CSCI 104
Inheritance

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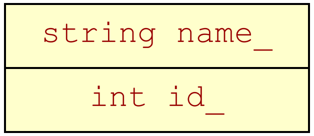
Files for Today

- $ mkdir inh
- $ cd inh
- $ wget http://ee.usc.edu/~redekopp/cs104/inh.tar
- $ tar xvf inh.tar
- $ make

Constructor Initialization Lists

```
class Person{
 public:
  Person();
  Person(string myname);
  Person(string myname, int myid);
  string get_name() { return name; }
  void add_grade(int score);
  int get_grade(int index);
private:
  string name_;
  int id_;
};
Person::Person() { }
Person::Person(string myname)
{ name_ = myname;
  id_ = -1;
}
Person::Person(string myname, int myid)
{ name_ = myname;
  id_ = myid;
}
...
```



string name_

int id_

- C++ constructors often have a bunch of assignments and initializations to the data members.

Constructor Initialization Lists

```
Person::Person()  /* mem allocated here */
{
  name("Tommy Trojan");
  id = 12313;
}
```

You can't call member constructors in the {…}

```
Person::Person(string myname)  :
     name(myname), id(12313)
{   }
```

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

- Rather than writing many assignment statements we can use a special initialization list technique for C++ constructors
  - Constructor(param_list) : member1(param/val), …, memberN(param/val)
    { … }
- We are really calling the respective constructors for each data member

Constructor Initialization Lists

```
Person::Person()
{
  name = "Tommy Trojan";
  id = 12313
}
```

You can still assign data members in the {…}

```
Person::Person() :
    name(), id()
    // calls to default constructors
{
  name = "Tommy Trojan";
  id = 12313
}
```

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

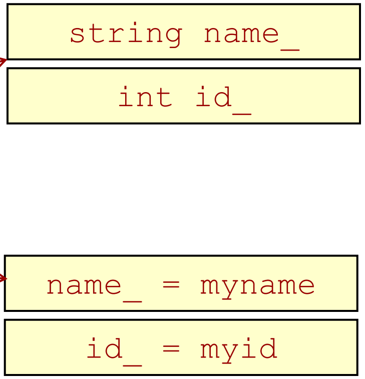
- You can still assign values in the constructor but realize that the **default constructors** will have been called already
- So generally if you know what value you want to assign a data member it's **good practice** to do it in the initialization list

Constructor Initialization Lists

```
Person::Person() { }
Person::Person(string myname)
{ name_ = myname;
  id_ = -1;
}
Person::Person(string myname, int myid)
{ name_ = myname;
  id_ = myid;
}
...
```

String Operator=() Called

Initialization using assignment



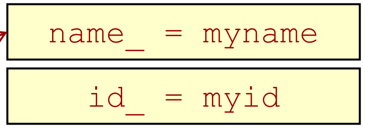
Memory is allocated before the '{' …

…then values copied in when assignment performed

```
Person::Person() { }
Person::Person(string myname) :
                 name_(myname), id_(-1)
{  }
Person::Person(string myname, int myid) :
                 name_(myname), id_(myid)
{   }
...
```

String Copy Constructor Called

Initialization List approach



Memory is allocated and filled in "one-step"

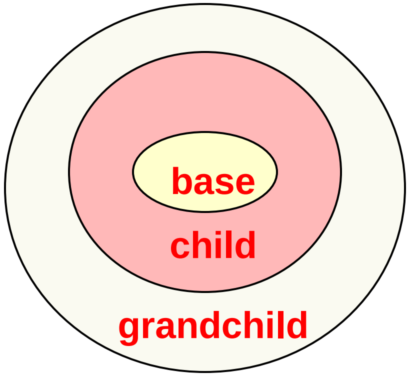
INHERITANCE

Object Oriented Design

- Encapsulation
  - Combine data and operations on that data into a single unit (e.g. a class w/ public and private aspects)
- Inheritance
  - Creating new objects (classes) from existing ones
- Polymorphism
  - Using the same expression to denote different operations

