CSCI 104
Classes

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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;
}
```

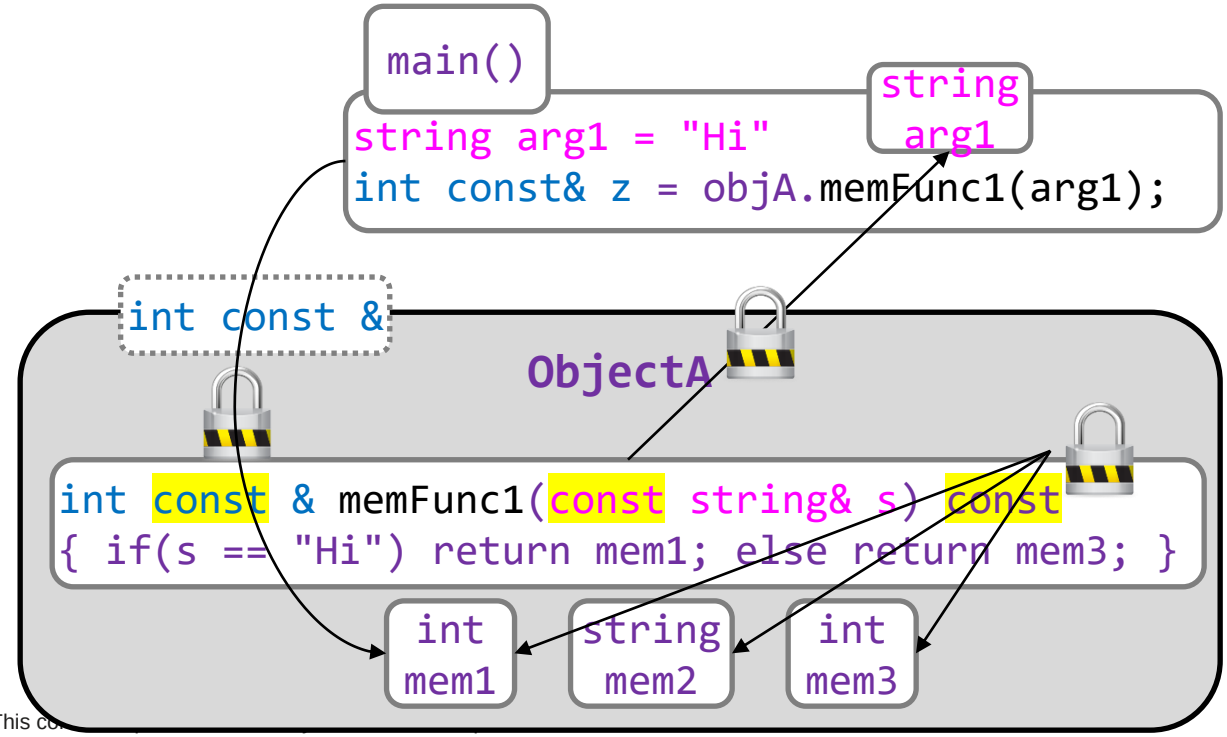
Const member functions

- 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?

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; }
};
```

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"); // want id = 1
  USCStudent s2("Jill");  // want id = 2
          // but will we get what we want?


}
```

One For All

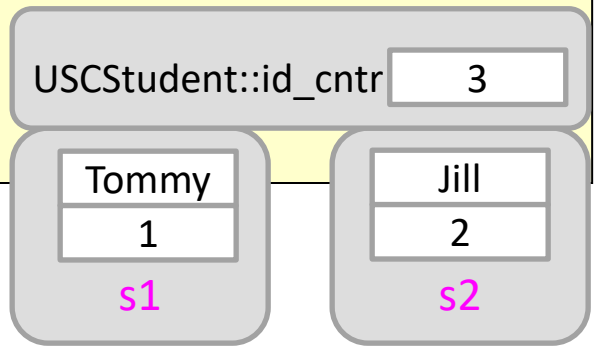
- It's not something that we can do from within an instance
  - A student doesn't assign themselves an ID, they are told their ID
- Sometimes there are functions or data members that make sense to be part of a class but are shared (only 1 exists) amongst all instances
  - The variable or function doesn't 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/

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 "string.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

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;
};
```

