Array, Vector, List

Shusen Wang

http://wangshusen.github.io/

Array

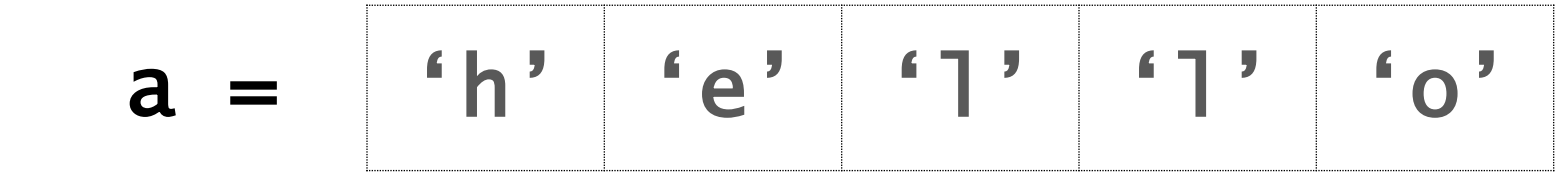
Array

a =

‘h’	‘e’	‘l’	‘l’	‘o’

- `char a[5] = {'h', 'e', 'l', 'l', 'o'};`

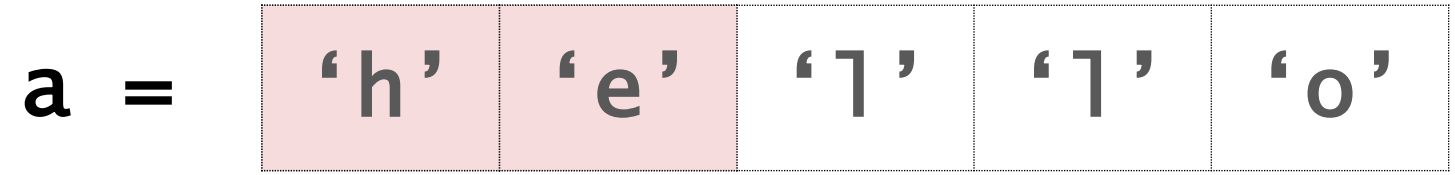
Array



- `char a[5] = {'h', 'e', 'l', 'l', 'o'};`

Array: Fixed size, contiguous memory.

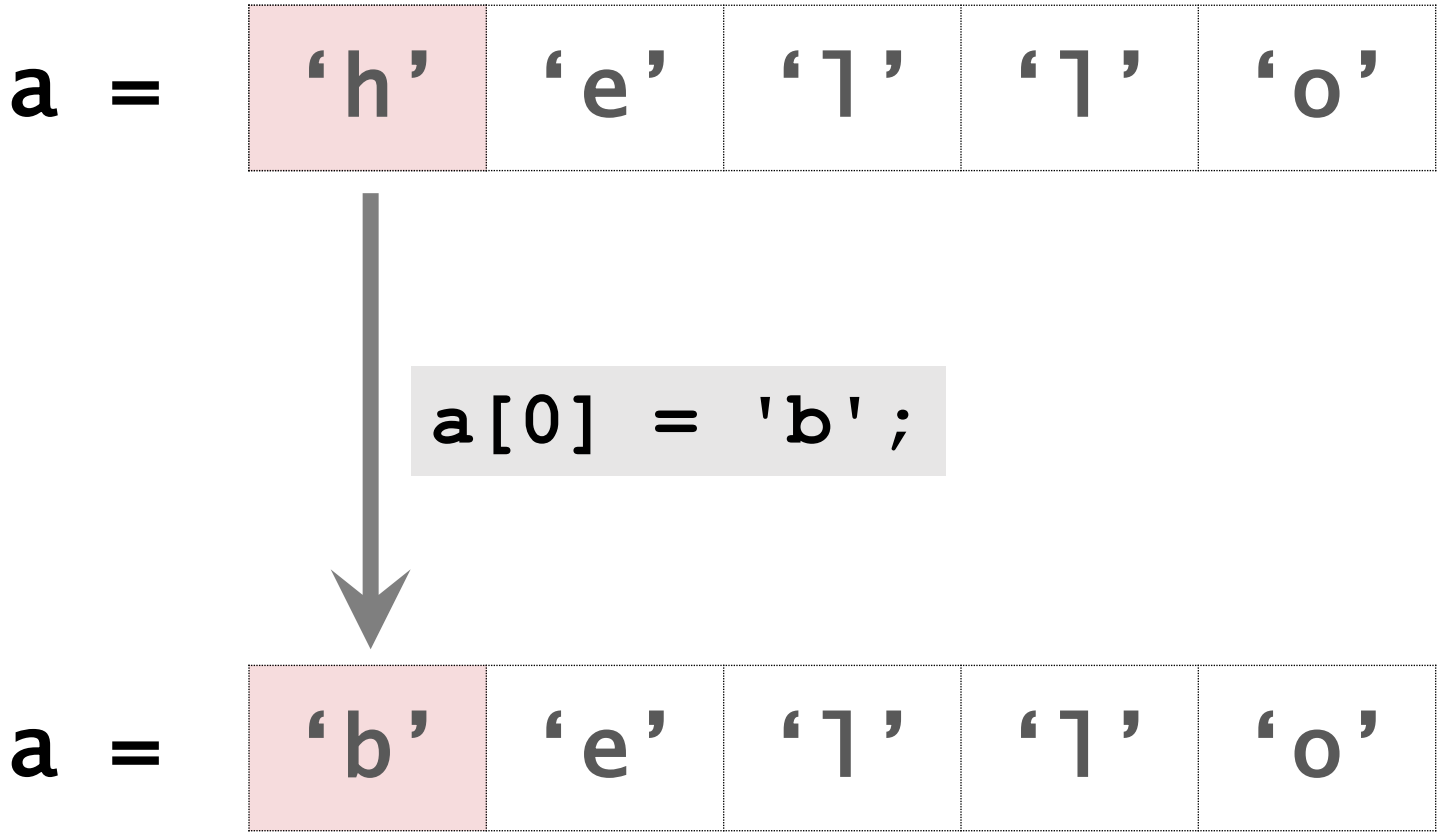
Array




```
// random access
```

- `char x = a[1];   // x is 'e'`

Array



Dynamic Allocation of Arrays

- A size-n array can be created in this way:

```
char a[n];
```

- When writing the code, n must be known.
- What if n is unknown until program is running?

