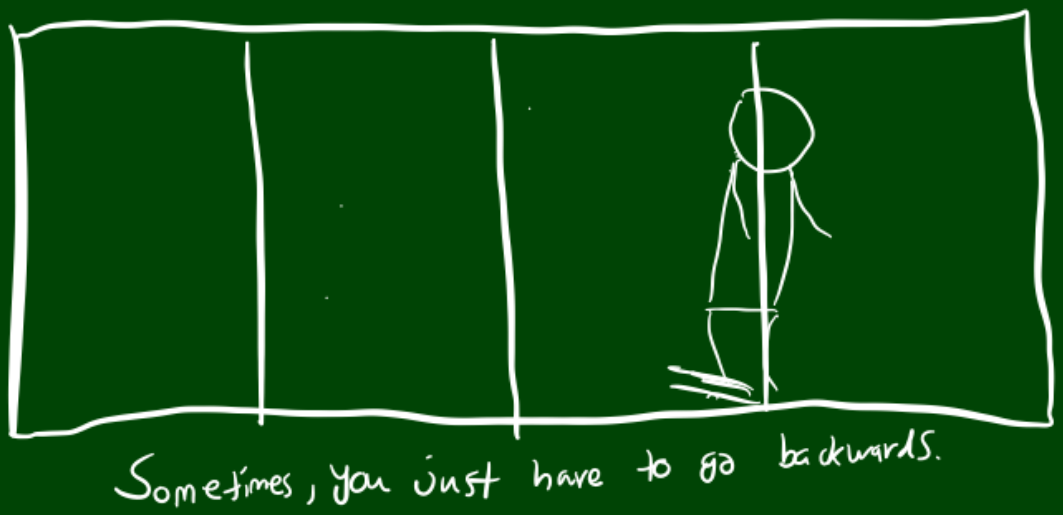
CS 2

Introduction to Programming Methods

Lists, Memory, and Arrays



Outline

```
1 Lollipop l1 = new Lollipop("Cherry");
2 Lollipop l1Again = l1;
3 Lollipop l2 = new Lollipop("Strawberry");
4 Lollipop l3 = new Lollipop("Cherry");
```

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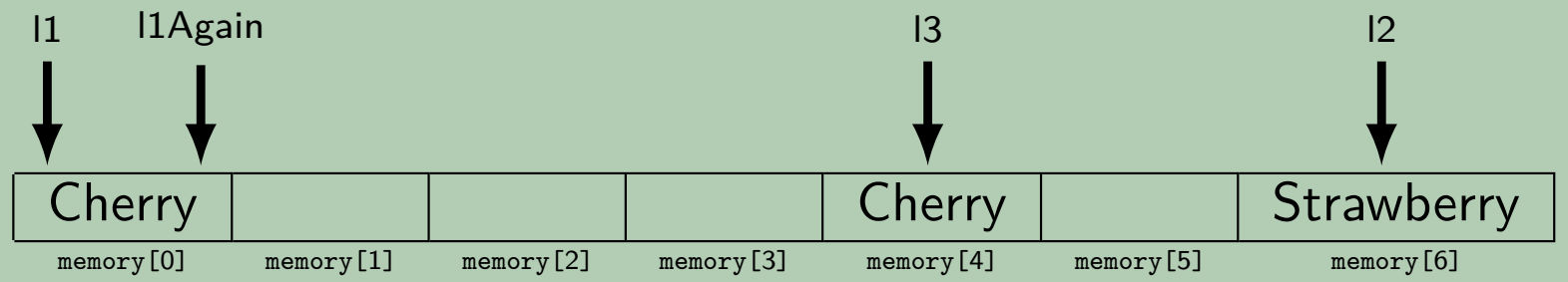
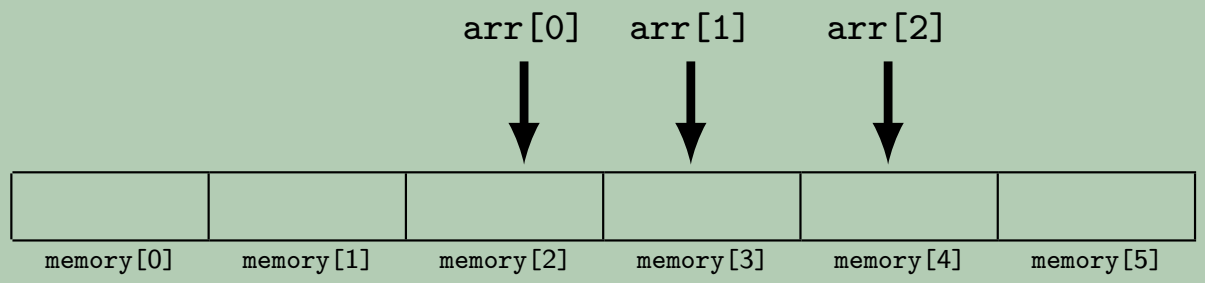
```

Lollipops in Memory



