CS24 Week 3 Lecture 2

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Overview

- C++
  - Classes
  - Constructors
  - Destructors
- List ADT
  - Array Lists
  - Linked Lists

Note on Minor C++ Points

- Differences with `#include`, namespaces, and terminal I/O won't be covered in class
- You are still expected to know these
- Slides online for last lecture have this content

`Car` Class Example

`Rectangle` Class Example

Creating Class Instances

- Can be made either on the stack or the heap
  - On the stack: `Car c(speed);`
  - On the heap: `Car* c = new Car(speed);`
- Both of these examples call the same constructor
- For the heap, can free with: `delete c;`

Constructors in C++

Constructors

- C++ lets us define multiple constructors for a class
- Each can be used to make a class instance

Default Constructor

Default Constructor

- A constructor of special mention is the *nullary*, AKA *default* constructor
  - Takes no arguments
- Used when creating an array of objects on the stack: `Car c[20];`
  - Why?

Default Constructor

- A constructor of special mention is the *nullary*, AKA *default* constructor
  - Takes no arguments
- Used when creating an array of objects on the stack: `Car c[20];`
  - Why? - how would you pass the arguments if it weren't this way?

Default Constructor

- What happens?

```
class Foo {
  private:
    int x;
};
...
Foo f;
```

Default Constructor

- All OK - the compiler generates a *default constructor* for you

```
class Foo {
  private:
    int x;
};
...
Foo f;
```

Default Constructor

- What happens?

```
class Foo {
  private:
    int x;
};
...
Foo f; f.x;
```

Default Constructor

- Undefined - `f.x` can be set, but not accessed

```
class Foo {
  private:
    int x;
};
...
Foo f; f.x;
```

Default Constructor

- What happens?

```
class Foo {
  public:
    Foo(int y);
  private:
    int x;
};
...
Foo f;
```

Default Constructor

- Compile-time error: compiler cannot generate a default constructor

```
class Foo {
  public:
    Foo(int y);
  private:
    int x;
};
...
Foo f;
```

Copy Constructor

Copy Constructor

- Used in contexts where we need to copy an object
  - Declarations with initialization
  - Function calls

```
Car(const Car& other);
```

Copy Constructor

- What happens?

```
class Foo {
  public:
    Foo(int y);
  private:
    int x;
};
...
Foo a(1);
Foo b = a; // copy constructor
```

Copy Constructor

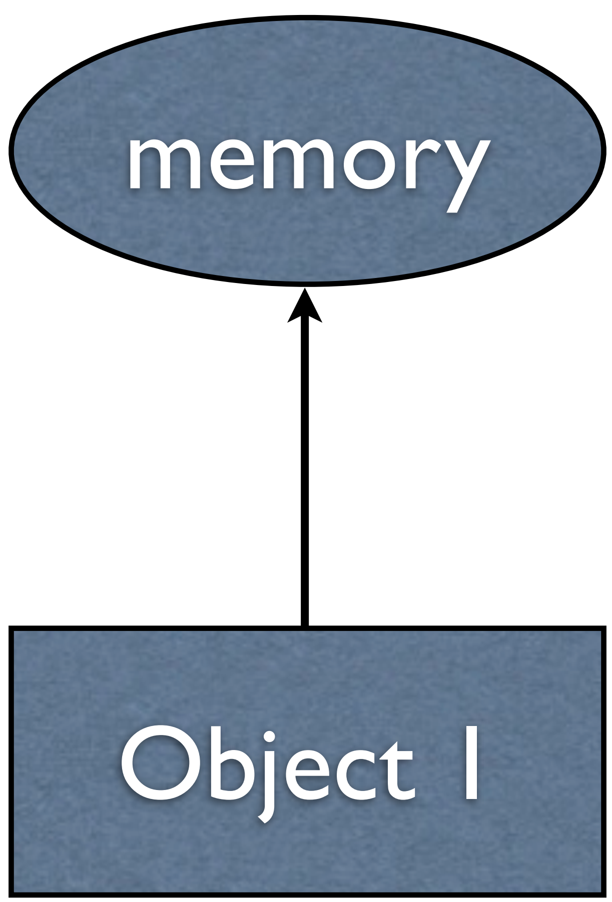
- All ok - the compiler generates a default copy constructor that copies everything

```
class Foo {
  public:
    Foo(int y);
  private:
    int x;
};
...
Foo a(1);
Foo b = a; // copy constructor
```

