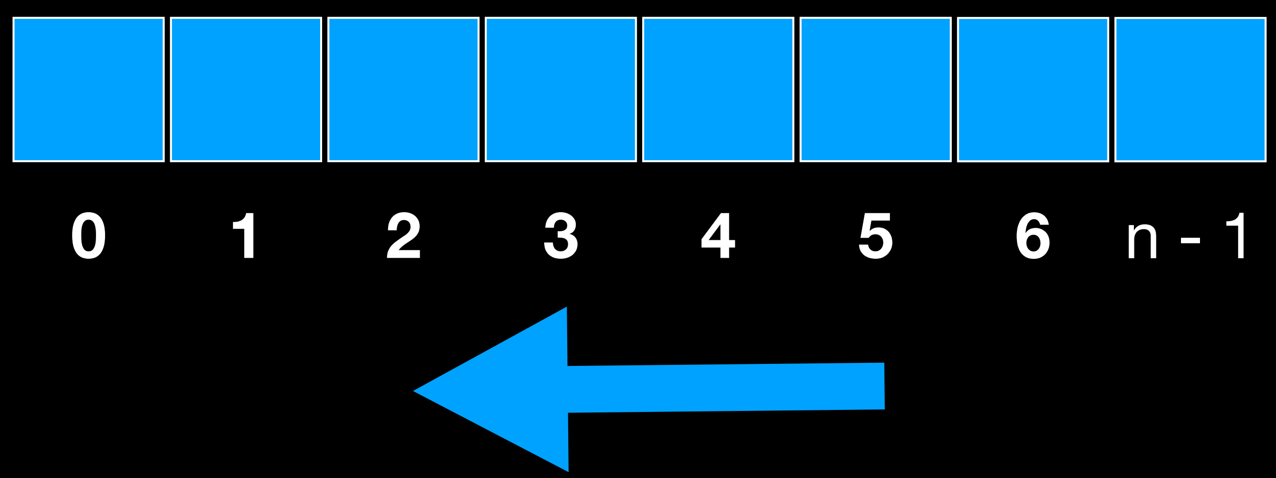
0	1	2	3	4	5	6	7	8
15	3	45	13	75	84	55	38	97

RIGHTWARD DRIFT!!!
At some point queue will be full even if it contains only a few elements

