CSCI 103 Unit 5c - Classes Revisited

CSCI 103L Teaching Team

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OBJECT ORIENTED IDEALS

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Before C++, There was C

- C introduced the idea of a struct, but it was different than it is now
  - C
    - No `class`, only `struct`
    - Structs ONLY allowed data members and everything was PUBLIC (any code could modify anything!)
    - Some declaration nuances
  - C++
    - Introduced classes (data + functions)
    - Structs become equivalent to a class (data + member functions)
    - Default access of `struct` is **public** whereas `classes` default to **private**

```
struct Deck {
  int cards[52];
  int top_index;
};

int main()
{
  // Anyone can modify
  // b/c members are public
  const int ACE = 12;
  Deck d1;
  d1.cards[0] = ACE;
  d1.top_index = 5;
  // probably not correct

  return 0;
}
```

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Classes & OO Ideals

- Classes are used as the primary way to organize code
- Encapsulation
  - Place data and operations on data into one code unit
  - Protect who can access data via private members
- Abstraction
  - Depend only on an interface (the what) regardless of implementation (the how) to create low degree of ***coupling*** between different components
  - Unit of decomposition that allows us to break our large software components into smaller, reusable components
  - Unit of composition that allows us to create larger and more powerful components from smaller ones
  - Delegation/separation of responsibility
- Polymorphism & Inheritance (more on this later)

Protect yourself from users & protect your users from themselves

deck.h

```
class Deck {
 public:
   Deck();   // Constructor
   ~Deck();  // Destructor
   void shuffle();
   void cut();
   int get_top_card();
 private:
   int cards[52];
   int top_index;
};
```

cardgame.cpp

```
#include<iostream>
#include "deck.h"

int main(int argc, char *argv[]) {
  Deck d;
  int hand[5];

  d.shuffle();
  d.cut();

  d.cards[0] = ACE; //won't compile
  d.top_index = 5;  //won't compile
}
```

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Coupling

- Coupling refers to how much components depend on each other's implementation details (i.e. how much work it is to remove one component and drop in a new implementation of it)
  - Placing a new battery in your car vs. a new engine
  - Adding a USB device vs. a new video adapter to your laptop
- OO Design seeks to reduce coupling as much as possible by
  - Creating well-defined interfaces to update (write) or access (read) the state of an object
  - Allow alternate implementations that do NOT require interface changes

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Reminders About C++ Classes

- Member data can be public or private (and later protected)
  - Defaults is private (only class functions can access)
  - Must explicitly declare something public
- Most common operators (e.g. ==, +, <<, >>, etc.) will NOT work by default
  - You can't cout an object (`cout << myobject;` won't work)
  - The only one you get for free is '=' which does a member-by-member (shallow) copy
- Classes may be used just like any other data type (e.g. int)
  - Get pointers/references to them (`Obj*, Obj&`)
  - Pass them to functions (by copy, reference or pointer)
  - Dynamically allocate them (`new Obj, new Obj[100]`)
  - Return them from functions (`Obj f1(int x);`)

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CONSTRUCTORS

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C++ Classes: Default Constructors

- Called when a class is instantiated allowing you to initialize data members to desired values
- No return value
- **Default (no argument) Constructor**
  - Can have one or none in a class
  - Signature: `ClassName();`
  - **If class defines NO constructors, C++ will create a default constructor for you…but it is just an empty constructor.**
    - **Example: Student::Student() { }**
- **Overloaded/Initializing Constructors**
  - More on the next slide

```
class Student {
 public:
  // Default constructor
  Student( );

  // Initializing constructor
  Student(const string& name);
  ...
 private:
   string name_;
   int id_;
   vector<int> grades_;
};
```

```
struct Item {
  string name;
  vector<int> grades;
// compiler adds Item() { }
};
```

```
int main() {
  Item x;  // calls Item()
  Item data[10]; // will compile
   // calling Item() for all 10 items
}
```

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C++ Classes: Initializing Constructors

- **Overloaded/Initializing Constructors**
  - Can have zero or more
  - These constructors take in arguments
  - **Appropriate version is called based on how many and what type of arguments are passed when a particular object is created**
    - `Student s1("Tristan");`
    - `Student s2(123456789);`
  - If you define a constructor with arguments the compiler **will NOT give you the default constructor** for free.
    - When arrays of a type are declared, C++ automatically calls default constructor for that type on each array element
    - **That implies: no Default constructor => no arrays can be declared**
    - So you ***should*** **also** define a default constructor if you want to support arrays of that type

```
class Student {
 public:
  // Compiler-generated version
  Student( );

  // Initializing constructor
  Student(const string& name);

  // Initializing constructor
  Student(int id);
  ...
 private:
   string name_;
   int id_;
   vector<int> grades_;
};
```

```
int main() {
 Student x;      //won't compile
 Student s[10]; //won't compile
}
```

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Examples of Constructors

1a

```
class Obj {
 public:
  // no user-defined constructors
  void setNum(int n);
  string getStr();
 private:
  int num; string s1;
};
```

2a

```
class Obj {
 public:
  // Initializing constructor
  Obj(int n, string s)
   { num = n; s1 = s; }
  void setNum(int n);
  string getStr();
  int num; string s1;
};
```

1b

```
class Obj {
 public:
  Obj() { }
   // compiler generated
   // default constructor

  void setNum(int n);
  string getStr();
  ...
};
```

2b

```
class Obj {
 public:
  Obj() { }
   // compiler does not generate
   // constructor
  Obj(int n, string s)
  void setNum(int n);
  string getStr();
  ...
};
```

