Data Structures

Lists, Maps, and Sets

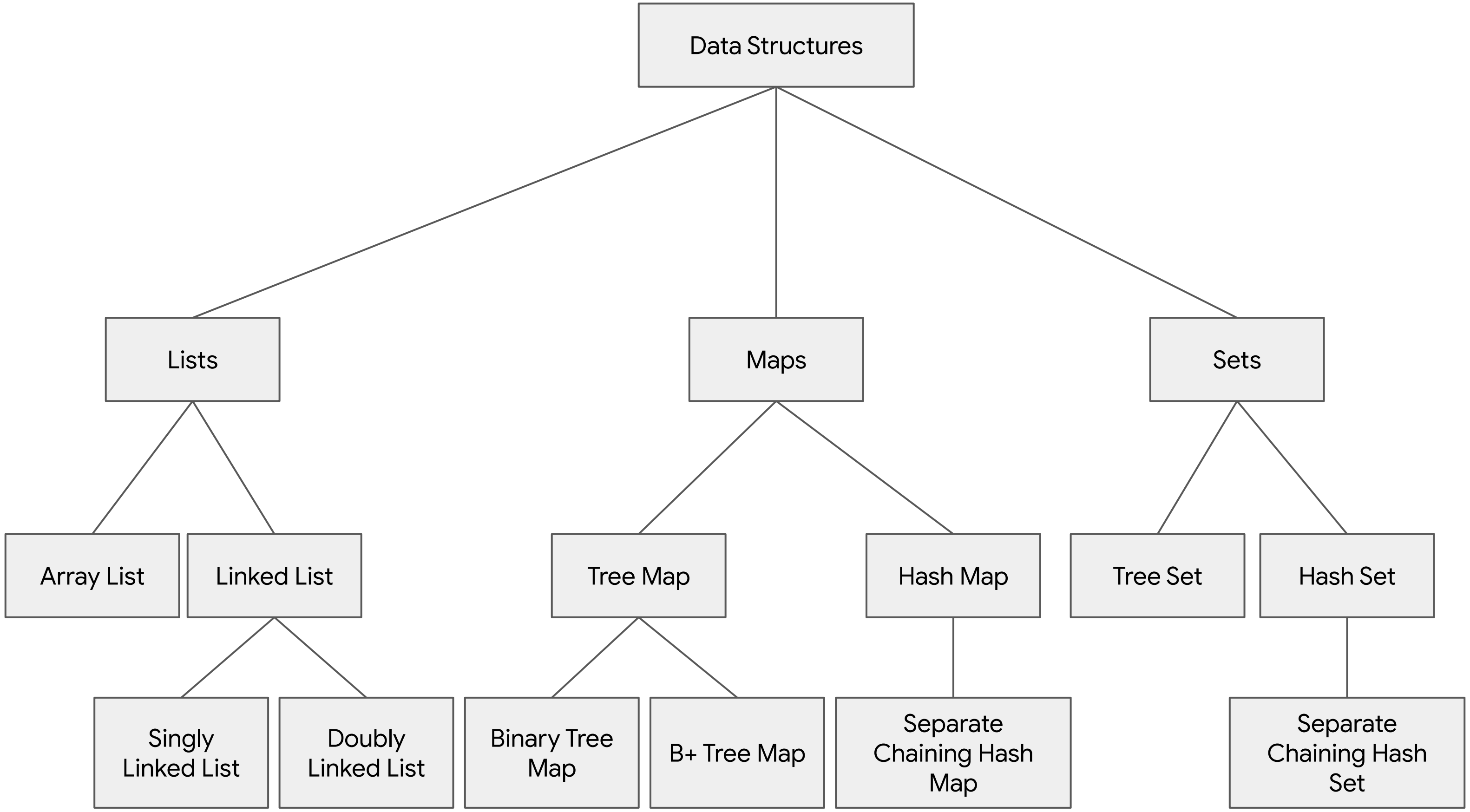
Objectives

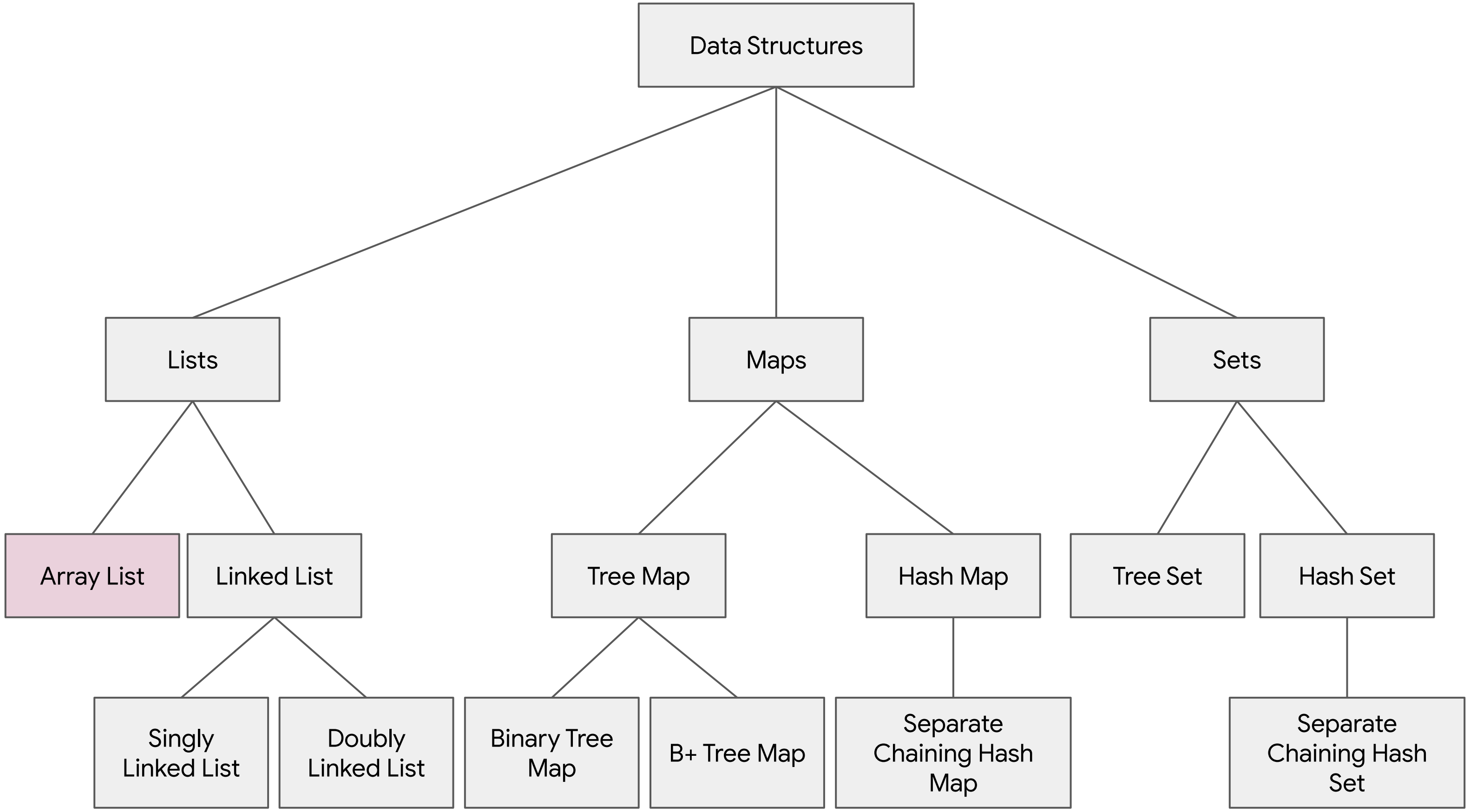
Primary Objectives

- What is a **list** and when could I use it?
- What is a **set** and when could I use it?
- What is a **map** and when could I use it?

Secondary Objectives

- What trade-offs am I making when I use a **list**?
- What trade-offs am I making when I use a **set**?
- What trade-offs am I making when I use a **map**?