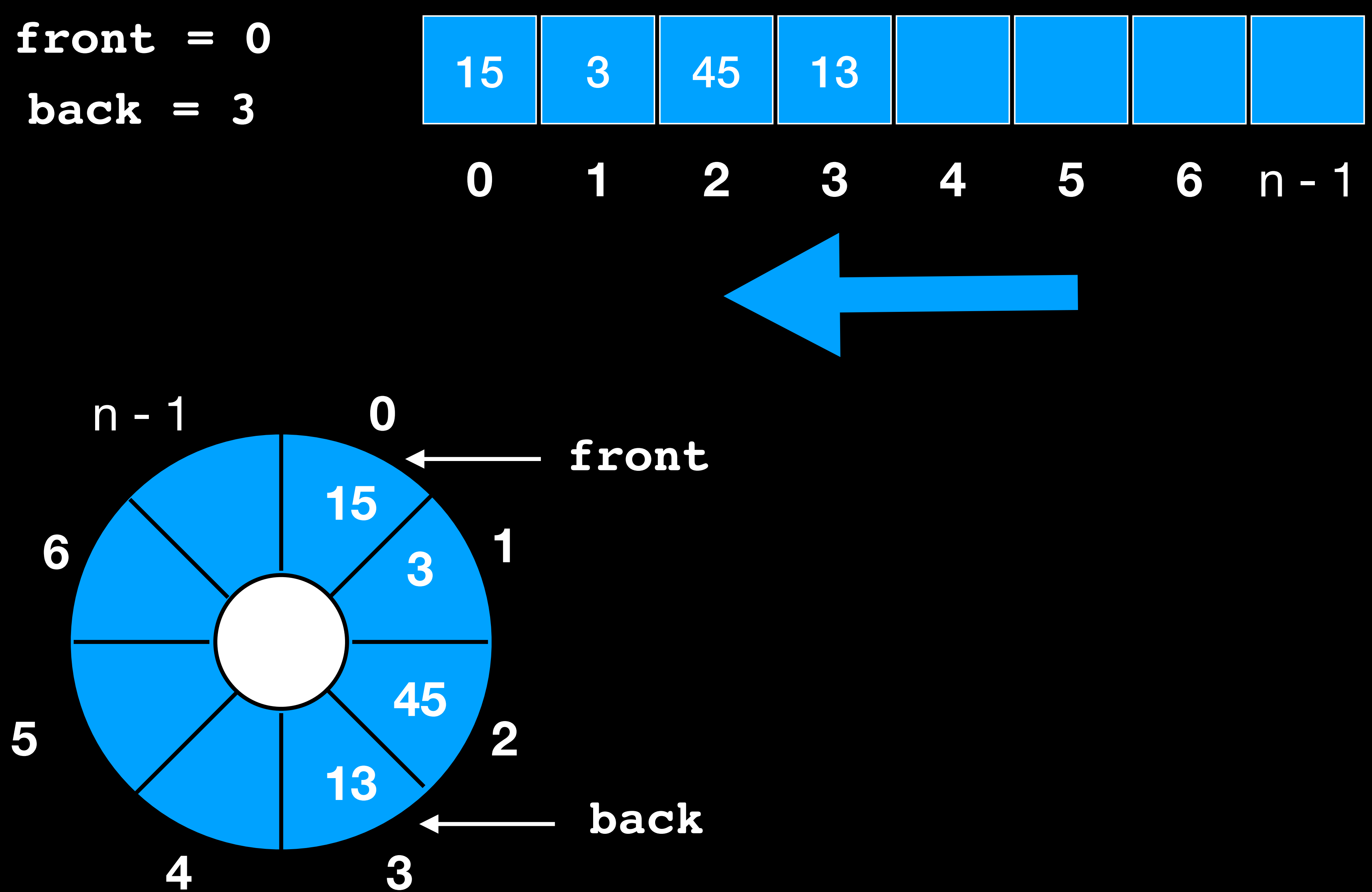
No Good

Circular Array Implementation

`front = 0`
`back = -1`

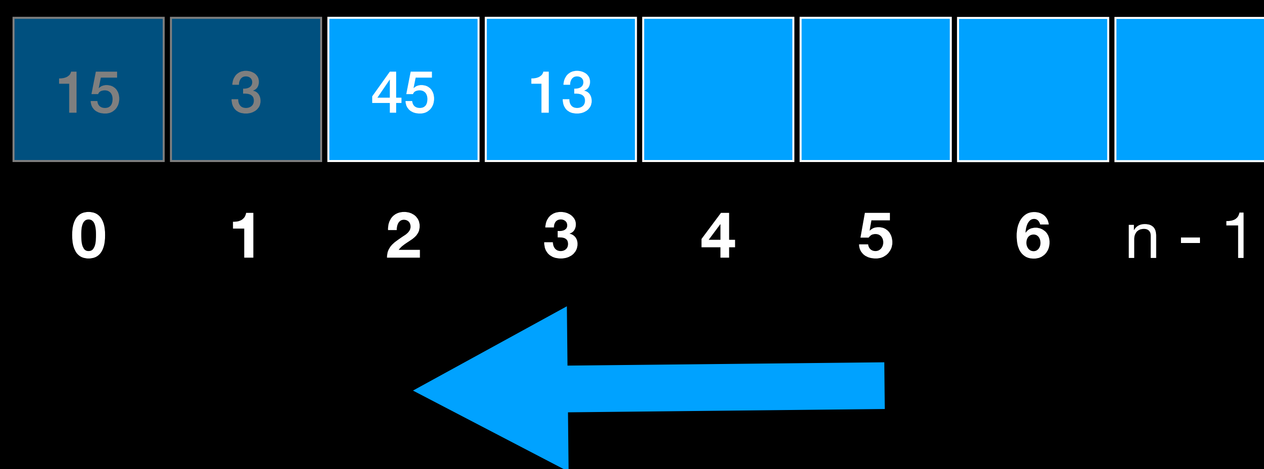


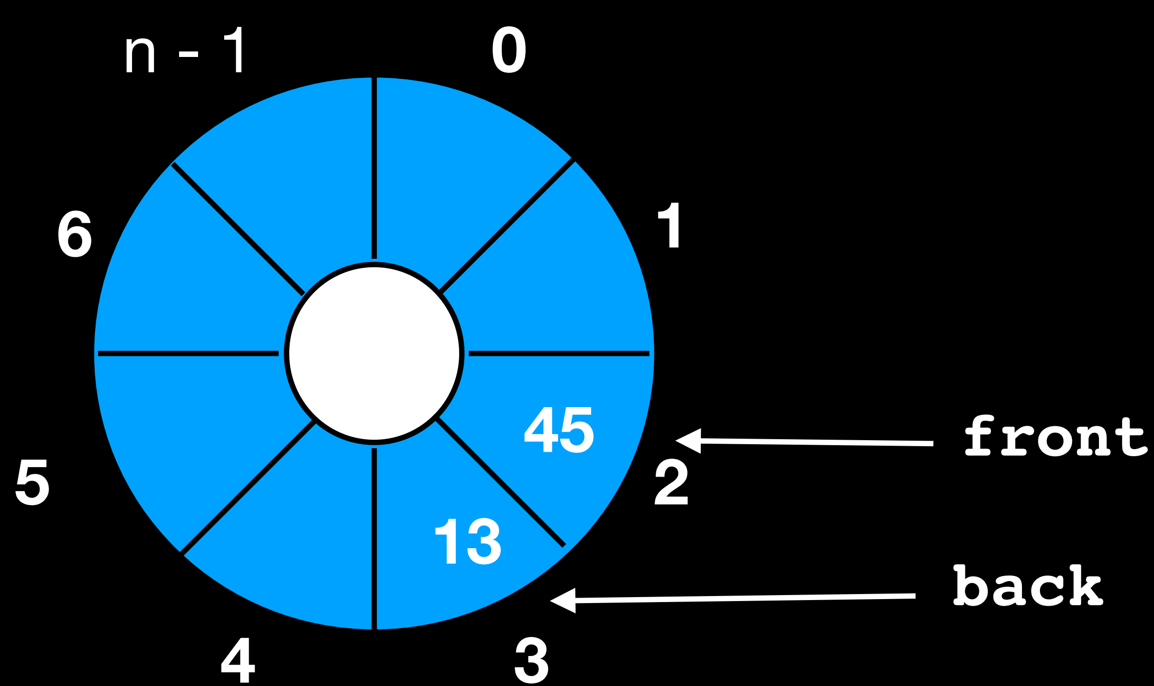
Circular Array Implementation



Circular Array Implementation

```
front = 2
back = 3
```

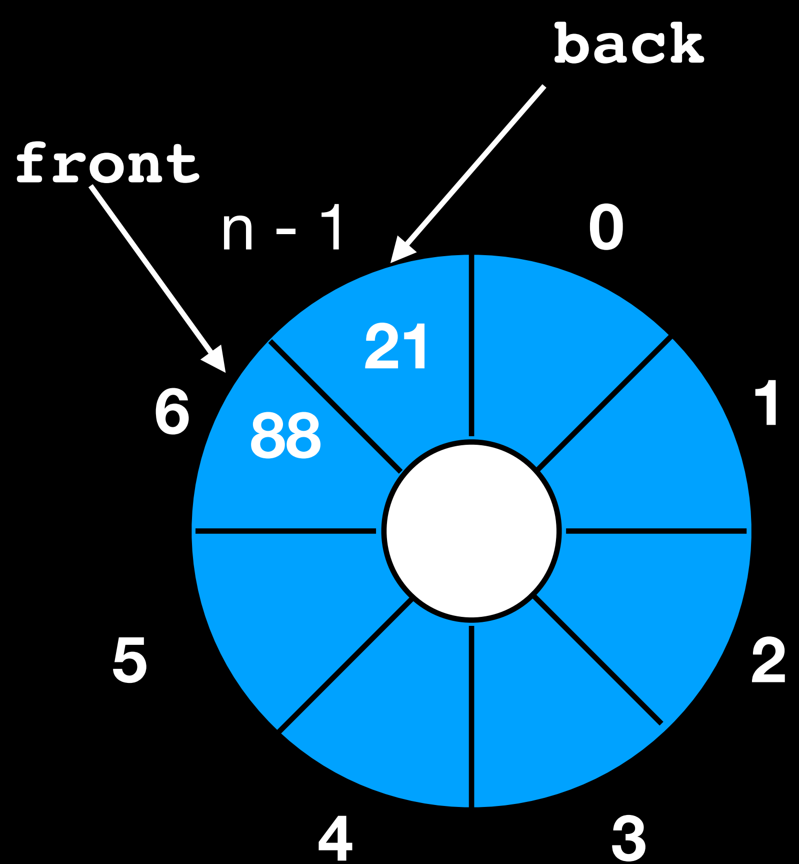




Circular Array Implementation

```
front = 6