Inheritance

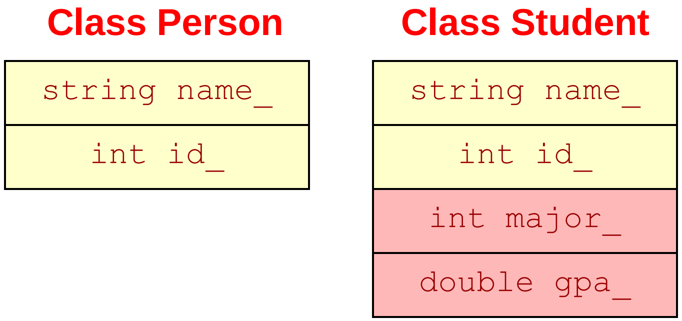
- A way of defining interfaces, re-using classes and extending original functionality
- Allows a new class to inherit all the data members and member functions from a previously defined class
- Works from more general objects to more specific objects
  - Defines an "is-a" relationship
  - Square is-a rectangle is-a shape
  - Square inherits from Rectangle which inherits from Shape
  - Similar to classification of organisms:
    - Animal -> Vertebrate -> Mammals -> Primates



Base and Derived Classes

- Derived classes inherit all data members and functions of base class
- Student class inherits:
  - get_name() and get_id()
  - name_ and id_ member variables

```
class Person {
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private:
  string name_; int id_;
};
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  int get_major();
  double get_gpa();
  void set_gpa(double new_gpa);
 private:
  int major_; double gpa_;
};
```



Class Person

string name_

int id_

Class Student

string name_

int id_

int major_

double gpa_

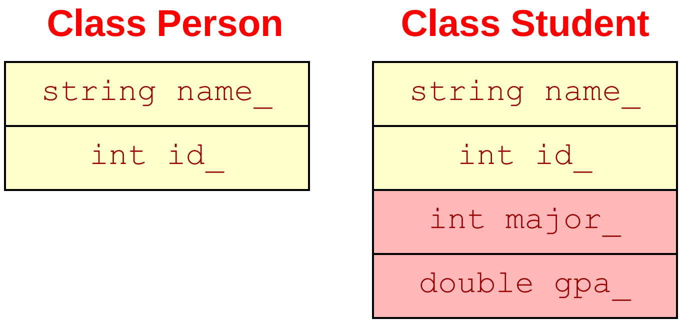
Base and Derived Classes

- Derived classes inherit all data members and functions of base class
- Student class inherits:
  - get_name() and get_id()
  - name_ and id_ member variables

```
class Person {
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private:
  string name_; int id_;
};
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  int get_major();
  double get_gpa();
  void set_gpa(double new_gpa);
 private:
  int major_; double gpa_;
};

int main()
{
  Student s1("Tommy", 1, 9);
  // Student has Person functionality
  // as if it was written as part of
  // Student
  cout << s1.get_name() << endl;

}
```