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

1

2

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

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

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

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

2

3

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

}
```

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

3

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

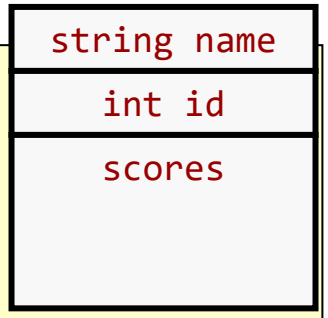
Consider this Struct/Class

- 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.

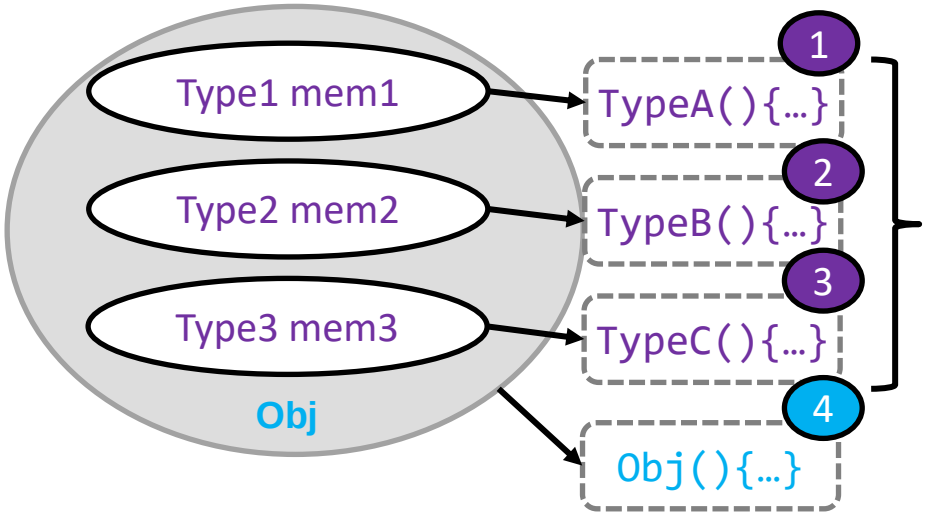



```
#include <string>
#include <vector>

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

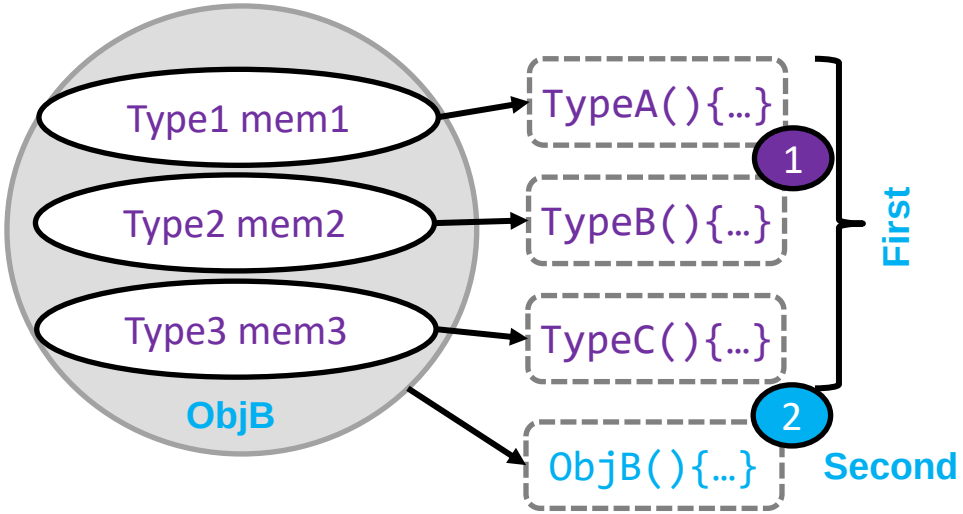
- When an object is constructed the individual members are constructed first
  - Member constructors are called BEFORE object's constructor