1c

```
int main() {
  Obj x;  // calls
          // default constructor

}
```

2c

```
int main() {
  Obj x, y[100]; // no arrays
     // if no def. constructor
  Obj y(5, "hi");
}
```

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Identify that Constructor

- Prototype what Student constructors are being called here and whether they will compile.
- s1
  - `Student::_____`
- s2
  - `Student::_____`
- Prototype what vector constructor will be called.
- dat
  - `vector<int>::_____`

```
class Student {
 public:
  // Default constructor
  Student( );

  // Initializing constructor
  Student(const string& name);
  ...
 private:
   string name_;
   int id_;
   vector<int> grades_;
};

int main()
{
  Student s1;
  Student s2("Tommy", 12345);

  vector<int> vals(10);
  ...
}
```

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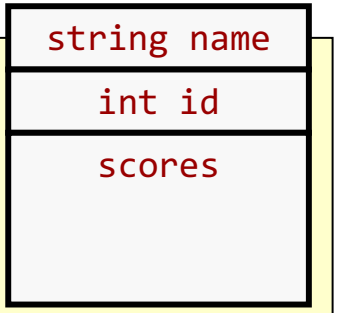
Initializing data members of a class

CONSTRUCTOR INITIALIZATION LISTS

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Consider this Struct/Class

- Examine this struct/class definition…
  - How can I initialize the members?
  - The members themselves are objects (string and vector) and thus need their own constructors called




```
#include <string>
#include <vector>

struct Student
{ std::string name;
  int id;
  std::vector<double> scores;
   // say I want 10 test scores per student

  Student(); // default constructor

  Student(std::string n, int ident);
    // initializing constructor
};

int main()
{
  Student s1;
  Student s2("Tommy", 12345);
}
```

```
// Potential intializing constructor
Student::Student(std::string n, int ident)
{
  name = n;
  id = ident;
  scores.resize(10);
}
```

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Composite Objects

- **Fun Fact 4**: **Before the constructor of an object executes, all of its data members must be constructed**
  - **Before a baby is born all its organs must develop and start working**
- **Fun Fact 5**: Constructors for objects get called (and can *ONLY EVER* get called) at the time of creation (when memory is allocated)
  - Once the object's constructor starts executing, it is too late to call data members' constructors. The data members have already been constructed.




```
#include <string>
#include <vector>

struct Student
{
  std::string name;
  int id;
  std::vector<double> scores;
   // say I want 10 test scores per student

  Student()
   // constructors for members called here
  {
    // TOO LATE TO CALL DATA MEMBER
    // CONSTRUCTORS
    name("Tommy Trojan");
    id = 12313;
    scores(10);
  }
};

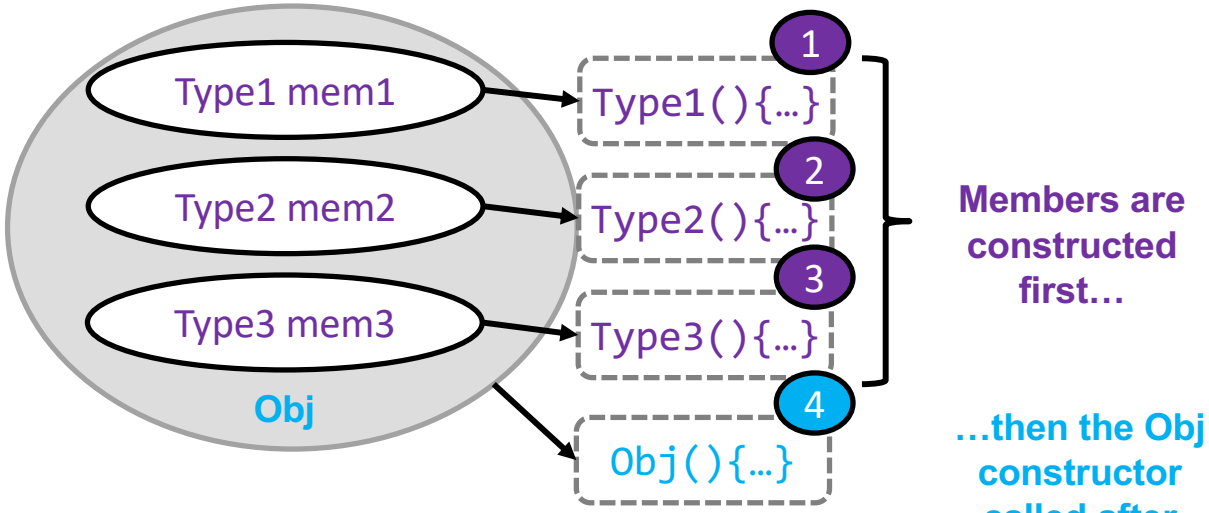
int main()
{ Student s1; // memory for Student allocated
  //...
}
```

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Initializing Members

- When an object is constructed **the constructor for each data members is implicitly called first**
  - Member constructors are called BEFORE object's constructor