Class Person

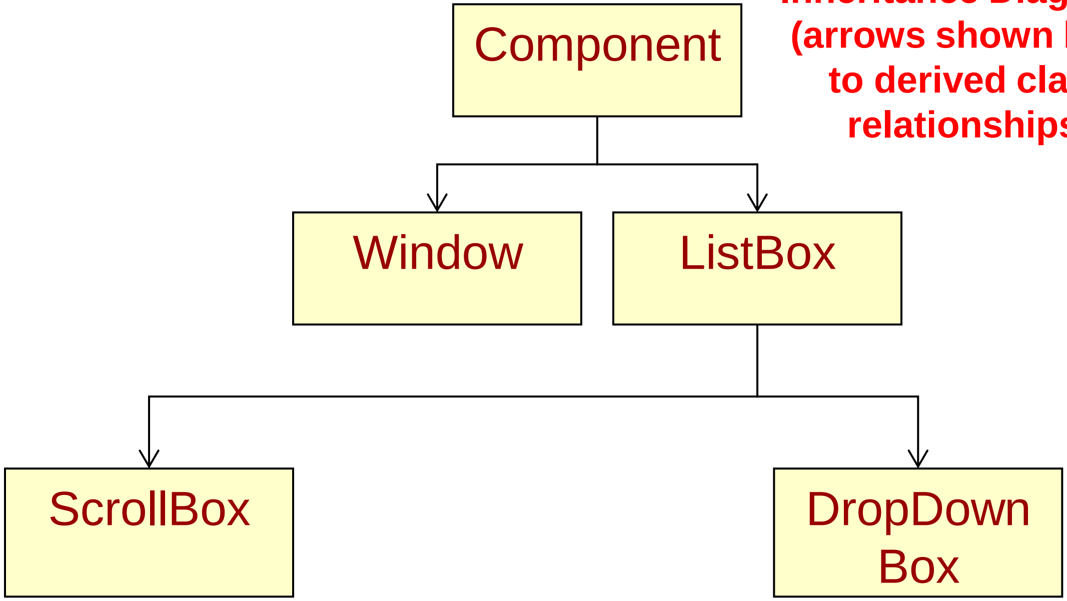
string name_
int id_

Class Student

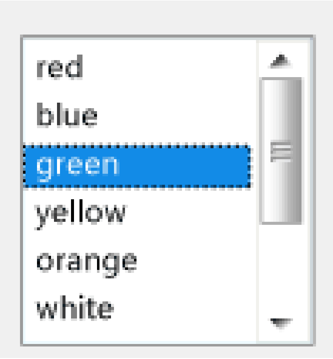
string name_
int id_
int major_
double gpa_

Inheritance Example

- Component
  - Draw()
  - onClick()
- Window
  - Minimize()
  - Maximize()
- ListBox
  - Get_Selection()
- ScrollBox
  - onScroll()
- DropDownBox
  - onDropDown()



Inheritance Diagrams (arrows shown base to derived class relationships)



red
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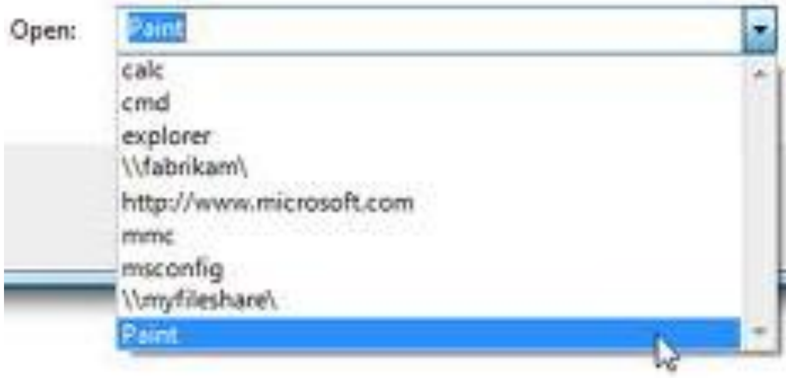
green
yellow
orange
white



Open: Paint

calc
cmd
explorer
\\fabrikam\
http://www.microsoft.com
mmc
msconfig
\\myfileshare\
Paint

Constructors and Inheritance

- How do we initialize base class data members?
- Can't assign base class members if they are private

```
class Person {
 public:
  Person(string n, int ident);
  ...
 private:
  string name_;
  int id_;
};
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  ...
 private:
  int major_;
  double gpa_;
};

Student::Student(string n, int ident, int mjr)
{
   name_ = n;    // can't access name_ in Student
   id_  = ident;
   major_ = mjr;
}
```

Constructors and Inheritance

- Constructors are only called when a variable 'enters scope' (i.e. is created) and cannot be called directly
  - How to deal with base constructors?
- Also want/need base class or other members to be initialized before we perform this object's constructor code
- Use initializer format instead
  - See example below