Default Copy Constructor

- Caveat: the copy performed is a *shallow* copy

Before Copy



Default Copy Constructor

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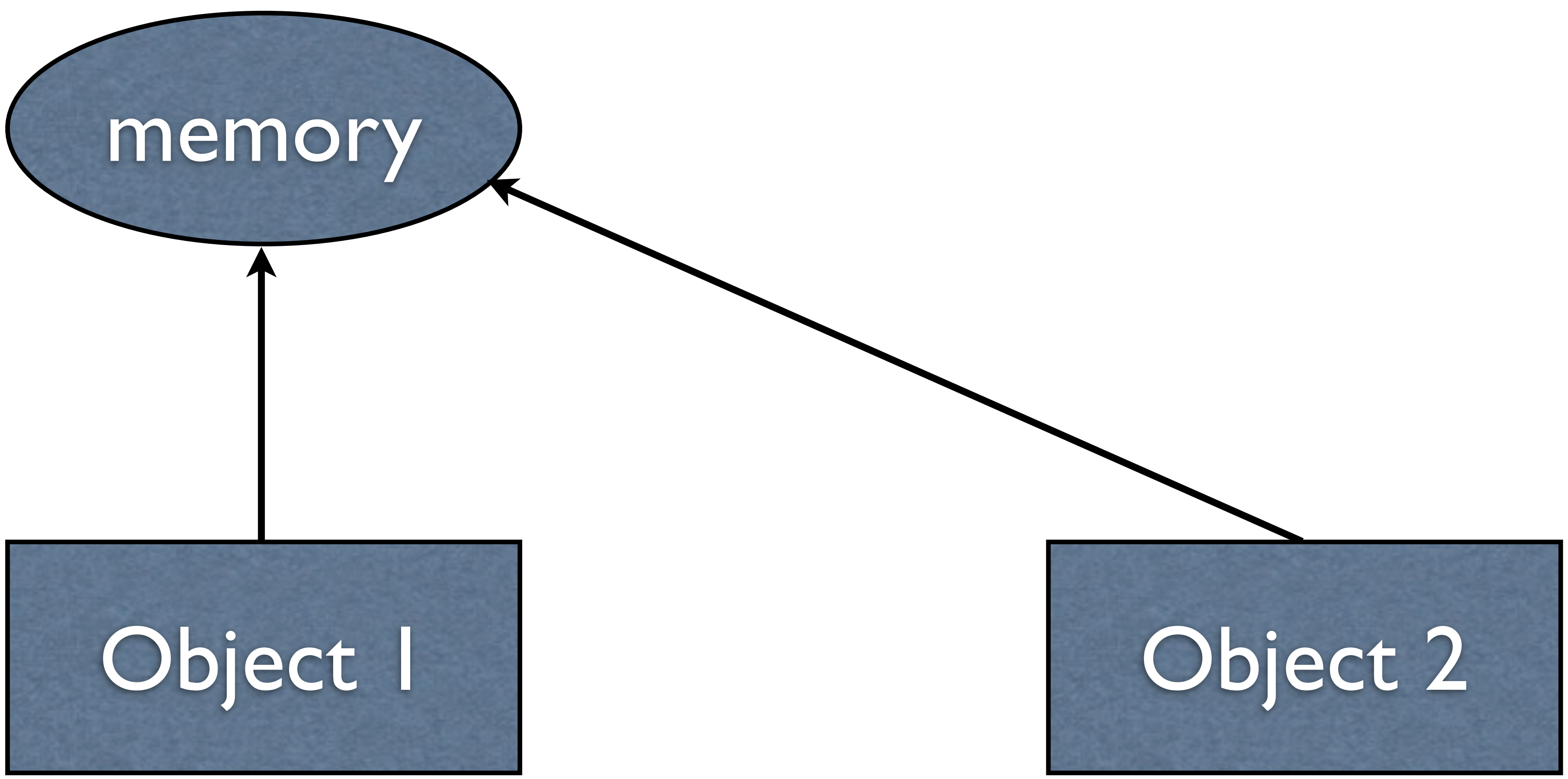
After Copy