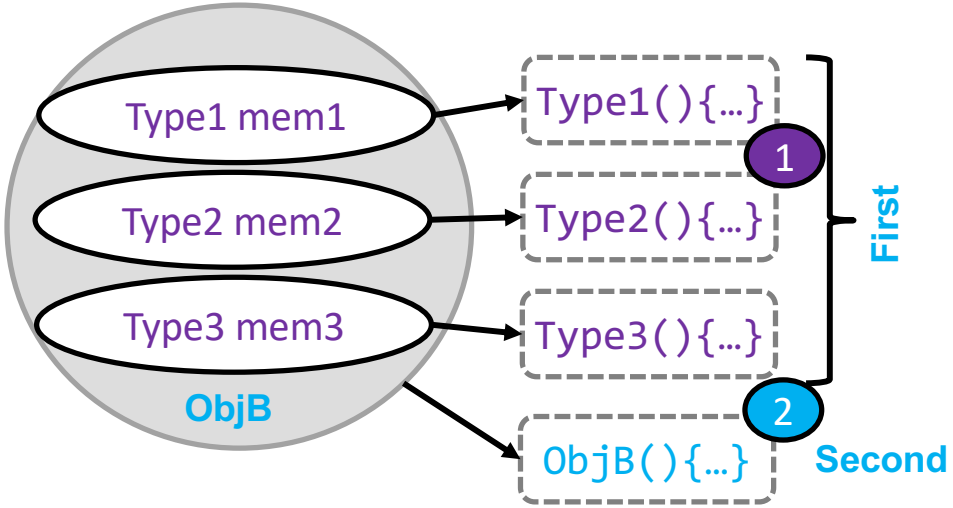
```
Class Obj
{ public:
    Obj();
    // public members
  private:
    Type1 mem1;
    Type2 mem2;
    Type3 mem3;
};
```



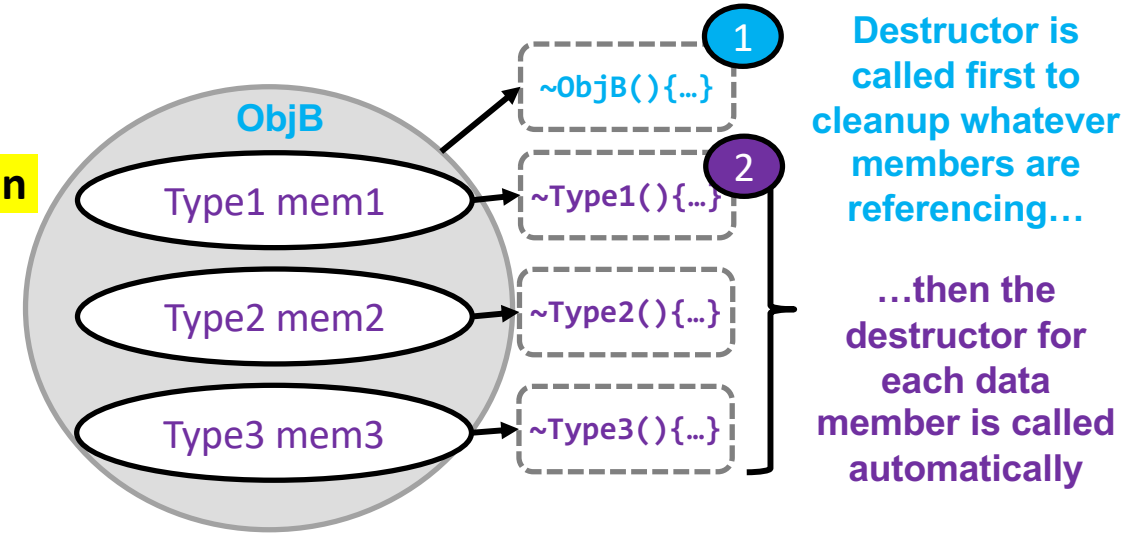
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Allocating and Deallocating Members

- Members of an object have their constructor called automatically **BEFORE** the object's constructor executes
  - Construction works **inside-out (from smaller to larger)**
- When an object is destructed the members are destructed automatically **AFTER** the object's destructor runs
  - Destruction works **outside-in (from larger to smaller)**



Construction



Destruction

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What NOT to do!

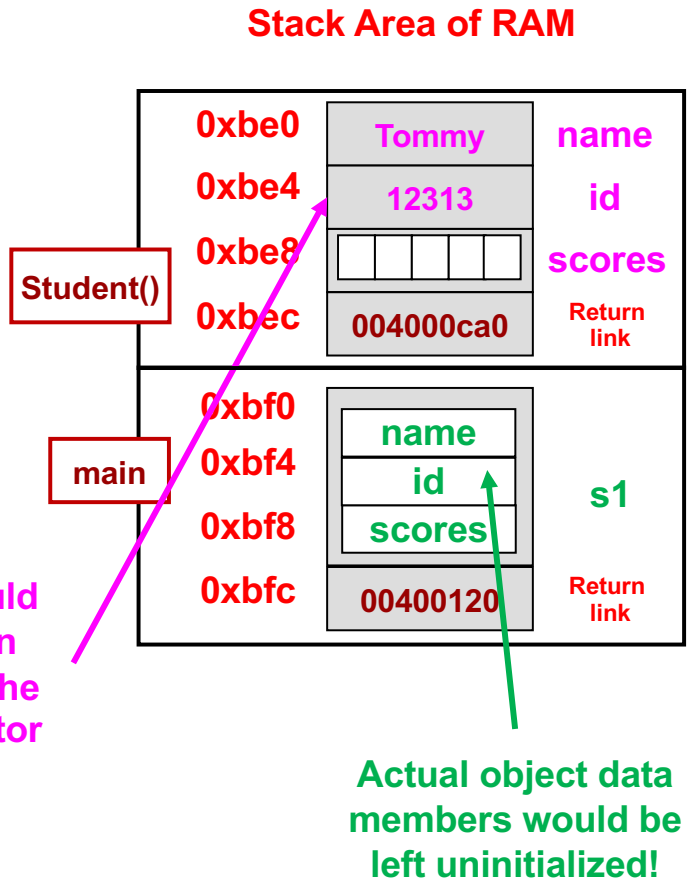
- So, we CANNOT call constructors on data members INSIDE the constructor
  - So what can we do??? Use initialization lists!

```
#include <string>
#include <vector>

struct Student
{ std::string name;
  int id;
  std::vector<double> scores;
   // say I want 10 test scores per student

  Student() /* mem allocated here */
  { // Can I do this to init. members?
    string name("Tommy"); // or
    // name("Tommy")
    int id = 12313;
    vector <double> scores(10);
  }
};
int main()
{ Student s1;
  //...
}
```