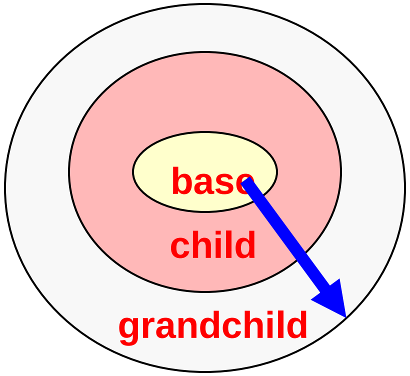
```
class Person {
 public:
  Person(string n, int ident);
  ...
 private:
  string name_;
  int id_;
};
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  ...
 private:
  int major_;
  double gpa_;
};

Student::Student(string n, int ident, int mjr)
{
  // How to initialize Base class members?
  Person(n, ident); // No! can't call Construc.
                    //   as a function
}
```

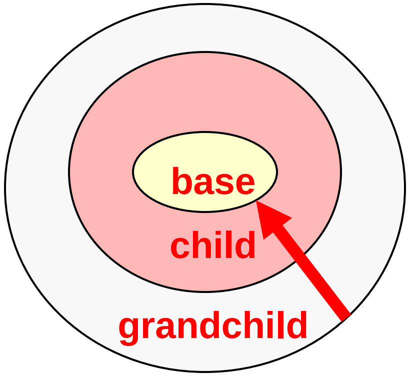
```
Student::Student(string n, int ident, int mjr) : Person(n, ident)
{
  cout << "Constructing student: " << name_ << endl;
  major_ = mjr;   gpa_ = 0.0;
}
```

Constructors & Destructors

- Constructors
  - A Derived class will automatically call its Base class constructor **BEFORE** it's own constructor executes, either:
    - Explicitly calling a specified base class constructor in the initialization list
    - Implicitly calling the default base class constructor if no base class constructor is called in the initialization list
- Destructors
  - The derived class will call the Base class destructor automatically **AFTER** it's own destructor executes
- General idea
  - Constructors get called from base->derived (smaller to larger)
  - Destructors get called from derived->base (larger to smaller)



Constructor call ordering



Destructor call ordering

Constructor & Destructor Ordering

```
class A {
  int a;
public:
  A()  { a=0; cout << "A:" << a << endl; }
  ~A() { cout << "~A" << endl; }
  A(int mya) { a = mya;
               cout << "A:" << a << endl; }
};

class B : public A {
  int b;
public:
  B()  { b = 0; cout << "B:" << b << endl; }
  ~B() { cout << "~B "; }
  B(int myb) { b = myb;
               cout << "B:" << b << endl; }
};

class C : public B {
  int c;
public:
  C()  { c = 0; cout << "C:" << c << endl; }
  ~C() { cout << "~C "; }
  C(int myb, int myc) : B(myb) {
     c = myc;
     cout << "C:" << c << endl; }
};
```

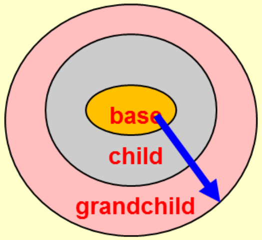
Sample Classes

```
int main()
{
  cout << "Allocating a B object" << endl;
  B b1;
  cout << "Allocating 1st C object" << endl;
  C* c1 = new C;
  cout << "Allocating 2nd C object" << endl;
  C c2(4,5);
  cout << "Deleting c1 object" << endl;
  delete c1;
  cout << "Quitting" << endl;
  return 0;
}
```

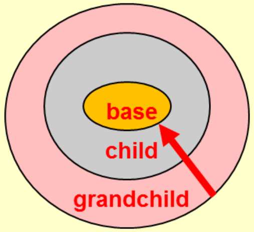
Test Program

```
Allocating a B object
A:0
B:0
Allocating 1st C object
A:0
B:0
C:0
Allocating 2nd C object
A:0
B:4
C:5
Deleting c1 object
~C ~B ~A
Quitting
~C ~B ~A
~B ~A
```