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

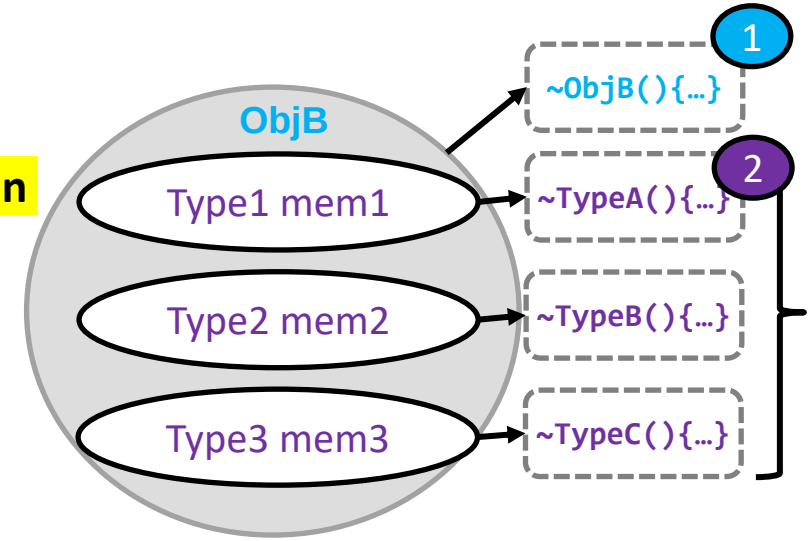


Allocating and Deallocating Members

- 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



Destructor is called first to cleanup whatever members are referencing…

…then the destructor for each data member is called automatically

Destruction

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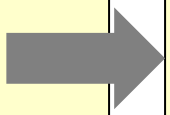
Old Initialization Approach

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



```
Student::Student() :
    name(), id(), scores()
    // calls to default constructors
{
  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 {…}
- You can then assign values (left side code)
  - But this is a **2-step** process: default construct, then replace with desired value

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)
{
}
```

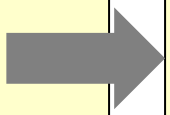
Default constructors implicitly called and then values reassigned in constructor

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(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);
}
```



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

You can still assign data members in the {…}

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)

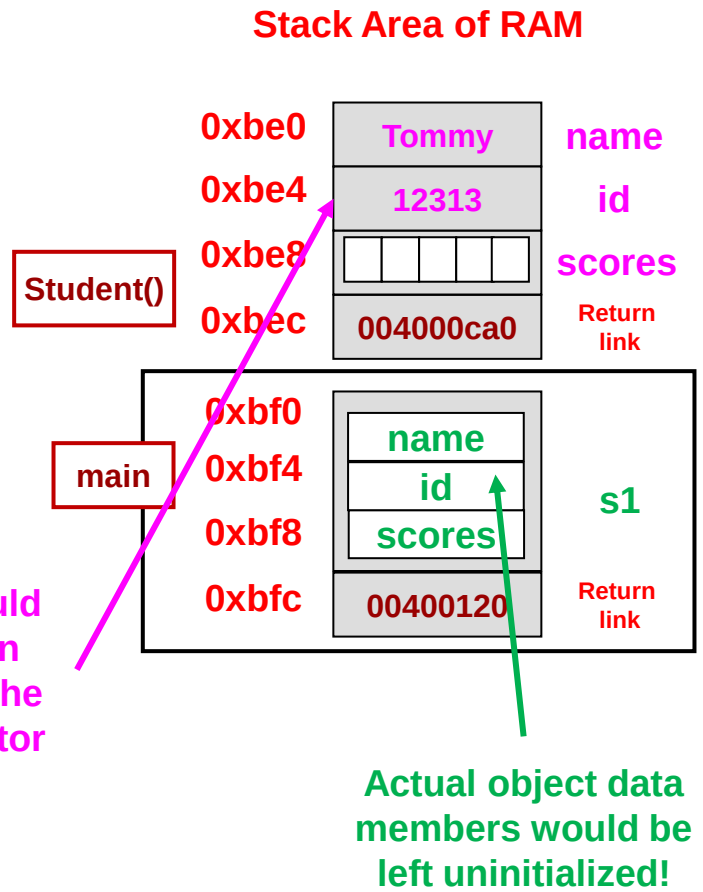
Exercise: cpp/cs104/classes/constructor_init2

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



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...
}
```

