Lecture #2

- Constructors
- Destructors
- Class Composition
- Composition with Initializer Lists
- Learning how to use the VC debugger
- For on-your-own study:
  - A few final topics required for Project #1

Constructors: Class Ini

Every class should have an initialization function that can be used to reset new variables before they're used.

```
class CSNerd
{
public:
  void Init(int PCs, bool usesMac)
  {
     m_numPCs = PCs; // # of PCs owned
     m_macUser = usesMac;
  }
```

But there's one problem with such an Init function…

What is it?

2 false

david

```
void Init(int PCs, bool usesMac)
{
  m_numPCs = PCs;
  m_macUser = usesMac;
}
int getNerdScore(void)
{
   if(m_macUser == true)
    return(0);
   return(10 * m_numPCs);
}
```

m_numPCs -32 m_macUser false

Utoh! Remember, all simple variables (e.g., ints, bools, etc.) in C++ start out with random values unless they're explicitly initialized!

```
int main()
{
  CSNerd david;
  david.Init(2,false); //
  cout << david.getNerdScore();
}
```

Right! Our programmer might forget to call the Init function before using their variable…

Let's see what happens!

```
class CSNerd
{
public:
  void Init(int PCs, bool usesMac)
  {
    m_numPCs = PCs;
    m_macUser = usesMac;
  }

  int getNerdScore(void)
  {
    if(m_macUser == true)
      return(0);
    return(10 * m_numPCs);
  }

private:
  int m_numPCs;
  bool m_macUser;
};
```

Constructors

Wouldn't it be great if C++ would guarantee that every time we create a new class variable, it'll be auto-initialized?

Well, as it turns out, that's exactly what the C++ constructor does!

```
int main()
{
  CSNerd david;

  cout << david.getNerdScore();
}
```

```
class CSNerd
{
public:
   CSNerd(int PCs, bool usesMac)
   {
      m_numPCs = PCs;
      m_macUser = usesMac
   }

   int getNerdScore(void)
   {
      if(m_macUser == true)
        return(0);
      return(10 * m_numPCs);
   }

private:
   int m_numPCs;
   bool m_macUser;
};
```

Since the constructor is called automatically any time you define a new variable… there's no chance of a new variable being uninitialized accidentally.

Instead of being called Init, the constructor function has the same name as the class! (Confusing, huh?)

```
int main()
{
   CSNerd chen(3,true);


   cout <<
    chen.getNerdScore();
}
```

hen

3 true

```
CSNerd(int PCs, bool usesMac)
{
  m_numPCs = PCs;
  m_macUser = usesMac;
}
int getNerdScore(void)
{
   if(m_macUser == true)
    return(0);
   return(10 * m_numPCs);
}
```

m_numPCs [ ] m_macUser [ ]

The constructor is called automatically every time you create a new instance of your class.

A constructor is a special member function that *automatically* initializes every new variable you create of a class.

ctors

The constructor has no return type… Not void, int or bool!

The constructor always has the same name as the class it's in.

```
cl    CSNerd
{
pu    lic:
  CSNerd(int PCs, bool usesM
  {
     m_numPCs = PCs;
     m_macUser = usesMac;
    return(true); //illegal!
  }
...
private:
  int m_numPCs;
  bool m_macUser;
};
```

Thus, it's not allowed to return any value at all!

You can define the constructor in the class declaration (see above)…

And remember to also include just the function header, followed by a semicolon, in the class declaration itself.

```
class CSNer
{
public:
  CSNerd(int PCs, bool usesMac);

  ...

private:
   int m_numP
   bool m_m    se
};
CSNerd::CSNerd(int PCs, bool usesMac)
{
   m_numPCs = PCs;
   m_macUser = usesMac;
}
```

Boy, isn't that syntax ugly? Just remember, to define a constructor outside the class declaration:

use the class name, followed by ::, followed by the class name

Or, outside the class declaration, like this…

Constructors

```
class CSNerd
{
public:
  CSNerd(int PCs, bool usesMac)
  {
     m_numPCs = 0;
     m_macUser = false;
  }

  int getNerdScore(void)
  {
     if(m_macUser == true)
       return(0);
     return(10 * m_numPCs);
  }

private:
   int m_numPCs;
   bool m_macUser;
};
```