Output



Constructor call ordering



Destructor call ordering

Protected Members

- Private members of a base class can not be accessed directly by a derived class member function
  - Code for print_grade_report() would not compile since ‘name_’ is private to class Person
- Base class can declare variables with protected storage class
  - Private to anyone not inheriting from the base
  - Derived classes can access directly

```
class Person {
 public:
  ...
 private:
  string name_; int id_;
};

class Student : public Person {
 public:
   void print_grade_report();
 private:
   int major_; double gpa_;
};
```

```
void Student::print_grade_report()
{
  cout << "Student " << name_ << ...   X
}
```

```
class Person {
 public:
  ...
 protected:
  string name_; int id_;
};
```

Public/Private/Protected Access

- Derived class sees base class members using the base class' specification
  - If Base class said it was **public** or **protected**, the derived class **can** access it directly
  - If Base class said it was **private**, the derived class **cannot** access it directly
- public/private identifier before base class indicates HOW the public base class members are viewed by clients (those outside) of the derived class
  - public => public base class members are public to clients (others can access)
  - private => public & protected base class members are private to clients (not accessible to the outside world)

```
class Person {
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private: // INACCESSIBLE TO DERIVED
  string name_; int id_;
};
```

Base Class

```
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  int get_major();
  double get_gpa();
  void set_gpa(double new_gpa);
 private:
  int major_; double gpa_;
};
class Faculty : private Person {
 public:
  Faculty(string n, int ident, bool tnr);
  bool get_tenure();
 private:
  bool tenure_;
};
```

Derived Classes

Inheritance Access Summary

- Base class
  - Declare as protected if you want to allow a member to be directly accessed/modified by derived classes
- Derive as public if…
  - You want users of your derived class to be able to call base class functions/methods
- Derive as private if…
  - You only want your internal workings to call base class functions/methods

Inherited Base	Public	Protected	Private
Public	Public	Protected	Private
Protected	Protected	Protected	Private
Private	Private	Private	Private

External client access to Base class members is always the more restrictive of either the base declaration or inheritance level

```
class Person {
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private: // INACCESSIBLE TO DERIVED
  string name_; int id_;
};
```

Base Class

```
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  int get_major();
  double get_gpa();
  void set_gpa(double new_gpa);
 private:
  int major_; double gpa_;
};
class Faculty : private Person {
 public:
  Faculty(string n, int ident, bool tnr);
  bool get_tenure();
 private:
  bool tenure_;
};
```

```
int main(){
  Student s1("Tommy", 73412, 1);
  Faculty f1("Mark", 53201, 2);
  cout << s1.get_name() << endl; // works
  cout << f1.get_name() << endl; // fails
}
```

When to Inherit Privately

- Suppose I want to create a FIFO (First-in, First-Out) data structure where you can only
  - Push in the back
  - Pop from the front
- FIFO is-a special List
- Do I want to inherit publicly from List
- NO!!! Because now the outside user can call the base List functions and break my FIFO order
- Inherit privately to hide the base class public function and make users go through the derived class' interface
  - Private inheritance defines an "as-a" relationship

```
class List{
 public:
  List();
  void insert(int loc, const int& val);
  int size();
  int& get(int loc);
  void pop(int loc;)
 private:
  IntItem* _head;
};
```

Base Class

```
class FIFO : public List // or private List
{ public:
  FIFO();
  push_back(const int& val)
    { insert(size(), val); }
  int& front();
    { return get(0); }
  void pop_front();
    { pop(0); }
};
```

Derived Class

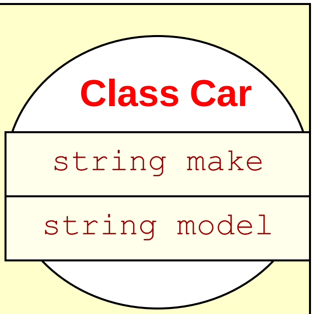
```
FIFO f1;
f1.push_back(7); f1.push_back(8);
f1.insert(0,9)
```

Overloading Base Functions

- A derived class may want to redefined the behavior of a member function of the base class
- A base member function can be overloaded in the derived class
- When derived objects call that function the derived version will be executed
- When a base objects call that function the base version will be executed