Default Copy Constructor

- If you want a *deep copy*, you must do it yourself with your own copy constructor

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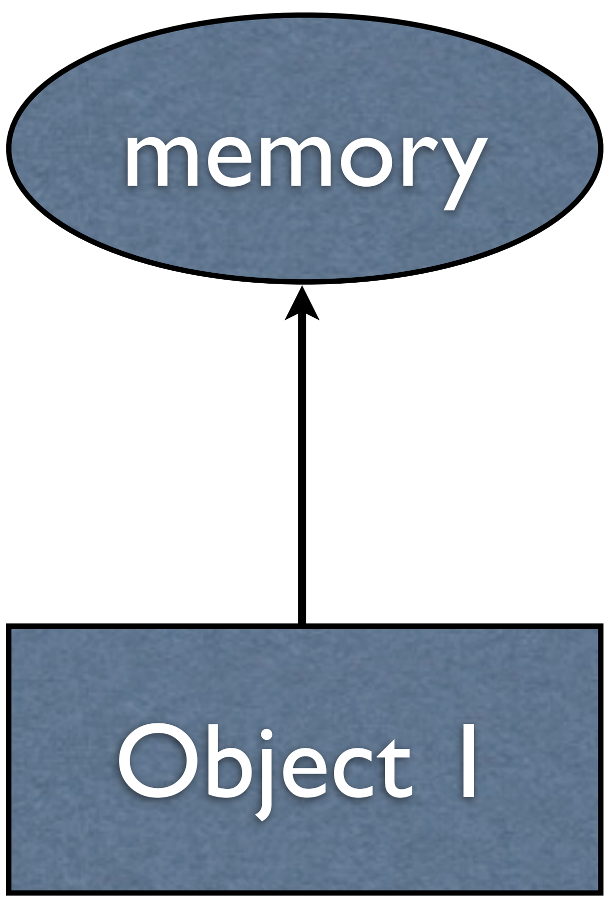
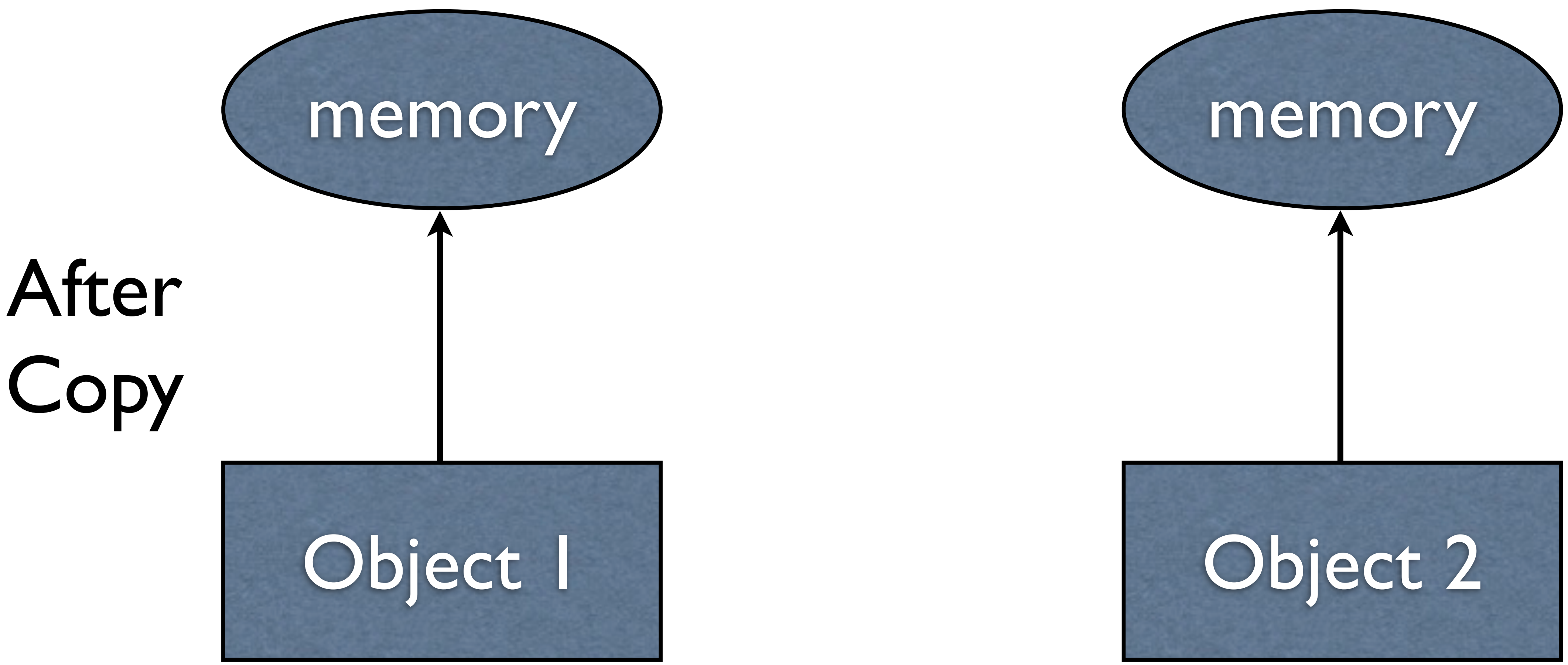