If a constructor requires parameters:

You must provide values for those parameters when you create a new variable:

```
int main()
{
  CSNerd ed(1,true);  // OK

  CSNerd alan; // invalid!

}
```

Constructors

```
class CSNerd
{
public:
  CSNerd(int PCs, bool usesMac= true )
  {
     m_numPCs = PCs;
     m_macUser = usesMac;
  }

  int getNerdScore(void)
  {
     if(m_macUser == true)
       return(0);
     return(10 * m_numPCs);
  }

private:
   int m_numPCs;
   bool m_macUser;
};
```

Just like any C++ function, a constructor can have one or more default parameters…

```
int main()
{

 CSNerd lyn(1,false);

 CSNerd ned(5); // OK!

 CSNerd dave; //invalid!



}
```

nstructors

Your class can have many different constructors. This is called overloading constructors.

```
class CSNerd
{
public:
  CSNerd(int PCs=1, bool usesMac=true)
  {
     m_numPCs = PCs;
     m_macUser = usesMac;
  }
  CSNerd()
  {
    m_numPCs = 1;
    m_macUser = false;
  }
  int getNerdScore(void)
  {
    if(m_macUser == true)
      return(0);
    return(10 * m_numPCs);
  }
private:
  int m_numPCs;
  bool m_macUser;
};
```

C++: "I'm confused! Should I call this constructor with default parameters…"

C++: "…or should I call this constructor with no parameters?"

```
int main()
{
 CSNerd lyn(1,false);
 CSNerd ned(5); // OK!
 CSNerd dave; //invalid!
}
```

One more thing: If you have 2 or more constructors, they cannot have the exact same parameters/types.

Constructors

```
class CSNerd
{
public:
 CSNerd() // generated by compiler
 {
   // I don't initialize scalar member
   // variables… So be careful!!!
 }

 int getNerdScore(void)
 {
   if(m_macUser == true)
     return(0);
   return(10 * m_numPCs);
 }

private:
  int m_numPCs;
  bool m_macUser;
};
```

These variables will have random values!

If you don't define any constructors at all…

Then C++ generates an implicit, default constructor for you.

Why would it do this? Well, we'll see why in a bit. ☺

But this default constructor won't initialize your object's scalar member variables!

So be careful!

Scalar variables include native C++ types like int, float, double, bool, etc.

Non-scalars include string, CSNerd, etc.

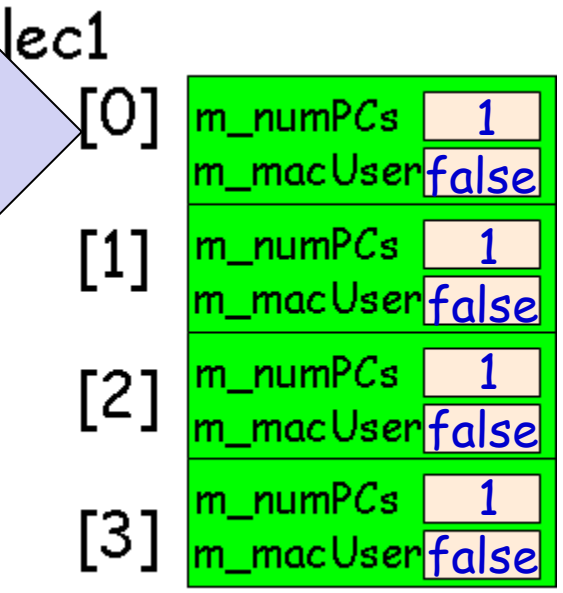
```
t main()
{

 CSNerd  carey;

 cout <<
   carey.getNerdScore(); //??
}
```

Constructors & Arrays

```
class CSNerd
{
public:
  CSNerd(int PCs, boo
  {
     m_numPCs = PCs;
     m_macUser = usesMac;
  }
  CSNerd()
  {
    m_numPCs = 1;
    m_macUser = false;
  }
  ...

private:
   int m_numPCs;
   bool m_macUser;
};
```

The constructor is then run on *every* element in the array!

