C++ Tutorial

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Overview

- Basic Syntax
- Pointers
- Dynamic Memory
- Parameter passing
- Class basics
- Constructors & destructors
- Class Hierarchy
- Virtual Functions
- Organizational Strategy
- Coding tips
- Compiling

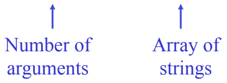
The basic C++ program

```
#include <iostream>                 Includes function definitions for
using namespace std;                console input and output

float c(float x) {                  Function declaration
  return x*x*x;                     Function definition
}

int main() {                        Program starts here
  float x;                          Local variable declaration
  cin >> x;                         Console input
  cout << c(x) << endl;             Console output

  return 0;                         Exit main function
}
```

The main function

This is where your code begins execution

```
int main(int argc, char** argv);
```



Number of arguments

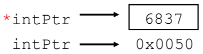
Array of strings

`argv[0]` is the program name

`argv[1]` through `argv[argc-1]` are command-line input

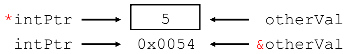
Pointers

```
int *intPtr;                Create a pointer

intPtr = new int;           Allocate memory

*intPtr = 6837;             Set value at given address
```



```
*intPtr ──→ 6837
 intPtr ──→ 0x0050
```

```
delete intPtr;              Deallocate memory

int otherVal = 5;           Change intPtr to point to
intPtr = &otherVal;         a new location
```



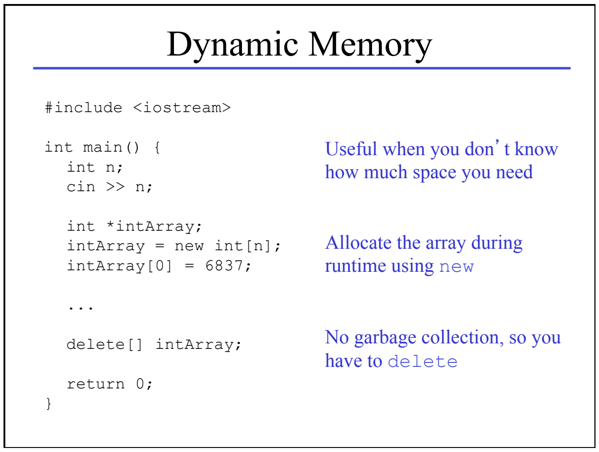
```
*intPtr ──→   5    ←── otherVal
 intPtr ──→ 0x0054 ←── &otherVal
```

Dynamic Memory

Fixed size array

```
int intArray[10];
intArray[0] = 6837;
```

```
#include <iostream>

int main() {
  int n;                        Arrays must have known sizes
  cin >> n;                     at compile time
  int intArray[n];
  intArray[0] = 6837;           This doesn't compile

  return 0;
}
```



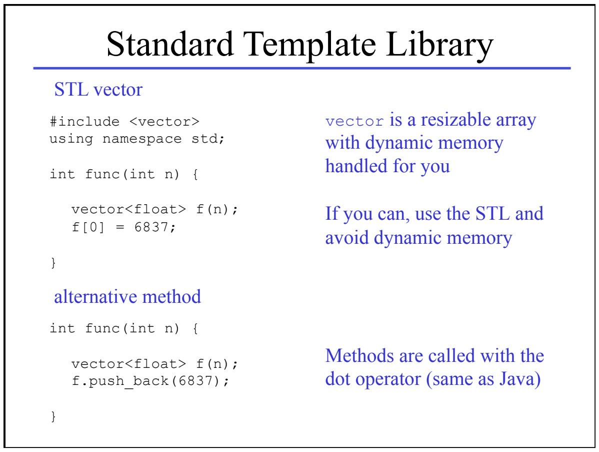
Dynamic Memory

```
#include <iostream>

int main() {
  int n;
  cin >> n;

  int *intArray;
  intArray = new int[n];
  intArray[0] = 6837;

  ...

  delete[] intArray;

  return 0;
}
```

