The C++ Class

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1. What is a *class*?

- Unit of encapsulation:
  - Public operations
  - Private implementation
- Abstraction:
  - string: abstracts char* of C
  - student
  - sprite
- C++ Classes: easy to write, difficult to get right!
- Lots of examples

1.1. The actions of a *class*

- Initialize it's data attributes
- Allocate memory when needed
- De-allocate memory when necessary




1.2. C++ *class* vs C++ *struct*

- Default access is only difference

Bad class	Good Class

`class Student {`
`public:`
`  string name;`
`  float gpa;`
`};`
	`class Student {`
	`  string name;`
	`  float gpa;`
	`};`

1.3. Object: an instantiated class

- C++ objects can be stored on the stack:

```
class A{};
int main() {
  A a, b;
};
```

- Or on the heap:

```
int main() {
  A *a = new A;
  A *b = new B;
};
```

- Compiler does stack; programmer does heap!




2. Constructors & Destructor

- Constructors:
  - init data & allocate memory
  - Init data through initialization lists
- Destructors deallocate memory
- The three types of constructors are:
  1. Default
  2. Conversion
  3. Copy

```
class Student {
public:
  Student();
  Student(char * n);
  Student(const Student&);
  ~Student();
};
```



2.1. Prefer initialization to assignment

- Initialization is more efficient for data members that are objects
- Only way to pass parameters to base class

```
class Person {
public:
   Person(int a) : age(a) {}
private:
   int age;
};
class Student : public Person {
public:
  Student(int age, float g) : Person(age), gpa(g) {}
private:
  float gpa;
};
```

2.2. Init performed in order of declare

```
class Student {
public:
  Student(int a) : age(a), iq(age+100) {}
private:
  int iq;
  int age;
};
```

2.3. Principle of Least Privilige

- Make "everything" **const**!
- Can reduce debugging
- Provides documentation
- Can prevent a member function from modifying data attributes
- Allow a function enough data access to accomplish its task and no more!
- Most beginners take them all out . . . probably need more!

2.4. Least Privilege example

```
class string {
public:
  string(const char* n) : buf(new char[strlen(n)+1]) {
    strcpy(buf, n);
  }
  const char* get() const { return buf; }
private:
  char *buf;
};
std::ostream&
operator<<(std::ostream& out, const string& s) {
  return out << s.get();
}
int main() {
  string x("Hello");
  std::cout << x.get() << std::endl;
}
```

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2.5. What operations does a class need?

1. All classes should have default constructor
2. Heap based data: *canonical form*:
   (a) Copy constructor
   (b) Destructor
   (c) Overloaded assignment

```
class string {
public:
  string();
  string(const string&);
  ~string();
  string operator=(const string&);
private:
  char *buf;
};
ostream& operator<<(ostream&, const string&);
```

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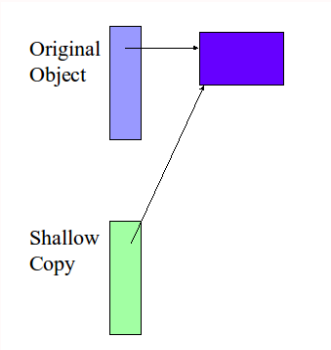
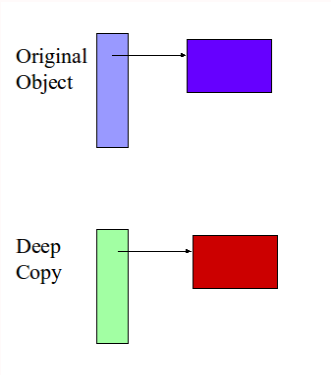
2.6. Why canonical form?



2.7. Why canonical form?



2.8. What can go wrong?

```
 1 #include <iostream>
 2 #include <cstring>
 3 using std::cout; using std::endl;
 4
 5 class string {
 6 public:
 7   string() : buf(new char[1]) { buf[0] = NULL; }
 8   string(const char * s) : buf(new char[strlen(s)+1]) {
 9     strcpy(buf, s);
10   }
11   ~string() { delete [] buf; }
12   const char* getBuf() const { return buf; }
13 private:
14   char * buf;
15 };
```

Looks like a well written class, but it is an accident waiting to happen!

2.9. Unseen Functions

Write this:

```
class Empty{};
```

Get this:

```
class Empty {
public:
  Empty();
  Empty(const Empty &);
  ~Empty();

  Empty& operator=(const Empty &);
  Empty * operator&();
  const Empty * operator&() const;
};
```

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2.10. Here's what they look like:

```
inline Empty::Empty() {}
inline Empty::~Empty() {}

inline Empty * Empty::operator&() {return this;}

inline const Empty * Empty::operator&() const {
   return this;
}
```

The copy constructor & assignment operator simply do a member wise copy, i.e., shallow. Note that the default assignment may induce a memory leak.