Data Structures
Lists
Maps
Sets
Array List
Linked List
Tree Map
Hash Map
Tree Set
Hash Set
Singly Linked List
Doubly Linked List
Binary Tree Map
B+ Tree Map
Separate Chaining Hash Map
Separate Chaining Hash Set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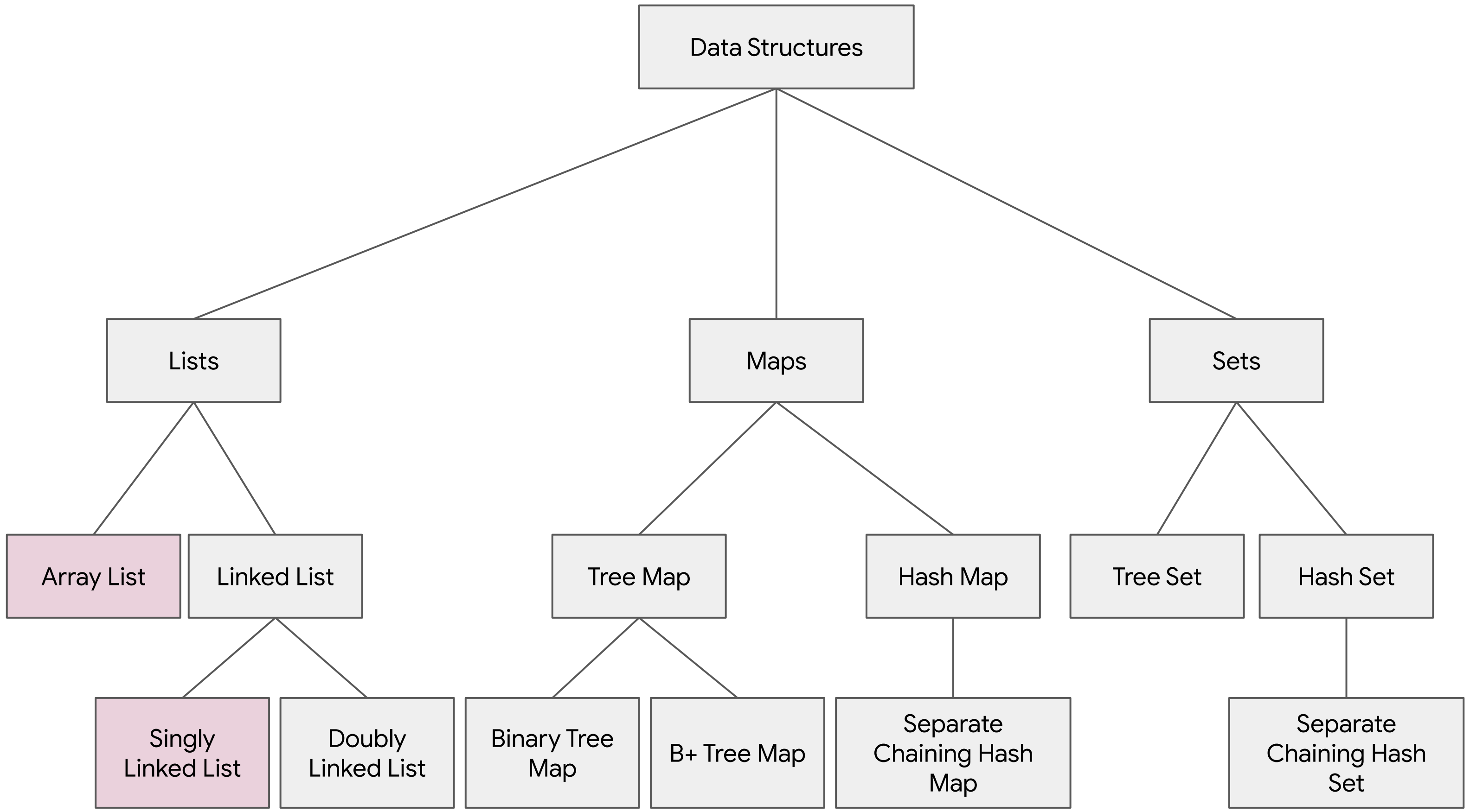
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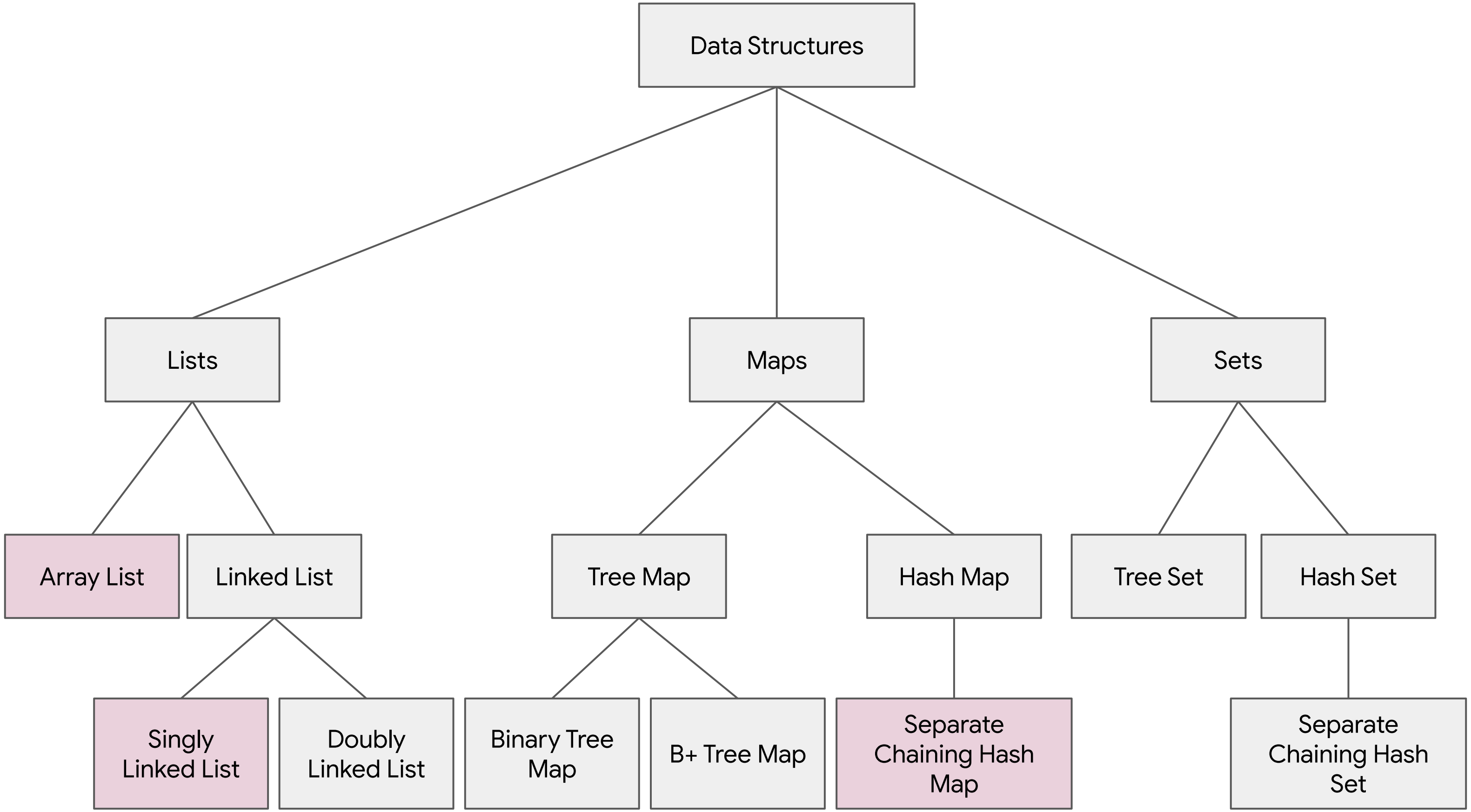
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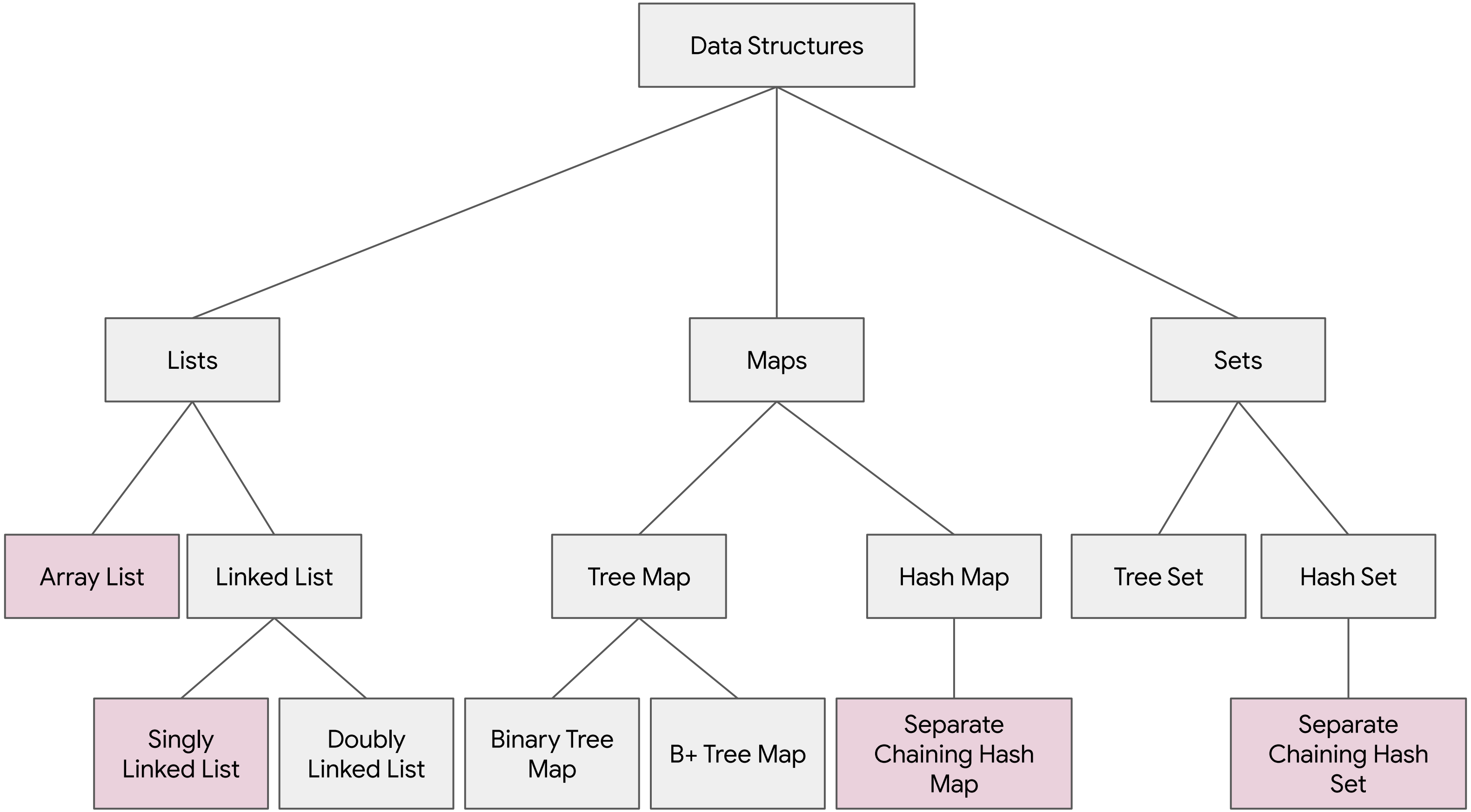
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Lists

