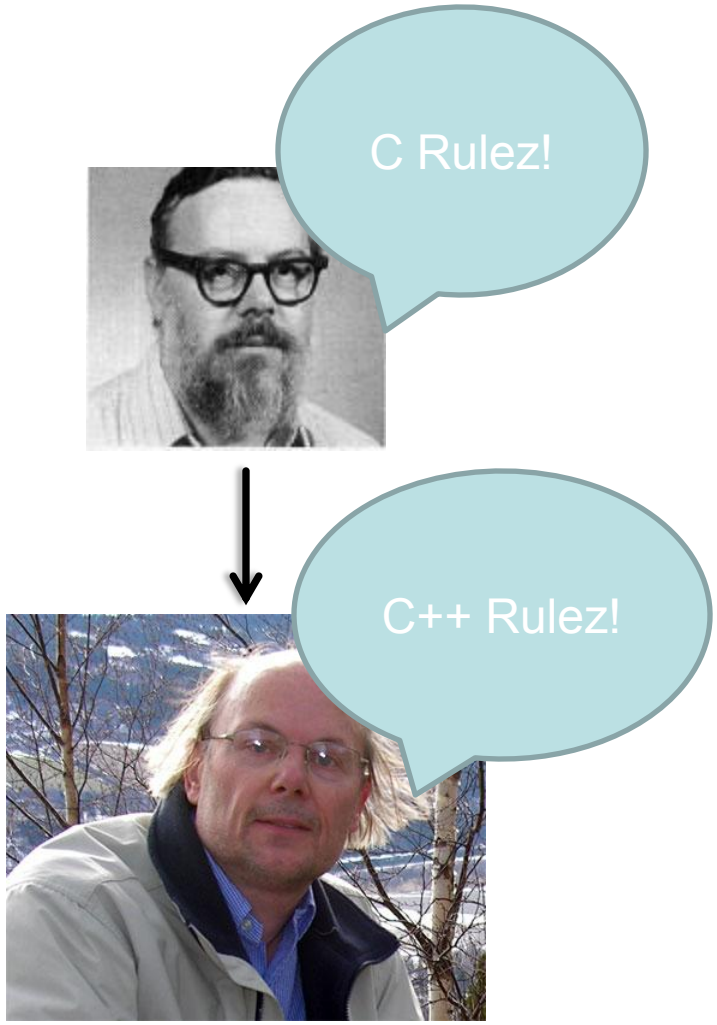
C++ Mini-Course

- Part 1: Mechanics
- Part 2: Basics
- Part 3: References
- Part 4: Const
- Part 5: Inheritance
- Part 6: Libraries
- Part 7: Conclusion



C++ Mini-Course

Part 1: Mechanics

C++ is a superset of C

- New Features include
  - Classes (Object Oriented)
  - Templates (Standard Template Library)
  - Operator Overloading
  - Slightly cleaner memory operations

Some C++ code

Segment.h

```
#ifndef __SEGMENT_HEADER__
#define __SEGMENT_HEADER__

class Point;
class Segment
{
public:
    Segment();
    virtual ~Segment();
private:
    Point *m_p0, *m_p1;
};


#endif //__SEGMENT_HEADER__
```

Segment.cpp

```
#include "Segment.h"
#include "Point.h"

Segment::Segment()
{
    m_p0 = new Point(0, 0);
    m_p1 = new Point(1, 1);
}
Segment::~Segment()
{
    delete m_p0;
    delete m_p1;
}
```