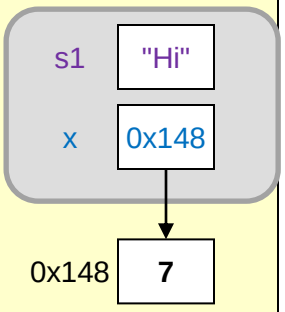
Can we use Student() inside Student(string name) to initialize the data members to defaults and then just replace the name?

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

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

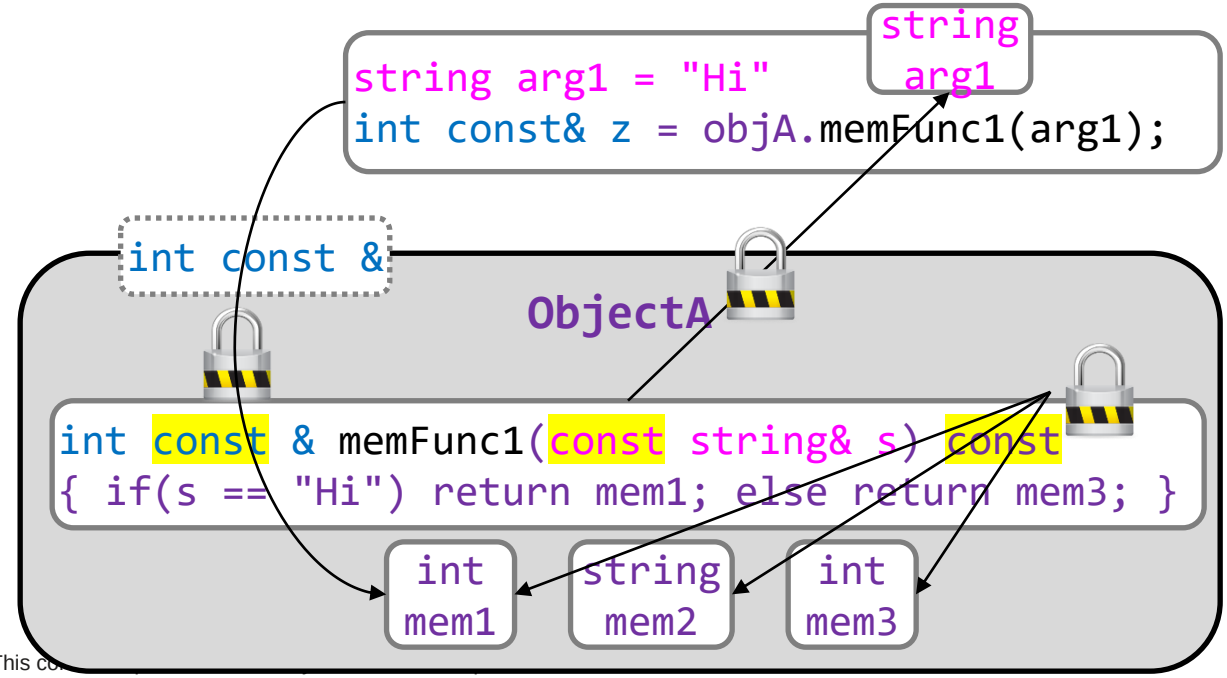
Member Functions

- 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; }
};
```