back = n - 1
```

15	3	45	13	75	59	88	21
0	1	2	3	4	5	6	n - 1

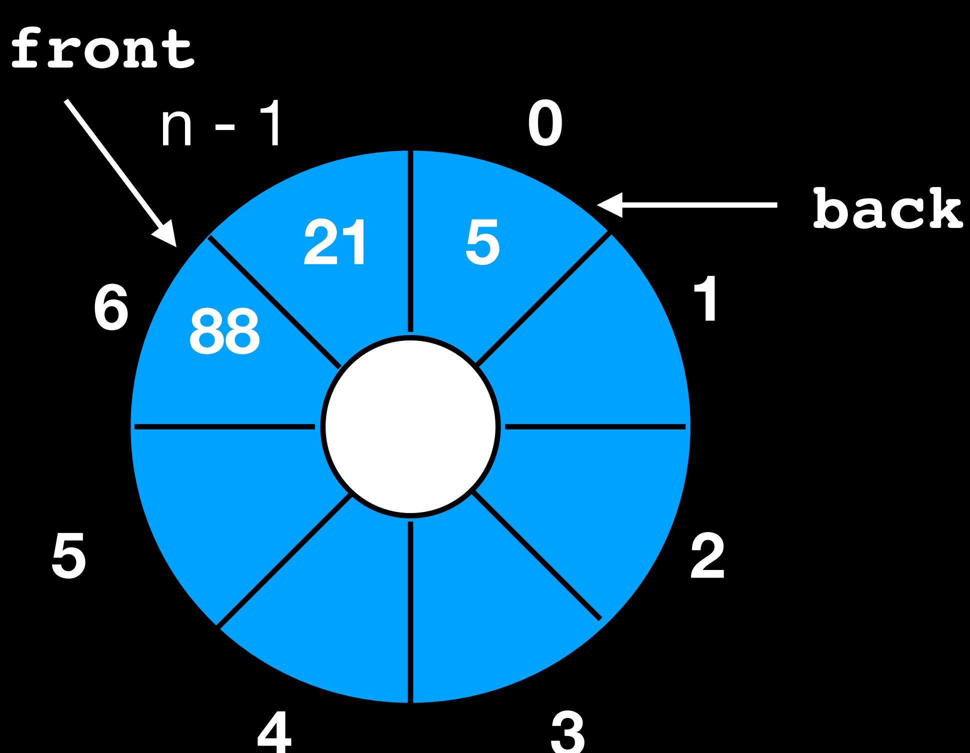


Circular Array Implementation

front = 6

back = 0

5	3	45	13	75	59	88	21
0	1	2	3	4	5	6	n - 1



WRAP AROUND USING MODULO ARITHMETIC

Circular Array Implementation

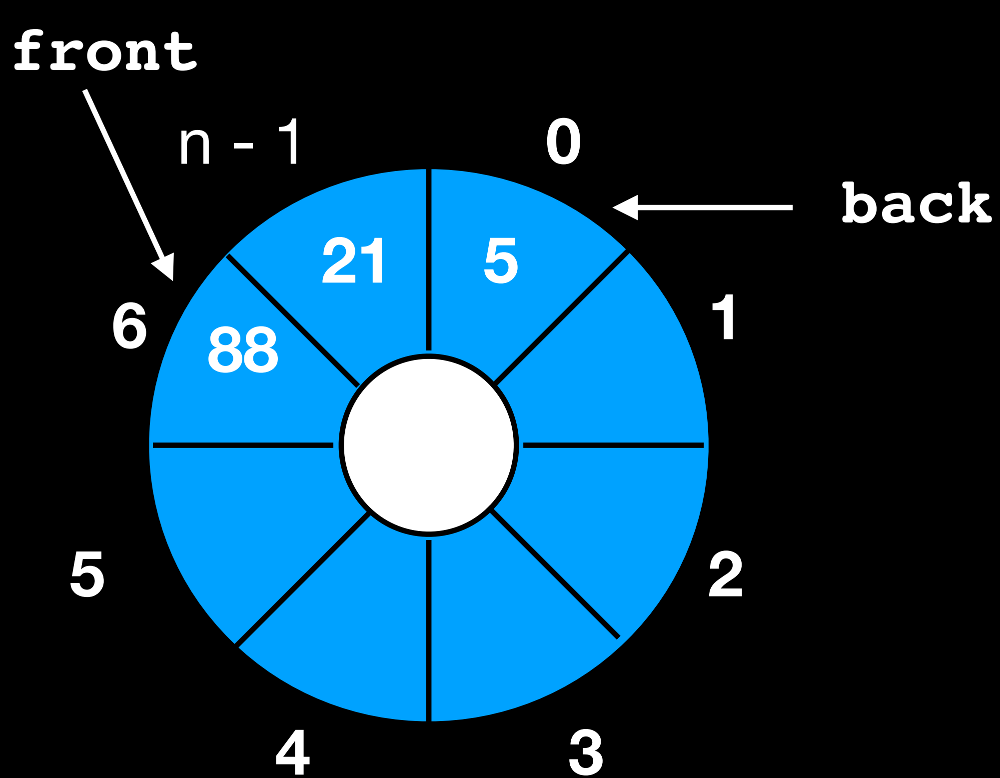
enqueue

```
back = (back + 1) % n
add element to items_[back]
```