#include

```
#include "Segment.h"
```

Insert header file at this point.

```
#include <iostream>
```

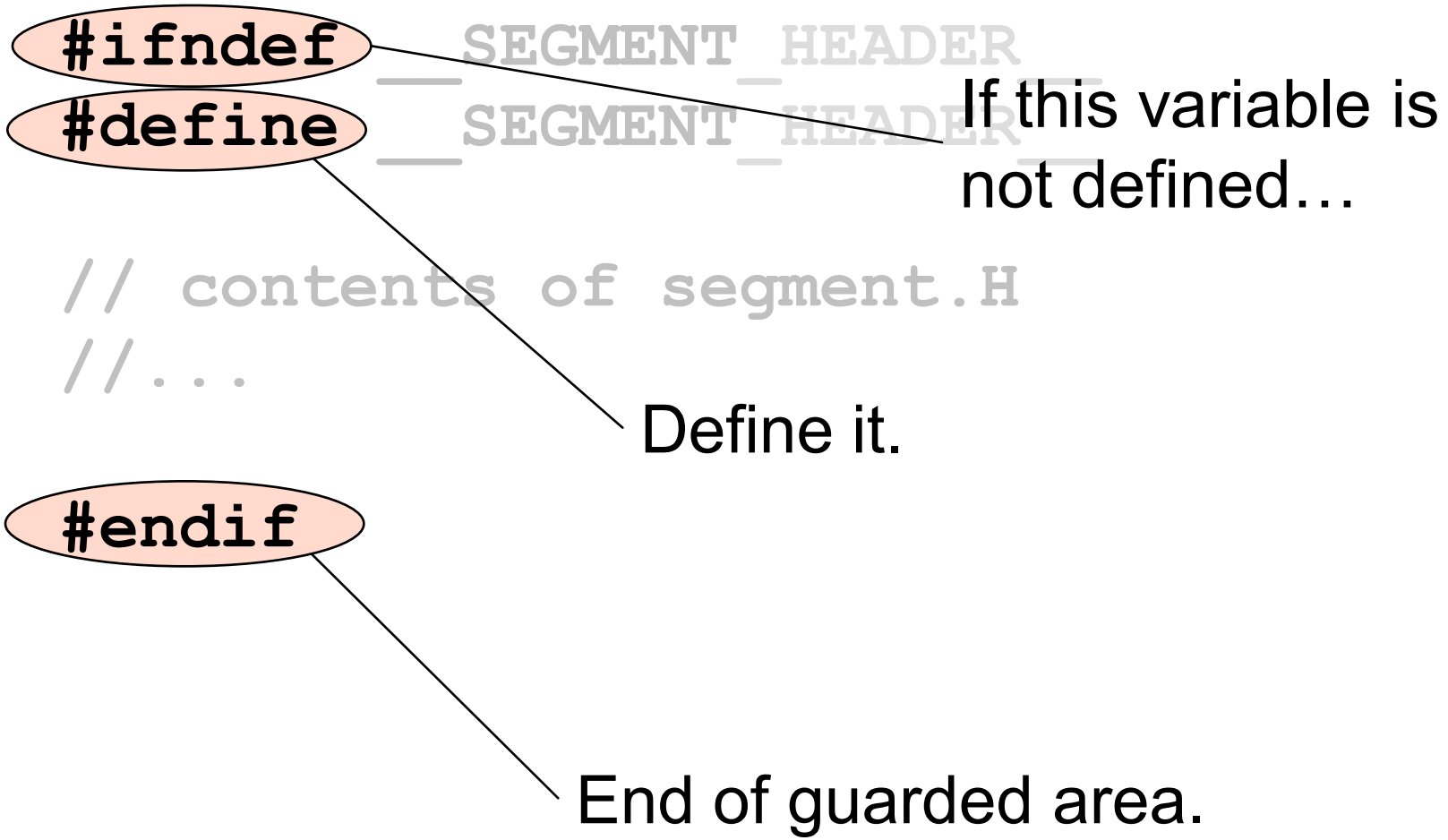
Use library header.