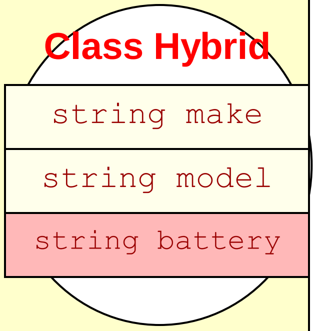
```
class Car{
 public:
  double compute_mpg();
 private:
  string make; string model;
};

double Car::compute_mpg()
{
  if(speed > 55) return 30.0;
  else return 20.0;
}
```



```
class Hybrid : public Car {
 public:
  void drive_w_battery();
  double compute_mpg();
 private:
  string batteryType;
};

double Hybrid::compute_mpg()
{
  if(speed <= 15) return 45; // hybrid mode
  else if(speed > 55) return 30.0;
  else return 20.0;
}
```



Scoping Base Functions

- We can still call the base function version by using the scope operator (::)
  - `base_class_name::function_name()`

```
class Car{
 public:
  double compute_mpg();
 private:
  string make; string model;
};

class Hybrid : public Car {
 public:
  double compute_mpg();
 private:
  string batteryType;
};

double Car::compute_mpg()
{
  if(speed > 55) return 30.0;
  else return 20.0;
}


double Hybrid::compute_mpg()
{
  if(speed <= 15) return 45; // hybrid mode
  else return Car::compute_mpg();
}
```

Inheritance vs. Composition

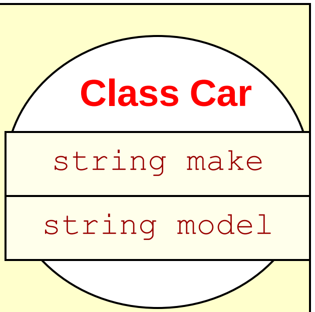
- Software engineers debate about using ***inheritance (is-a)*** vs. ***composition (has-a)***
- Rather than a Hybrid "is-a" Car we might say Hybrid "has-a" car in it, plus other stuff
  - Better example when we get to Lists, Queues and Stacks
- While it might not make complete sense verbally, we could re-factor our code the following ways…
- Interesting article I'd recommend you read at least once:
  - http://berniesumption.com/software/inheritance-is-evil-and-must-be-destroyed/

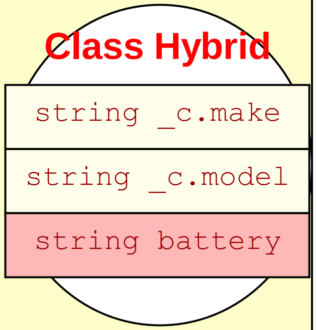
```
class Car{
 public:
  double compute_mpg();
 public:
  string make; string model;
};


double Car::compute_mpg()
{
  if(speed > 55) return 30.0;
  else return 20.0;
}


class Hybrid {
 public:
  double compute_mpg();
 private:
  Car c_;   // has-a relationship
  string batteryType;
};

double Hybrid::compute_mpg()
{
  if(speed <= 15) return 45; // hybrid mode
  else return c_.compute_mpg();
}
```





Another Composition

- We can create a FIFO that "has-a" a List as the underlying structure
- Summary:
  - Public Inheritance => "is-a" relationship
  - Composition => "has-a" relationship
  - Private Inheritance => "as-a" relationship "implemented-as"

```
class List{
 public:
  List();
  void insert(int loc, const int& val);
  int size();
  int& get(int loc);
  void pop(int loc;)
 private:
  IntItem* _head;
};
```

Base Class

```
class FIFO
{ private:
   List mylist;
  public:
   FIFO();
   push_back(const int& val)
    { mylist.insert(size(), val); }
   int& front();
    { return mylist.get(0); }
   void pop_front();
    { mylist.pop(0); }
   int size() // need to create wrapper
     { return mylist.size(); }
};
```

FIFO via Composition