CSCI 104
Classes

CSCI 104L Teaching Team

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Review from CS 103 [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;
}
```

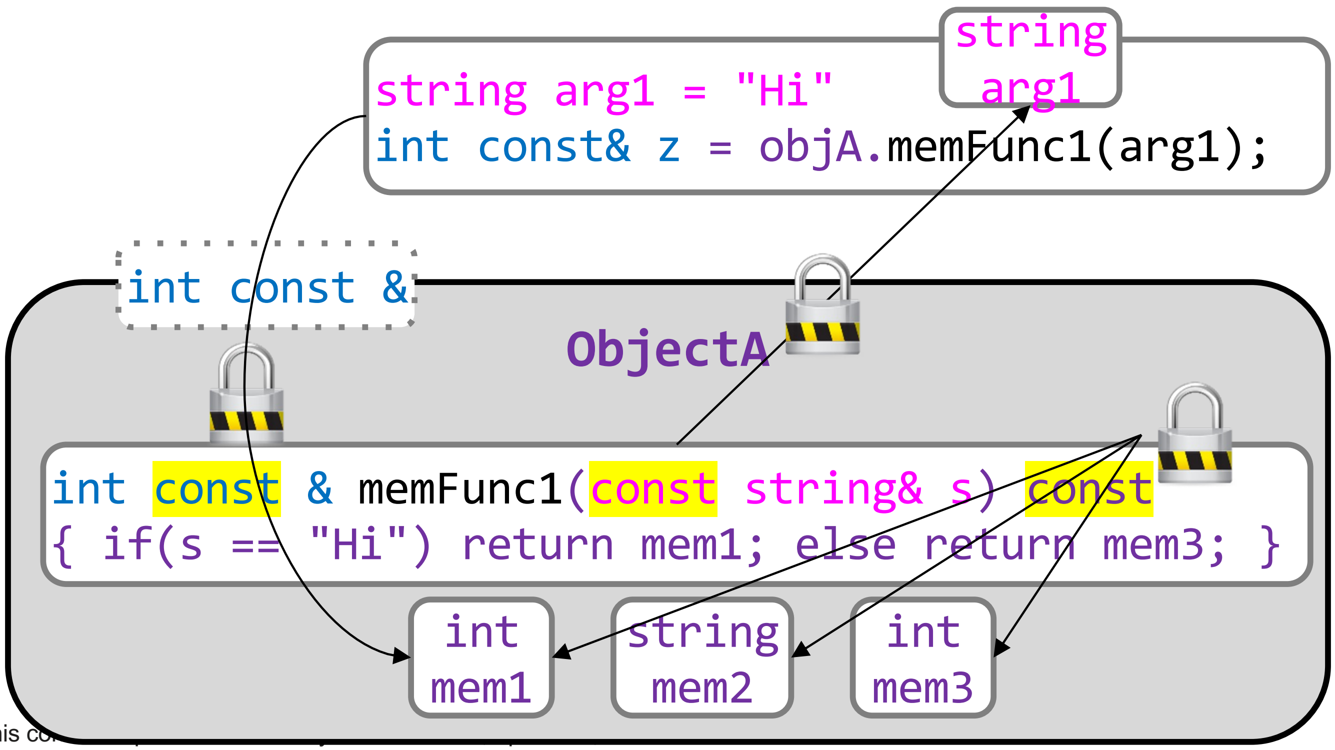
Const member functions

- 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!
}
```

'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



Exercises

- cpp/cs104/classes/const_members
- cpp/cs104/classes/const_members2
- cpp/cs104/classes/const_return

Review from CS 103 [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;
}
```

Review from CS 103 [3]

Friend Functions

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

```
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?
- If not, how can class ABC grant access to DEF?