Characteristics

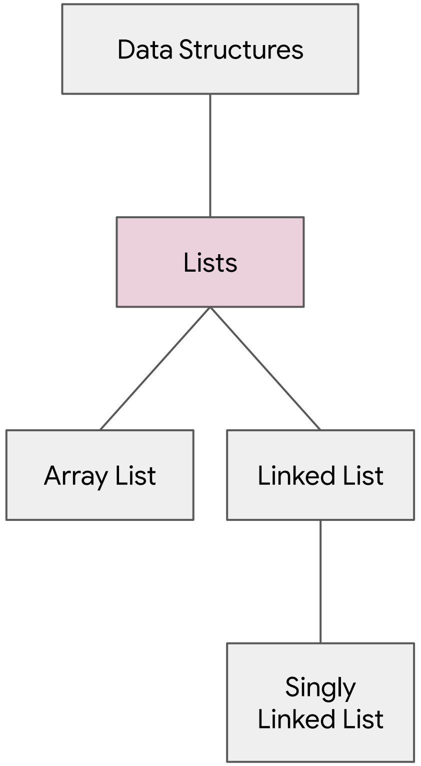
- Ordered indexable sequences
- Can contain duplicate values

General Strengths

- Good insertion
- Good iteration

General Weaknesses

- Poor look-up
- Poor removal



Array Lists

Structure

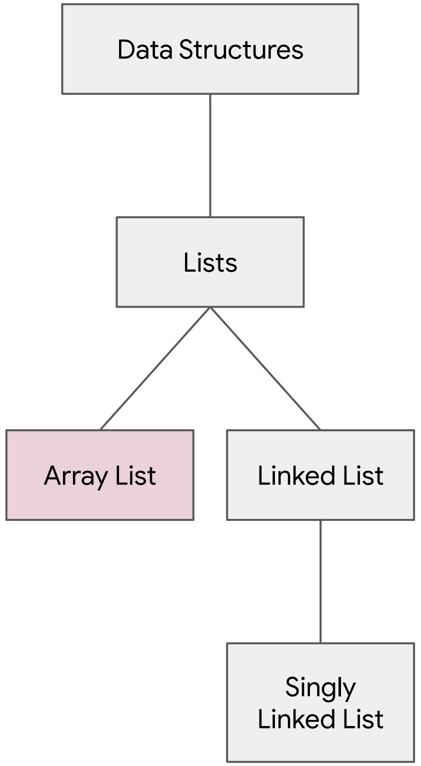
- Logic + Array

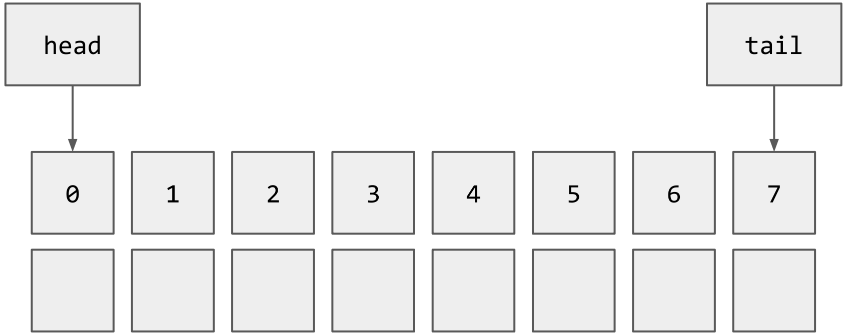
General Strengths

- Fast iterations
- Fast Indexing

General Weaknesses

- "Growing" the array is slow

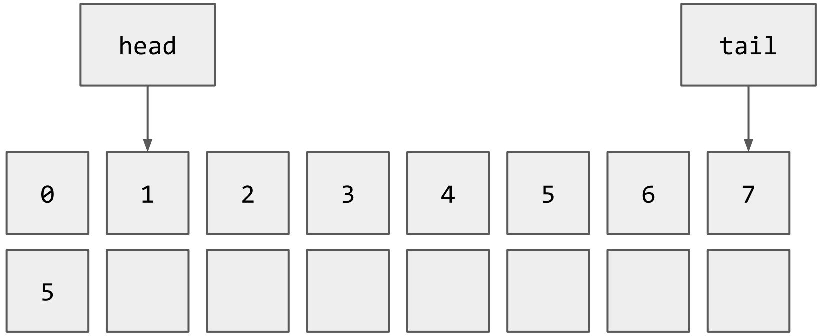



head
tail
0
1
2
3
4
5
6
7

```
ArrayList<Integer> list = new ArrayList<>();

list.add(5);

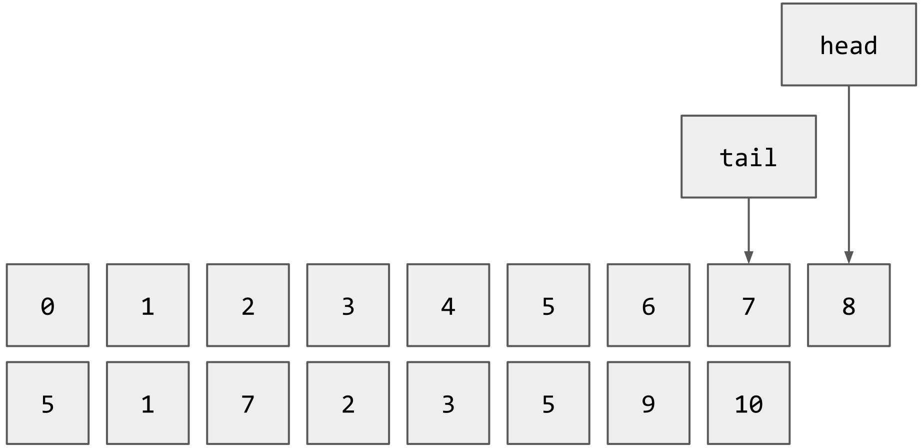
list.size();  // 1
```