```
1  Lollipop[] arr = new Lollipop[3];
```

Arrays in Memory



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`add`, `remove`, `indexOf`, etc.

What state do we keep track of? (Fields)

Implementor View of `ArrayList`

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- Elements stored in the `ArrayList` (probably stored as an array!)
- Size of `ArrayList`

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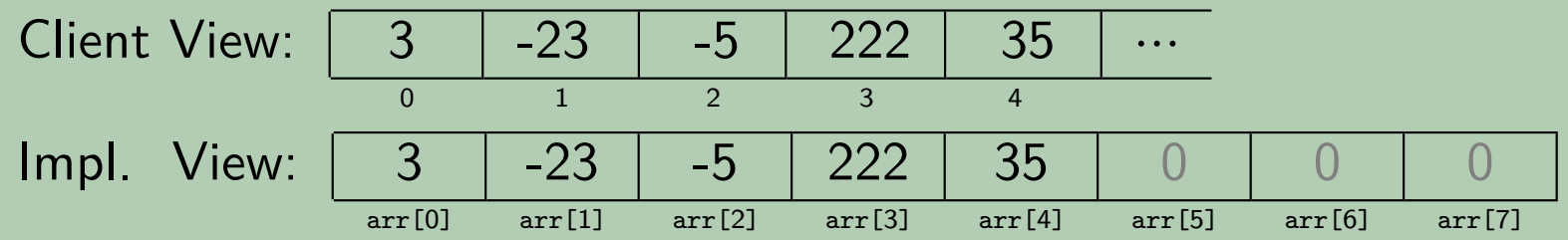
`add`, `remove`, `indexOf`, etc.

What state do we keep track of? (Fields)

- Elements stored in the `ArrayList` (probably stored as an array!)
- Size of `ArrayList`

Two Views of an `ArrayList`



- No generics (only stores ints)
- Fewer methods: `add`(value), `add`(index, value), `get`(index), `set`(index, value), `size`(), `isEmpty`(), `remove`(index), `indexOf`(value), `contains`(value), `toString`()

Printing an `ArrayIntList`

`System.out.println` automatically calls `toString` on the given object. `toString` looks like:

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1 public String toString() {
2    ...
3 }
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`ArrayIntList toString`:

```
1  public String toString() {
2     if (this.size == 0) {
3        return "[]";
4     }
5     else {
6        String result = "[" + this.data[0];
7        for (int i = 1; i < this.size; i++) {
8           result += ", " + this.data[i];
9        }
10       result += "]";
11       return result;
12    }
13 }
```

Implementing `add`

(size = 4)

3	8	2	45	0	0	0	0
`lst[0]`	`lst[1]`	`lst[2]`	`lst[3]`	`lst[4]`	`lst[5]`	`lst[6]`	`lst[7]`

`lst.add(222)`:

(size = 5)

3	8	2	45	**222**	0	0	0
`lst[0]`	`lst[1]`	`lst[2]`	`lst[3]`	`lst[4]`	`lst[5]`	`lst[6]`	`lst[7]`

How do we add to the end of the list?

Implementing `add`

(size = 4)

3	8	2	45	0	0	0	0
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- Put the element in the last slot
- Increment the size

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How do we add to the end of the list?

- Put the element in the last slot
- Increment the size

```
1 public void add(int value) {
2    this.data[this.size] = value;
3    this.size++;
4 }
```

Implementing `add` #2

(size = 4)

3	8	2	45	0	0	0	0
`list[0]`	`list[1]`	`list[2]`	`list[3]`	`list[4]`	`list[5]`	`list[6]`	`list[7]`

`list.add(1, 222)`:

(size = 5)

3	**222**	**8**	**2**	**45**	0	0	0
`list[0]`	`list[1]`	`list[2]`	`list[3]`	`list[4]`	`list[5]`	`list[6]`	`list[7]`

How do we add to the middle of the list?

Implementing `add` #2

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3	8	2	45	0	0	0	0
`list[0]`	`list[1]`	`list[2]`	`list[3]`	`list[4]`	`list[5]`	`list[6]`	`list[7]`

`list.add(1, 222)`:

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How do we add to the middle of the list?

- Shift over all elements starting from the end
- Put the new element in its index
- Increment the size

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How do we add to the middle of the list?

- Shift over all elements starting from the end
- Put the new element in its index
- Increment the size