Header Guards

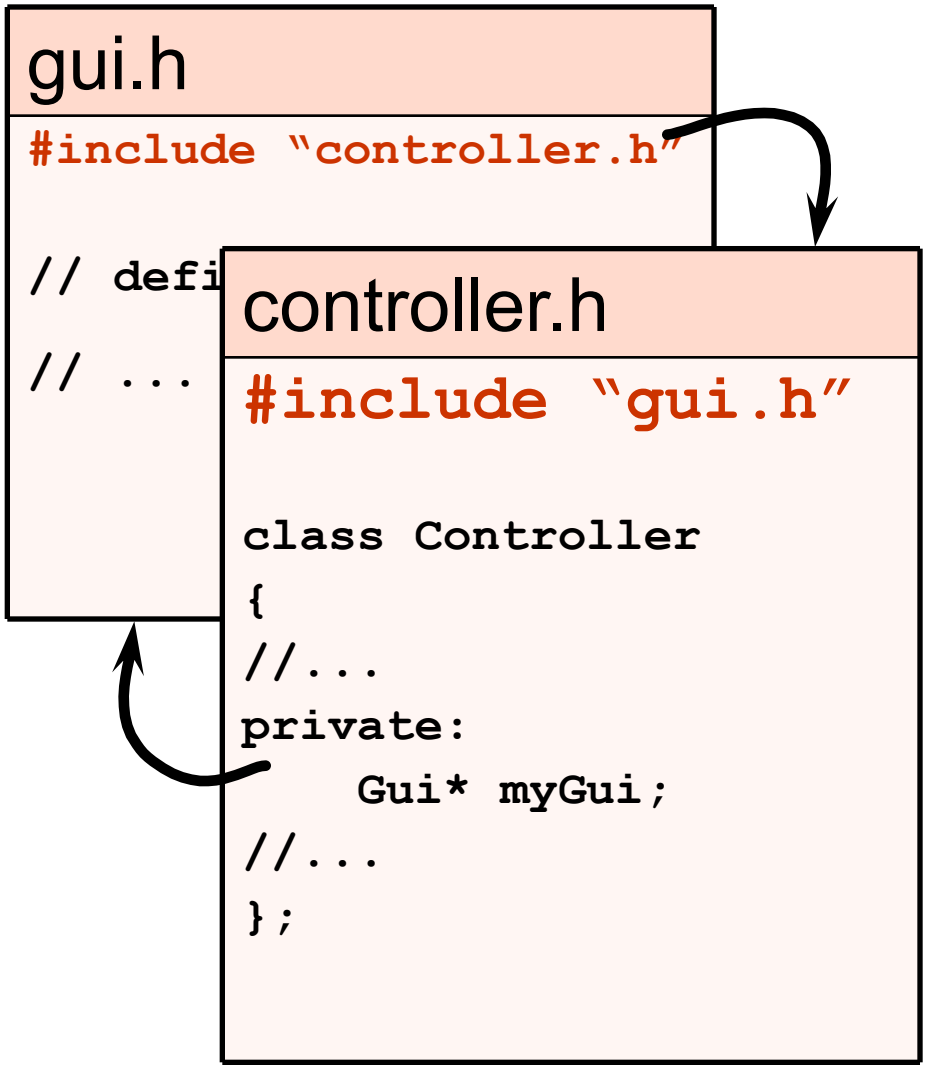
```
#ifndef __SEGMENT_HEADER__
#define __SEGMENT_HEADER__

// contents of Segment.h
//...

#endif
```

- To ensure it is safe to include a file more than once.

Header Guards



Circular Includes



- What's wrong with this picture?
- How do we fix it?

Forward Declarations

gui.h

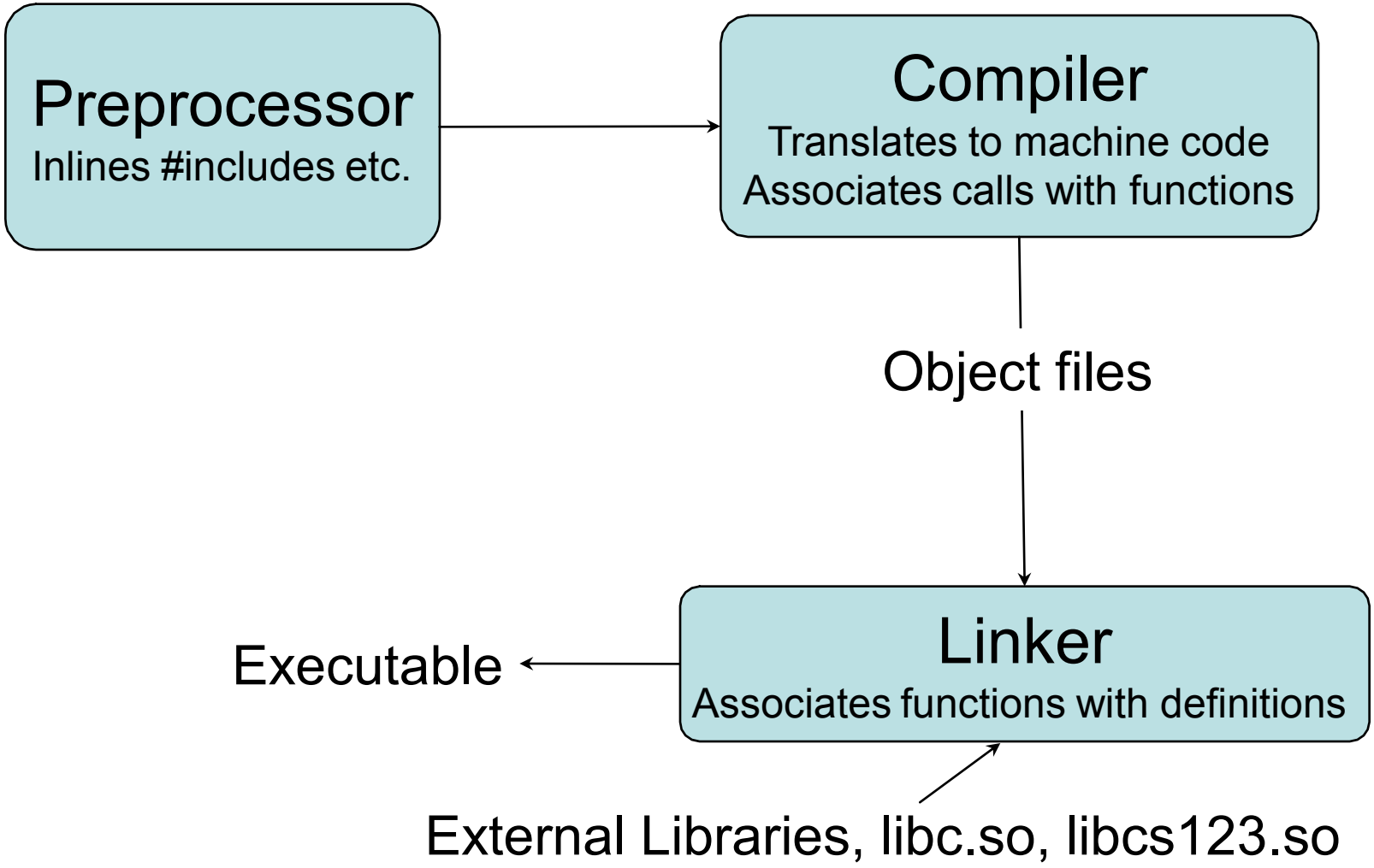
```
//Forward Declaration
class Controller;

// defi

// ...
```