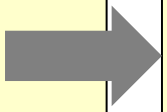
Local variables would be created but then immediately die at the end of the constructor



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Old Initialization Approach

```
Student::Student()
{
  name = "Tommy Trojan";
  id = 12313
  scores.resize(10);
}
```



```
Student::Student() :
    name(), id(), scores()
    // calls string(), int(), vector<double>()
{
  name = "Tommy Trojan"; // now modify
  id = 12313
  scores.resize(10);
}
```

If you write this…

The compiler will still generate this.

- Though you do not see it, realize that the **default constructors** are implicitly called for each data member before entering the {…} of your constructor
- You can then assign values (left side code)
  - But this is a **2-step** process:
    1.) default construct, then 2.) replace with desired value

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New Initialization Approach

```
Student::Student() :
 name(), id(), scores() /* compiler generated */
{
  name = "Tommy Trojan";
  id = 12313
  scores.resize(10);
}
```



```
Student::Student() :
    name("Tommy"), id(12313), scores(10)
{
}
```

Default constructors implicitly called and then values reassigned in constructor

You would have to call the member constructors in the initialization list context

- We can initialize with a **1-step** process using a C++ **constructor initialization list**
  - `Constructor(arguments) :`
    `member1(param/val), member2(param/val), …, memberN(param/val)`
    `{ … }`
- We are really calling the respective constructors for each data member at the time memory is allocated

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Summary

```
Student::Student()
{
  name = "Tommy Trojan";
  id = 12313
  scores.resize(10);
}
```

You can still assign data members in the {…}

```
Student::Student() :
    name(), id(), scores()
    // calls to default constructors
{
  name = "Tommy Trojan";
  id = 12313
  scores.resize(10);
}
```

But any member not in the initialization list will have its default constructor invoked before the {…}

- You can still assign values in the constructor but realize that the **default constructors** will have been called already
- So, if you know what value you want to assign a data member it's **good practice** to do it in the initialization list

```
Student::Student() :
    name("Tommy"), id(12313), scores(10)
{  }
```

This would be the preferred approach especially for any non-primitive type members (i.e. an object)

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Calling Constructors

- You CANNOT use one constructor as a helper function to help initialize members
  - DON'T call one constructor from another constructor for your class

```
struct Student
{ std::string name;
  int id;
  std::vector<double> scores;

  Student() : name("Tommy"), id(-1), scores(10)
  {
  }
  Student(string n)
  {
    Student();
    name = n;
  }
};

int main()
{
  Student s1("Jane Doe");
  // more code...
}
```



Can we use Student() inside Student(string name) to initialize the data members to defaults and then just replace the name?

No!! Calling a constructor always allocates memory for another object. So rather than initializing the members of s1, we have created some new, anonymous Student object which will die at the end of the constructor

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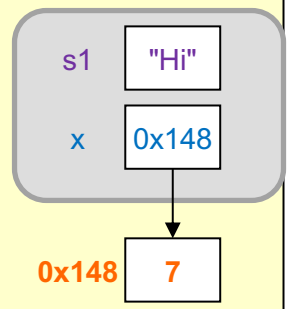
C++ Classes: Destructors

- Destructors are called when an object goes out of scope or is freed from the heap (by "delete")
- Destructors
  - Can have **one** or **none** (if no destructor defined by the programmer, compiler will generate an empty destructor)
  - Have no return value
  - Have the name ~ClassName()
  - Data members of an object have their destructor's called automatically upon completion of the destructor.
- Why use a destructor?
  - Not necessary in simple cases
  - Clean up resources that won't go away automatically (e.g. when data members **are pointing to** dynamically allocated memory that should be deallocated when the object goes out of scope)
  - Destructors are only needed if there are **external** resources (beyond your immediate data members) that must be cleaned up or freed (e.g. release resources, close files, deallocate what pointers are point to, etc.)

```
class Thing
{ string s1;
  int* x;
 public:
  Item();
  ~Item();
};

Thing::Thing()
{ s1 = "Hi";
  x = new int;
  *x = 7;
}

Thing::~Thing()
{
  delete x;
} // data members
  // destructed here
```



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C++ Classes: Other Notes

- Should be split across two files
  - `class.h` – Contains interface description
  - `class.cpp` – Contains implementation details

```
#ifndef DECK_H
#define DECK_H
#include <vector>
class Deck{
public:
  Deck();
private:
  std::vector<int> cards_;
};
#endif
```

deck.h

```
#include "deck.h"
Deck::Deck() {
  for(int i=0; i < 52; i++){
    cards_.push_back(i);
  }
}
```

deck.cpp

- DON'T put `using namespace` statements in header (.h) files

```
#ifndef DECK_H
#define DECK_H
#include <vector>
using namespace std;
class Deck{
public:
  Deck();
private:
  vector<int> cards_;
};
#endif
```

deck.h

```
// specifically, don't want
// to use namespace std;
#include "deck.h"
// Guess we're using std; whether
// we wanted to or not
int main()
{
}
```

app.cpp

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CONDITIONAL COMPILATION

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C++ Classes: Use header guards