Your class must have a constructor that requires no arguments!



If you want to have an array of your class…

```
int main()
{
 CSNerd lec1[4];


 …
}
```

When Constructors ed

```
int main()
{
    CSNerd carey(3,false), bill;

    CSNerd arr[52];

    CSNerd *ptr = new CSNerd(1,3);

    CSNerd *justAPtr;

}
```

A constructor is called any time you create a new variable of a class.

A constructor is called N times (once for each array element) when you create an array of size N.

A constructor is called when you use new to dynamically allocate a new variable.

The constructor is *not called* when you just define a pointer variable!

Class Challenge

Name all the times the CSNerd constructor is called in this example…

```
class CSNerd
{
public:
 CSNerd()
 {
   m_numPCs = 1;
   m_macUser = true;
 }
 ...
private:
  int m_numPCs;
  bool m_macUser;
};
```

```
void foo()
{
   CSNerd *herbert = new CSNerd;
}

int main(void)
{
   int j;
   CSNerd *ptrToNerd;
   CSNerd xavier;

   for (j=0;j<3;j++)
   {
        CSNerd a[5];
        foo();
   }
}
```

And now it's time for…

Figure out what the obfuscated C program does!

Destructors

Just as every class has a constructor, every class also has a destructor function (it may have *only one* of these).

The job of the destructor is to de-initialize or destruct a class variable when it goes away.

Here's how we define a destructor directly inside our class definition…

```
class SomeClass
{
public:
  ~SomeClass()
  {
     // your destructor
     // code goes here
  }

private:
    …
};
```

It looks just like a constructor function except for the tilde ~ which identifies it as a destructor.

To define a destructor function, place a tilde ~ character in front of the name of the class.

Destructors

Just as every class has a constructor, every class also has a destructor function (it may have *only one* of these).

The job of the destructor is to de-initialize or destruct a class variable when it goes away.

Here's how we define a destructor directly inside our class definition…

You can also define a destructor outside your class definition…

```
class SomeClass
{
public:
  ~SomeClass()
  {
     // your destructor
     // code goes here
  }

private:
    …
};
```

Destructors must NOT have any parameters. Destructors must NOT return a value either.

First, define a function header for your destructor inside your class. Don't forget the semicolon!

```
class So        s
{
public:
    ~SomeClass();
    …
};

SomeClass::~SomeClass()
{
    // your destructor
    // code goes here
}
```

Then define your actual destructor function outside the class like this…

Destructors

```
class CSNerd
{
public:
  CSNerd()
  {
     m_numPCs = 0;
     m_macUser = false;
  }

  int getNerdScore(void)
  {
    if(m_macUser == true)
      return(0);
    return(10 * m_numPCs);
  }
  ~CSNerd() // generated by compiler
  {
  }
private:
   int m_numPCs;
   bool m_macUser;
};
```

If you don't define your own destructor for a class…

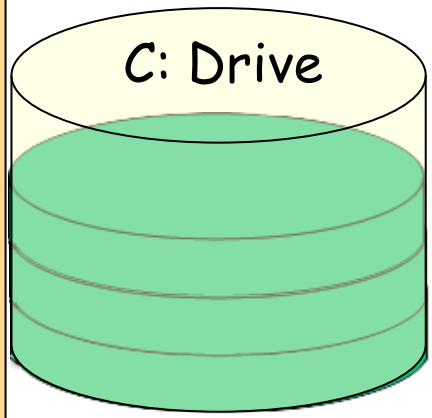
Then C++ will define an implicit one for you…

This ensures that objects of your class properly go away when they go out of scope.

Why Do We Need Destructors?

Notice – our class doesn't have a destructor. Let's see what happens!