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

   ...
};

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

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NESTED TYPES

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
```

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);
}
```

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);
   // ...
}
```

STATIC MEMBERS

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");



}
```

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




}
```

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
  ...


}
```

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

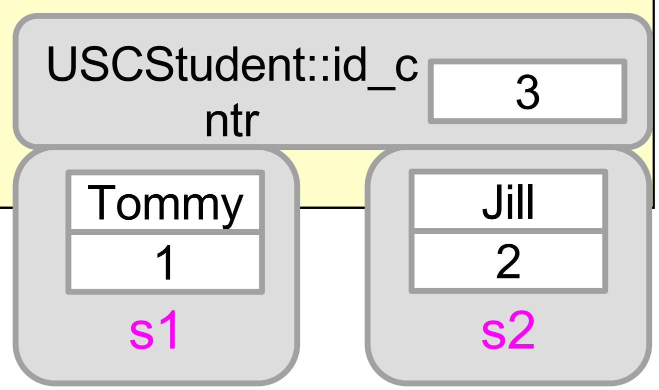
```
class USCStudent {
 public:
   USCStudent(string n) : name(n)
   {  id = id_cntr++; }

 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
  ...

}
```



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/

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;
}
```

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;



}
```

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);

}
```

DEFAULT ARGUMENTS

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
  ...
}
```

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)
```

CONDITIONAL COMPILATION

Multiple Inclusion

- Often separate files may #include's of the same header file
- This may cause compiling errors when a duplicate declaration is encountered
  - See example
- Would like a way to include only once and if another attempt to include is encountered, ignore it

```
class string{
... };
```

string.h

```
#include "string.h"
class Widget{
 public:
  string s;
};
```

widget.h

```
#include "string.h"
#include "widget.h"
int main()
{ }
```

main.cpp

```
class string { // inc. from string.h
};
class string{ // inc. from widget.h
};
class Widget{
... }
int main()
{ }
```

main.cpp after preprocessing

Conditional Compiler Directives

- 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
- Encapsulate header declarations inside a
  - #ifndef XX
    #define XX
    …
    #endif

```
#ifndef STRING_H
#define STRING_H
class string{  ... };
#endif
```

string.h

```
#include "string.h"
class Widget{
 public:
   string s;
};
```

widget.h

```
#include "string.h"
#include "widget.h"
```

main.cpp

```
class string{ // inc. from string.h
};
class Widget{ // inc. from widget.h
...
```

main.cpp after preprocessing

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
```

PRE-SUMMER 2021 SLIDES

OVERVIEW AND CONCEPTS

C Structs vs. Classes

- Needed a way to group values that are related, but have different data types
- NOTE: struct has changed in C++!
  - C
    - Only data members
    - Some declaration nuances
  - C++
    - Like a class (data + member functions)
    - Default access is **public** where as class' default to **private**

```
struct Person{
  char name[20];
  int age;
};

int main()
{
  // Anyone can modify
  // b/c members are public
  Person p1;
  p1.age = -34;
  // probably not correct

  return 0;
}
```

Classes & OO Ideas

- 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 regardless of implementation to create low degree of ***coupling*** between different components
    - Ex. USB interface (any USB device can plug into many different kinds of computer systems)
- Unit of composition
  - Create really large and powerful software systems from tiny components
    - Define small pieces that can be used to compose larger pieces
  - 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
}
```

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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PARTS OF A CLASS

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 IntLinkedList {
  public:
    IntLinkedList( );
    IntLinkedList( int n ) ;
    ~IntLinkedList( );
    void prepend(int n);
    void remove(int toRemove);
    void printList();
    void printReverse();
  private :
    void printHelper(Item *p);
    Item *head;
};
```

Notes About 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 C++ operators will not work by default (e.g. ==, +, <<, >>, etc.)
  - You can't cout an object (`cout << myobject;` won't work)
  - The only one you get for free is '=' and even that may not work the way you want (more on this soon)
- 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);`)

C++ Classes: 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 has no constructors, C++ will make a default
    - But it is just an empty constructor (e.g. Student::Student() { })
  - When arrays of an Object are declared, C++ automatically calls default constructor on each array element
- **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**
  - If you define a constructor with arguments you ***should* also** define a default constructor (otherwise no default constructor will be available)

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

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

  // Destructor
  ~Student( );
  ...
 private:
   string name_;
   int id_;
   vector<int> grades_;
};
```

Examples of Constructors

1

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

1

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

2

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

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

2