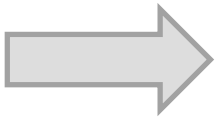
```
class MyStr {
public:
  MyStr();
private:
  char* str_;
};
```
mystr.h

```
#include "mystr.h"
class Student {
  ...
  MyStr name_;
};
```
student.h

```
#include "student.h"
#include "mystr.h"

int main() {
   ...
}
```
app.cpp

- Many headers may include the **same file**
- This may lead to **multiple** inclusions and definitions



```
class MyStr {
  ...
};
class Student {
   ...
  MyStr name_;
};
class MyStr { // second def.
  ...          // error!!
};
int main() {
  ...
}
```

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Conditional Compiler Directives / Header Guards

- Compiler directives start with '#'
  - `#define XXX`
    - Sets a flag named XXX in the compiler
  - `#ifdef, #ifndef XXX … #endif`
    - Continue compiling code below until #endif, if XXX is (is not) defined
- Nest header declarations inside a
  - `#ifndef XX`
    `#define XX`
    `…`
    `#endif`

```
#ifndef MYSTR_H
#define MYSTR_H
class MyStr {
public:
  MyStr();
private:
  char* str_;
};
#endif
```
mystr.h

```
#include "mystr.h"
class Student {
  ...
  MyStr name_;
};
```
student.h

```
#include "student.h"
#include "mystr.h"

int main() {

}
```
app.cpp

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C++ Classes: Use header guards

```
#ifndef MYSTR_H
#define MYSTR_H
class MyStr {
public:
  MyStr();
private:
  char* str_;
};
#endif
```

mystr.h

```
#include "mystr.h"
class Student {
  ...
  MyStr name_;
};
```

student.h

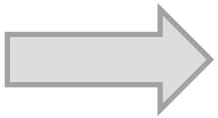
```
#include "student.h"
#include "mystr.h"

int main() {

}
```

app.cpp

- Avoids multiple inclusion!



```
class MyStr {
  ...
};
class Student {
  ...
  MyStr name_;
};

// Not included a second time

int main() {
  ...
}
```

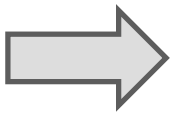
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Alternative on most C++ Compilers

- Rather than 3 lines:
  - `#ifndef, #define, …, #endif`
- Use 1 line:
  - `#pragma once`

```
#ifndef MYSTR_H
#define MYSTR_H
class MyStr {
public:
  MyStr();
private:
  char* str_;
};
#endif
```

mystr.h



```
#pragma once
class MyStr {
public:
  MyStr();
private:
  char* str_;
};
```

mystr.h

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Conditional Compilation

- Often used to compile additional DEBUG code
  - Place code that is only needed for debugging and that you would not want to execute in a release version
- Place code in a `#ifdef NAME...#endif` bracket
- Compiler will only compile if a `#define NAME` is found
- Can specify `#define` in:
  - source code
  - At compiler command line with (-DNAME) flag
    - `g++ -o stuff –DDEGUG stuff.cpp`

```
int main()
{
  int x, sum=0, data[10];
  ...
  for(int i=0; i < 10; i++){
    sum += data[i];
#ifdef DEBUG
    cout << "Current sum is ";
    cout << sum << endl;
#endif
  }
  cout << "Total sum is ";
  cout << sum << endl;
```

stuff.cpp

```
$ g++ -o stuff –DDEBUG stuff.cpp
```

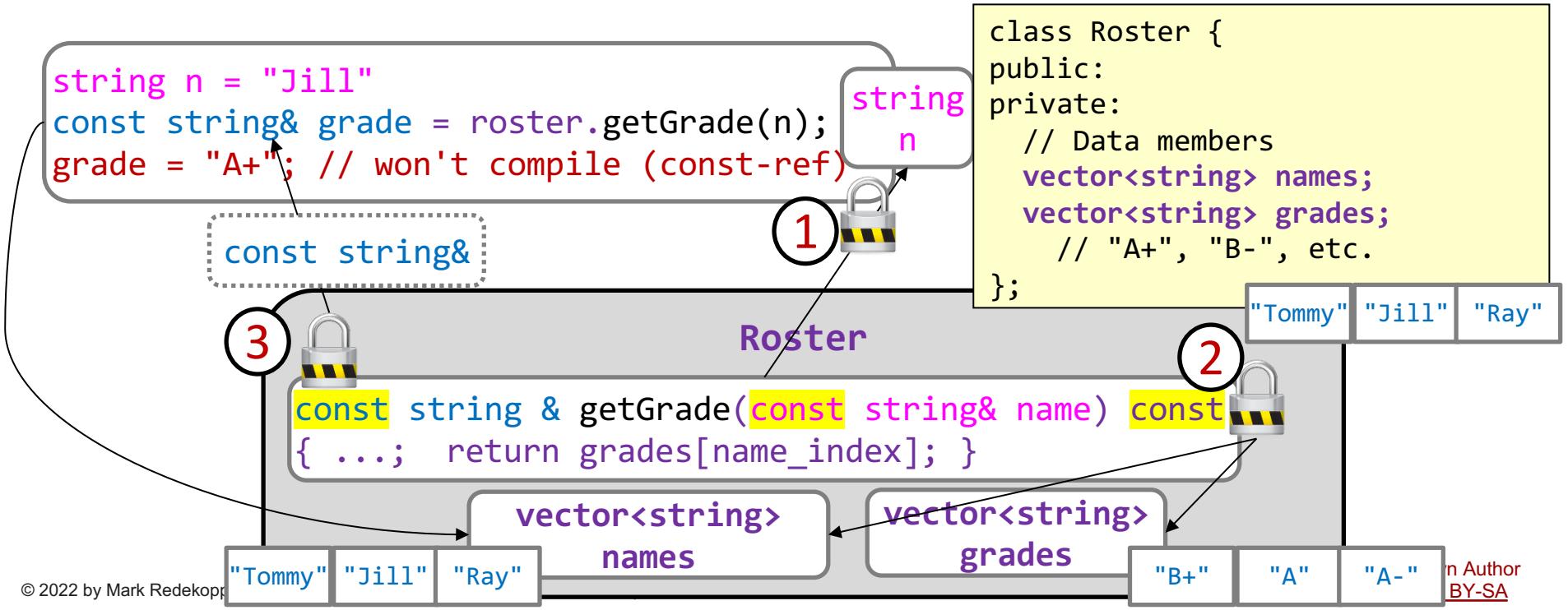
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OTHER IMPORTANT CLASS DETAILS