controller.h

```
//Forward declaration
class Gui;

class Controller
{
//...
private:
     Gui* myGui;
//...
};
```

- In header files, only include what you must.
- If only pointers to a class are used, use forward declarations.

Compilation



OK, OK. How do I run my Program?

```
> make
```

And if all goes well…

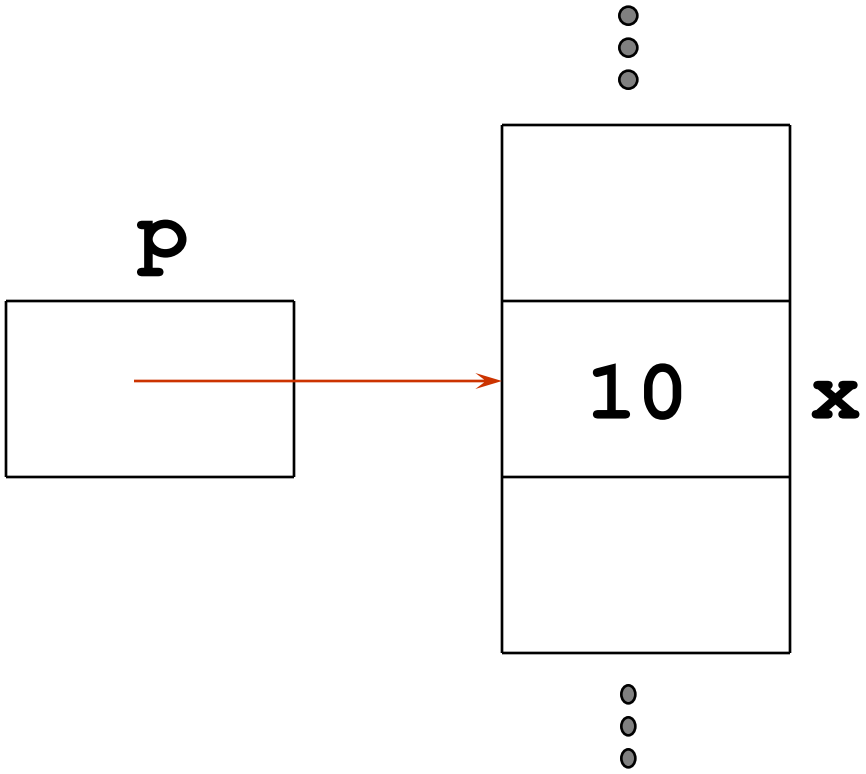
```
> ./myprog
```

C++ Mini-Course

Part 2: Basics

What is a pointer?