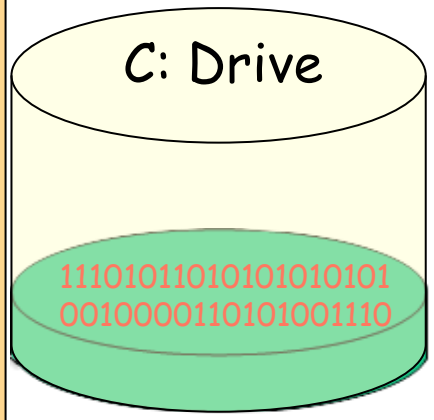
```
class MP3Player
{
public:
    MP3Player()
    {
        reserveSpaceOnDisk(100000000); // 100MB
    }

   void getSong(const std::string &songURL)
   {
       downloadToReservedSpace(songURL);
   }

   void playSong()
   {
       playMP3InReservedSpace();
    }

   void doneWithMusic()
   {
        freeReservedSpaceOnDisk();
   }


};
```




```
int main()
{
   string url = "www.music.com/song.mp3";

   // obsessively play song 100 times!

   for (int i=0;i<100;i++)
   {
       MP3Player p;
       p.getSong(url);
       p.playSong();
   }
}
```

Why Do We Need Destructors?

```
class MP3Player
{
public:
    MP3Player()
    {
        reserveSpaceOnDisk(100000000); // 100MB
    }

   void getSong(const std::string &songURL)
   {
       downloadToReservedSpace(songURL);
   }

   void playSong()
   {
       playMP3InReservedSpace();
    }
   void doneWithMusic()
   {
        freeReservedSpaceOnDisk();
   }
  ~MP3Player()
   {
       freeReservedSpaceOnDisk();
   }
};
```




```
int main()
{
   string url = "www.music.com/song.mp3";

   // obsessively play song 100 times!

   for (int i=0;i<100;i++)
   {
       MP3Player p;
       p.getSong(url);
       p.playSong();
   }
}
```

When must you have a destructor?

Any time a class allocates a system resource…

Reserves memory using the *new* command

Opens a disk file

Connects to another computer over the network

Your class must have a destructor that…

Frees the allocated memory with the *delete* command

Closes the disk file

Disconnects from the other computer

Don't forget or you'll FAIL!

Destr

So when is a destructor called anyway?

```
void Dingleberry(void)
{
    SomeClass a;

  for (int j=0;j<10;j++)
  {
    SomeClass b;
    // do something
  } ← b's destructor is called each time we hit the end of the block

  MP3Player *m = new MP3Player;
  m->getSong("www.music.com/x.wav");
  m->playSong();
  delete m; ← m's destructor is called here
```

(if you don't use delete, m's d'tor is ***never*** called – ***not even when the program ends!***)

```
} ← a's destructor is called here
```

Local objects defined in a function are destructed when they "go out of scope."

Local variables defined in a block are destructed when the block finishes.

Dynamically allocated variables (e.g., allocated using the new command) are destructed when delete is called, *before* the memory is actually freed by the OS.

Destructors

So when is a destructor called anyway?

```
void Dingleberry(void)
{
    SomeClass a;
    SomeClass x[42];

  for (int j=0;j<10;j++)
  {
    SomeClass b;
    // do something
  }


  MP3Player *m = new MP3Player;
  m->getSong("www.music.com/x.wav");
  m->playSong();
  delete m;


}
```

Finally, when you define an array of N items, the destructor is called N times when the array goes away…

The destructor is called 42 times for x here!