`front = 6`

`back = 0`

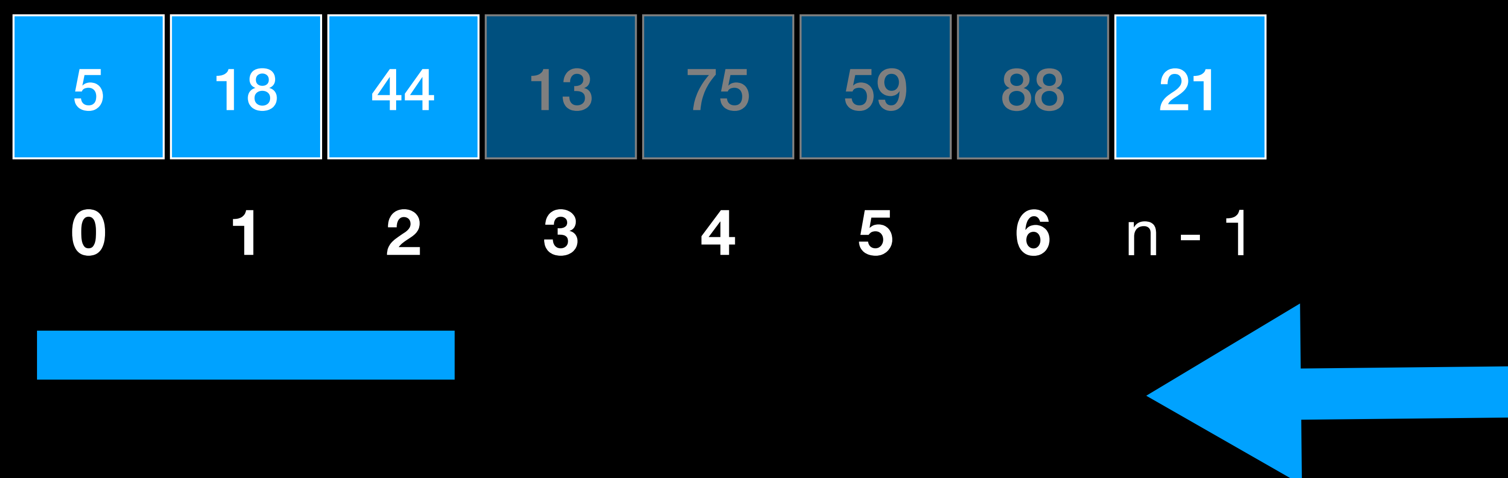
5	3	45	13	75	59	88	21
0	1	2	3	4	5	6	n - 1