```
1 public void add(int index, int value) {
2    for (int i = this.size; i > index; i--) {
3       this.data[i] = this.data[i - 1];
4    }
5    this.data[index] = value;
6    this.size++;
7 }
```

Redundant add Methods

```
1  /* Inside the ArrayIntList class... */
2  public void add(int value) {
3     this.set(size, value); /* THIS LINE IS DUPLICATED BELOW!!! */
4     this.size++;           /* THIS LINE IS DUPLICATED BELOW!!! */
5  }
6
7  /* Inserts value into the list at index. */
8  public void add(int index, int value) {
9     for (int i = size; i > index; i--) {
10       this.set(i, this.get(i-1));
11    }
12    this.set(size, value); /* THIS LINE IS DUPLICATED ABOVE!!! */
13    this.size++;           /* THIS LINE IS DUPLICATED ABOVE!!! */
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The fix is to call the **more general** add method from the **less general** one. (As a rule of thumb, methods with fewer arguments are less general.)

Redundant add Methods

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```

The fix is to call the **more general** add method from the **less general** one. (As a rule of thumb, methods with fewer arguments are less general.) So, we'd replace the **first** method with:

Fixed add Method

```
1  public void add(int value) {
2     add(this.size, value);
3  }
```

Duplicated Code: Constructors

We'd like to have two constructors for `ArrayIntList`:

- One that uses a default size
- One that uses a size given by the user

Redundant Constructors

```
1  /* Inside the ArrayIntList class... */
2  public ArrayIntList() {
3     this.data = new int[10];
4     this.size = 0;
5  }
6
7  public ArrayIntList(int capacity) {
8     this.data = new int[capacity];
9     this.size = 0;
10 }
```

This is a lot of redundant code! How can we fix it?

We'd like to have two constructors for `ArrayIntList`:

- One that uses a default size
- One that uses a size given by the user

Redundant Constructors

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7  public ArrayIntList(int capacity) {
8     this.data = new int[capacity];
9     this.size = 0;
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```

This is a lot of redundant code! How can we fix it?

Fixed Constructor

Java allows us to call one constructor from another using `this(...)`:

```
1  public ArrayIntList() {
2     this(10);
3  }
```

Looking back at the constructor, what's ugly about it?

```
1 public ArrayIntList() {
2    this(10);
3 }
```

The 10 is a "magic constant"; this is really bad style!! We can use:

`public static final` **type name = value**

to declare a **class constant**.

So, for instance:

`public static final int DEFAULT_CAPACITY = 10.`

Class CONSTANT

A class constant is a **global**, **unchangable** value in a class. Some examples:

- `Math.PI`
- `Integer.MAX_VALUE`, `Integer.MIN_VALUE`
- `Color.GREEN`

```
1 public class Circle {
2    int radius;
3    int x, y;
4    ...
5
6    public void moveRight(int numberOfUnits) {
7       this.x += numberOfUnits;
8    }
9 }
```

Are there any arguments to `moveRight` that are "invalid"?

Yes! We shouldn't allow negative numbers.

The implementor is responsible for (1) telling the user about invalid ways to use methods and (2) preventing a malicious user from getting away with using their methods in an invalid way!

Precondition

A **precondition** is an assertion that something must be true for a method to work correctly. The objective is to tell clients about invalid ways to use your method.

Example Preconditions:

- For `moveRight(int numberOfUnits)`:
- For `minElement(int[] array)`:
- For `add(int index, int value)`:

Preconditions are important, because they explain method behavior to the client, but **they aren't enough**! The client can still use the method in invalid ways!

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Example Preconditions:

- For `moveRight(int numberOfUnits)`:
  `// pre: numberOfUnits >= 0`
- For `minElement(int[] array)`:
  `// pre: array.length > 0`
- For `add(int index, int value)`:
  `// pre: capacity >= size + 1; 0 <= index <= size`

Preconditions are important, because they explain method behavior to the client, but **they aren't enough**! The client can still use the method in invalid ways!