Dynamic Allocation of Arrays

a = NULL

- `char* a = NULL;`

Dynamic Allocation of Arrays

a = NULL

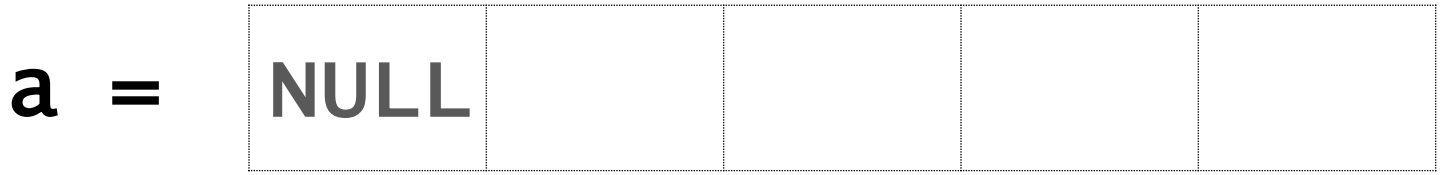
- `char* a = NULL;`
- `int n; // array size`

Dynamic Allocation of Arrays

a = NULL

- `char* a = NULL;`
- `int n; // array size`
- `cin >> n; // read in the size, e.g., get n=5`

Dynamic Allocation of Arrays



- `char* a = NULL;`
- `int n; // array size`
- `cin >> n; // read in the size, e.g., get n=5`
- `a = new char[n];`

Dynamic Allocation of Arrays

a =

‘h’	‘e’	‘l’	‘l’	‘o’

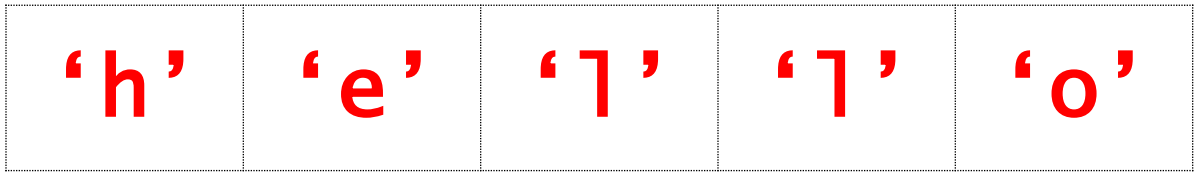
```
// store something in the array
```

- `a[0] = 'h';`
- `a[1] = 'e';`

⋮

- `a[4] = 'o';`

Dynamic Allocation of Arrays

a = 


```
// When done, free memory.
// Otherwise, memory leak can happen.
```

- **`delete [] a;`**

Dynamic Allocation of Arrays

```
a =  NULL
```

```
// When done, free memory.
// Otherwise, memory leak can happen.
```

- `delete [] a;`
- `a = NULL;`

Properties of Array

a =	'h'	'e'	'l'	'l'	'o'

1. The size is fixed. (New elements cannot be appended.)
2. Random access using `a[i]` has $O(1)$ time complexity.
3. Removing an element in the middle has $O(n)$ time complexity. (Require moving the remaining items leftward.)

Vector

Vector

- Vector is almost the same as array.
- The main difference is that vector's capacity can automatically grow.
- New elements can be appended using `push_back()` in $O(1)$ time (on average).
- The last element can be removed using `pop_back()` in $O(1)$ time.

Vector

v =

‘h’	‘e’	‘l’	‘l’	‘o’

- `vector<char> v = {'h', 'e', 'l', 'l', 'o'};`

Vector

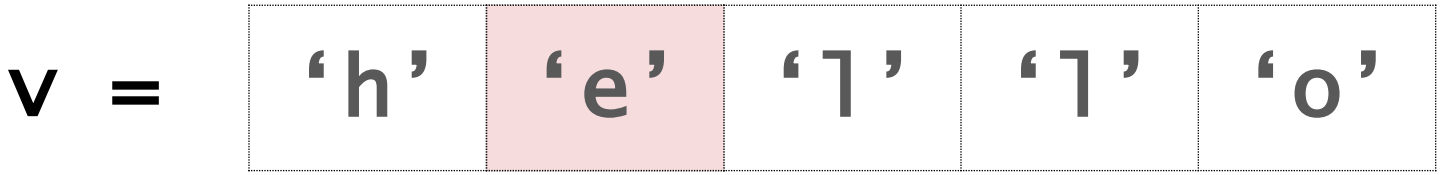
v =

‘h’	‘e’	‘l’	‘l’	‘o’

- `vector<char> v = {'h', 'e', 'l', 'l', 'o'};`

Vector: dynamic size, contiguous memory.

Vector




```
// random access
char x = v[1];    // x is 'e'
```

Vector

v =

‘b’	‘e’	‘l’	‘l’	‘o’

```
// assignment
```

- `v[0] = 'b';`

Insert

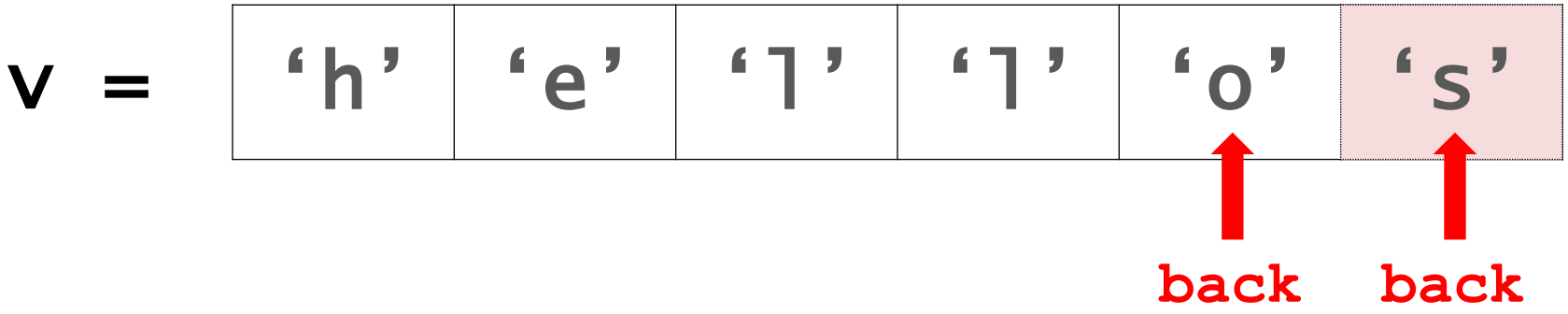
v =

‘h’	‘e’	‘l’	‘l’	‘o’	‘s’

```
// insert a new element to the end
```

- `v.push_back('s');`

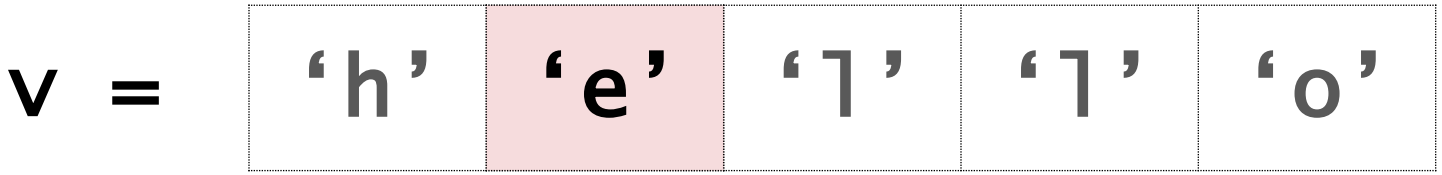
Delete




```
// delete the element in the end
```

- **`v.pop_back();`**

Delete




```
// delete an element in the middle
```

- `v.erase(v.begin()+1);`

Delete

v =

‘h’		‘l’	‘l’	‘o’

```
// delete an element in the middle
```

- `v.erase(v.begin()+1);`

Delete

v =

‘h’	‘l’	‘l’	‘o’	

```
// delete an element in the middle
```

- `v.erase(v.begin()+1);`

$O(n)$ time complexity! Slow!