Useful when you don’t know how much space you need

Allocate the array during runtime using `new`

No garbage collection, so you have to `delete`



Standard Template Library

STL vector

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

int func(int n) {

  vector<float> f(n);
  f[0] = 6837;

}
```

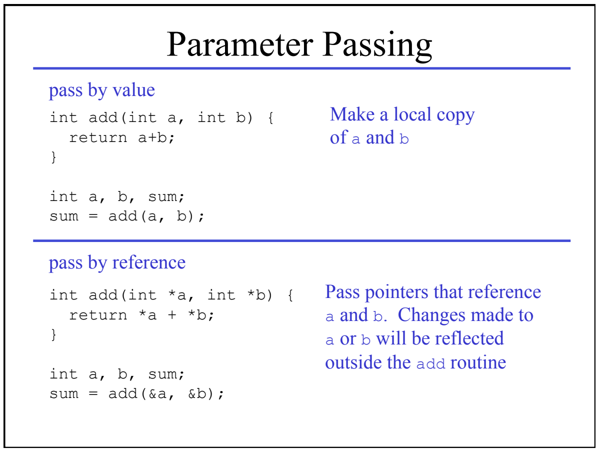
`vector` is a resizable array with dynamic memory handled for you

If you can, use the STL and avoid dynamic memory

alternative method

```
int func(int n) {

  vector<float> f(n);
  f.push_back(6837);

}
```

Methods are called with the dot operator (same as Java)



Parameter Passing

pass by value

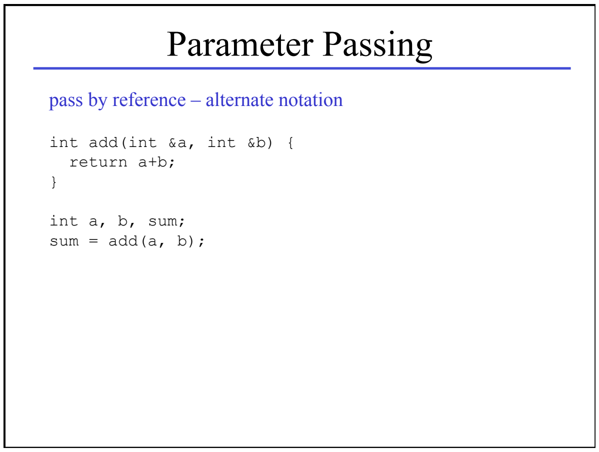
```
int add(int a, int b) {
  return a+b;
}

int a, b, sum;
sum = add(a, b);
```

Make a local copy of `a` and `b`

pass by reference

```
int add(int *a, int *b) {
  return *a + *b;
}

int a, b, sum;
sum = add(&a, &b);
```

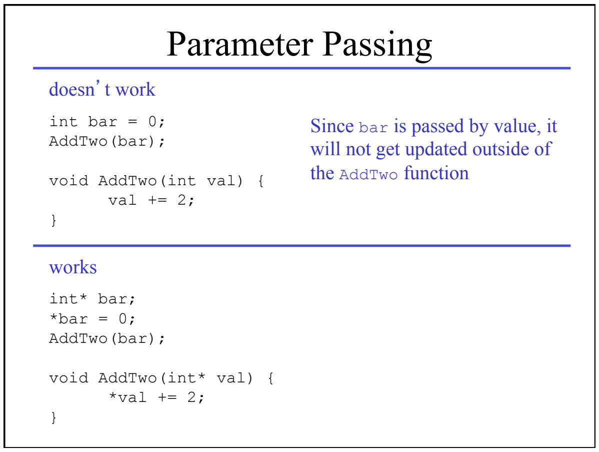
Pass pointers that reference `a` and `b`. Changes made to `a` or `b` will be reflected outside the `add` routine



Parameter Passing

pass by reference – alternate notation