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'const' Keyword

- `const` keyword can be used with
  1. Input arguments to ensure they aren't modified
  2. After a member function to ensure data members aren't modified by the function
  3. Return values to ensure they aren't modified



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DEFAULT ARGUMENTS

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Default Arguments

- Default arguments can be provided
  - User can provide a different value or not provide any, in which case the default is taken
- Only list the default argument in the prototype **but not both** the prototype and definition

```
class IntVector {
public:
  // usually put default arg in prototype
  IntVector(size_t n = 10);
  ...
private:
 size_t n_; int* array;
};

// Should not repeat the default arg
IntVector::IntVector(size_t n) : n_(n)
{
   array = new int[n_];
}

int main()
{
  // both call the same constructor above
  IntVector vec1(50); // size 50
  IntVector vec2;  // will use default 10
  ...
}
```

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Other Limitations

- You can have many default arguments, but they must terminate the argument list; a non-default argument CANNOT come AFTER a default argument
- Ensure that two functions signature is not ambiguous

```
// good
void good1(int a, int b = 10, string s = "hi");

// bad (non-default arg, s, after default arg, b)
void bad1(int a, int b = 10, string s);

// bad – ambiguous with other func due to default args()
void good1(int b);
```

```
17:12: error: call of overloaded 'good1(int)' is ambiguous
17:12: note: candidates are:
4:6: note: void good1(int, int, std::string)
12:6: note: void good1(int)
```

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Exercises

- Const Exercises

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REVIEW

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Review [1]

Const function arguments

- Will this code compile?
- Indicate what will be printed (assuming it compiles)

```
void f1(const vector<int>& x){
  x.push_back(103);
  x.push_back(104);
}

void f2(string& y){
  y = "Bye";
}

int main()
{
   vector<int> a; string b = "Hi";
   f1(a);
   f2(b);
   cout << b.size() << endl;
   return 0;
}
```

Const member functions

- What does the highlighted `const` keyword imply in the code below?

```
class Item
{ int val;
 public:
  void foo();
  int bar() const;
};

void Item::foo()
{ val = 5; }

int Item::bar() const
{ return val+1; }

void f1(const Item& arg) {
  int x = arg.bar(); // fine
  arg.foo(); // Compiler Error!
}
```

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Review [2]

Constructor Initialization Lists

- What is the most efficient means to initialize the vals member to an initial array size of 20 and s to a user-defined argument?

```
class Thing {
 public:
  Thing(const std::string& s_init);
 private:
  vector<int> vals;
  string s;
};

Thing::Thing(const std::string& s_init)

{
   // is this the most efficient way?
   vals.resize(20);
   s = s_init;
}
```

Construction Order

- What is printed by the code below?

```
class ABC {
 public:
  ABC() { cout << "ABC" << endl; }
};
class DEF {
 public:
  DEF() { cout << "DEF" << endl; }
};
class XYZ {
  ABC m1;  DEF m2;
 public:
  XYZ()
    { cout << "XYZ" << endl; }
};
int main() {
  XYZ x1;
  return 0;
}
```

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Review [3]

Friend Functions

- What does the highlighted `friend` keyword imply in the code below?
- What would break if we remove it?

Friend Classes

- Can DEF::clear() access obj.x?
- If not, how can class ABC grant access to DEF?

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  friend Complex operator+(const int&, const Complex&);
 private:
  double real, imag;
};

Complex operator+(const int& lhs, const Complex &rhs)
{
  Complex temp;
  temp.real = lhs + rhs.real;   temp.imag = rhs.imag;
  return temp;
}
```

```
class ABC {
 int x;  // data member
 public:

   ...
};

class DEF {
public:
  void clear(ABC& obj) { obj.x = 0; }
};
```

SOLUTIONS

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Identify that Constructor

- Prototype what constructors are being called here
- s1
  - `Student::Student()`
    `// default constructor`
- s2
  - `Student::Student(string, int )` or
    `Student::Student(const char*, int )`
- dat
  - `vector<int>::vector<int>( int );`

```
class Student {
 public:
  // Default constructor
  Student( );

  // Initializing constructor
  Student(const string& name);
  ...
 private:
   string name_;
   int id_;
   vector<int> grades_;
};

int main()
{
  Student s1;
  Student s2("Tommy", 12345);

  vector<int> vals(10);
  ...
}
```

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Review [1] Solutions

Const function arguments

- Will this code compile? **No, modification of x in f1()**
- Indicate what will be printed (assuming it compiles) – b.size() will be 3

```
void f1(const vector<int>& x){
  x.push_back(103);
  x.push_back(104);
}

void f2(string& y){
  y = "Bye";
}

int main()
{
   vector<int> a; string b = "Hi";
   f1(a);
   f2(b);
   cout << b.size() << endl;
   return 0;
}
```

Const member functions

- What does the highlighted `const` keyword imply in the code below?
  - No data members can be modified nor non-const member functions called

```
class Item
{ int val;
 public:
  void foo();
  int bar() const;
};

void Item::foo()
{ val = 5; }

int Item::bar() const
{ return val+1; }
```

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Review [2] Solutions

Constructor Initialization Lists

- What is the most efficient means to initialize the vals member to an initial array size of 20 and s to a user-defined argument?