```
class Obj {
 public:
  Obj() { }
    // compiler does not generate
    // constructor

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

3

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

}
```

3

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

Identify that Constructor

- Prototype what constructors are being called here
- s1
  - Student::______________________
- s2
  - Student::________________________
- 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");
    // note: anything in "" is
    //  type const char*
  vector<int> vals(10);
  ...
}
```

Identify that Constructor

- Prototype what constructors are being called here
- s1
  - `Student::Student()`
    `// default constructor`
- s2
  - `Student::Student(const char* )`
- 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");
    // note: anything in "" is
    //  type const char*
  vector<int> vals(10);
  ...
}
```

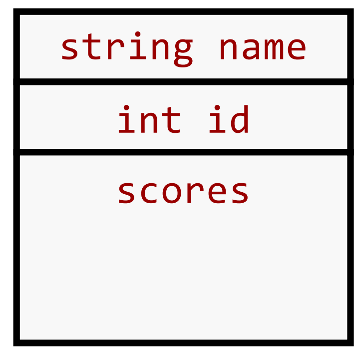
Initializing data members of a class

CONSTRUCTOR INITIALIZATION LISTS

Consider this Struct/Class

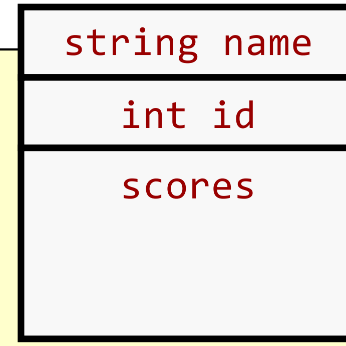
- Examine this struct/class definition…
  – How can I initialize the members?

```
#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);
}
```



Composite Objects

- **Fun Fact 1**: **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 2**: 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.

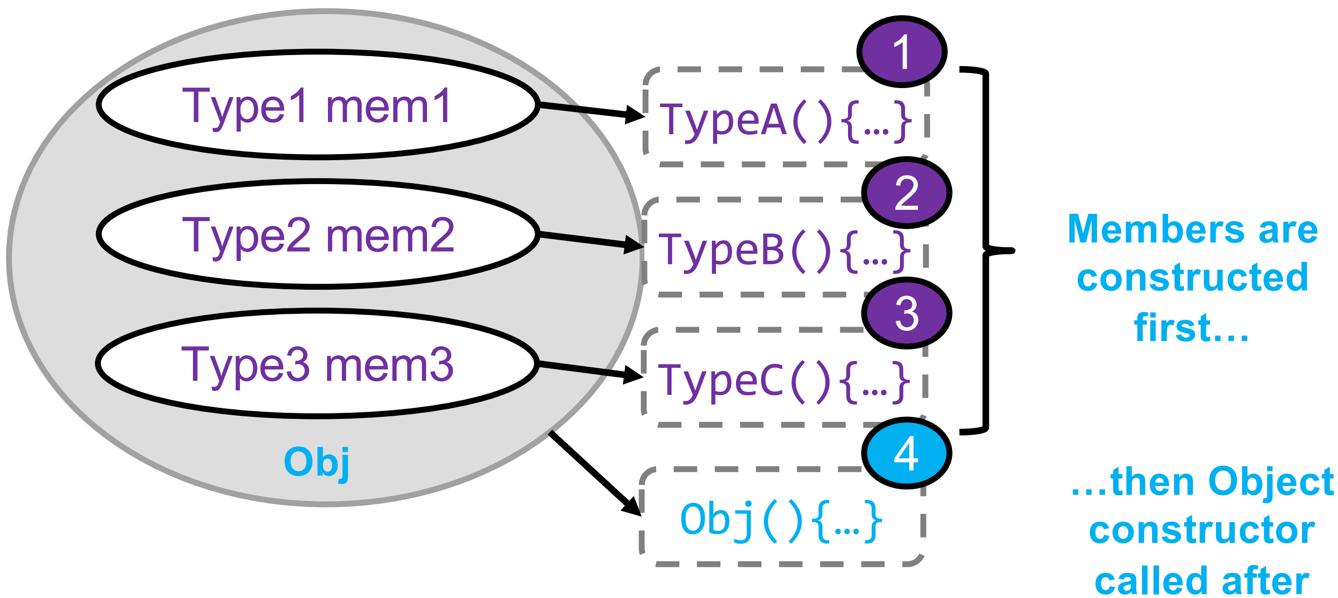