Vector capacity can grow

- `vector<char> v(100);`
- `cout << v.size();` `// print “100”`
- `cout << v.capacity();` `// print “100”`

Vector capacity can grow

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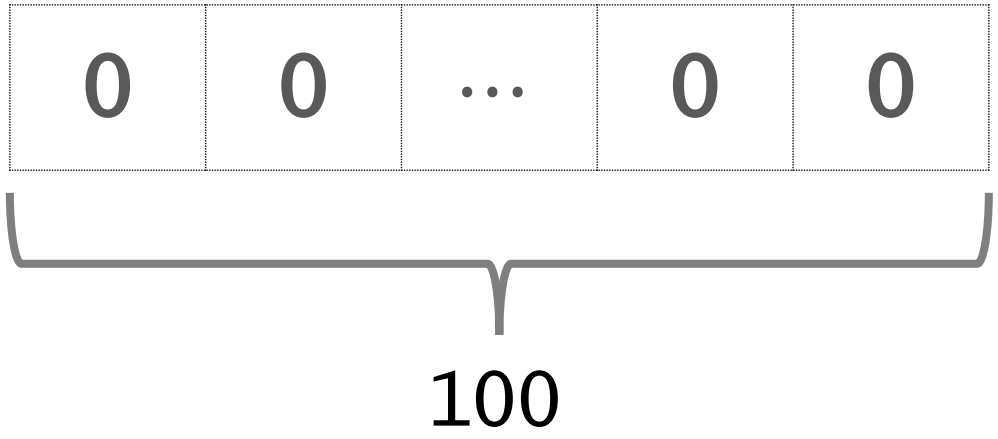
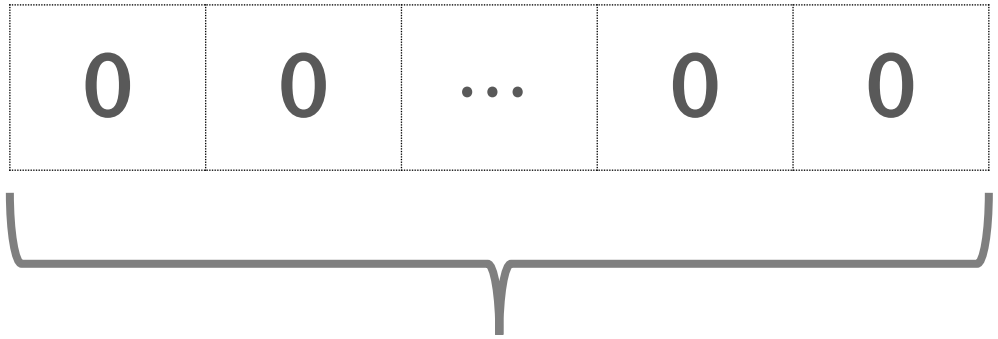
- `cout << v.size();` `// print “100”`
- `cout << v.capacity();` `// print “100”`

- `v.push_back('x');`
- `cout << v.size();` `// print “101”`
- `cout << v.capacity();` `// print “200”`

Vector capacity can grow

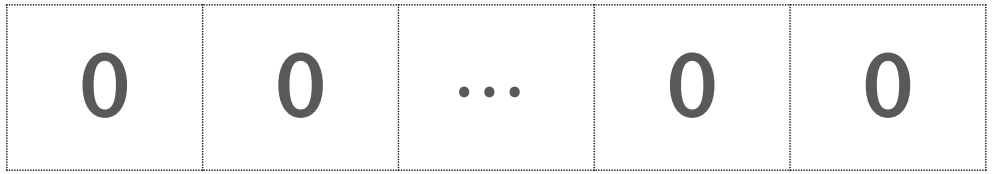


Vector capacity can grow



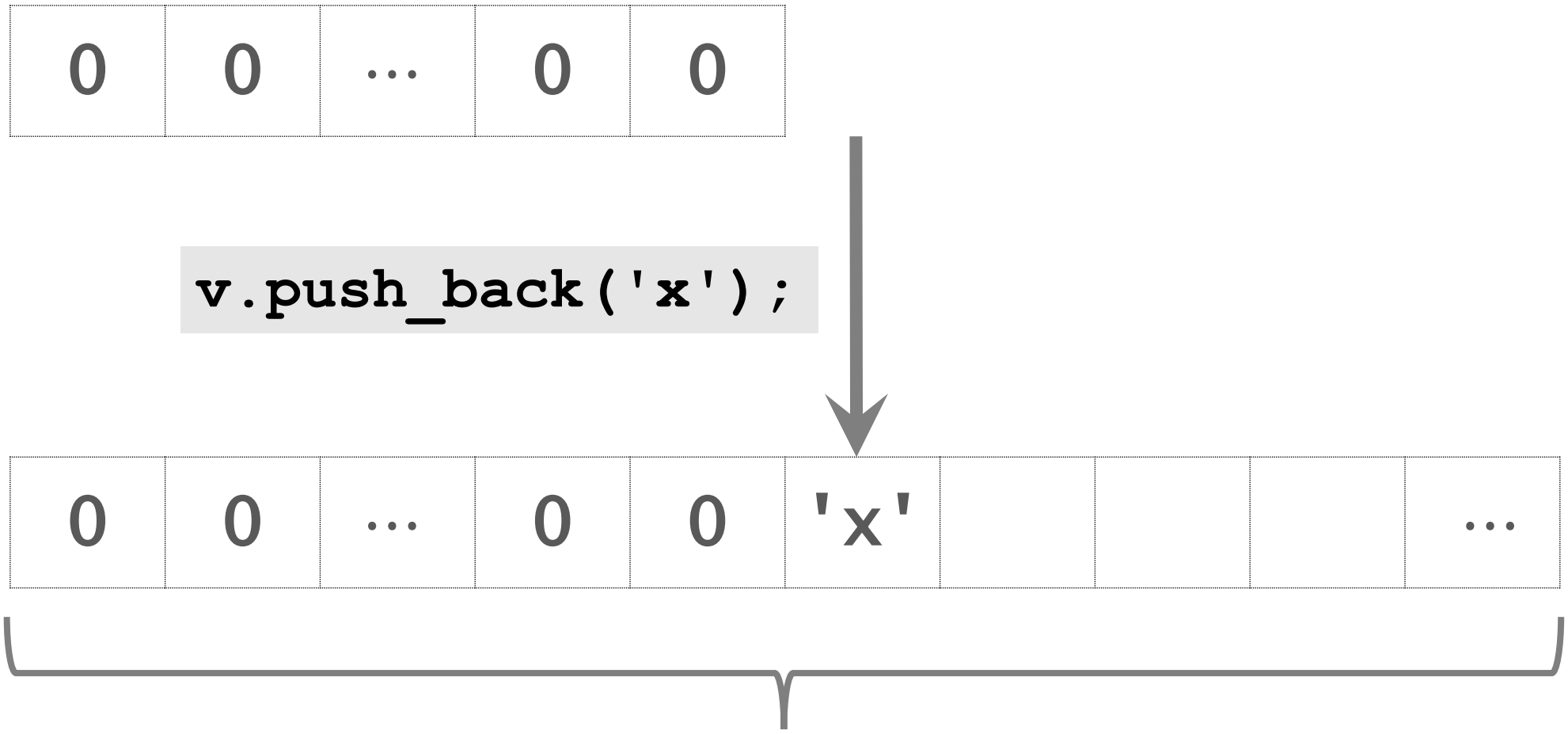

```
capacity of vector = 100
  size of vector = 100
```