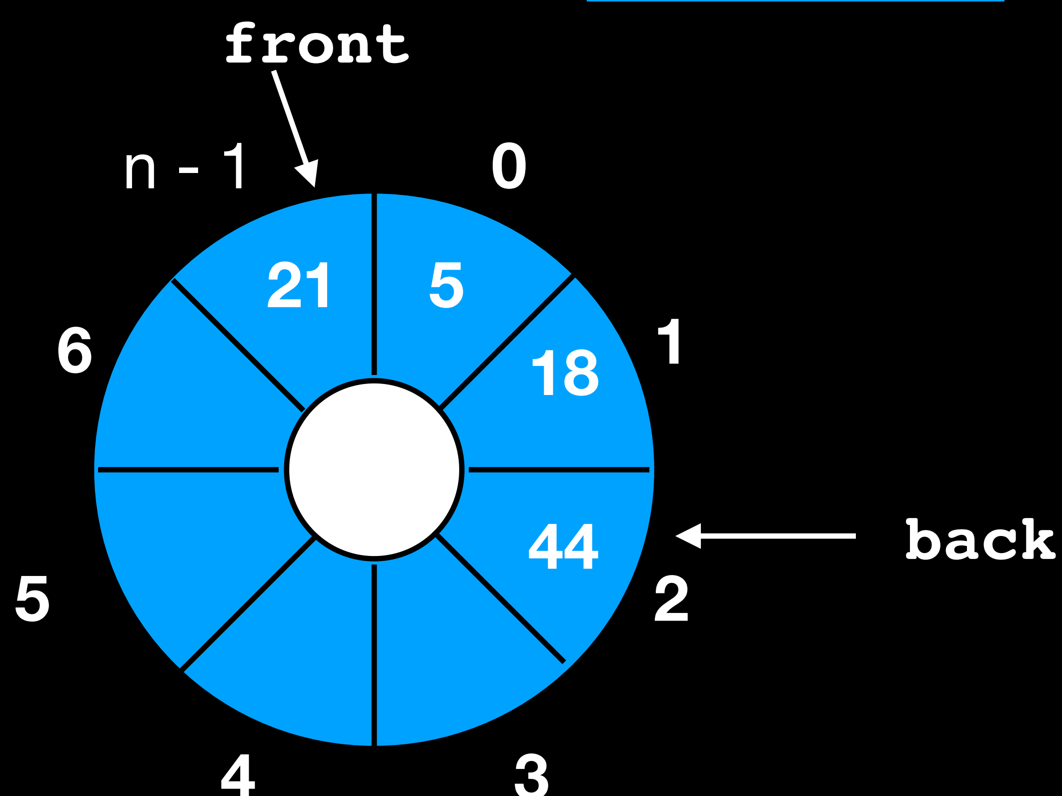


Circular Array Implementation

front = n-1

back = 2

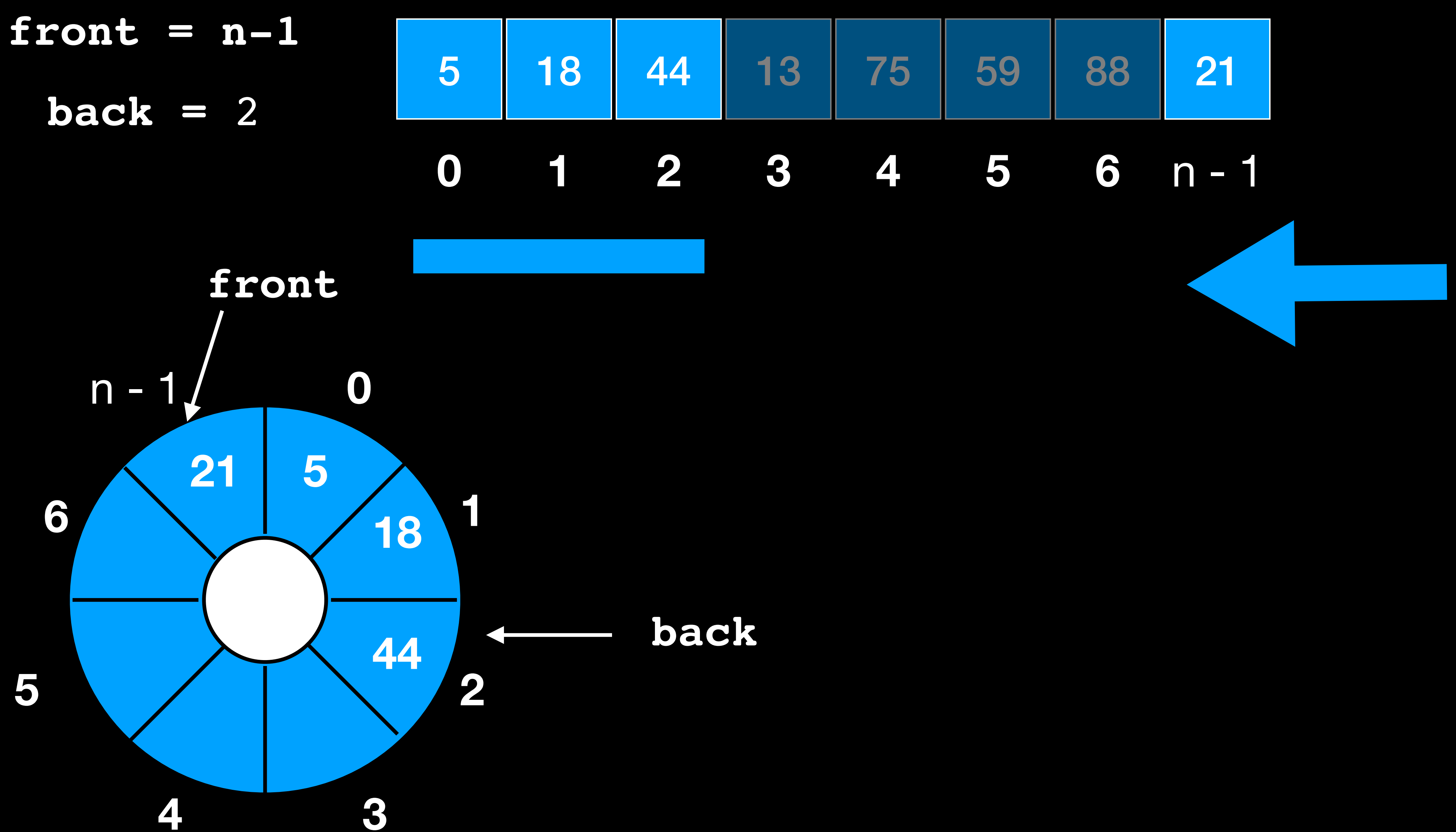




Circular Array Implementation

dequeue

```
front = (front + 1) % n
```



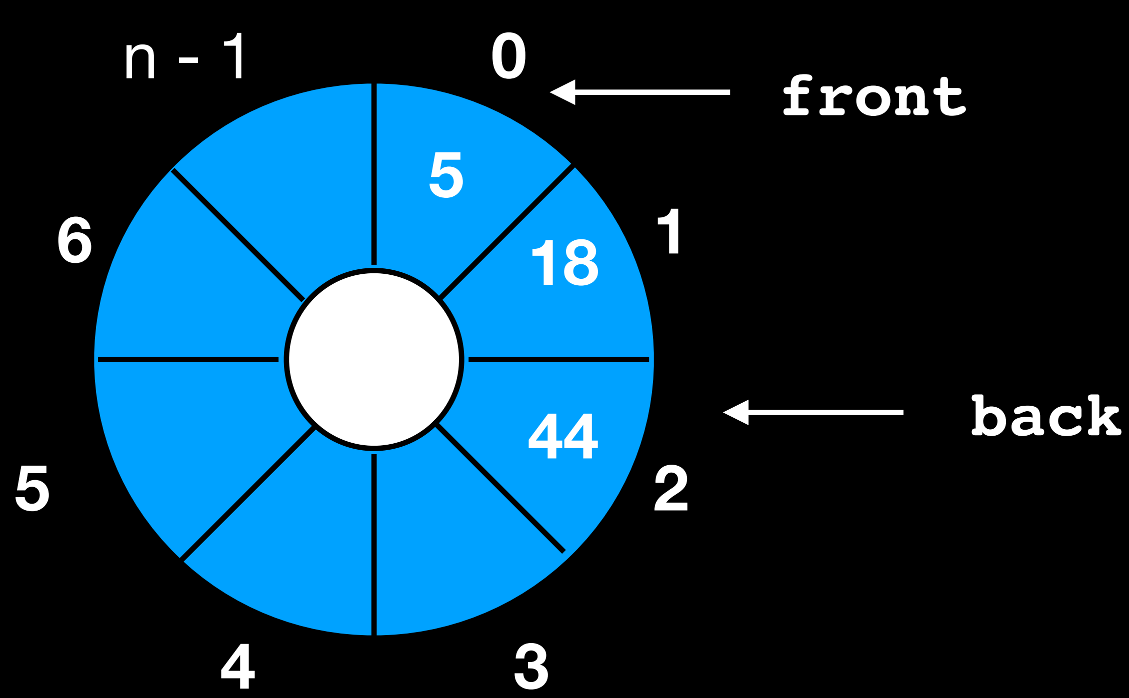
Circular Array Implementation

dequeue

```
front = (front + 1) % n
```