```
#include <string>
#include <vector>

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
  //...
}
```

Initializing Members

- When an object is constructed the individual members are constructed 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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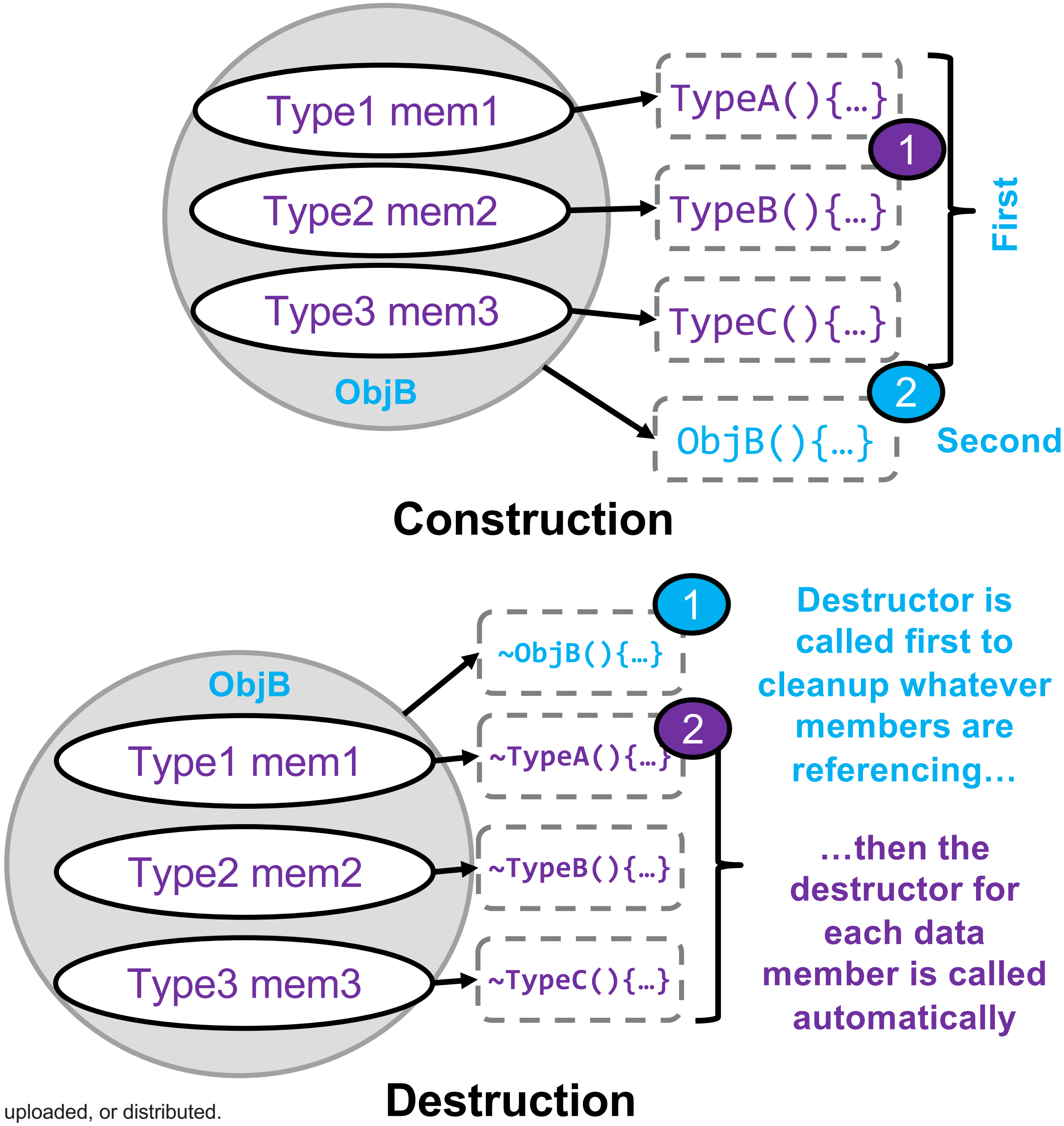
Allocating and Deallocating Members

- 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)**



Old Initialization Approach

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

If you write this…

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

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 {…}
- You can then assign values (left side code)
  – But this is a **2-step** process: default construct, then 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);
}
```