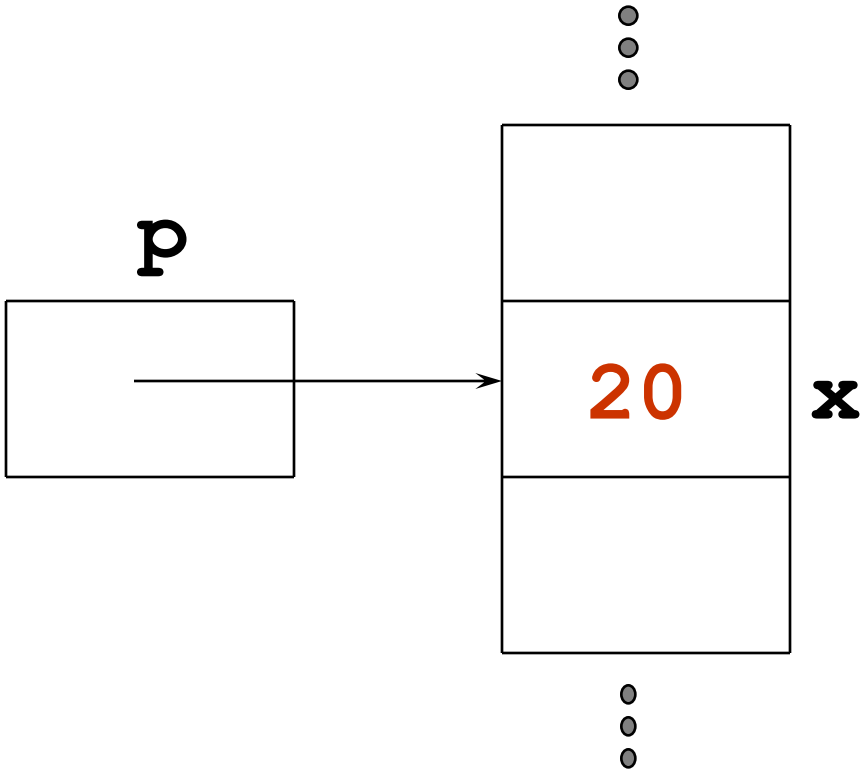
```
int x = 10;
int *p;

p = &x;
```



p gets the address of **x** in memory.

What is a pointer?

```
int x = 10;
int *p;

p = &x;

*p = 20;
```



`*p` is the value at the address `p`.

What is a pointer?

```
int x = 10;
int *p = NULL;
```

Declares a pointer to an integer

```
p = &x;
```

`&` is **address** operator
gets address of x

```
*p = 20;
```

`*` **dereference** operator
gets value at the location stored in `p`

Allocating memory using **new**

```
Point *p = new Point(5, 5);
```

- **`new`** can be thought of as a function with slightly strange syntax
- **`new`** allocates space to hold the object.
- **`new`** calls the object's constructor.
- **`new`** returns a pointer to that object.

Deallocating memory using **delete**

```
// allocate memory
Point *p = new Point(5, 5);
...
// free the memory
delete p;
p = NULL;
```

For every call to **new**, there must be exactly one call to **delete**. It's a good practice to set to **NULL** afterwards to protect against double deletes.

Using **new** with arrays

```
int x = 10;
int* nums1 = new int[10];  // ok
int* nums2 = new int[x];   // ok
```

- Initializes an array of 10 integers on the heap.
- Equivalent to the following C code

  ```
  int* nums = (int*)malloc(x * sizeof(int));
  ```

- Equivalent to the following Java code

  ```
  int[] nums = new int[x];
  ```

Using **new** with multidimensional arrays

```
int x = 3, y = 4;
int** nums3 = new int[x][4];// ok
int** nums4 = new int[x][y];// BAD!
```

- Initializes a multidimensional array
- Only the first dimension can be a variable. The rest must be constants.
- Use single dimension arrays to fake multidimensional ones

Using **delete** on arrays

```
// allocate memory
int* nums1 = new int[10];
int* nums3 = new int[x][4][5];


...
// free the memory
delete[] nums1;
delete[] nums3;
```

- Have to use **`delete[]`**, or else only the first element is deleted.

Destructors

- **`delete`** calls the object's **destructor**.
- **`delete`** frees space occupied by the object.

- A **destructor** cleans up after the object.
- Releases resources such as memory.