Vector capacity can grow

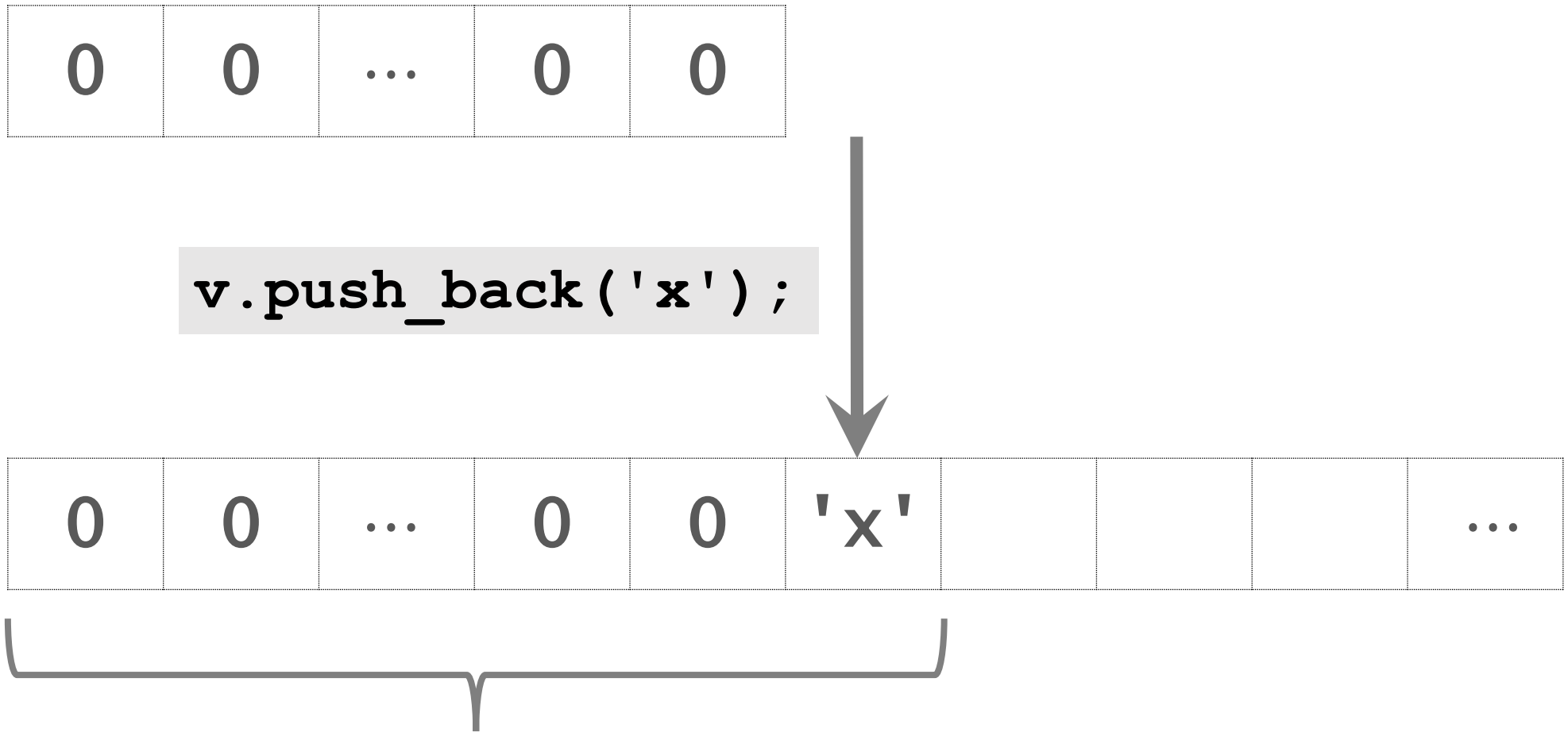



```
v.push_back('x');
```

Vector capacity can grow



Vector capacity can grow



Vector capacity can grow

What happens when size is going to exceed capacity?

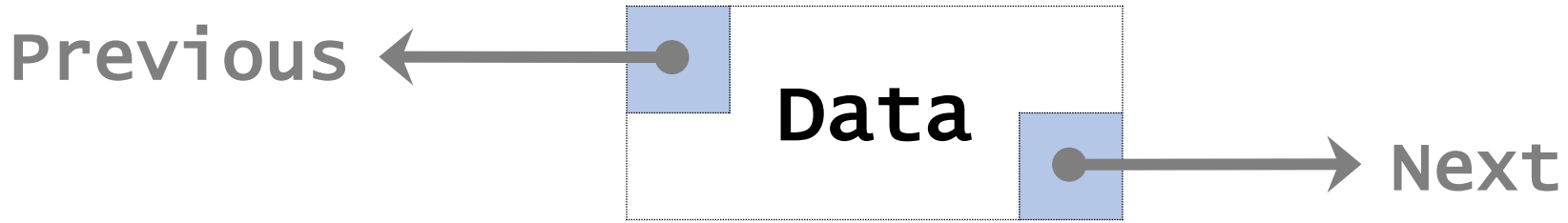
Vector capacity can grow

What happens when size is going to exceed capacity?

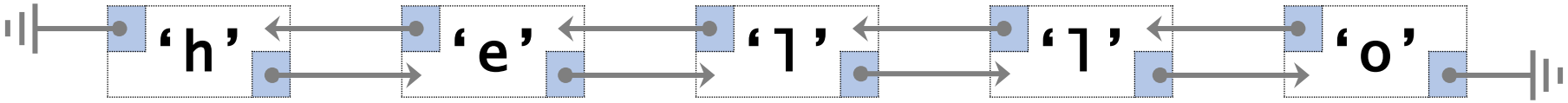
- Create a new array of capacity 200.
- Copy the 100 elements from the old array to the new.
- Put the new element in the 101st position.
- Free the old array from memory.

List

A Node

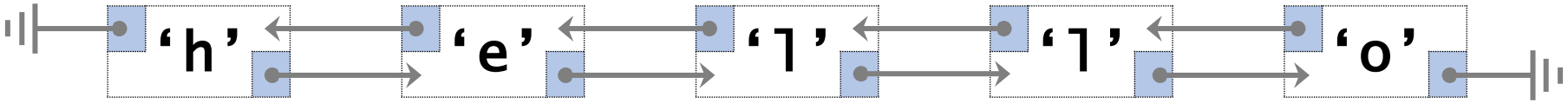


Doubly Linked List



- `list<char> l = {'h', 'e', 'l', 'l', 'o'};`

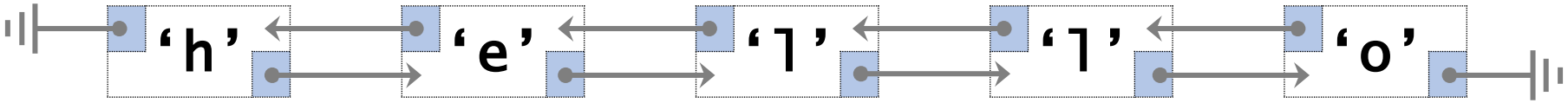
Doubly Linked List



- `list<char> l = {'h', 'e', 'l', 'l', 'o'};`

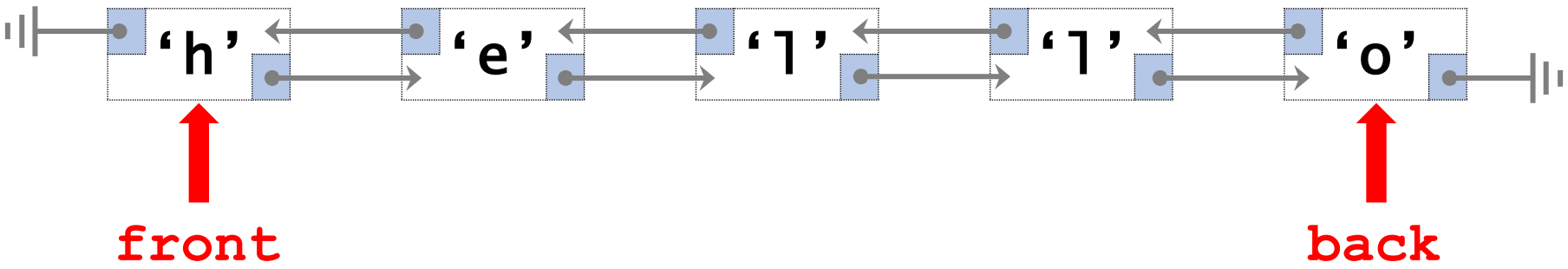
List: dynamic size, not contiguous memory.