Class Challenge #2

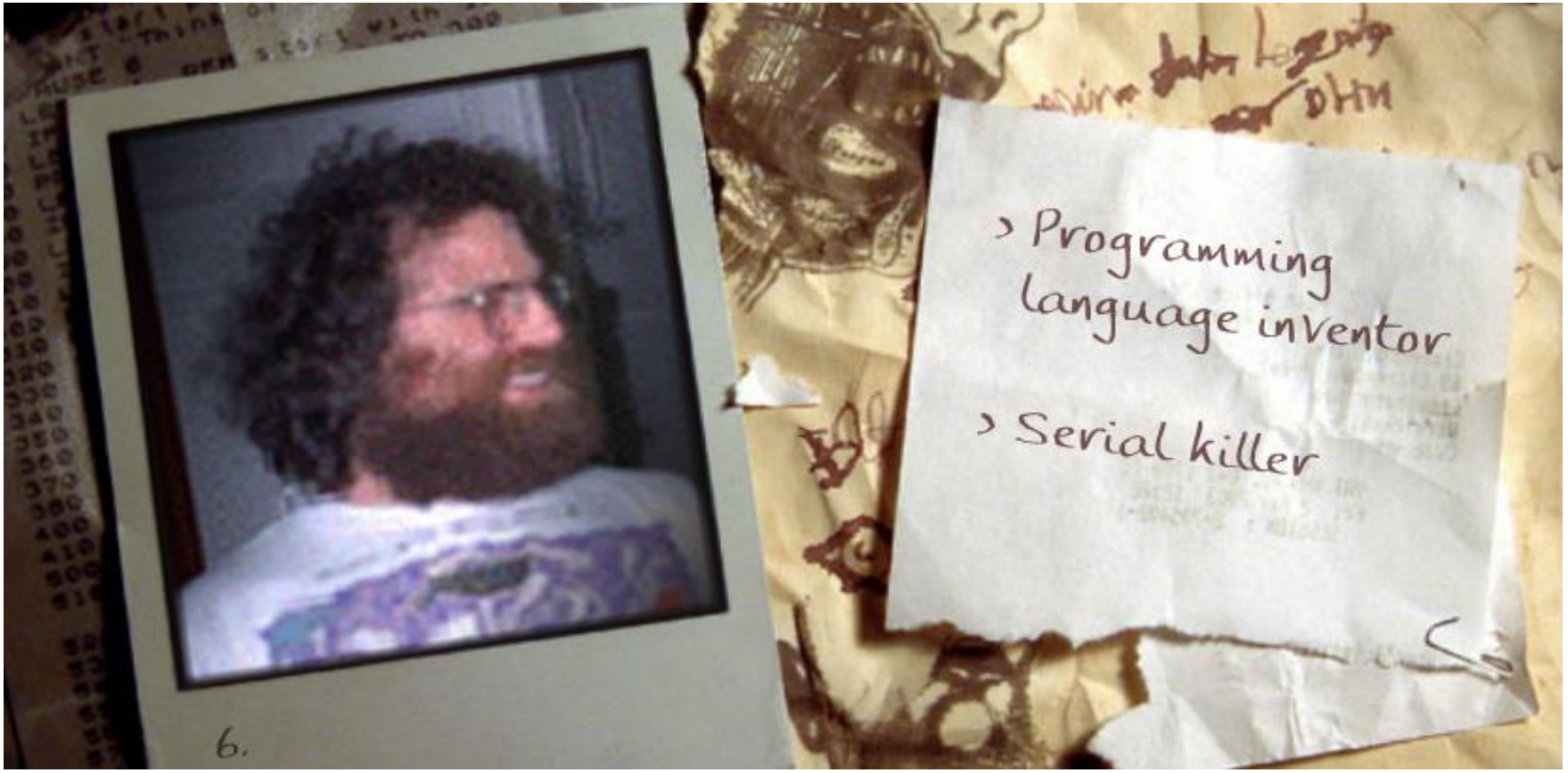
Name all the times the CSNerd destructor is called in this example…

```
class CSNerd
{
public:
 CSNerd()
 {
   m_numPCs = 1;
   m_macUser = true;
 }

 ~CSNerd()
 {
   cout <<"Argh! I'm dying. Where's my
          iphone?";
 }
 ...
private:
  int m_numPCs;
  bool m_macUser;
};
```

```
void foo()
{
   CSNerd a, *b;
}

int main(void)
{
   int j;
   CSNerd *ptr, x;

   ptr = new CSNerd;
   for (j=0;j<3;j++)
   {
        CSNerd  a[5];
        foo();
   }
   delete ptr;
}
```

Question: How could we make our program more efficient? (Hint: Look where this is pointing)

Can you guess?



See if you can guess who uses a keyboard and who uses a chainsaw!

Class Composition

Class composition is when a class contains one or more member variables that are objects.

Note: string is a class just like Car and GasTank! So if your class contains a string member, you're doing composition!

myTank is an object of the GasTank class.