Destructors – an Example

```
class Segment
{
public:
    Segment();
    virtual ~Segment();
private:
    Point *m_p0, *m_p1;
};
```

Destructors – an Example

```
Segment::Segment()
{
    m_p0 = new Point(0, 0);
    m_p1 = new Point(1, 1);
}
Segment::~Segment()
{
    delete m_p0;
    delete m_p1;
}
```

New vs Malloc

- **Never** mix new/delete with malloc/free

Malloc	New
Standard C Function	Operator (like ==, +=, etc.)
Used sparingly in C++; used frequently in C	Only in C++
Used for allocating chunks of memory of a given size without respect to what will be stored in that memory	Used to allocate instances of classes / structs / arrays and will invoke an object's constructor
Returns void* and requires explicit casting	Returns the proper type
Returns NULL when there is not enough memory	Throws an exception when there is not enough memory
Every malloc() should be matched with a free()	Every new/new[] should be matched with a delete/delete[]

Syntactic Sugar “->”

```
Point *p = new Point(5, 5);

// Access a member function:
(*p).move(10, 10);

// Or more simply:
p->move(10, 10);
```

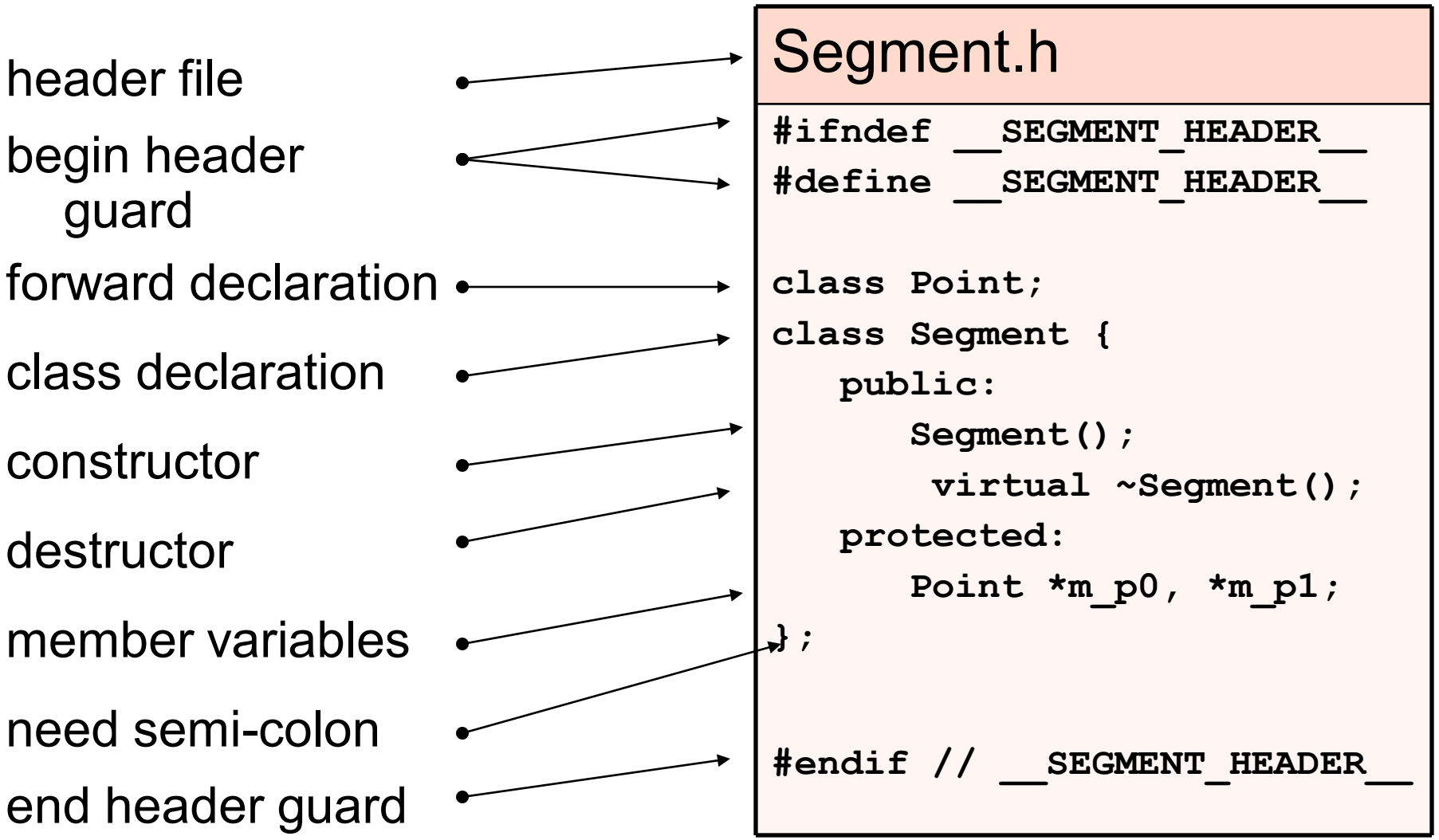
Stack vs. Heap

On the Heap / Dynamic allocation	On the Stack / Automatic allocation

`drawStuff() {`
`  Point *p = new Point();`
`  p->move(10,10);`
`  //...`
`}`
	`drawStuff() {`
	`  Point p();`
	`  p.move(5,5);`
	`  //...`
	`}`

What happens when **`p`** goes out of scope?