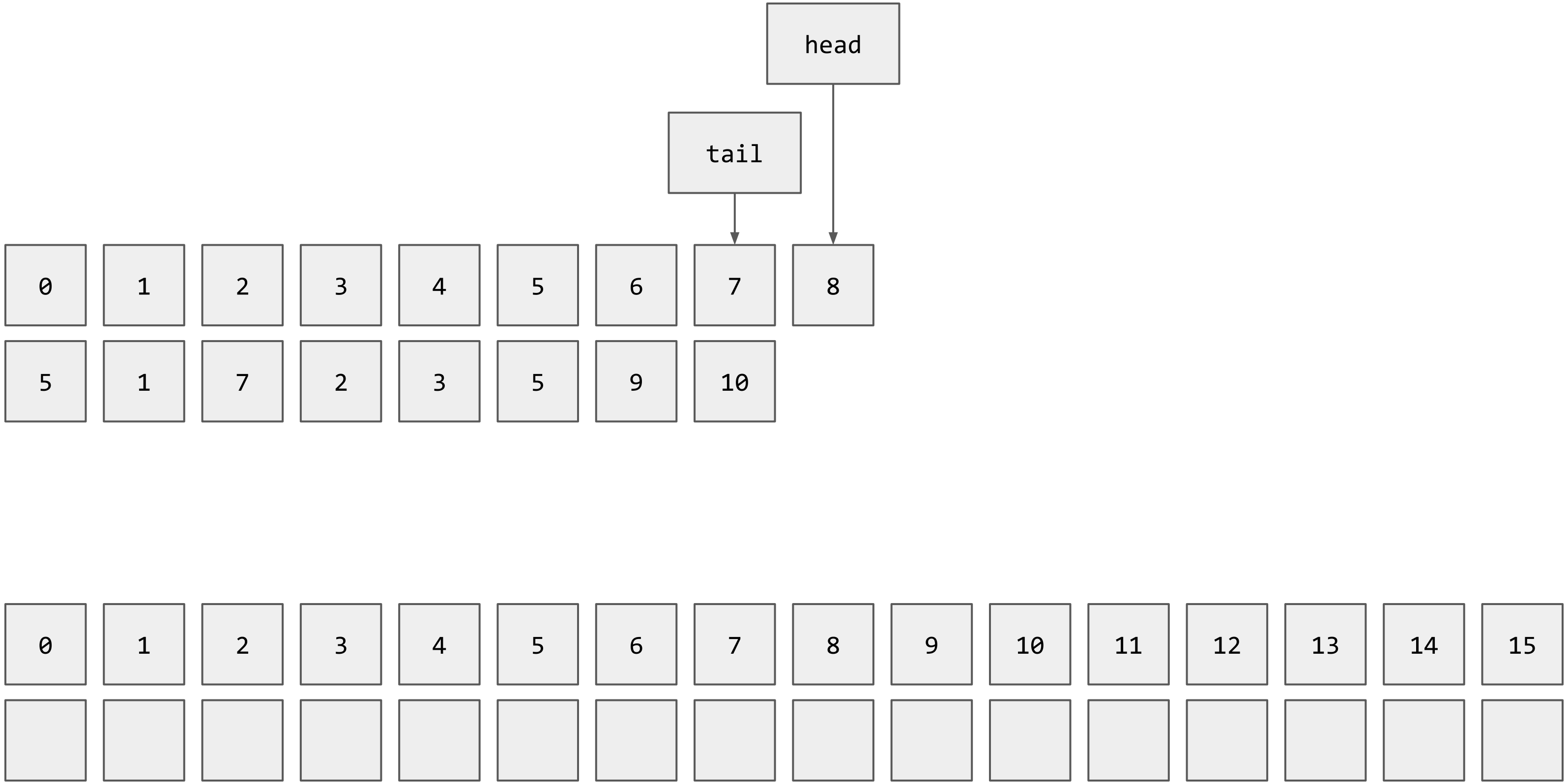


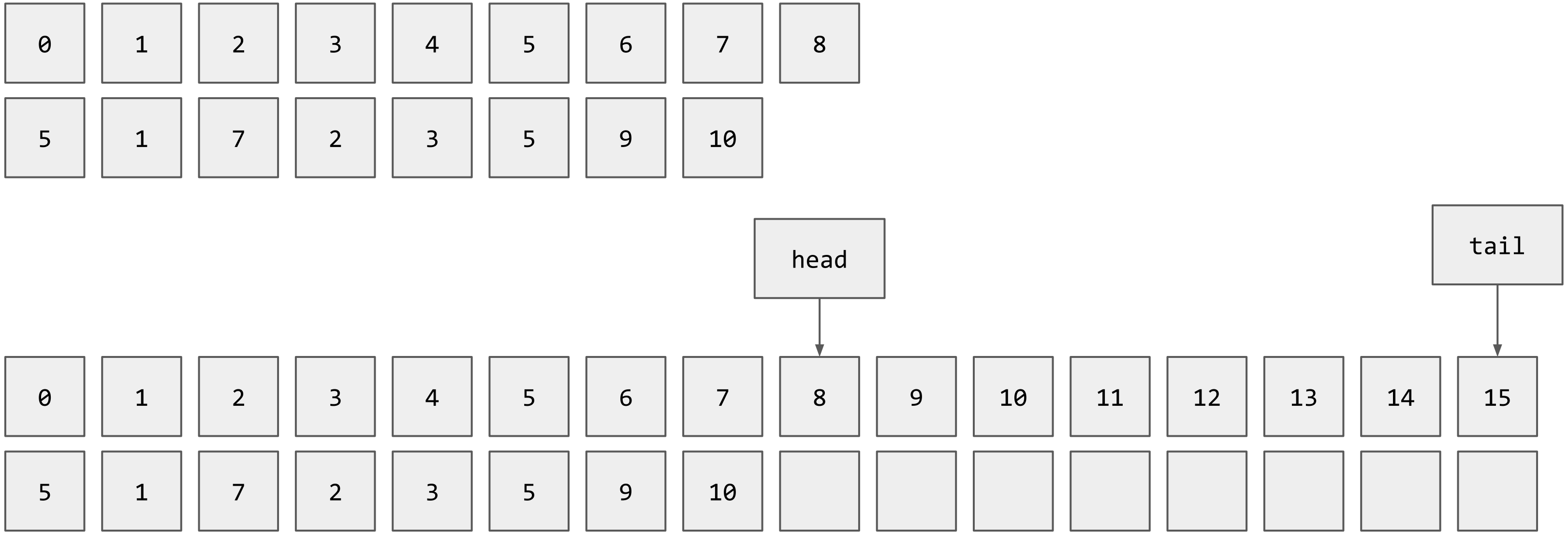
```
ArrayList<Integer> list = new ArrayList<>();

list.add(5);
list.add(1);
list.add(7);
list.add(2);
list.add(3);
list.add(5);
list.add(9);
list.add(10);

list.add(13); // There is no room!
```



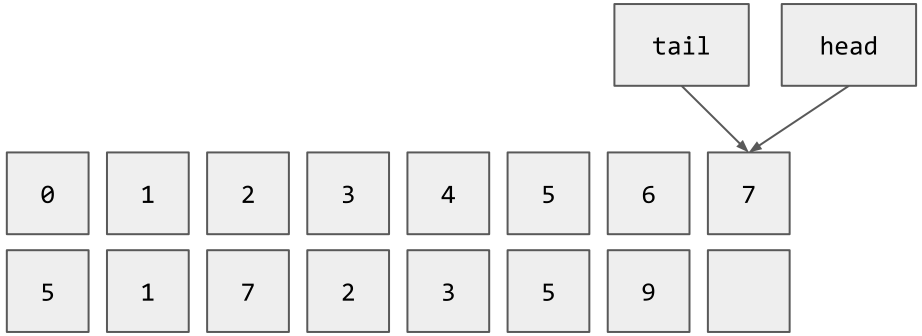

head
tail
0 1 2 3 4 5 6 7 8
5 1 7 2 3 5 9 10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


0
1
2
3
4
5
6
7
8
5
1
7
2
3
5
9
10
head
tail
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
5
1
7
2
3
5
9
10

```
ArrayList<Integer> list = new ArrayList<>();

list.add(5);
list.add(1);
list.add(7);
list.add(2);
list.add(3);
list.add(5);
list.add(9);
list.add(10);

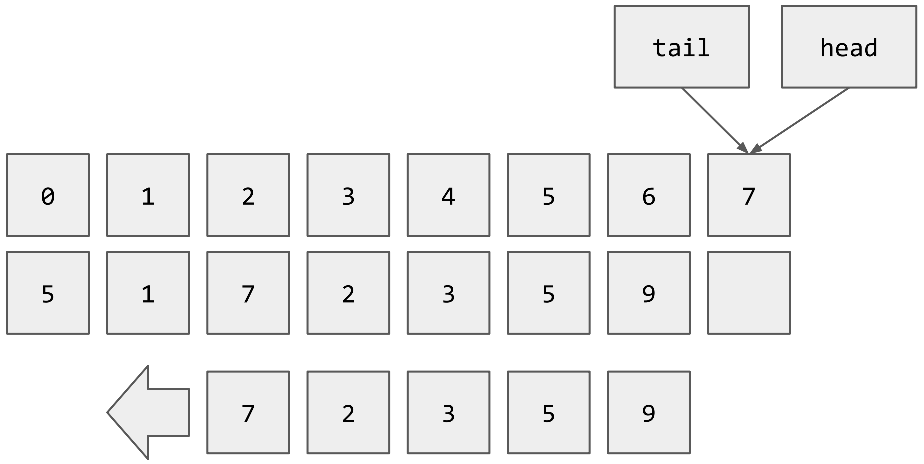
list.remove(1);
```



```
ArrayList<Integer> list = new ArrayList<>();

list.add(5);
list.add(1);
list.add(7);
list.add(2);
list.add(3);
list.add(5);
list.add(9);
list.add(10);

list.remove(1);
```



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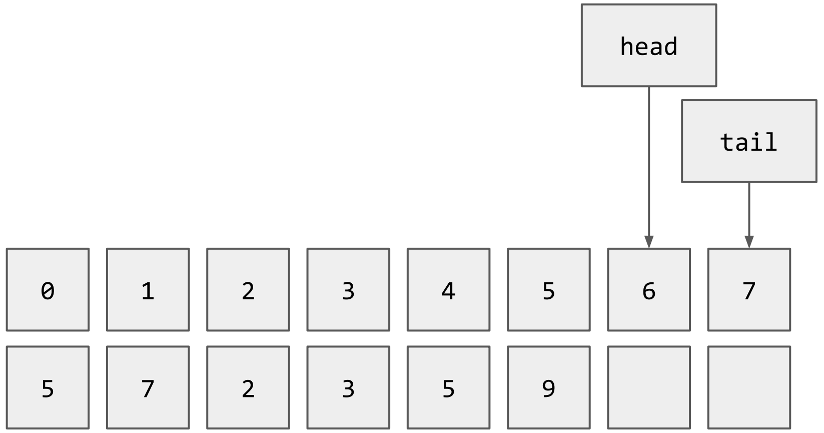
list.add(7);
list.add(2);
list.add(3);
list.add(5);
list.add(9);
list.add(10);