So our Car class is using class composition.

```
class GasTank
{
 ...
};

class Car
{
  ...
private:
   GasTank myTank;
   int horsePower;
   string modelName;
};
```

```
class Valve
{
   ...
};
class Heart
{
      ...
 private:
    Valve m_valves[4];
};
class TinMan
{
   ...
private:
  Heart m_myHeart;
};
```

Class Composition

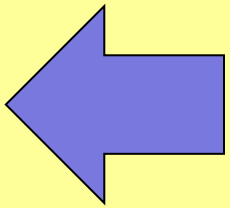
Class Composition

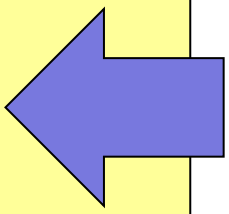
Class Composition

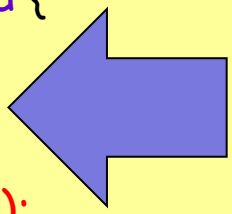
Class Composition

Class Composition

```
class Stomach {
public:
   Stomach() { myGas = 0; }
   void eat()  { myGas ++; }
   ...
};

class Brain {
public:
    Brain()       { myIQ = 100; }
    void think() { myIQ += 10; }
    ...
};
class HungryNerd {
public:
   HungryNerd()
   {
      myBelly.eat();
      myBrain.think();
   }
private:
   Stomach myBelly;
   Brain      myBrain;
};
```







So how does construction work when we use class composition?

Well, let's assume that we have three classes…

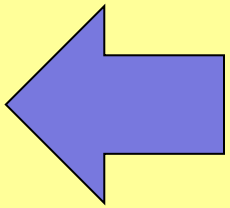
So if I define a HungryNerd variable, how is it actually constructed?

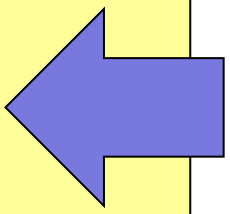
Well, a HungryNerd has a constructor. But it also contains a Stomach and a Brain, and they have constructors too!

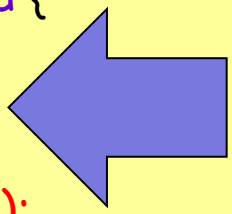
So how does C++ handle all this?

```
int main()
{
   HungryNerd carey;
   ...
}
```

```
class Stomach {
public:
   Stomach() { myGas = 0; }
   void eat()  { myGas ++; }
   ...
};

class Brain {
public:
    Brain()       { myIQ = 100; }
    void think() { myIQ += 10; }
    ...
};
class HungryNerd {
public:
   HungryNerd()
   {
      myBelly.eat();
      myBrain.think();
   }
private:
   Stomach myBelly;
   Brain      myBrain;
};
```







Class Composition

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Well, let's assume that we have three classes…

So if I define a HungryNerd variable, how is it actually constructed?

Well, a HungryNerd has a constructor. But it also contains a Stomach and a Brain, and they have constructors too!

So how does C++ handle all this?

```
int main()
{
   HungryNerd carey;
   ...
}
```

```
class Stomach {
public:
   Stomach() { myGas = 0; }
   void eat()  { myGas ++; }
   ...
};

class Brain {
public:
    Brain()       { myIQ = 100; }
    void think() { myIQ += 10; }
    ...
};
class HungryNerd {
public:
   HungryNerd()
   {
      myBelly.eat();
      myBrain.think();
   }
private:
   Stomach myBelly;
   Brain      myBrain;
};
```

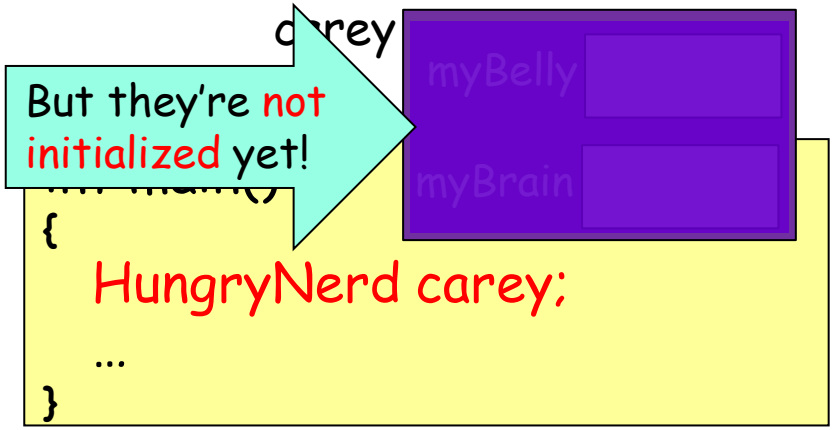
Uses myBelly and myBrain!