```
int add(int &a, int &b) {
  return a+b;
}

int a, b, sum;
sum = add(a, b);
```



Parameter Passing

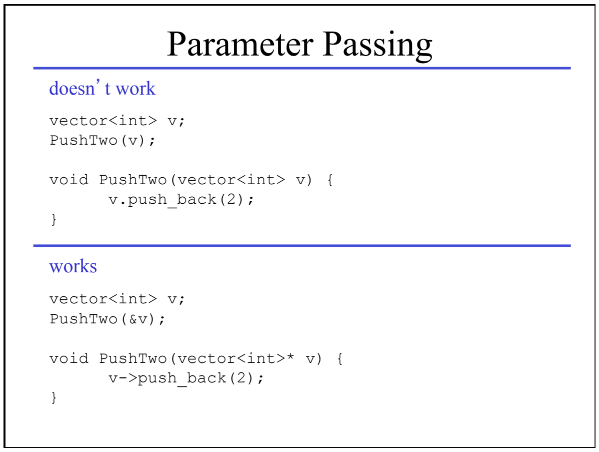
doesn’t work

```
int bar = 0;
AddTwo(bar);

void AddTwo(int val) {
      val += 2;
}
```

Since `bar` is passed by value, it will not get updated outside of the `AddTwo` function

works

```
int* bar;
*bar = 0;
AddTwo(bar);

void AddTwo(int* val) {
      *val += 2;
}
```



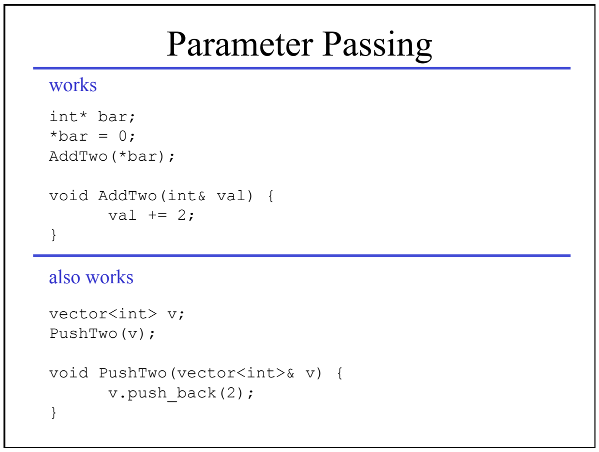
Parameter Passing

doesn’t work

```
vector<int> v;
PushTwo(v);

void PushTwo(vector<int> v) {
      v.push_back(2);
}
```

works

```
vector<int> v;
PushTwo(&v);

void PushTwo(vector<int>* v) {
      v->push_back(2);
}
```



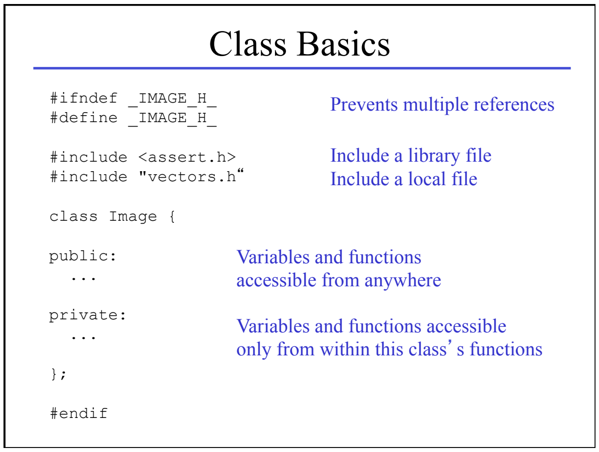
Parameter Passing

works

```
int* bar;
*bar = 0;
AddTwo(*bar);

void AddTwo(int& val) {
      val += 2;
}
```

also works

```
vector<int> v;
PushTwo(v);