list.remove(1);
```



Array List Summary

General Strengths

- Good insertion
- Good (Fast) iteration
- Fast Indexing

General Weaknesses

- Poor look-up
- Poor removal
- "Growing" the array is slow

Runtime Analysis	
add value	O(1) amortized
remove by index	O(n)
get by index	O(1)
contains value	O(n)

Singly Linked Lists

Structure

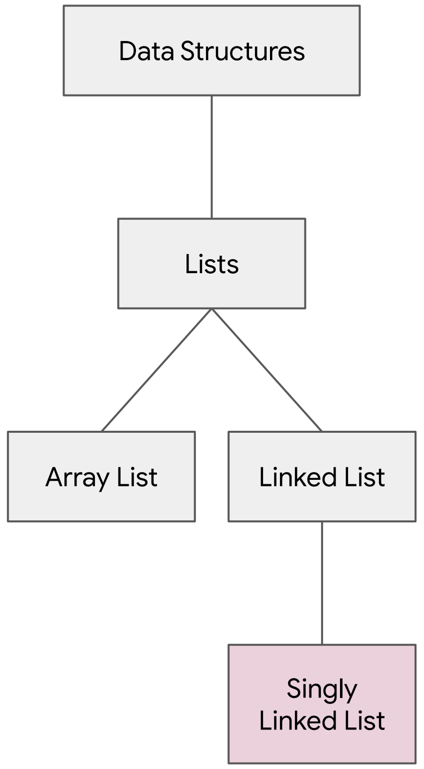
- Chaining "nodes" together

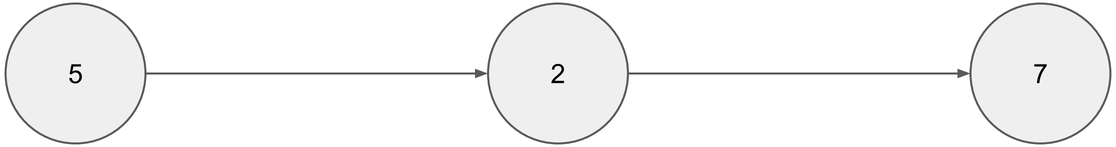
General Strengths

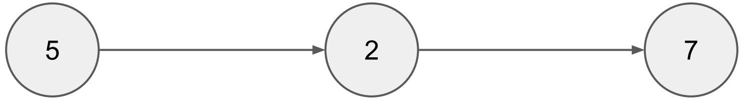
- Good middle-of-list insertion
- Good middle-of-list removals

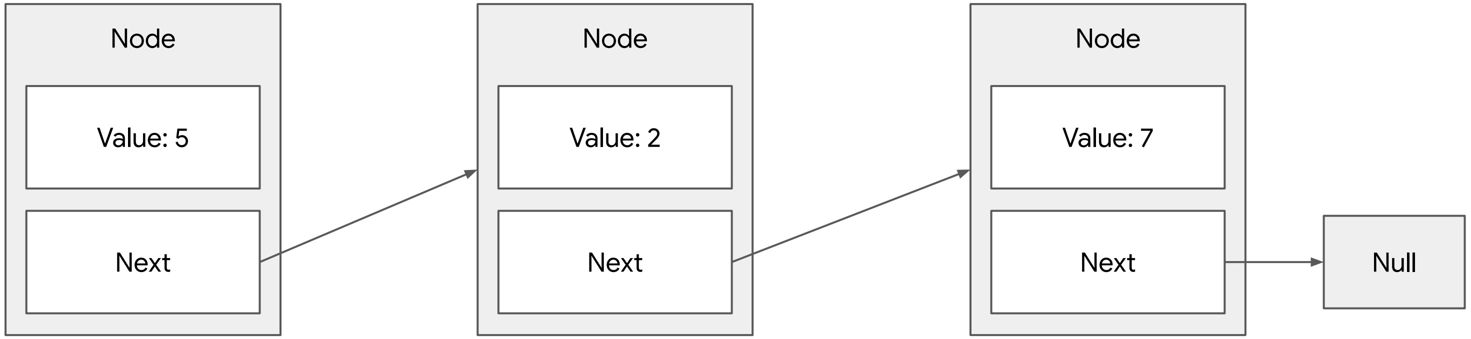
General Weaknesses

- Poor memory locality
- Poor indexing

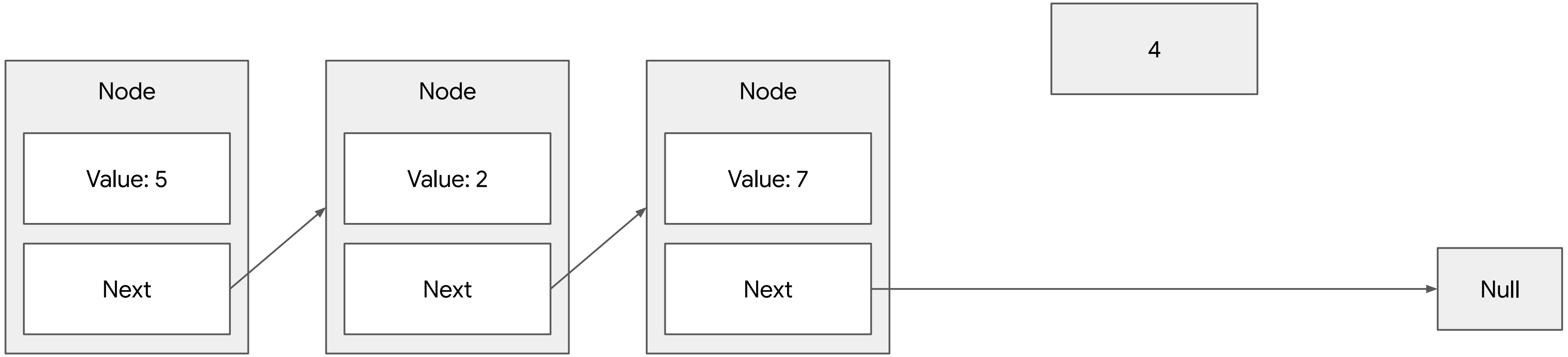



5
2
7

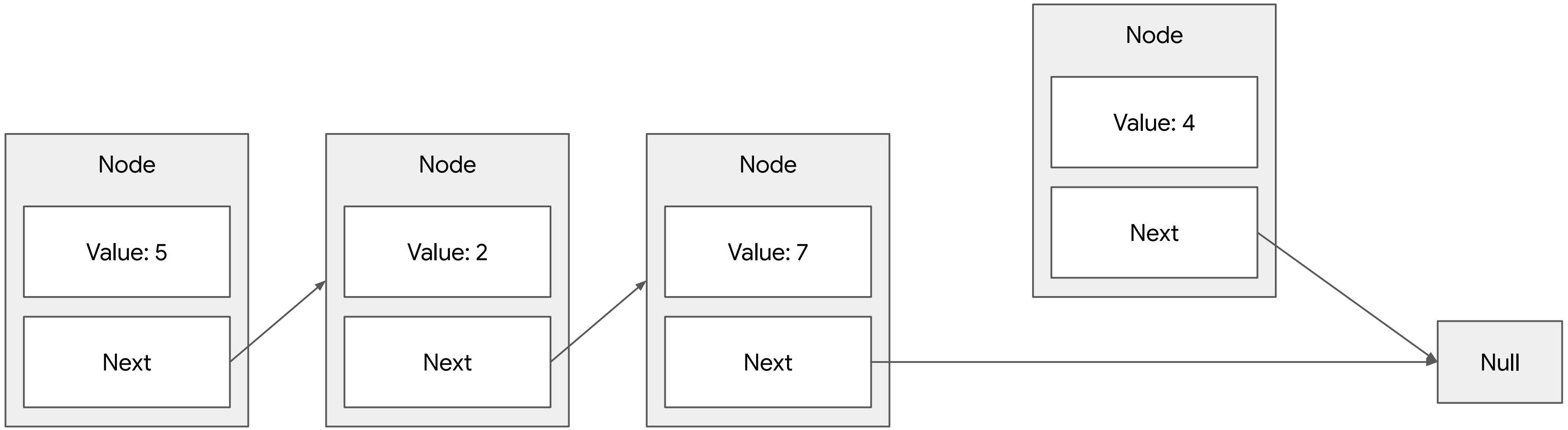

5
2
7


Node
Value: 5
Next
Node
Value: 2
Next
Node
Value: 7
Next
Null

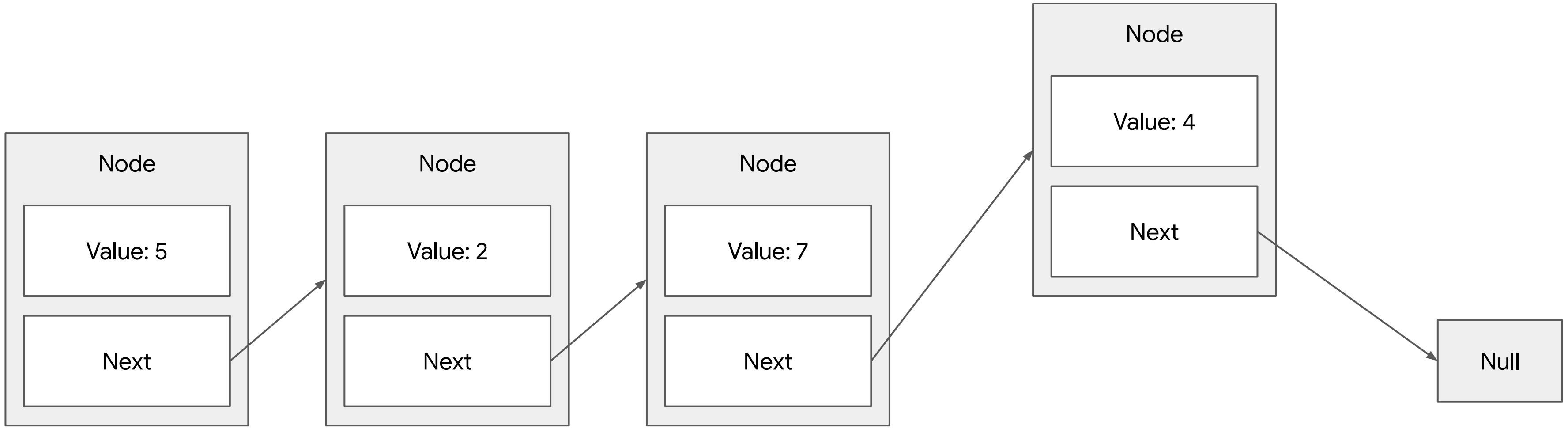
list.add(4)



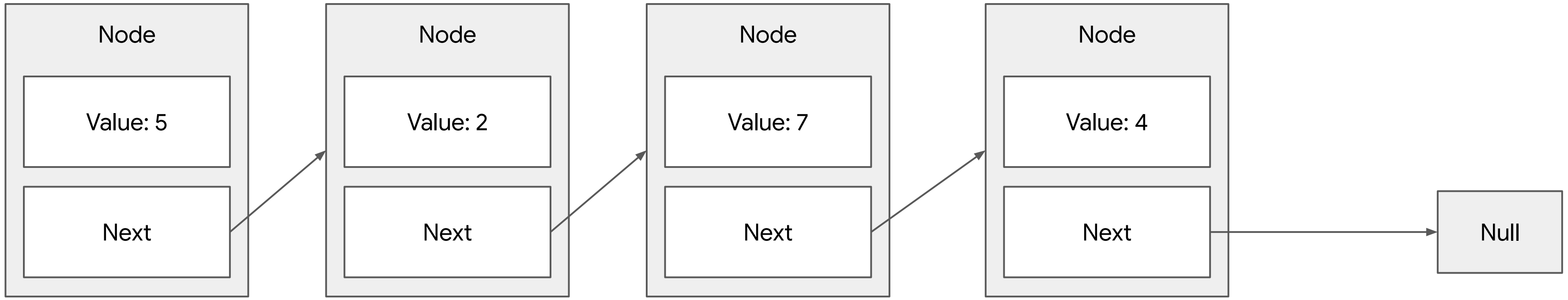
list.add(4)


Node
Value: 5
Next
Node
Value: 2
Next
Node
Value: 7
Next
Node
Value: 4
Next
Null

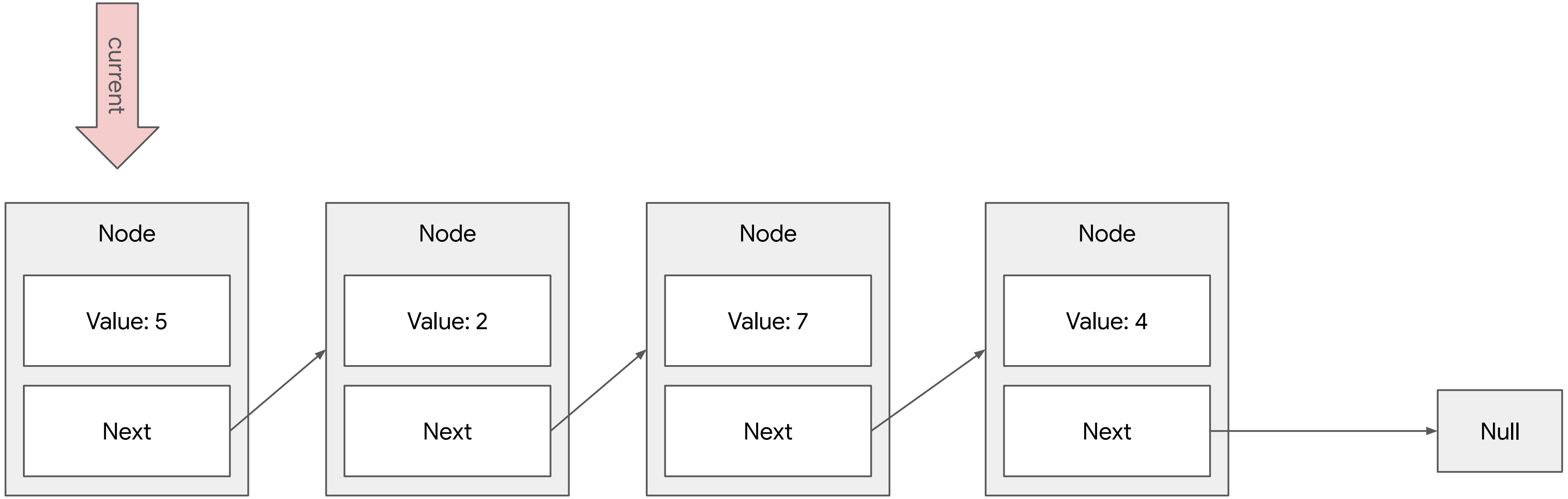
list.add(4)


Node
Value: 5
Next
Node
Value: 2
Next
Node
Value: 7
Next
Node
Value: 4
Next
Null

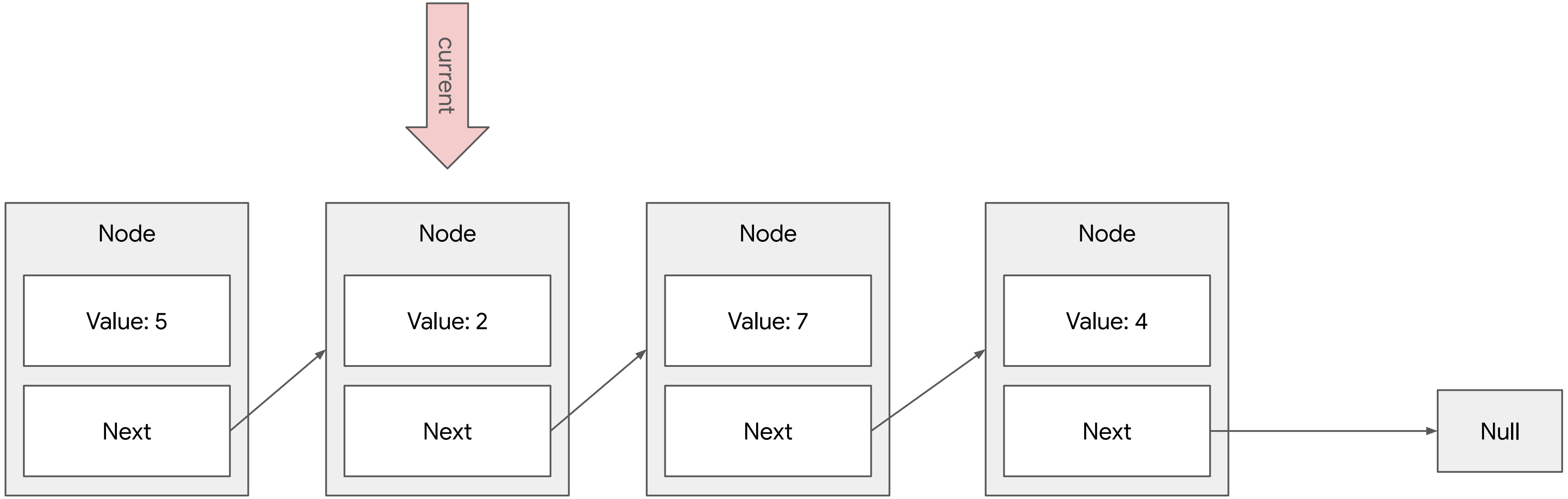
list.remove(7)