Well, HungryNerd's constructor should run first, right?

But wait! Our HungryNerd constructor uses its Brain and Stomach variables…

But how can it use these variables if they haven't yet been constructed?

It can't! HungryNerd needs to construct these variables first, before its own constructor can run and use them!



```
class Stomach {
public:
   Stomach() { myGas = 0; }
   void eat()  { myGas ++; }
};

class Brain {
public:
    Brain()       { myIQ = 100; }
    void think() { myIQ += 10; }
};
class HungryNerd {
public:
   HungryNerd()
      Call myBelly 's default constructor
      Call myBrain's default constructor
   {
      myBelly.eat();
      myBrain.think();
   }
private:
   Stomach myBelly;
   Brain      myBrain;
};
```

This code is automagically added by the compiler!

Member objects

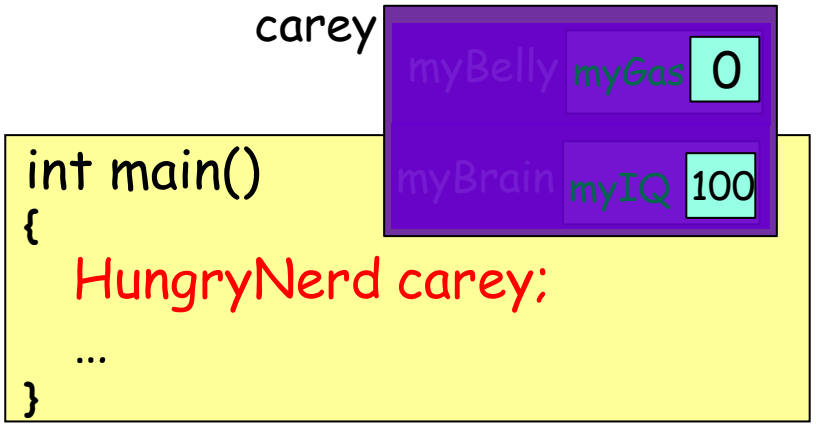
And that's exactly what happens!

When an outer object contains member objects…

C++ automatically adds code to the outer object's constructor to FIRST call the DEFAULT constructors of all the member objects…

And then AFTER they're constructed, it runs the body of the outer object's constructor.

Now our outer constructor can safely use any of the member variables!



```
class Stomach {
public:
   Stomach() { myGas = 0; }
   void eat()  { myGas ++; }
   ~Stomach() { cout << "Fart!\n"; }
};

class Brain {
public:
    Brain()       { myIQ = 100; }
    void think() { myIQ += 10; }
    ~Brain() { cout << "Argh!\n"; }
};

class HungryNerd {
public:
   ~HungryNerd()
   {
      myBelly.eat();    // last meal
      myBrain.think();  // last thought
   }
priv
   St
   Bra
};
```

Uses myBelly and myBrain!

So they can only be destructed after the outer destructor finishes!

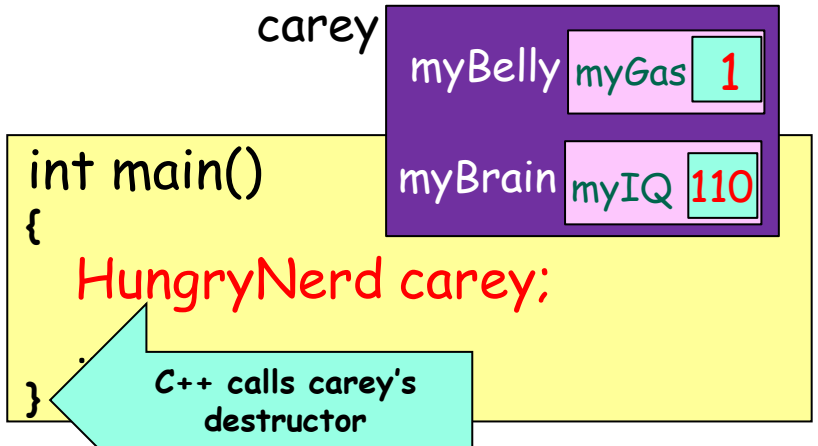
OK, that makes sense.
But what about destruction?