```
front = 0
back = 2
```

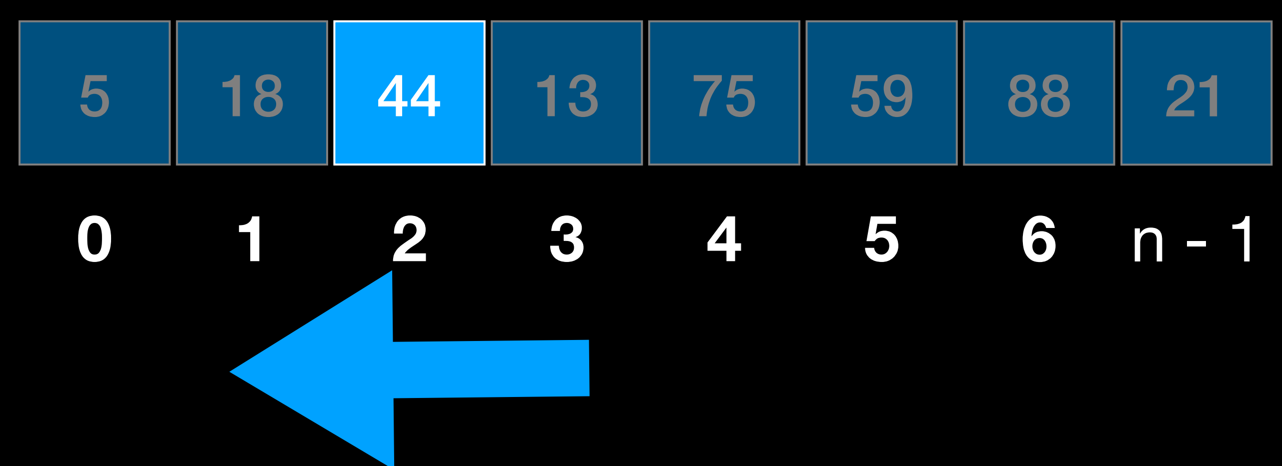
5	18	44	13	75	59	88	21
0	1	2	3	4	5	6	n - 1

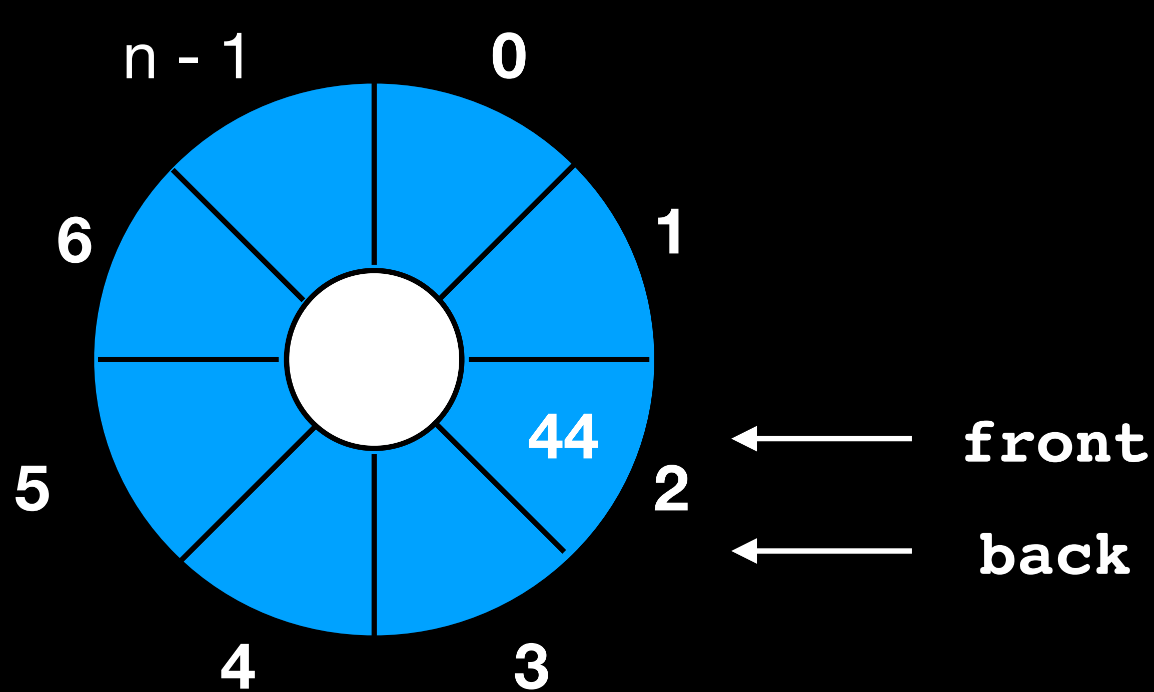


Circular Array Implementation

`front = 2`

`back = 2`





Circular Array Implementation

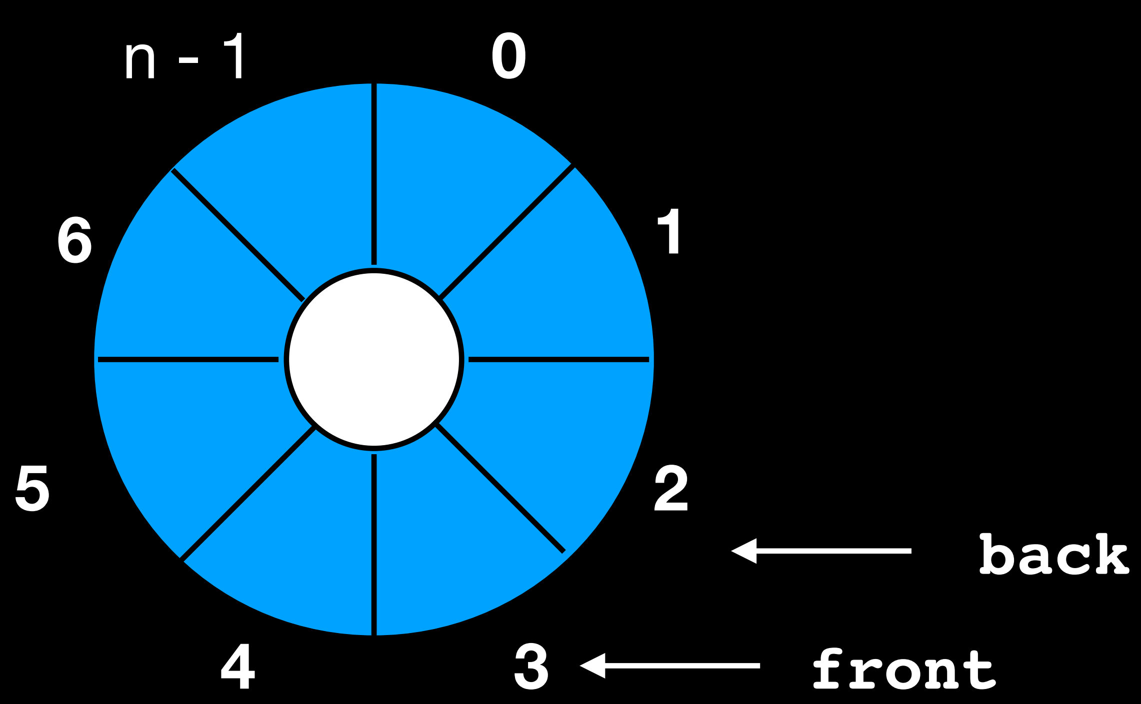
dequeue

```
front = (front + 1) % n
```