Summary with Header File



Syntax Note

- The following two statements mean the same thing
- They both allocate space for a Point object on the stack:
  - `Point p();`
  - `Point p = Point();`

C++ Mini-Course

Part 3: References

Passing by value

```
void Math::square(int i) {
     i = i*i;
}

int main() {
     int i = 5;
     Math::square(i);
     cout << i << endl;
}
```

Passing by reference

```
void Math::square(int &i) {
     i = i*i;
}

int main() {
     int i = 5;
     Math::square(i);
     cout << i << endl;
}
```

What is a reference?

- An alias – another name for an object.

```
int x = 5;
int &y = x; // y is a
            // reference to x
y = 10;
```

- What happened to x?
- What happened to y?

What is a reference?

- An alias – another name for an object.

```
int x = 5;
int &y = x; // y is a
            // reference to x
y = 10;
```

- What happened to x?
- What happened to y? – y **is** x.

Why are they useful?

- Unless you know what you are doing, do not pass objects by value; either use a pointer or a reference.
- Some people find it easier to deal with references rather then pointers, but in the end there is really only a syntactic difference (neither of them pass by value).
- Can be used to return more than one value (pass multiple parameters by reference)

Passing by reference: the bottom line

- The syntax is as though the parameter was passed by value.
- But behind the scenes, C++ is just passing a pointer.
- The following two are basically the same thing:

```
void increment(int &i)
{
     i = i + 1;
}
...
     int i;
     increment(i);
```

```
void increment(int *i)
{
     *i = i + 1;
}
...
     int i;
     increment(&i);
```

How are references different from Pointers?

Reference	**Pointer**
`int &a;`	`int *a;`

`int a = 10;`
`int b = 20;`
`int &c = a;`
`c = b;`
	`int a = 10;`
	`int b = 20;`
	`int *c = &a;`
	`c = &b;`

Asterisks and Ampersands

- In a type declaration, ‘*’ indicates that you are declaring a pointer type.
  - Otherwise ‘*’ is a dereference operator—gets the actual object from a pointer to the object.
- In a type declaration, ‘&’ indicates that you are declaring a reference.
  - Otherwise ‘&’ is the “address of” operator—gets a pointer to an object from the object itself.

C++ Mini-Course

Part 4: const

Introducing: `const`

```
void Math::printSquare(const int &i){
    i = i*i;
    cout << i << endl;
}

int main() {
    int i = 5;
    Math::printSquare(i);
    Math::printCube(i);
}
```

Can also pass pointers to `const`

```
void Math::printSquare(const int *pi) {
    *pi = (*pi) * (*pi);
    cout << pi << endl;
}

int main() {
    int i = 5;
    Math::printSquare(&i);
    Math::printCube(&i);
}
```

⟵ Still won't compile.

Declaring things **const**

```
const River nile;

const River* nilePc;

River* const nileCp;

const River* const nileCpc
```

Read pointer declarations right to left

```
// A const River
const River nile;

// A pointer to a const River
const River* nilePc;

// A const pointer to a River
River* const nileCp;

// A const pointer to a const River
const River* const nileCpc
```

Let's Try References

```
River nile;

const River &nileC = nile;

// Will this work?
River &nile1 = nileC;
```

How does **`const`** work here?

```
void Math::printSquares(const int &j,
  int &k) {
    k = k*k;  // Does this compile?
    cout << j*j << ", " << k << endl;
}

int main() {
    int i = 5;
    Math::printSquares(i, i);
}
```

Returning `const` references is OK

```
class Point {
   public:
      const double &getX() const;
      const double &getY() const;
      void move(double dx, double dy);

   protected:
      double m_x, m_y;
};
```

```
const double &
Point::getX() const {
     return m_x;
}
```

Function won't change `*this`.