Default Copy Constructor

- If you want a *deep copy*, you must do it yourself with your own copy constructor



Destructors

Destructors

- Optionally, you can define a destructor for a class: `Car::~Car() {}`
- Destructors are called during deallocation
  - When is this for something on the stack?
  - When is this for something on the heap?

Destructors

- Optionally, you can define a destructor for a class: `Car::~Car() {}`
- Destructors are called during deallocation
  - When is this for something on the stack?
    - Return from scope that introduced it
  - When is this for something on the heap?
    - When `delete` is called on it

Destructors

- Useful for objects which dynamically allocate memory internally
  - Why?

Destructors

- Useful for objects which dynamically allocate memory internally
  - Why? - Allows for memory to be deallocated in synchronization with the object being deallocated

Additional Use of `const`

- We've seen `const` already in two positions:

What is pointed to is constant	The pointer itself is constant

```
void foo(const char* const s) {
  s[0] = 'a'; // disallowed
  s = NULL; // disallowed
}
```

Additional Use of `const`

- We can also tag whole methods with const, indicating that they may not change any state of the class they are called on
- Great for *accessors*, as opposed to *mutators*

```
class Foo {
  public:
    Foo(int a) { b = a; }
    void setValue(int a) { b = a; }
    int getValue() const { return b; }
  private:
    int b;
};
```

List ADT

Motivation

- We often work with a series of items
  - Addresses in a phone book, cards in a deck, etc.
- Arrays can be painful
  - Fixed size
  - Error-prone (e.g., index too large)
  - Repeated similar operations

Idea: A "List" ADT

- Handles the storage of elements and the addition of elements
- Holds common operations (e.g., checking if an item is contained within)
- Can protect against out-of-bounds

A List ADT

- What should the List ADT have at the logical/abstract/interface level?