Default constructors implicitly called and then values reassigned in constructor

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

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(param_list) : member1(param/val), …, memberN(param/val) { … }
- We are really calling the respective constructors for each data member at the time memory is allocated

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 generally 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-scalar members (i.e. an object)

Exercise: cpp/cs104/classes/constructor_init2

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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!

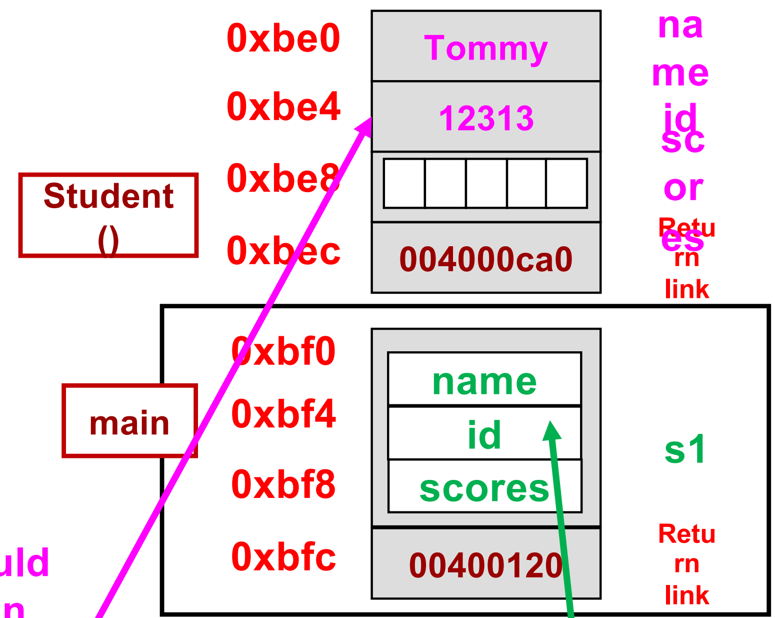
```
#include <string>
#include <vector>

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

Stack Area of RAM



Actual object data members would be left uninitialized!

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!! <u>Calling a constructor always allocates memory for another object</u>. 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

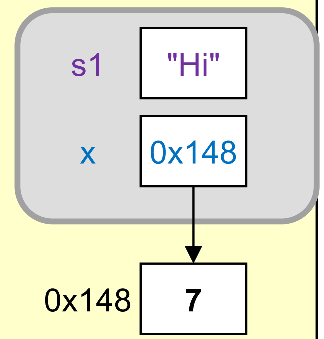
C++ Classes: Destructors

- 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 only if you need to do more than that (i.e. if you need to release resources, close files, deallocate what pointers are point to, etc.)
  - The destructor need only clean up resources that are referenced by data members

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

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

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



OTHER IMPORTANT CLASS DETAILS

Member Functions

- Object member access uses dot (.) operator