C++ Mini-Course

Part 5: Inheritance

Classes vs Structs

- Default access specifier for classes is private; for structs it is public
- Except for this difference, structs are functionally the same as classes, but the two are typically used differently: structs should be thought of as lightweight classes that contain mostly data and possibly convenience methods to manipulate that data and are hardly ever used polymorphically

```
struct Point {
    int x;
    int y;

    // convenience constructor
    Point(int a, int b)
       : x(a), y(b)
    { }

    // @returns distance to another point
    double distance(const Point &pnt) {
        int dx = m_x - pnt.x;
        int dy = m_y - pnt.y;
        return math.sqrt(dx*dx + dy*dy);
    }
};
```

```
class Segment {
   public:
        Segment();
        virtual ~Segment();

        void setPoints(int x0, int y0, int x1, int y1);

    protected:
        Point *m_p0, *m_p1;
};

void Segment::setPoints(int x0, int y0, int x1, int y1) {
    m_p0 = new Point(x0, y0);
    m_p1 = new Point(x1, y1);
}
```

How does inheritance work?

must include parent header file

DottedSegment publicly inherits from Segment

```
#include "Segment.h"
class DottedSegment : public Segment
{
        // DottedSegment declaration
};
```

virtual

- In Java every method invocation is dynamically bound, meaning for every method invocation the program checks if a sub-class has overridden the method. You can disable this (somewhat) by using the keyword “final” in Java
- In C++ you have to declare the method virtual if you want this functionality. (So, “virtual” is the same thing as “not final”)
- You should declare methods virtual when they are designed to be overridden or will otherwise participate in an inheritance hierarchy.

pure virtual functions

- In Java, the “abstract” keyword means the function is undefined in the superclass.
- In C++, we use pure virtual functions:
  - virtual int mustRedfineMe(char *str) = 0;
  - This function must be implemented in a subclass.

Resolving functions

In Java:

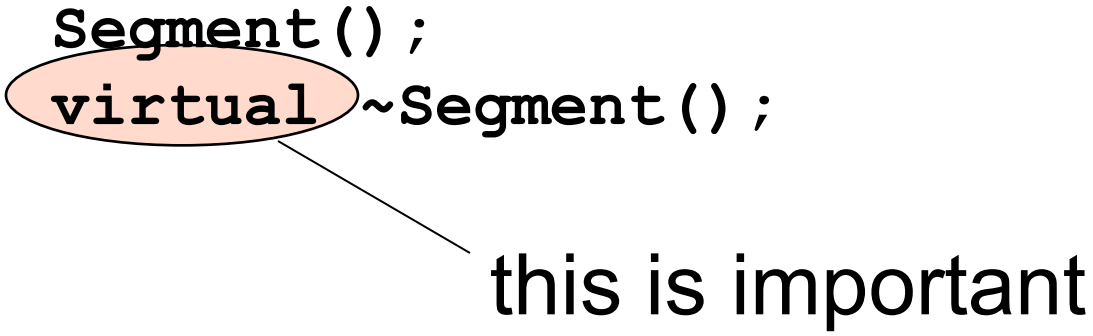
```
// Overriding methods
public void overloaded(){
  println("woohoo");
  super.overloaded();
}

//constructor
public Subclass(){
  super();
}
```

In C++:

```
// Overriding methods
void Subclass::overloaded(){
  cout<<"woohoo"<<endl;
  Superclass::overloaded();
}

//constructor
public Subclass() :
  Superclass()
{ }
```

Make destructors virtual

- Make sure you declare your destructors virtual; if you do not declare a destructor a non-virtual one will be defined for you



C++ Mini-Course

Part 6: Libraries

Namespaces

- Namespaces are kind of like packages in Java
- Reduces naming conflicts
- Most standard C++ routines and classes and under the **`std`** namespace
  - Any standard C routines (malloc, printf, etc.) are defined in the global namespace because C doesn't have namespaces

using namespace

```
#include <iostream>
...
std::string question =
            “How do I prevent RSI?”;
std::cout << question << std::endl;

using namespace std;

string answer = “Type less.”;
cout << answer << endl;
```

Bad practice to do in header files!

STL

- Standard Template Library
- Contains well-written, templated implementations of most data structures and algorithms
  - Templates are similar to generics in Java
  - Allows you to easily store anything without writing a container yourself
- Will give you the most hideous compile errors ever if you use them even slightly incorrectly!

STL example

```
#include <vector>
using namespace std;

typedef vector<Point> PointVector;
typedef PointVector::iterator PointVectorIter;

PointVector v;
v.push_back(Point(3, 5));

PointVectorIter iter;
for(iter = v.begin(); iter != v.end(); ++iter){
   Point &curPoint = *iter;
}
```

C++ Mini-Course

Part 7: Conclusion

Other Resources

- The Java To C++ tutorial on the website is probably your best source of information
- The big thick book by Stroustrop in the back of the Sun Lab is the ultimate C++ reference
- A CS 123 TA, or specifically your mentor TA if you have been assigned one

Question and Answer Session