Doubly Linked List



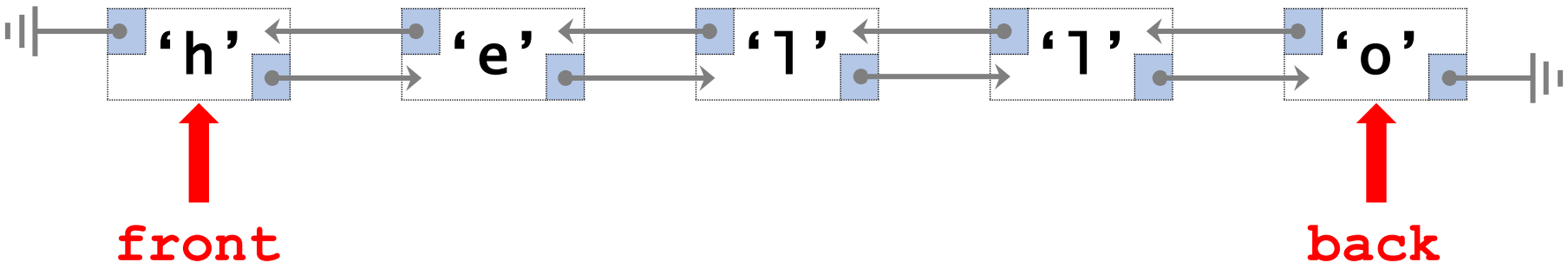
- `cout << l[2]; // does not work`
- `l[0] = 'a';  // does not work`

Doubly Linked List



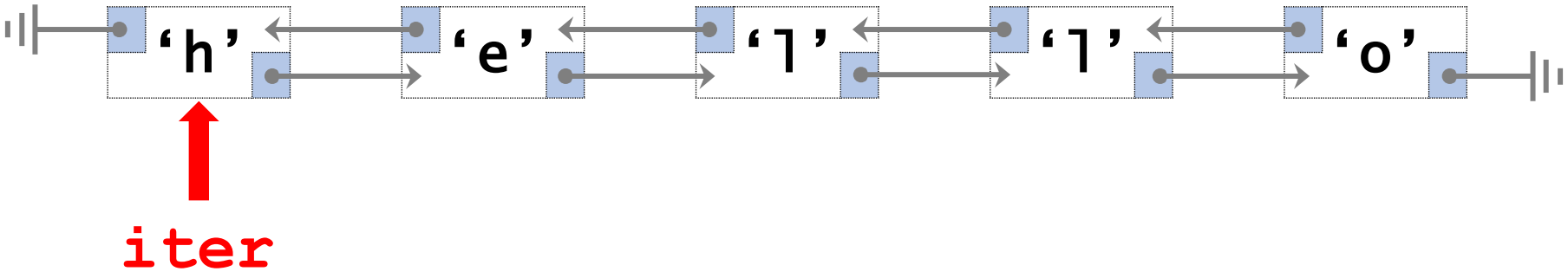
- `cout << l.front(); // print 'h'`

Doubly Linked List



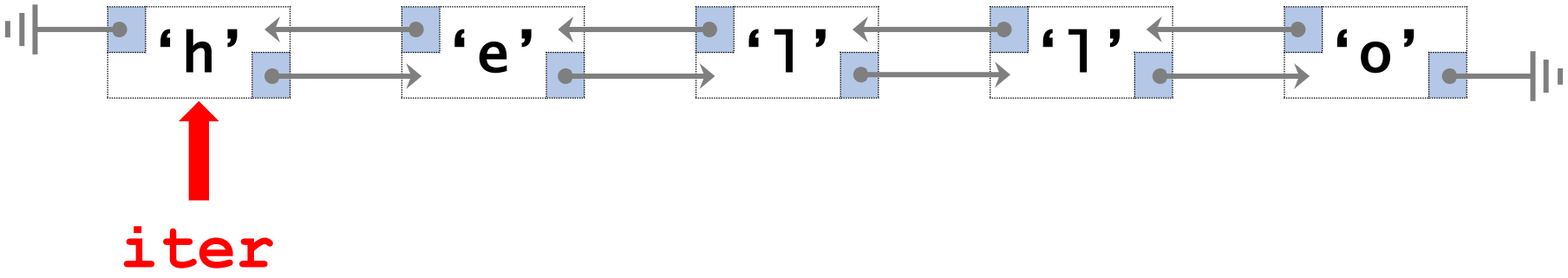
- `cout << l.front(); // print 'h'`
- `cout << l.back();  // print 'o'`

Iterator



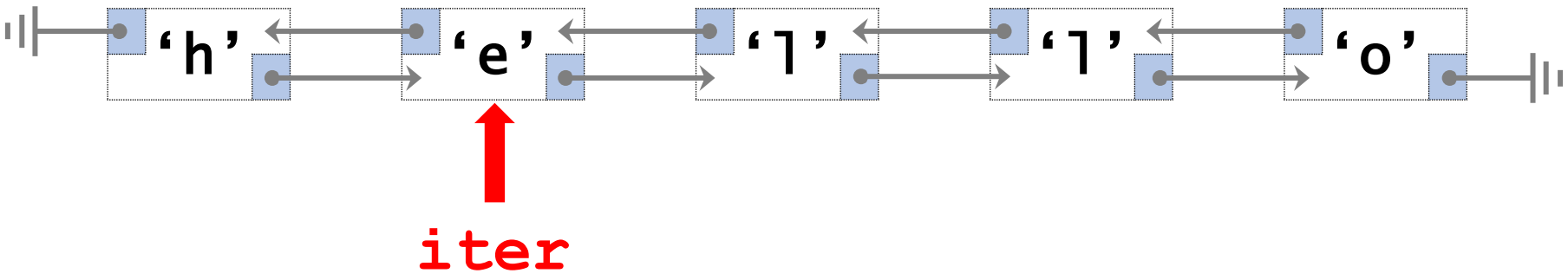
- `list<char>::iterator iter = l.begin();`
- `cout << *iter; // print 'h'`

Iterator



- `list<char>::iterator iter = l.begin();`
- `cout << *iter; // print 'h'`
- `iter++;`