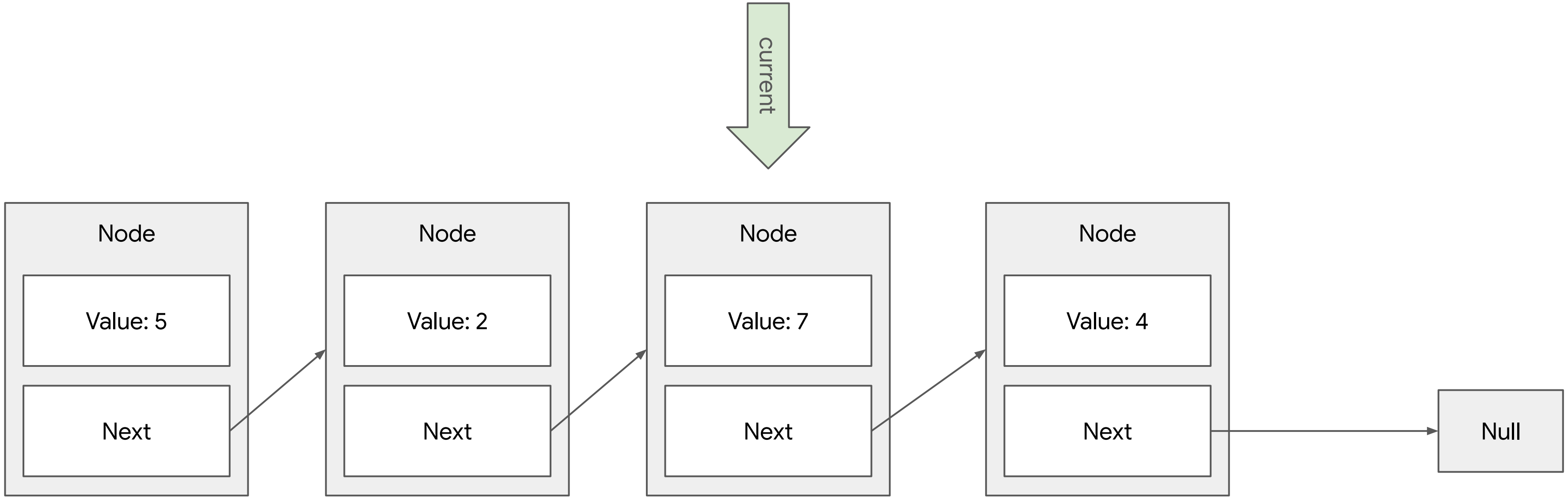
list.remove(7)



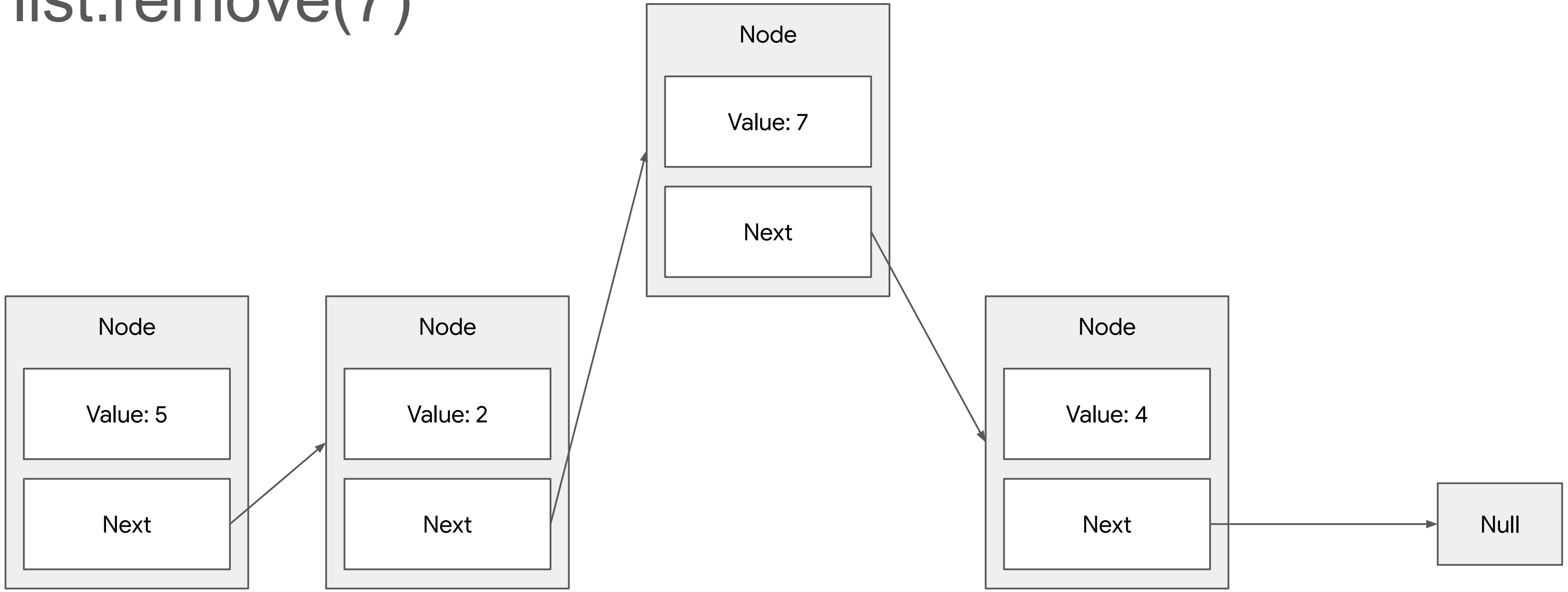
list.remove(7)



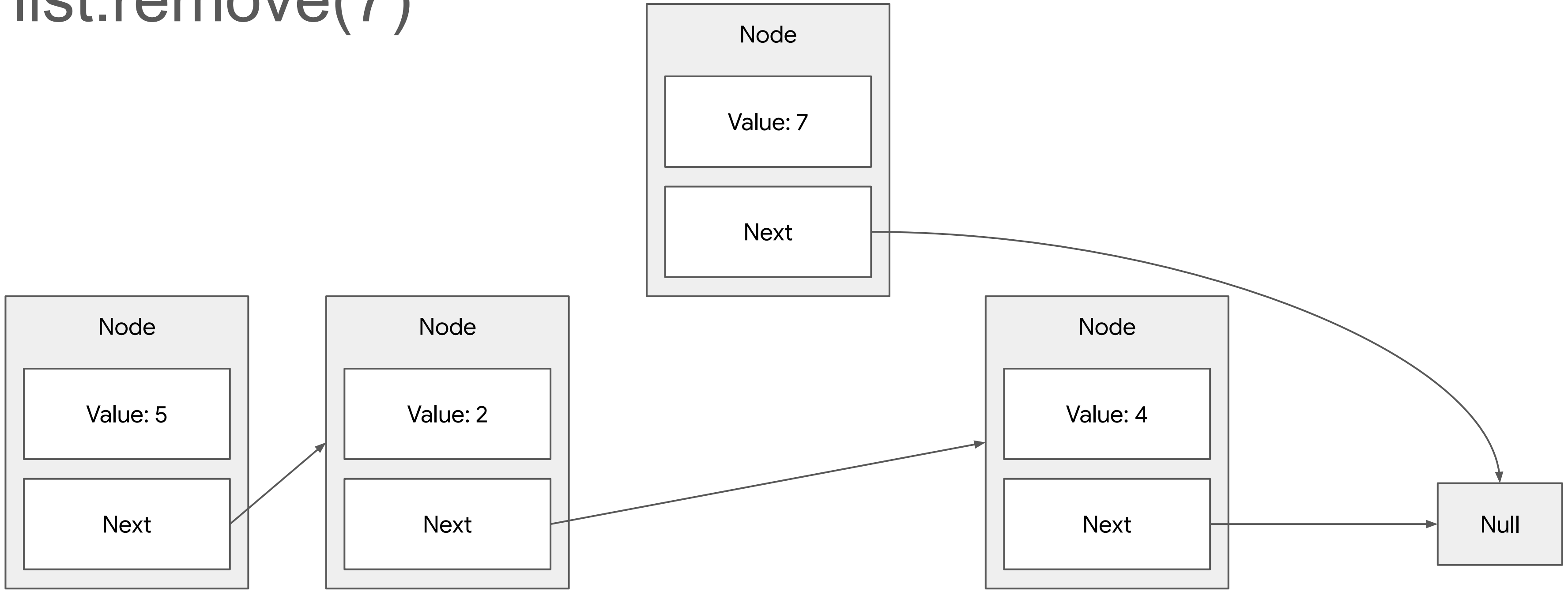
list.remove(7)



list.remove(7)



list.remove(7)



Singly Linked List Summary

General Strengths

- Good insertion
- Good (okay) iteration

General Weaknesses

- Poor indexing
- Poor look-up
- Poor removal
- Poor memory locality

Runtime Analysis	
add value	O(1)
remove by index	O(n)
get by index	O(n)
contains value	O(n)

Maps

Characteristics

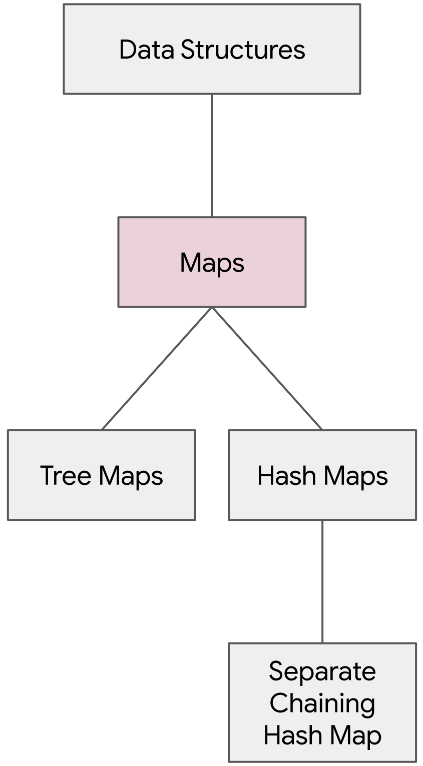
- Create associations between unique keys and non-unique values

General Strengths

- Good insertion
- Good removal
- Good look-up by value

General Weaknesses

- Poor iteration
- Poor memory locality
- Poor memory usage



Separate Chaining Hash Map

Characteristics

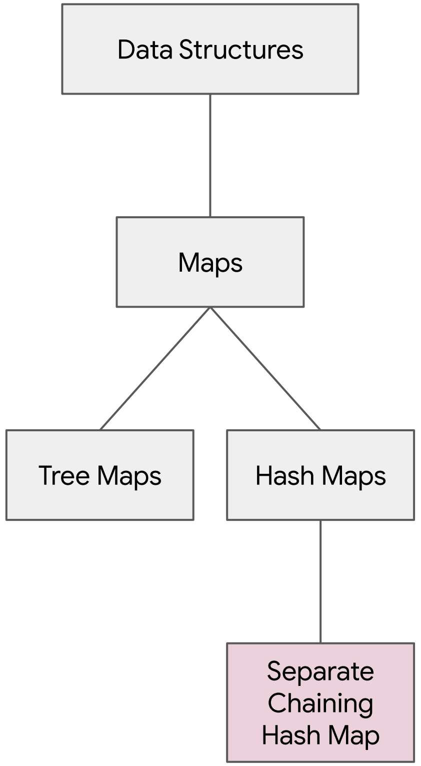
- Create associations between unique keys and non-unique values
- Unordered

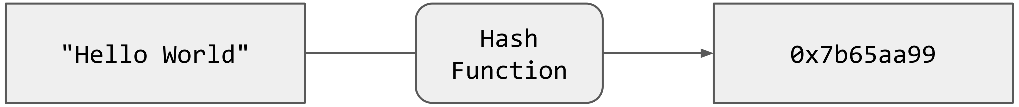
General Strengths

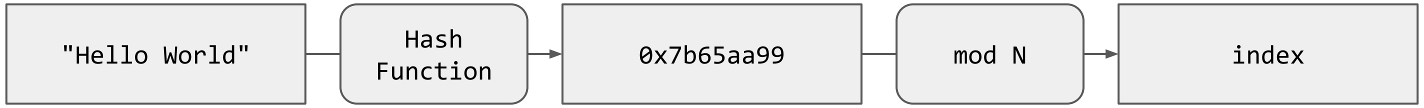
- Good insertion
- Good removal
- Good look-up by value

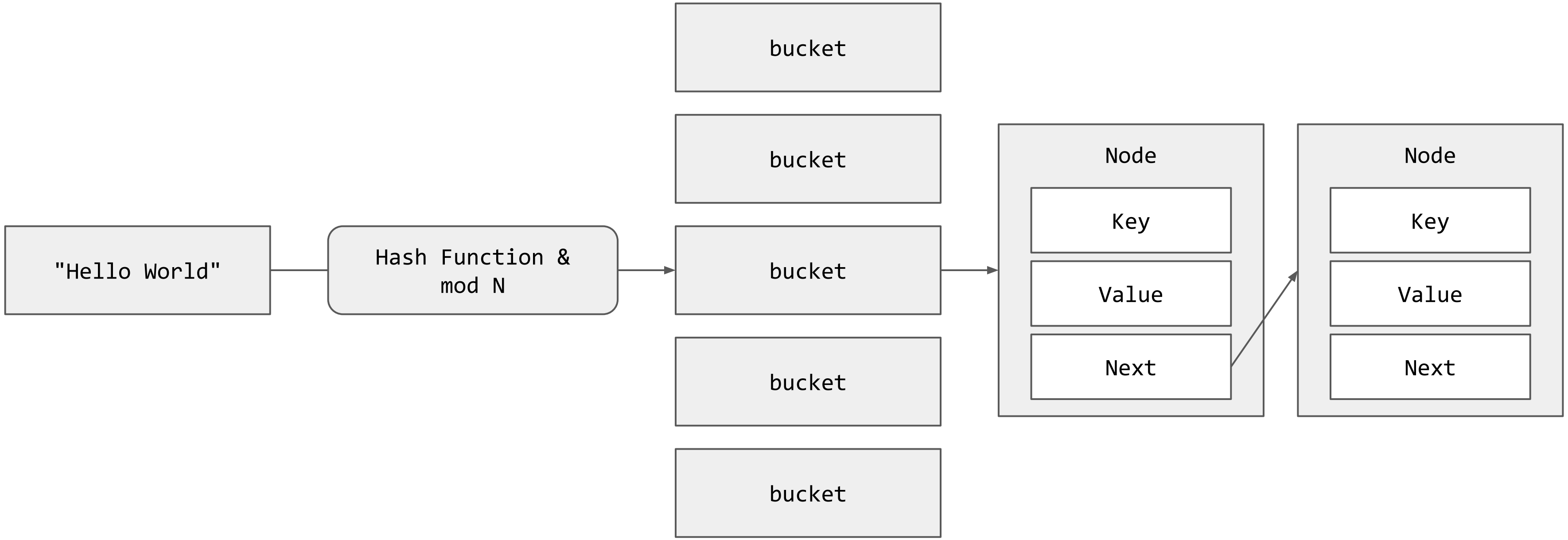
General Weaknesses

- Poor iteration
- Poor memory locality
- Poor memory usage