- Pointer-to-object member access uses arrow (->) operator
- Member functions have access to all data members of a class
- **Use "const" keyword if it won't change member data**
  - **This is good practice and you should starting doing it**

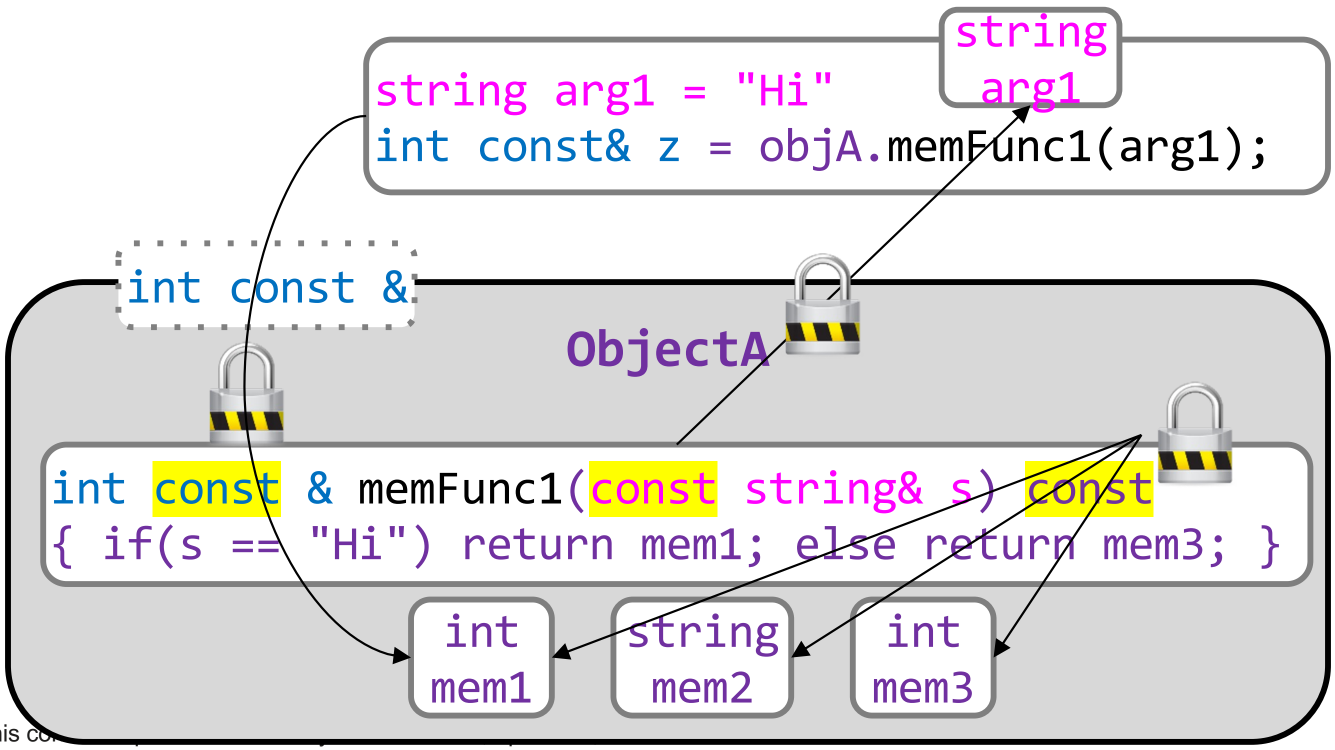
```
class Item
{ int val;
 public:
  void foo();
  int bar() const;
};
void Item::foo()
{ val = 5; }

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

int main()
{
  Item x;
  x.foo();
  Item *y = &x;
  (*y).bar();
  y->bar();  // equivalent
  return 0;
}
```

'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



Exercises

- cpp/cs104/classes/const_members
- cpp/cs104/classes/const_members2
- cpp/cs104/classes/const_return

C++ Classes: Other Notes

- Classes are generally split across two files
  - ClassName.h – Contains interface description
  - ClassName.cpp – Contains implementation details
- Make sure you remember to **prevent multiple inclusion errors** with your header file by using #ifndef, #define, and #endif

```
#ifndef CLASSNAME_H
#define CLASSNAME_H
class ClassName { … };

#endif
```

```
#ifndef STRING_H
#define STRING_H
class string{
  string();
  size_t length() const;
  /* ... */
};
#endif
```

string.h

```
#include "string.h"

string::string()
{ /* ... */ }

size_t string::length() const
{ /* ... */ }
```

string.cpp

SOLUTIONS

Review from CS 103 [1]

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; }
```

Review from CS 103 [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)
  : 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;
}
```

Review from CS 103 [3]

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; }
};
```