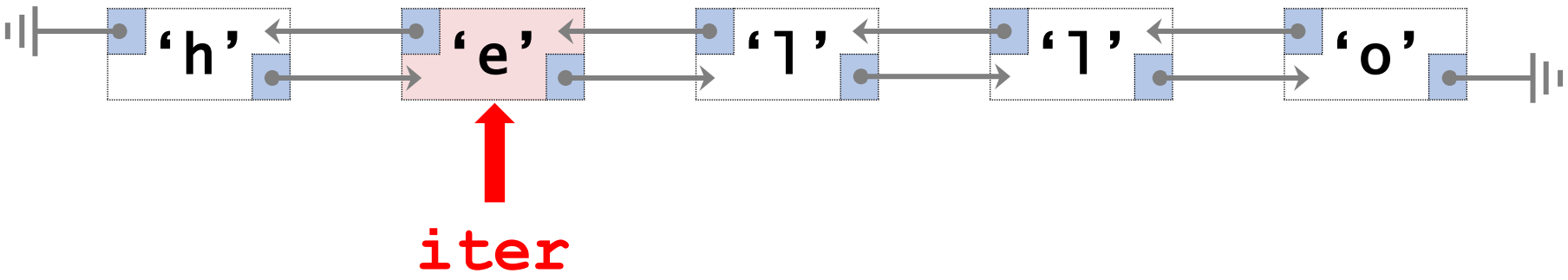
Iterator



- `list<char>::iterator iter = l.begin();`
- `cout << *iter; // print 'h'`

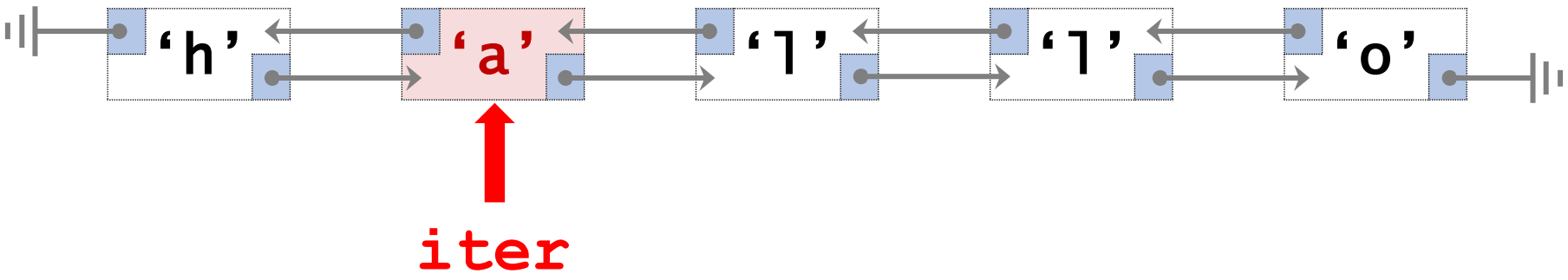
- `iter++;`
- `cout << *iter; // print 'e'`

Iterator



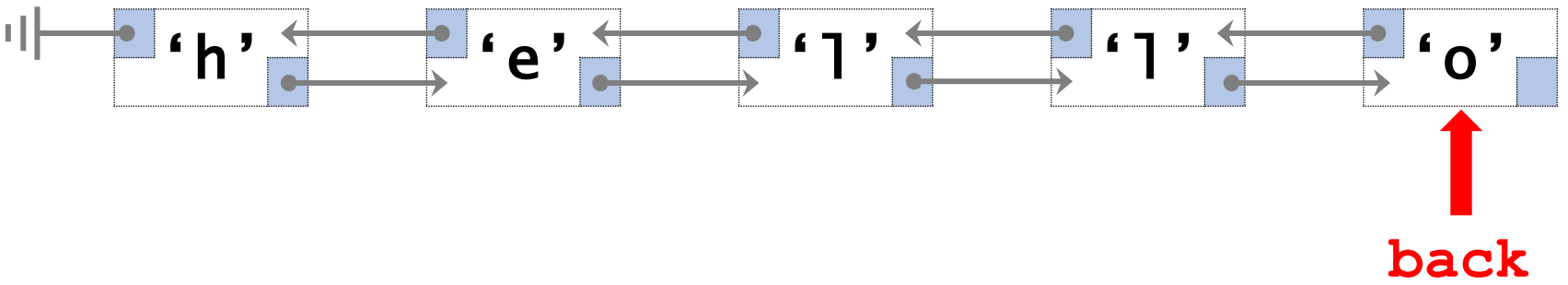
- `*iter = 'a'; // change 'e' to 'a'`

Iterator



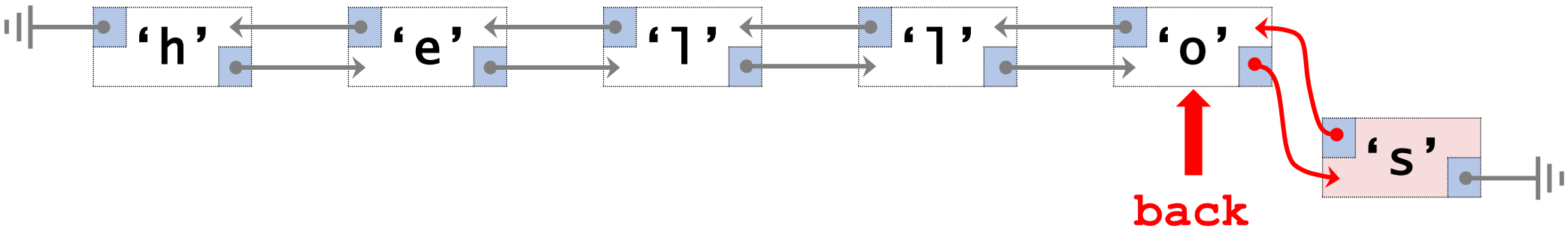
- `*iter = 'a'; // change 'e' to 'a'`

Insertion




```
l.push_back('s');
```

Insertion

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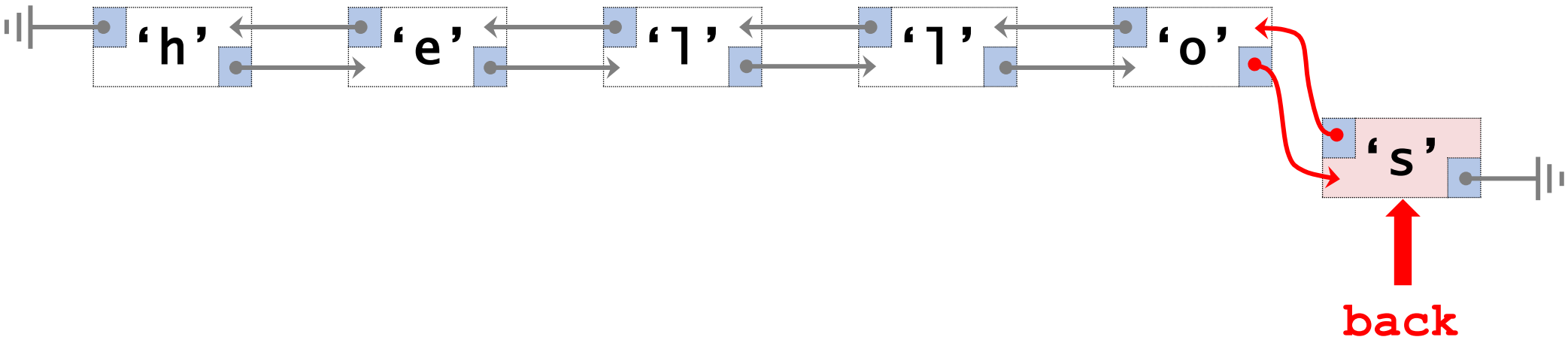
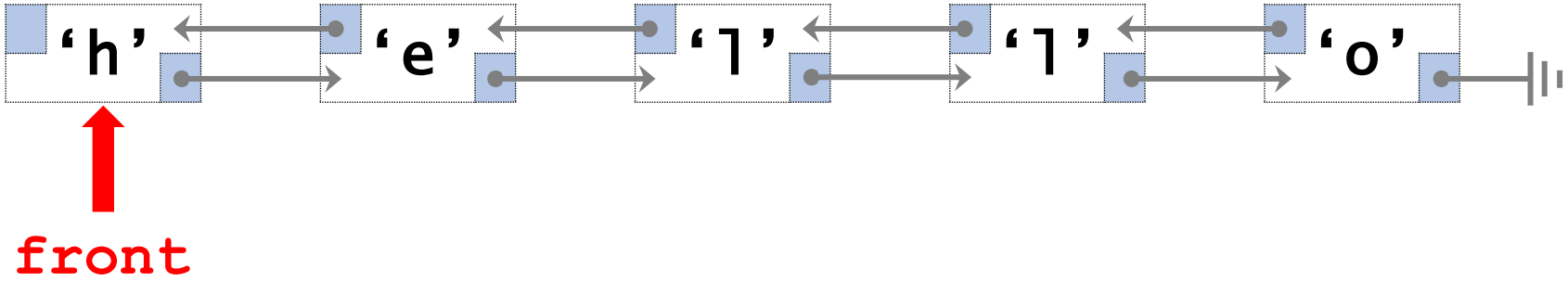
Insertion




```
l.push_back('s');
```

Only O(1) time.