A List ADT

- What should the List ADT have at the logical/abstract/interface level?
  - Basic examples: get item, add item, insert item at a position, remove item, get size
  - Many, many more examples possible

Idealized List ADT

```
List emptyList();
int getSize();
int getInt(int position);
bool containsInt(int item);
void addInt(int item);
void addIntAtPosition(int item,
                      int position);
void removeFirstInt(int item);
```

Implementing in C++

- Classes? Constructors? Methods?
- Which methods should be marked `const`?

```
List emptyList();
int getSize();
int getInt(int position);
bool containsInt(int item);
void addInt(int item);
void addIntAtPosition(int item,
                         int position);
void removeFirstInt(int item);
```

Implementing in C++

- Classes? Constructors? Methods?
- Which methods should be marked `const`?

```
List emptyList(); // Constructor
int getSize() const;
int getInt(int position) const;
bool containsInt(int item) const;
void addInt(int item);
void addIntAtPosition(int item,
                      int position);
void removeFirstInt(int item);
```

Implementing in C++

- For now, let's implement this via an array
- What other issues are present because of this design decision?

Implementing in C++

- For now, let's implement this via an array
- What other issues are present because of this design decision?
  - Size of the array?
  - Accessing out-of-bounds element?
  - Adding an element in the middle?
- How might we handle each?

Implementation in C++

Array-Based List

- What sort of operations were hard because arrays were used?

Array-Based List

- What sort of operations were hard or awkward because arrays were used?
  - Constructor needed an array size
  - Adding an element at an arbitrary position required pushing elements to the right
  - Removing an element required pushing elements to the left

Other Approaches

- How might we improve on these issues? (Fixed size, making arbitrary addition and removal easier)

Other Approaches

- How might we improve on these issues? (Fixed size, making arbitrary addition and removal easier)
  - Wide variety of answers
  - Approach we will take: linked lists

Fixed Size

- Observation: with arrays, we must allocate in blocks
  - We must pre-allocate room, and expanding this room is obnoxious
  - We would like to allocate as we go along, in a piecewise fashion

Piecewise Allocation

- How can we represent the list in a way that makes piecewise allocation possible? (Not just extending onto an array)

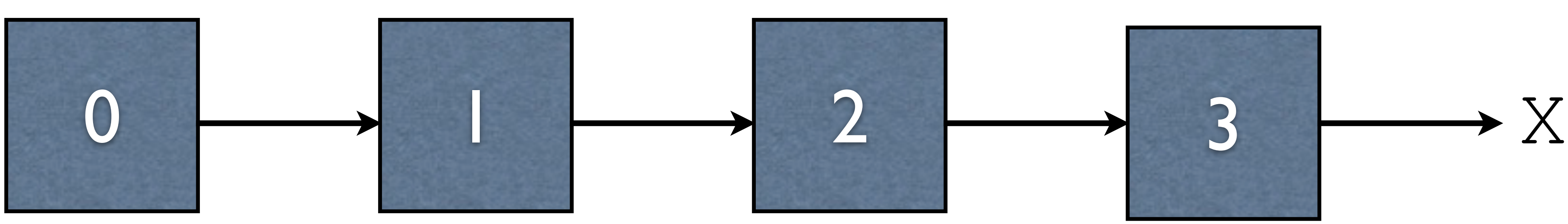
Piecewise Allocation

- How can we represent the list in a way that makes piecewise allocation possible? (Not just extending onto another array)
  - Piecewise implies separate chunks that hold onto single elements
  - How do we keep track of chunks?

Linked Lists

- Idea: have each chunk (called a *node*) keep track of both a list element *and* another chunk
- Need to keep track of only the *head* node

List: 0, 1, 2, 3



Node Representation

- What might a node look like in C/C++?

Node Representation

- What might a node look like in C?

```
struct Node {
  int item;
  struct Node* next;
};
```

Node Representation

- What might a node look like in C++?

```
class Node {
  public:
    Node(int i, Node* n);
    int getItem() const;
    void setItem(int i);
    Node* getNext() const;
    void setNext(Node* n);
  private:
    int item;
    Node* node;
};
```

C++ Implementation of Linked Lists