```
class Thing {
 public:
  Thing(const std::string& s_init);
 private:
  vector<int> vals;
  string s;
};

Thing::Thing(const std::string& s_init)
  : vals(20)
{



}
```

Construction Order

- What is printed by the code below?
  - **ABC**
    DEF
    XYZ

```
class ABC {
 public:
  ABC() { cout << "ABC" << endl; }
};
class DEF {
 public:
  DEF() { cout << "DEF" << endl; }
};
class XYZ {
  ABC m1;  DEF m2;
 public:
  XYZ() { cout << "XYZ" << endl; }
};
int main() {
  XYZ x1;
  return 0;
}
```

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Review [3] Solutions

Friend Functions

- What does the highlighted `friend` keyword imply in the code below?
  - That function can access Complex private members
- What would break if we remove it?
  - Could not access rhs.real / rhs.imag

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  friend Complex operator+(const int&, const Complex&);
 private:
  double real, imag;
};

Complex operator+(const int& lhs, const Complex &rhs)
{
  Complex temp;
  temp.real = lhs + rhs.real;   temp.imag = rhs.imag;
  return temp;
}
```

Friend Classes

- Can DEF::clear() access obj.x? Yes
- If not, how can class ABC grant access to DEF?
  - Add friend definition

```
class ABC {
 int x;  // data member
 public:
  friend class DEF;
  ...
};

class DEF {
public:
  void clear(DEF& obj) { obj.x = 0; }
};
```

YOU ARE NOT RESPONSIBLE FOR MATERIAL PAST THIS POINT

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NESTED TYPES

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Duplicate Types

- Recall linked lists use a helper struct to model each item in the list
  - Stores a value (of a certain type) and a pointer to the next
- If we want to use a different type list, we would need a different Item struct, but would need to name it differently
- Solution:
  - Different names: IntItem vs. DoubleItem
  - Templates (more later)
  - Nested Types!!

```
// integer linked list
struct Item {
  int val;
  Item* next;
};

class ListInt
{
  public:
   ListInt();
   ~ListInt();
   void append(int v); ...
  private:
   Item* head_;
};
```

```
// double linked list
struct Item {
  double val;
  Item* next;
};
// ERROR – Duplicate type name
```

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Nested Types

- A struct or class can be defined inside another and is known as a nested type
- Good practice to nest 'helper' types (i.e. structs/classes that exist SOLELY in support of the outer class)
- Nested types can share the same name but have different implementations when defined inside of **different** objects
- Examples:
  - Linked list Item struct
  - Iterators (later in the class)

```
// integer linked list
class ListInt {
public:
   // Define a nested type
   struct Item {
     int val;
     Item* next;
   };
   Item* find(int x) const;
private:
   Item* head_;
};

// double linked list
class ListDbl {
public:
   // Nested type
   struct Item {
     double val;
     Item* next;
   };
   Item* find(double x) const;
private:
   Item* head_;
};
```

```
int main()
{
  ListInt::Item x;
  x.val = 3;

  ListDbl ld;
  // ...
  ListDbl::Item* p;
  p=ld.find(2.5);
}
```

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Declaring and Using Nested Types

- Non-members must scope the type name:
  - `classname::typename`
- Member function code do not have to scope the type once inside the member function scope
  - Notice the return type of a function is not inside the member function scope

```
class ListInt {
public:
   // Define a nested type
   struct Item {
     int val; Item* next;
   };
   ListInt();
   void append(int v);
   Item* find(int v) const;
private:
   Item* head_;
};

void ListInt::append(int v){
   Item* x = new Item; // no scoping
}
// requires scoping the type
ListInt::Item* ListInt::find(int v) const
{ ... }

int main()
{  ListInt mylist;
   // requires scoping the type
   ListInt::Item* p = mylist.find(2);
   // ...
}
```

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STATIC MEMBERS

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One For All

- As USCStudent objects are created we want them to have unique IDs
- How can we accomplish this?

```
class USCStudent {
 public:
   USCStudent(string n) : name(n)
   {  id = _________ ; // ????
   }

 private:
   string name;
   int id;
}

int main()
{
  // should each have unique IDs
  USCStudent s1("Tommy");
  USCStudent s2("Jill");



}
```

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One For All

- Can we just make a counter data member of the USCStudent class?
- What's wrong with this?

```
class USCStudent {
 public:
   USCStudent(string n) : name(n)
   {  id = id_cntr++; }

 private:
   int id_cntr;
   string name;
   int id;
}


int main()
{
  USCStudent s1("Tommy"); // id = 1
  USCStudent s2("Jill");  // id = 2



}
```