void PushTwo(vector<int>& v) {
      v.push_back(2);
}
```



Class Basics

```
#ifndef _IMAGE_H_
#define _IMAGE_H_
```

Prevents multiple references

```
#include <assert.h>
#include "vectors.h“
```

Include a library file

Include a local file

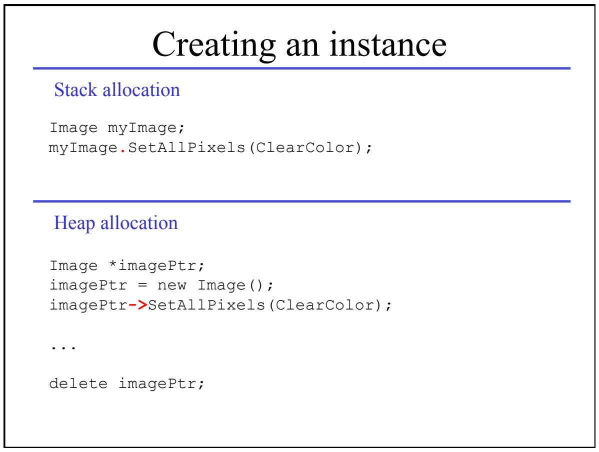
```
class Image {

public:
  ...
```

Variables and functions accessible from anywhere

```
private:
  ...
```

Variables and functions accessible only from within this class’s functions

```
};

#endif
```



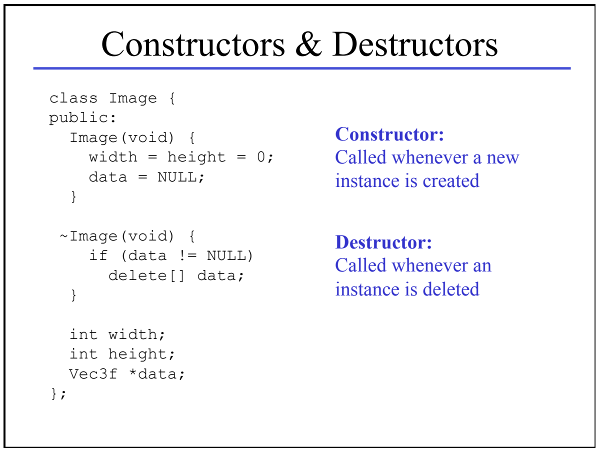
Creating an instance

Stack allocation

```
Image myImage;
myImage.SetAllPixels(ClearColor);
```

Heap allocation

```
Image *imagePtr;
imagePtr = new Image();
imagePtr->SetAllPixels(ClearColor);

...

delete imagePtr;
```



Constructors & Destructors

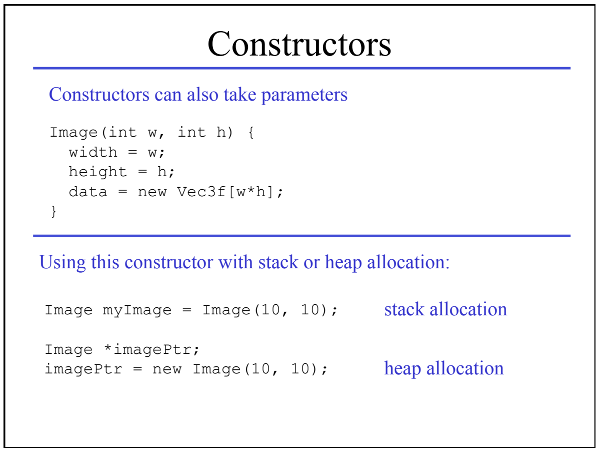
```
class Image {
public:
  Image(void) {
    width = height = 0;
    data = NULL;
  }
```

Constructor:
Called whenever a new instance is created

```
 ~Image(void) {
    if (data != NULL)
      delete[] data;
  }
```

Destructor:
Called whenever an instance is deleted

```
  int width;
  int height;
  Vec3f *data;
};
```



Constructors

Constructors can also take parameters

```
Image(int w, int h) {
  width = w;
  height = h;
  data = new Vec3f[w*h];
}
```

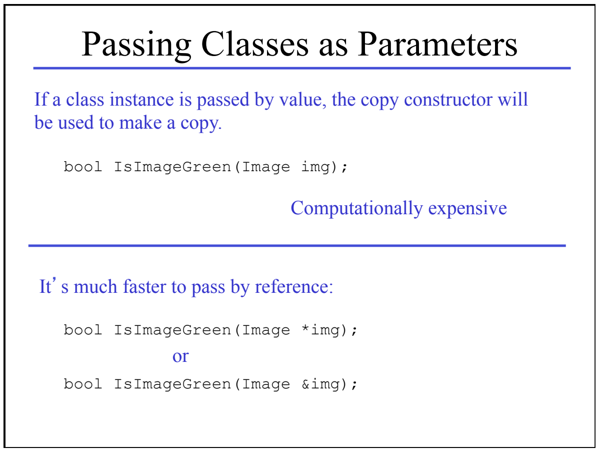
Using this constructor with stack or heap allocation:

```
Image myImage = Image(10, 10);
```

stack allocation

```
Image *imagePtr;
imagePtr = new Image(10, 10);
```

heap allocation



Passing Classes as Parameters

If a class instance is passed by value, the copy constructor will be used to make a copy.

```
bool IsImageGreen(Image img);
```

Computationally expensive

It’s much faster to pass by reference:

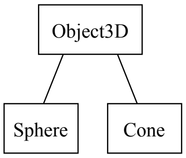
```
bool IsImageGreen(Image *img);
```

or

```
bool IsImageGreen(Image &img);
```

Class Hierarchy

Child classes inherit parent attributes



```
class Object3D {
  Vec3f color;
};

class Sphere : public Object3D {
  float radius;
};

class Cone : public Object3D {
  float base;
  float height;
};
```

Class Hierarchy

Child classes can *call* parent functions

```
Sphere::Sphere() : Object3D() {
  radius = 1.0;
}
```

Call the parent constructor

Child classes can *override* parent functions

Superclass

```
class Object3D {
  virtual void setDefaults(void) {
    color = RED; }
};
```

Subclass

```
class Sphere : public Object3D {
  void setDefaults(void) {
    color = BLUE;
    radius = 1.0 }
};
```

Virtual Functions

A superclass pointer can reference a subclass object

```
Sphere *mySphere = new Sphere();
Object3D *myObject = mySphere;
```

If a superclass has virtual functions, the correct subclass version will automatically be selected

Superclass

```
class Object3D {
  virtual void intersect(Ray *r, Hit *h);
};
```

Subclass

```
class Sphere : public Object3D {
  virtual void intersect(Ray *r, Hit *h);
};
```

```
myObject->intersect(ray, hit);
```

Actually calls `Sphere::intersect`

Pure Virtual Functions

A *pure virtual function* has a prototype, but no definition. Used when a default implementation does not make sense.

```
class Object3D {
  virtual void intersect(Ray *r, Hit *h) = 0;
};
```

A class with a pure virtual function is called a *pure virtual class* and cannot be instantiated. (However, its subclasses can).

Organizational Strategy

`image.h` Header file: Class definition & function prototypes

```
void SetAllPixels(const Vec3f &color);
```

`image.C` .C file: Full function definitions

```
void Image::SetAllPixels(const Vec3f &color) {
    for (int i = 0; i < width*height; i++)
      data[i] = color;
}
```

`main.C` Main code: Function references

```
myImage.SetAllPixels(clearColor);
```

Coding tips

Use the `#define` compiler directive for constants

```
#define PI 3.14159265
#define MAX_ARRAY_SIZE 20
```

Use the `printf` or `cout` functions for output and debugging

```
printf("value: %d, %f\n", myInt, myFloat);
cout << "value:" << myInt << ", " << myFloat << endl;
```

Use the `assert` function to test “always true” conditions

```
assert(denominator != 0);
quotient = numerator/denominator;
```

Coding tips

After you `delete` an object, also set its value to `NULL`
(This is not done for you automatically)

```
delete myObject;
myObject = NULL;
```

This will make it easier to debug memory allocation errors

```
assert(myObject != NULL);
myObject->setColor(RED);
```

`Segmentation fault (core dumped)`

Typical causes:

```
int intArray[10];
intArray[10] = 6837;
```

Access outside of array bounds

```
Image *img;
img->SetAllPixels(ClearColor);
```

Attempt to access a `NULL` or previously deleted pointer

These errors are often very difficult to catch and can cause erratic, unpredictable behavior.

Common Pitfalls