Insertion




```
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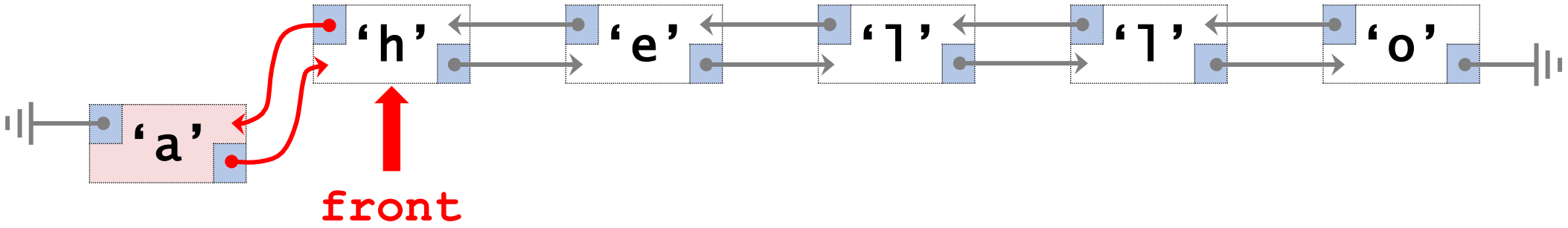
Insertion




```
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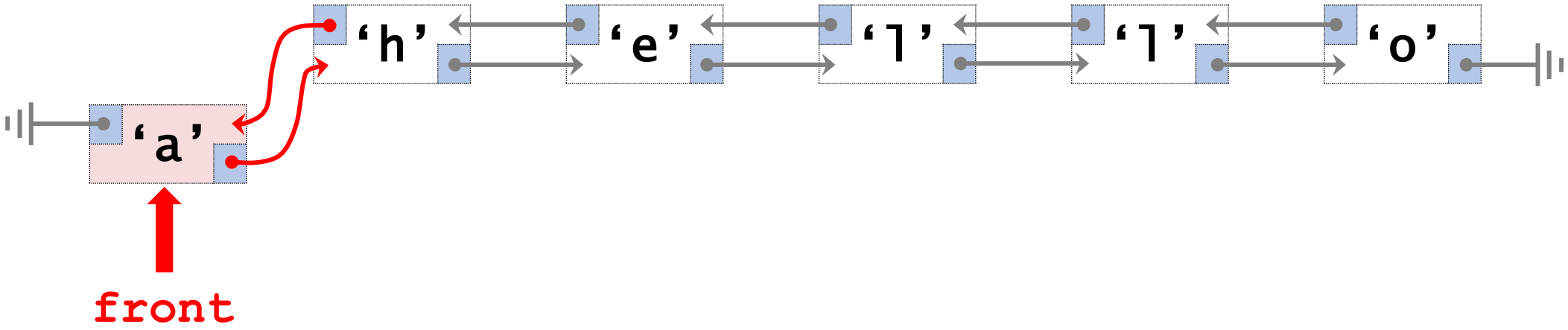
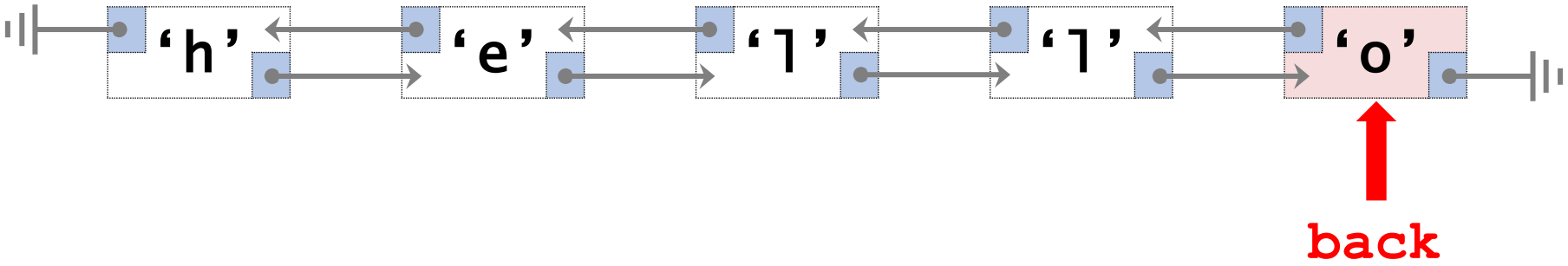



```
l.push_front('a');
```

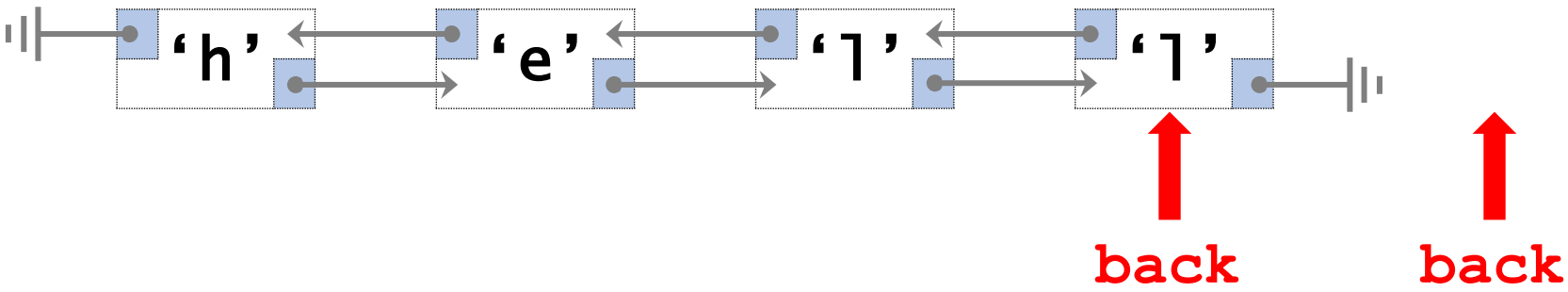
Only O(1) time.