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One For All

- It's not something that we can do from within an instance
  - A student doesn't assign themselves an ID, they are told their ID
- Sometimes there are functions or data members that make sense to be part of a class but are shared (only 1 exists) amongst all instances
  - The variable or function doesn't depend on the instance of the object, but just the general class (family of objects)
  - We can make these 'static' members which means one definition shared by all instances

```
class USCStudent {
 public:
   USCStudent(string n) : name(n)
   {  id = id_cntr++; }

 private:
   static int id_cntr;
   string name;
   int id;
}

// initialization of static member
int USCStudent::id_cntr = 1;

int main()
{
  USCStudent s1("Tommy"); // id = 1
  USCStudent s2("Jill");  // id = 2
  ...


}
```

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Static Data Members

- A **static** data member is a single variable that all instances of the class share
- Can think of it as belonging to the class and not each instance
- Declare with keyword `static`
- Initialize outside the class in a .cpp (can't be in a header)
  - Must be scoped with class name

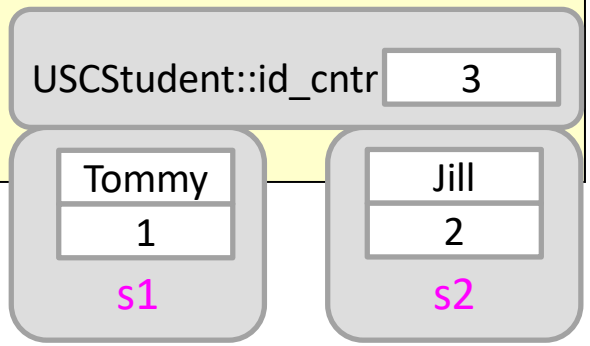
```
class USCStudent {
 public:
   USCStudent(string n) : name(n)
   {  id = id_cntr++; }

 private:
   static int id_cntr;
   string name;
   int id;
}

// initialization of static member
int USCStudent::id_cntr = 1;

int main()
{
  USCStudent s1("Tommy"); // id = 1
  USCStudent s2("Jill");  // id = 2
  ...


}
```



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Example: Class Constants (string::npos)

- Sometimes there are constants that are useful to define for a class but the same value for all instances
- `std::string::npos` is such a constant
  - Used as an input value for a length parameter that means *"until the end of the string"*
  - Returned by a call to `string::find()` or `string::rfind()` to indicate *"no match"*

```
#include <iostream>
#include <string>
using namespace std;

int main()
{
  string s1 = "cs104";
  if(s1.find("103") == string::npos)
  {
     cout << "We're not in 103 "
             "anymore" << endl;
  }
  return 0;
}

// Note: in the above example,
// C++ automatically concatenates
// multiple string constants on
// different lines if not
// separated by any operator
```

http://www.cplusplus.com/reference/string/basic_string/find/

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Example: Class Constants (string::npos)

- `std::string::npos` is set to the largest unsigned value supported by the system (all 1s in binary) which can be achieved by casting -1 (which is all 1s in signed binary) to an unsigned value

```
// simplified string class
class string {
public:
  static const size_t npos;
  ...
};

const size_t string::npos = (size_t)-1;
```

http://www.cplusplus.com/reference/string/basic_string/find/

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Another Example: Singleton

- In addition, to static data members, static member functions are also allowed
- Does NOT take a `this` pointer (not executing on an instance
  - Called by scoping with the class name
- Can access private members of the class

```
class President {
public:
  static President* makePresident(string name);
  void printName() const { cout << name_ << endl; }
private:
  string name_; // representative of data member
  // private to disallow other instances
  President(string name) : name_(name) {}
  static President* thePres;  // THE president
};
// init static member
President* President::thePres = nullptr;

President* President::makePresident(string name) {
   if(nullptr == thePres){
     // calls private constructor
     thePres = new President(name);
   }
   return thePres;
}
int main() {
  President* p = President::makePresident("Carol");
  President* p2 = President::makePresident("Mark");
  p->printName(); // prints "Carol"
  p2->printName(); // still "Carol"
  return 0;
}
```

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A Related Example

- All US Citizens share the same president, though it changes over time
- Rather than wasting memory for each citizen to store a pointer to the president, we can make it static
- However, private static members can't be accessed from outside functions
- For this we can use a static member functions

```
class USCitizen{
 public:
   USCitizen();



 private:
   static President* pres;
   string name;
   int ssn;
}

int main()
{
  USCitizen c1;
  USCitizen c2;
  President* curr = new President;

  // won't compile..pres is private
  USCitizen::pres = curr;



}
```

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Static Member Functions

- Static member functions do tasks at a class level and can't access data members (since they don't belong to an instance)
- Call them by preceding with 'className::'
- Use them to do common tasks for the class that don't require access to an instance's data members
  - Static functions could really just be globally scoped functions but if they are really serving a class' needs it makes sense to group them with the class

```
class USCitizen{
 public:
   USCitizen();
   static void setPresident(President* p)
    {  pres = p; }

 private:
   static President* pres;
   string name;
   int ssn;
}

int main()
{
  USCitizen c1;
  USCitizen c2;
  President* curr = new President;
  USCitizen::setPresident(curr);
  ...
  President* next = new President;
  USCitizen::setPresident(next);

}
```

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OLD

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Review: Parts of a C++ Class

- What are the main parts of a class?
  - Data members
    - What data is needed to represent the object?
  - Constructor(s)
    - How do you build an instance?
  - Member functions
    - How does the user need to interact with the stored data?
  - Destructor
    - How do you clean up an after an instance?

```
class LListInt {
 public:
    LListInt( );
    LListInt( int n ) ;
    ~LListInt( );
    void push_front(int n);
    void pop_front();
    void printList() const;
 private :
    Item* get(size_t loc);
    Item *head;
};
```

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