front = 3

back = 2

0	1	2	3	4	5	6	n - 1
5	18	44	13	75	59	88	21



`front` passes `back` when queue is EMPTY

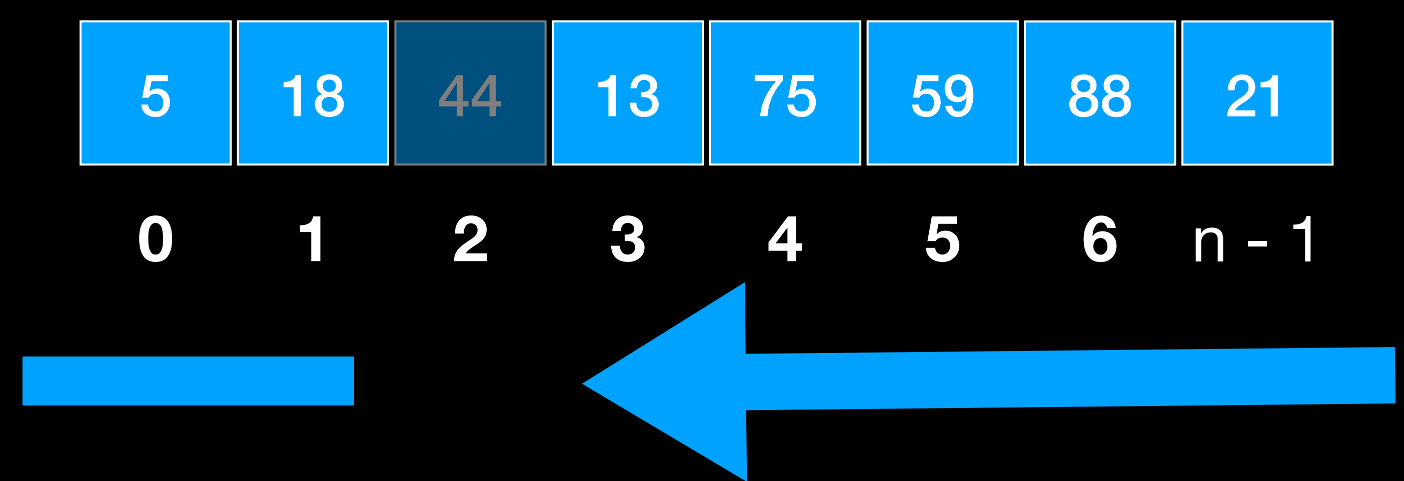
Circular Array Implementation

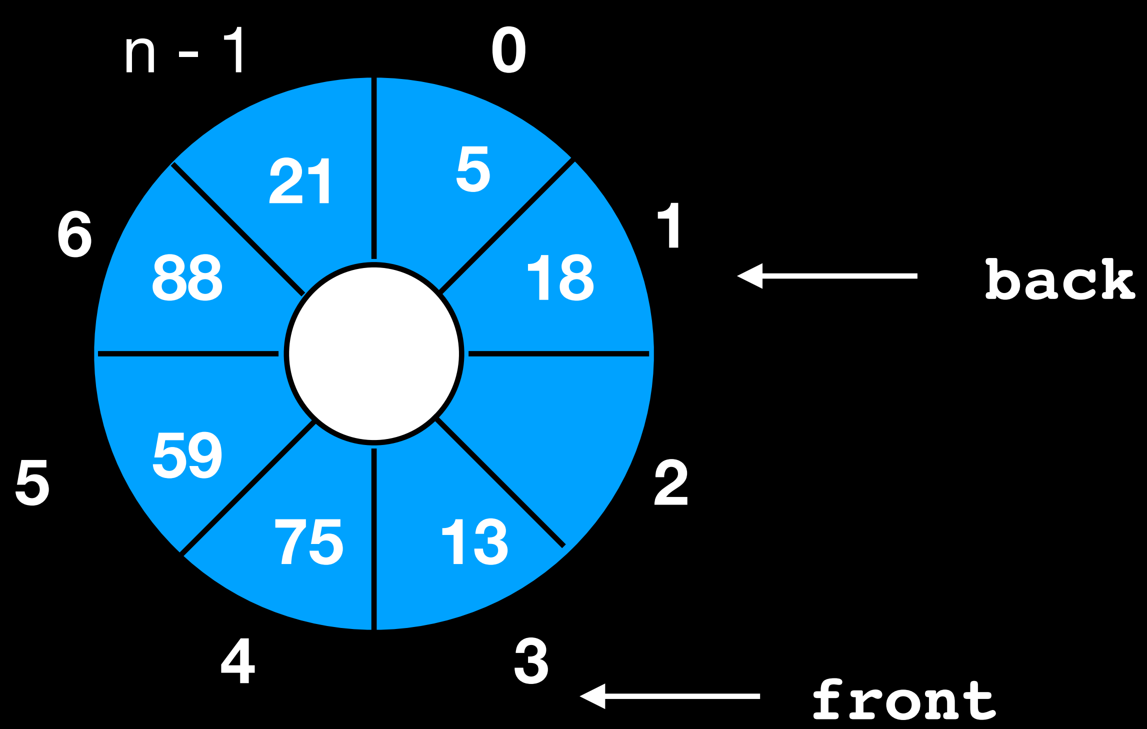
enqueue

```
back = (back + 1) % n
add element to items_[back]
```