"Hello World"
Hash Function
0x7b65aa99


"Hello World"
Hash Function
0x7b65aa99
mod N
index


"Hello World"
Hash Function & mod N
bucket
bucket
bucket
bucket
bucket
Node
Key
Value
Next
Node
Key
Value
Next

Separate Chaining Hash Map

General Strengths

- Good insertion
- Good removal
- Good look-up by value

General Weaknesses

- Poor iteration
- Poor memory locality
- Poor memory usage

Runtime Analysis	
add value	O(1)*
remove by key	O(1)*
get by key	O(1)*
contains key	O(1)*
contains value	O(n)

Sets

Characteristics

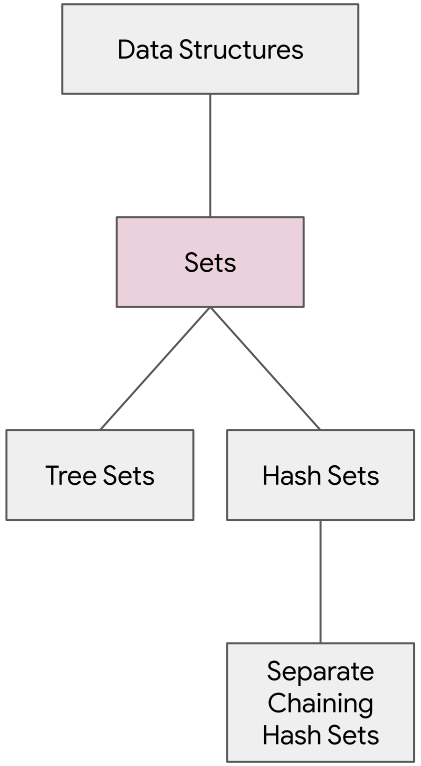
- Store unique values

General Strengths

- Good insertion
- Good removal
- Good look-up

General Weaknesses

- Poor iteration
- Poor memory locality
- Poor memory usage



Separate Chaining Hash Sets

Characteristics

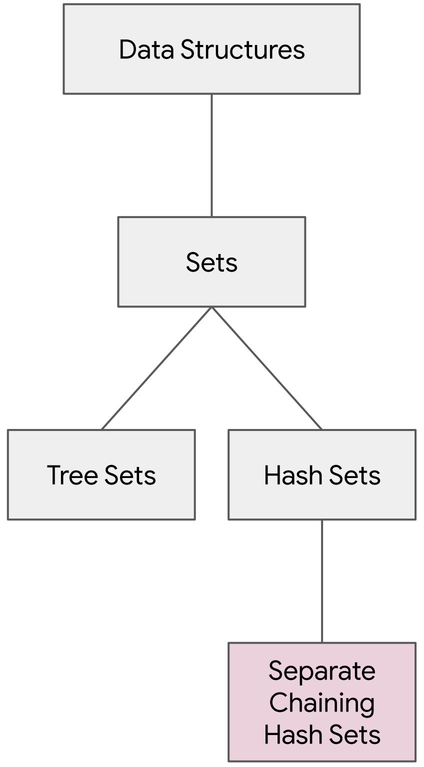
- Store unique values
- Unordered

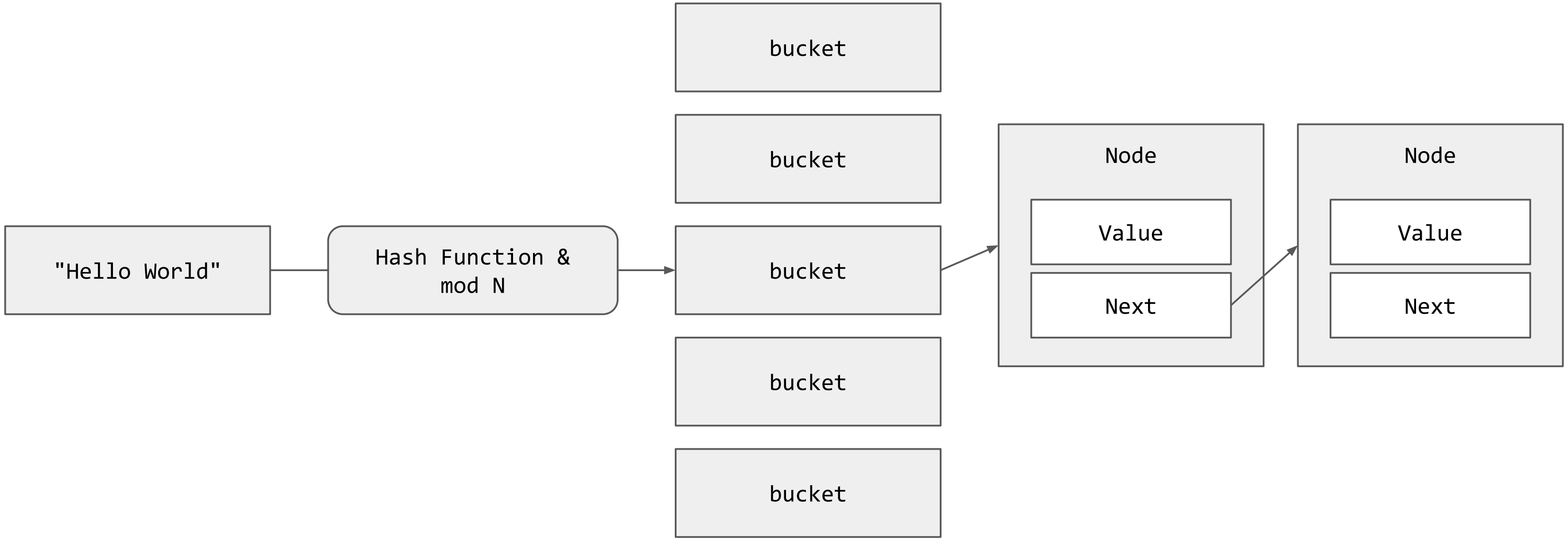
General Strengths

- Good insertion
- Good removal
- Good look-up

General Weaknesses

- Poor iteration
- Poor memory locality
- Poor memory usage




"Hello World"
Hash Function & mod N
bucket
bucket
bucket
bucket
bucket
Node
Value
Next
Node
Value
Next

Separate Chaining Hash Set

General Strengths

- Good insertion
- Good removal
- Good look-up

General Weaknesses

- Poor iteration
- Poor memory locality
- Poor memory usage

Runtime Analysis	
add value	O(1)*
remove value	O(1)*
contains value	O(1)*

Hash Functions

Objective

- Take arbitrary length input and produce fixed-length output.
- Have near random association with input and output.
- Deterministic

Important Notes

- Context
- Good Enough

(Poor) Hashing Examples

```
int simpleHash(char[] string) {
  int hash = 0;

  for (char c : string) {
    hash += c;
  }

  return hash;
}
```

What does it do?

Speed?

Collisions?

Final opinion?

(Poor) Hashing Examples

```
int bitRotateHash(char[] string) {
  int hash = 0;

  for (char c : string) {
    int high = (hash >> 24) & (0xFF);
    hash = (hash << 8) | (high ^ c);
  }

  return hash;
}
```

What does it do?

Speed?

Collisions?

Final opinion?

Reflection

Primary Objectives

- What is a **list** and when could I use it?
- What is a **set** and when could I use it?
- What is a **map** and when could I use it?

Secondary Objectives

- What trade-offs am I making when I use a **list**?
- What trade-offs am I making when I use a **set**?
- What trade-offs am I making when I use a **map**?