2.11. What's wrong with this class?

```
class Student {
public:
  Student(const char * n) : name(n) { }
  const getName() const { return name; }
  void setName(char *n) { name = n; }
private:
  char *name;
};
```

2.12. Practice: What's the output?

```
class String {
public:
  String() { cout << "default" << endl; }
  String(char * n) { cout << "convert" << endl; }
  String(const String&) { cout << "copy" << endl; }
  ~String() { cout << "destructor" << endl; }
private:
  char * buf;
};
int main() {
  String a("cat"), b = a;
  String * ptr = new String("dog");
  return 0;
}
```

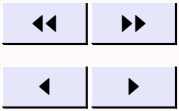

2.13. Practice: write class Student

```
void fun(Student stu) {
  std::cout << stu.getName() << std::endl;
}

int main() {
  Student a, b(Darth Maul, 3.5), c = b;
  Student * d = new Student(Anakin, 4.0);
  cout << *d << endl;
  fun(a);
  return 0;
}
```


3. Overload Operators

```
class string {
public:
  string();
  string(const char*);
  string(const string&);
  ~string();
  string operator+(const string&);
  string& operator=(const string&);
  char& operator[](int index);
  const char& operator[] const (int index);
private:
  char *buf;
};
ostream& operator<<(ostream&, const string&);
string operator+(const char*, const string&);
```



3.1. An overloaded binary operator:

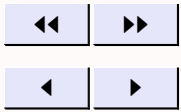
- Can be written in math form:

```
a = b;
c = a + b;
cout << stu;
```

- Or can be written in function invocation form:

```
a.operator=(b)
c.operator=(a.operator+(b));
cout.operator<<(stu)
```

- Man prefer the math form



3.2. How to overload assignment

```
Student & operator=(const Student & stu) {
  if (this == &stu) return * this;
  delete [] name;
  name = new char[strlen(stu.name)+1];
  strcpy(name, stu.name);
  gpa = stu.gpa;
  return *this;
}
```

(1) Why the comparison on the first line?
(2) Could the first line be: if (*this == stu)?
(3) Why return *this? What does it enable?
(4) Why not return stu, rather than *this?

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3.3. Formula for overloaded assignment:

- Check for equality of lhs & rhs
- delete storage for lhs
- Create new storage for lhs, thats size of rhs
- Copy rhs stuff to lhs
- return *this

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3.4. Overloading Operators

- Almost all operators can be overloaded
- Operators are binary or unary
- Have the same precedence as their compiler counterpart
- Can be members or friends
- Usually overloaded output operator should not be a member of a user defined class

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3.5. Overloading output as *friend*

```
class Student {
public:
  getName() const { return name; }
  getGpa()        { return gpa;    }
  friend ostream&
  operator<<(ostream &, const Student &);
private:
  char * name;
  float gpa;
};
ostream&
operator<<(ostream& out, const Student& s) {
  out << s.name << \t << s.gpa;
  return out;
}
```

3.6. Overloading output as stand-alone:

```
class Student {
public:
  getName() const { return name; }
  getGpa()        { return gpa;    }
private:
  char * name;
  float gpa;
};
ostream &
operator<<(ostream& out, const Student& s) {
  out << s.getName() << \t << s.getGpa();
  return out;
}
```

4. Interface vs Implementation

Interface goes in .h file:

```
class Student {
public:
getName() const { return name; }
getGpa() const { return gpa; }
private:
  char * name;
  float gpa;
};
ostream& operator <<(ostream &, const Student &);
```

Implementation goes in .cpp file:

```
ostream & operator<<(ostream& out, const Student& s) {
  out << s.getName() << s.getGpa();
  return out;
}
```

5. Naming Convention

- global constants: ALL CAPS!
- local & global variables: ALL LOWER CASE, USE UNDERSCORE
- Class names: BEGIN EACH WORD WITH UPPER CASE, NO UNDERSCORE
- Class member functions: BEGIN LOWER CASE, then BEGIN EACH WORKD WITH UPPER CASE
- Data members: SAME AS MEMBER FUNCTIONS

6. Makefiles

- Consist of definitions,
- Followed by sequences of 2 line commands.
  - First line begins with $< id >$**:**, followed by dependencies of $< id >$.
  - Second line is the rule to make $< id >$; this line MUST be preceded by a tab
- To use the make file type: make $\{< id >\}$




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6.1. Simple makefile

```
CCC=g++
FLAGS=-Wall

main:  main.o Binary.o
      $(CCC)  $(FLAGS) -o main main.o Binary.o

main.o: main.cpp Binary.h
      $(CCC)  $(FLAGS) -c main.cpp

Binary.o: Binary.cpp Binary.h
      $(CCC) $(FLAGS) -c Binary.cpp

clean:
      rm -f main *.o core
```

6.2. Discussion of Makefile

- $(CCC) permits us to easily switch to another compiler; e.g. CC
- *make clean* will clean the directory of large files
- -o option creates an executable
- -c option creates .o file

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7. Problems

- Design a class for Student
- Write a class string, that encapsulates strings
- Write Binary, an abstraction for binary math.
- Write Stack, an abstraction of a stack.
- Design an experiment to see which is faster: your list or standard C++ library list?
- Faster: your string or standard C++ string?
- Faster: char* or standard C++ string?

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7.1. Practice: What's the output?

```
class String {
public:
  String() { cout << "default" << endl; }
  String(char * n) { cout << "convert" << endl; }
  String(const String&) { cout << "copy" << endl; }
  ~String() { cout << "destructor" << endl; }
  String& operator=(const String &) {
    cout << "assign" << endl;
  }
private:
  char * buf;
};
void fun(String mule) { cout << mule << endl; }
int main() {
  String a("cat"), b = a;
  String * ptr = new String("dog");
  fun(a);
  mule =(*ptr);
}
```

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8. Template Classes

- Normal functions accept variables as parameters
- Template classes accept types as parameters

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8.1. Template class Stack

```
template <class T>
class Stack {
public:
  Stack() : count(EMPTY) {}
  void push(const T& n){ items[++count] =  n; }
  void pop()           { --count; }
  const T top()  const { return items[count]; }
  bool isEmpty() const { return count == EMPTY; }
  bool isFull()  const { return count == 99; }
private:
  enum {EMPTY =  -1};
  T items[100];
  int count;
};
```