`front = 3`

`back = 1`





Circular Array Implementation

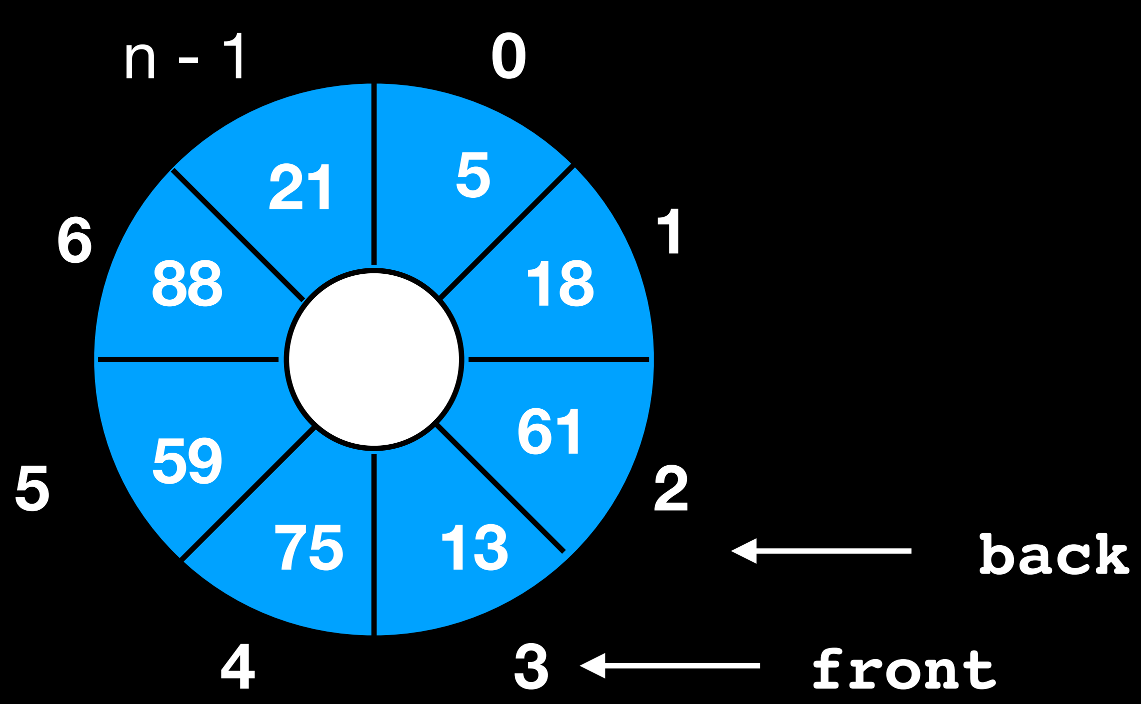
enqueue

`back = (back + 1) % n`
add element to `items_[back]`

`front = 3`

`back = 2`

5	18	61	13	75	59	88	21
0	**1**	**2**	**3**	**4**	**5**	**6**	n - 1



`front` **passes** `back` **ALSO when queue is FULL**

Circular Array Implementation

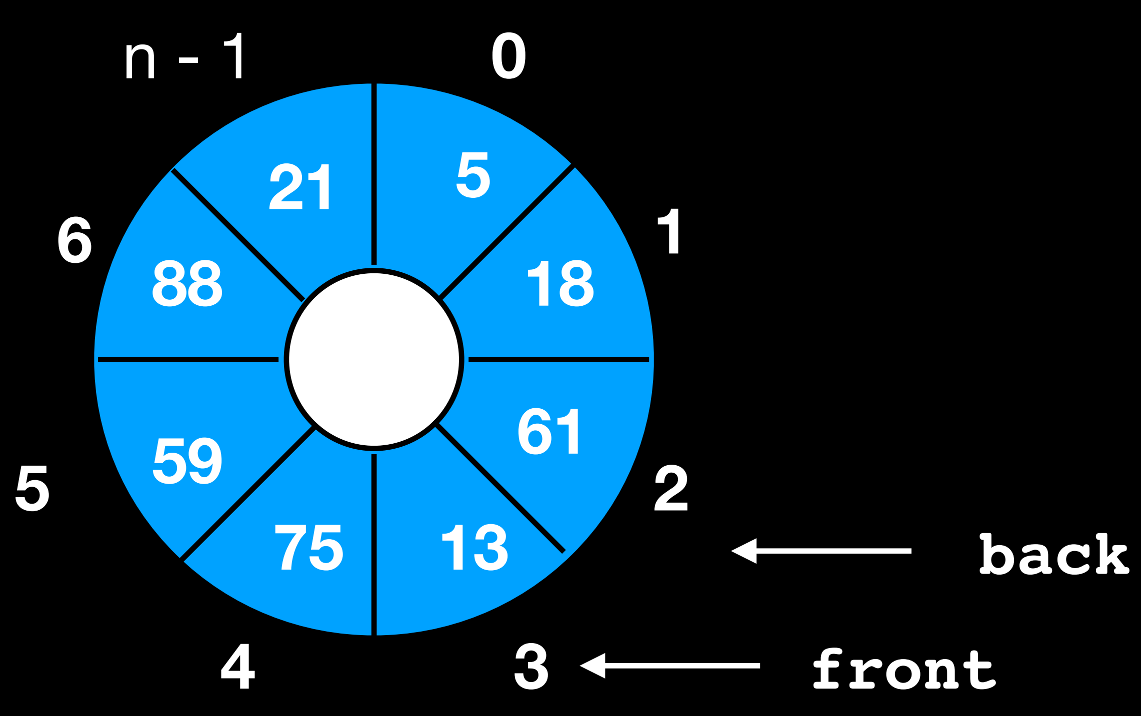
enqueue

`back = (back + 1) % n`
add element to `items_[back]`

`front = 3`

`back = 2`

5	18	61	13	75	59	88	21
0	1	2	3	4	5	6	n - 1



To distinguish between **empty** and **full** queue must keep a **COUNTER** for number of items

Queue ADT (Circular Array)

```
#ifndef QUEUE_H_
#define QUEUE_H_

template<typename ItemType>
class Queue
{
public:
    Queue();
    void enqueue(const ItemType& new_entry); //adds an element to back
    void dequeue(); // removes element from front of queue
    ItemType front() const; // returns a copy of the front element
    int size() const; // returns the number of elements in the queue
    bool isEmpty() const; // returns true if no elements in queue

private:
    static const int DEFAULT_SIZE = 100  // Max queue size
    ItemType items_[DEFAULT_SIZE];      // the queue
    int front_;                  // index of front of queue
    int back_;                // index of back of queue
    int item_count;              // number of items currently on the queue
};    //end Queue}; //end Queue

#include "Queue.cpp"
#endif // QUEUE_H_ `
```