Delete Node




```
l.pop_back();
```

Delete Node

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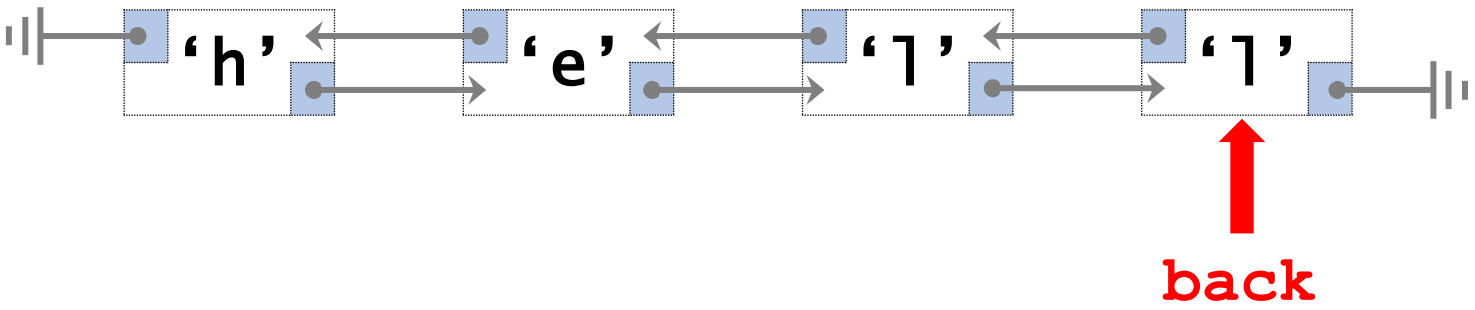
```

Delete Node




```
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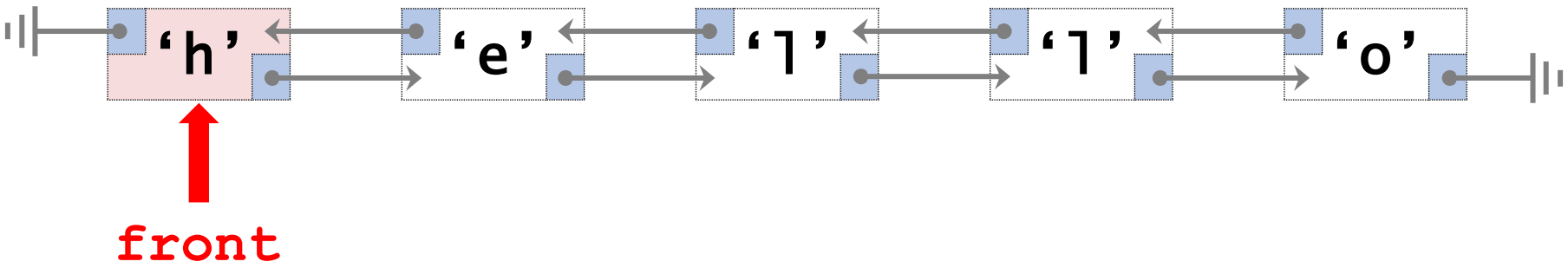
Delete Node




```
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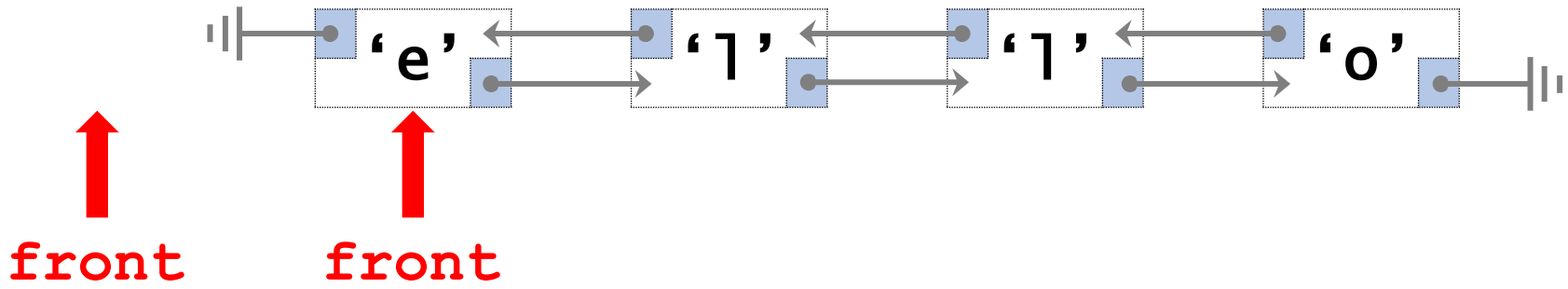
```

Delete Node

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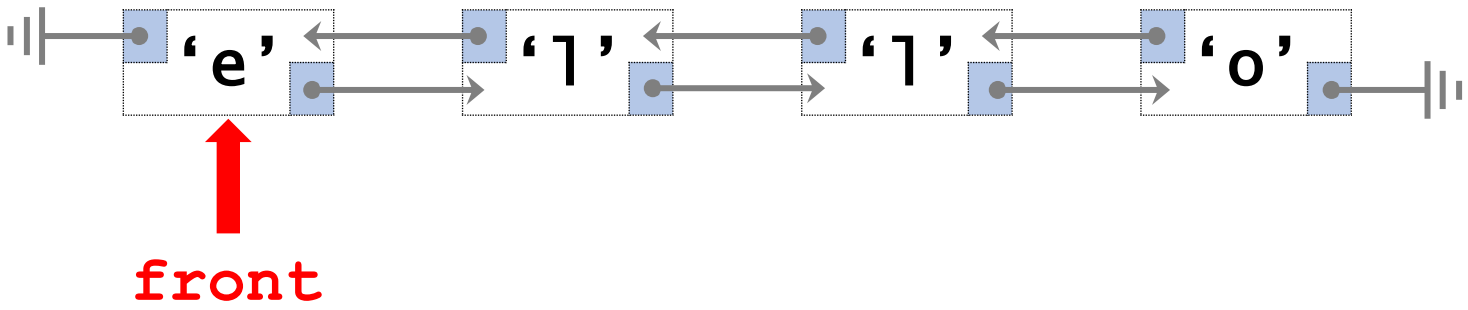
Delete Node




```
l.pop_front();
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Only O(1) time.

Summary

Properties

	Array	Vector	List
Size	fixed	can increase and decrease	can increase and decrease

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Size	fixed	can increase and decrease	can increase and decrease
Memory	contiguous	contiguous	not contiguous

Time Complexities

	`Array`	`Vector`	`List`
Rand Access	$O(1)$	$O(1)$	---

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	`Array`	`Vector`	`List`
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Time Complexities

	`Array`	`Vector`	`List`
Rand Access	$O(1)$	$O(1)$	---
`push_back()`	---	$O(1)$ (average)	$O(1)$
`pop_back()`	---	$O(1)$	$O(1)$
`insert()`	---	$O(n)$ (average)	$O(1)$

Time Complexities

	`Array`	`Vector`	`List`
Rand Access	$O(1)$	$O(1)$	---
`push_back()`	---	$O(1)$ (average)	$O(1)$
`pop_back()`	---	$O(1)$	$O(1)$
`insert()`	---	$O(n)$ (average)	$O(1)$
`erase()`	---	$O(n)$ (average)	$O(1)$

Which shall we use?

- **Array:** Fixed size throughout.

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- **Array:** Fixed size throughout.
- **Vector:**
  - Random access (i.e., read or write the i-th element) is fast.
  - Insertion and deletion at the end are fast.
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Which shall we use?

- **Array:** Fixed size throughout.
- **Vector:**
  - Random access (i.e., read or write the i-th element) is fast.
  - Insertion and deletion at the end are fast.
  - Insertion and deletion in the front and middle are slow.
- **List:**
  - Sequentially visiting elements is fast; random access is not allowed.
  - Frequent insertion and deletion at any position are OK.

Thank You!

http://wangshusen.github.io/