Exceptions

An **exception** is an indication to the programmer that something `unexpected` has happened. When an exception happens, the program **immediately** stops running.

To make an exception happen:

- `throw new` **`ExceptionType()`**`;`
- `throw new` **`ExceptionType("message")`**`;`

Common Exception Types

`ArithmeticException`, `ArrayIndexOutOfBoundsException`, `FileNotFoundException`, `IllegalArgumentException`, `IllegalStateException`, `IOException`, `NoSuchElementException`, `NullPointerException`, `RuntimeException`, `UnsupportedOperationException`, `IndexOutOfBoundsException`

Why Use Exceptions?

Exceptions prevent the client from accidentally using the method in a way it wasn't intended. They alert them about errors in their code!

An Example

```
1  public void set(int index, int value) {
2     if (index < 0 || index >= size) {
3        throw new IndexOutOfBoundsException(index);
4     }
5     this.data[index] = value;
6  }
7
8  public int get(int index) {
9     if (index < 0 || index >= size) {
10       throw new IndexOutOfBoundsException(index);
11    }
12    return data[index];
13 }
```

Uh oh! We have MORE redundant code!

Private Methods

A **private method** is a method that **only the implementor** can use. They are useful to abstract out redundant functionality.

Better set/get

```
1  private void checkIndex(int index, int max) {
2     if (index < 0 || index > max) {
3        throw new IndexOutOfBoundsException(index);
4     }
5  }
6
7  public void set(int index, int value) {
8     checkIndex(index, size - 1);
9     this.data[index] = value;
10 }
11
12 public int get(int index) {
13    checkIndex(index, size - 1);
14    return data[index];
15 }
```

Postcondition

A **postcondition** is an assertion that something must be true **after a method has run**. The objective is to tell clients what your method does.

Example Postconditions:

- For `moveRight(int numberOfUnits)`:
- For `minElement(int[] array)`:
- For `add(int index, int value)`:

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A **postcondition** is an assertion that something must be true **after a method has run**. The objective is to tell clients what your method does.

Example Postconditions:

- For `moveRight(int numberOfUnits)`:

```
// post:  Increases the x coordinate of the circle
//        by numberOfUnits
```

- For `minElement(int[] array)`:

```
// post:  returns the smallest element in array
```

- For `add(int index, int value)`:

```
// post:  Inserts value at index in the ArrayList;
//        shifts all elements from index to the end
//        forward one index; ensures capacity of
//        ArrayList is large enough
```

Postconditions are important, because they explain method behavior to the client.

Example `ArrayList`

Client View:

29	1	3	9	8	⋯
0	1	2	3	4	

Impl. View:

29	1	3	9	8
a[0]	a[1]	a[2]	a[3]	a[4]

Let's run `add(3, 8)`! Uh oh! There's no space left. What do we do?

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a[0]	a[1]	a[2]	a[3]	a[4]

Let's run `add(3, 8)`! Uh oh! There's no space left. What do we do?

Create a new array of *double* the size, and copy the elements!

Resizing (Implementor View)

Before:

29	1	3	9	8
a[0]	a[1]	a[2]	a[3]	a[4]

Resize:

29	1	3	9	8	0	0	0	0	0
a[0]	a[1]	a[2]	a[3]	a[4]	a[5]	a[6]	a[7]	a[8]	a[9]

Insert:

29	1	3	**8**	9	8	0	0	0	0
a[0]	a[1]	a[2]	a[3]	a[4]	a[5]	a[6]	a[7]	a[8]	a[9]

Implementing `remove`

(size = 5)

3	8	2	45	6	0	0	0
list[0]	list[1]	list[2]	list[3]	list[4]	list[5]	list[6]	list[7]

`list.remove(2)`:

(size = 3)

3	8	**45**	**6**	0	0	0	0
list[0]	list[1]	list[2]	list[3]	list[4]	list[5]	list[6]	list[7]

Implementing `remove`

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3	8	2	45	6	0	0	0
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list[0]	list[1]	list[2]	list[3]	list[4]	list[5]	list[6]	list[7]

How do we remove from the middle of the list?

Implementing `remove`

(size = 5)

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`list[0]`	`list[1]`	`list[2]`	`list[3]`	`list[4]`	`list[5]`	`list[6]`	`list[7]`

How do we remove from the middle of the list?

- Shift over all elements starting from the index to remove at
- Set the last element to 0 (Do we **need** to do this?)
- Decrement the size