```
Sphere* getRedSphere() {
  Sphere s = Sphere(1.0);
  s.setColor(RED);
  return &s;
}
```

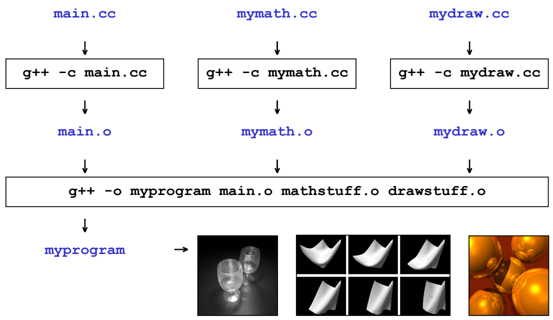
C++ automatically deallocates stack memory when the function exits, so the returned pointer is invalid.

The fix:

```
Sphere* getRedSphere() {
  Sphere *s = new Sphere(1.0);
  s->setColor(RED);
  return s;
}
```

It will then be your responsibility to delete the Sphere object later.

Compiling



Libraries

```
// This is main.cc
#include <GL/glut.h>
#include <iostream>
using namespace std;

int main() {
  cout << "Hello!" << endl;
  glVertex3d(1,2,3);
  return 0;
}
```

Include OpenGL functions
Include standard IO functions
Long and tedious explanation

Calls function from standard IO
Calls function from OpenGL

```
% g++ -c main.cc
% g++ -o myprogram -lglut main.o
% ./myprogram
```

Make object file
Make executable, link GLUT
Execute program

Makefiles

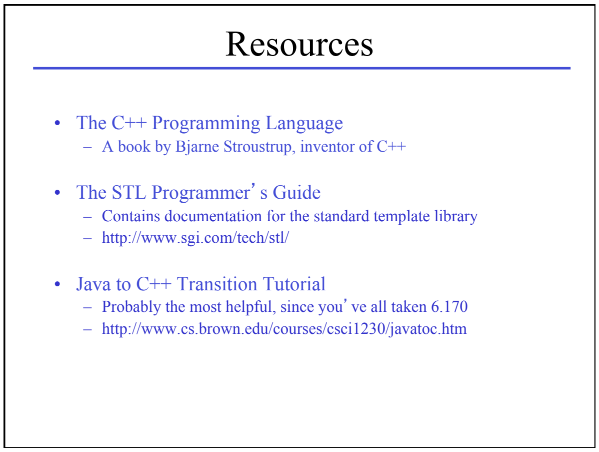
```
INCFLAGS  = \
      -I/afs/csail/group/graphics/courses/6.837/public/
      include
LINKFLAGS = \
      -L/afs/csail/group/graphics/courses/6.837/public/lib \
      -lglut -lvl
CFLAGS    = -g -Wall -ansi
CC        = g++
SRCS      = main.cc parse.cc curve.cc surf.cc camera.cc
OBJS      = $(SRCS:.cc=.o)
PROG      = a1

all: $(SRCS) $(PROG)

$(PROG): $(OBJS)
        $(CC) $(CFLAGS) $(OBJS) -o $@ $(LINKFLAGS)

.cc.o:
        $(CC) $(CFLAGS) $< -c -o $@ $(INCFLAGS)

depend:
        makedepend $(INCFLAGS) -Y $(SRCS)

clean:
        rm $(OBJS) $(PROG)

main.o: parse.h curve.h tuple.h

# ... LOTS MORE ...
```

Most assignments include makefiles, which describe the files, dependencies, and steps for compilation.

You can just type `make`

So you don't have to know the stuff from the past few slides.

But it's nice to know.



Resources

- The C++ Programming Language
  - A book by Bjarne Stroustrup, inventor of C++
- The STL Programmer’ s Guide
  - Contains documentation for the standard template library
  - http://www.sgi.com/tech/stl/
- Java to C++ Transition Tutorial
  - Probably the most helpful, since you’ ve all taken 6.170
  - http://www.cs.brown.edu/courses/csci1230/javatoc.htm