At the time when our object (carey) goes out of scope, C++ automatically calls its destructor.

OK, but which destructor runs first? HungryNerd's, Stomach's or Brain's?

Well HungryNerd is allowed to use its member variables in its destructor…

So they can't be destructed until HungryNerd's destructor finishes!



```
class Stomach {
public:
   Stomach() { myGas = 0; }
   void eat()  { myGas ++; }
   ~Stomach() { cout << "Fart!\n"; }
};

class Brain {
public:
    Brain()       { myIQ = 100; }
    void think() { myIQ += 10; }
    ~Brain() { cout << "Argh!\n"; }
};
class HungryNerd {
public:
   ~HungryNerd()
   {
      myBelly.eat();      // last meal
      myBrain.think();  // last thought
   }
    Call myBelly 's destructor
    Call myBrain 's destructor
private:
   Stomach myBelly;
   Brain      myBrain;
};
```

So what happens?

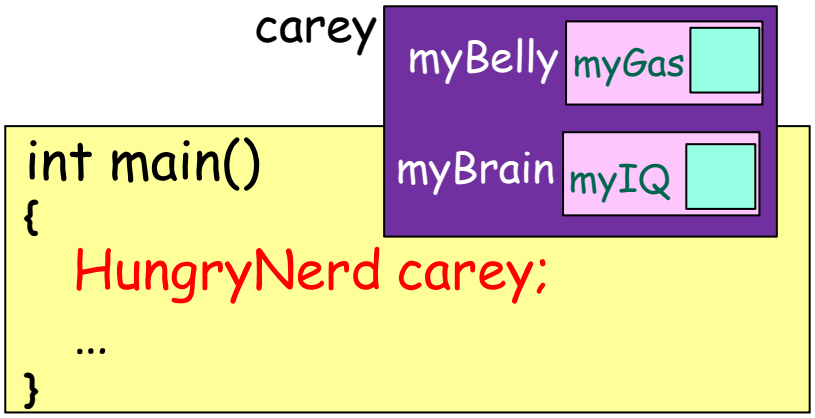
The C++ compiler adds code to the end of the outer destructor to call the inner objects' destructors.

So the outer destructor runs first.

Then, after the outer destructor runs, it calls the destructors of the inner objects (in reverse order of construction).

Finally, after all embedded objects have been destructed, the outer object's memory is freed.

And of course, if an embedded object has its own embedded object(s), this process is repeated.



Back to Auto-generated Constructors and Destructors

```
class HungryNerd
{
public:
  HungryNerd()  // implicitly added by compiler
    Call myBelly's  default constructor
    Call myBrain's default constructor
  {
    // empty
  }
  ~HungryNerd()  // implicitly added by compiler
  {
    // empty
  }
    Call myBrain's destructor
    Call myBelly's destructor
  void celebrate()
  {
     myBelly.eat();   // mmmm
  }
private:
    Belly myBelly;
    Brain myBrain;
};
```

So why does C++ auto-generate constructors and destructors for your classes if you don't define your own?

Answer:
To ensure that each member object is properly constructed and destructed!

This ensures that by the time your other member functions use your embedded object variables, they'll be properly initialized!

Back to Auto-generated Constructors and Destructors

```
class HungryNerd
{
public:
  HungryNerd()  // implicitly added by compiler
    Call myBelly's  default constructor
    Call myBrain's default constructor
  {
    // empty
  }
```

This implicitly added constructor…

so they'll have a random value here!

```
  void celebrate()
  {
    cout << "Happy " << myAge <<
         "'th birthday!";
  }
private:
    Belly myBelly
    Brain myBrai
    int   myAge;
```

wont initialize your object's scalar variables…

Just be careful!

Remember, that the auto-added default constructor…

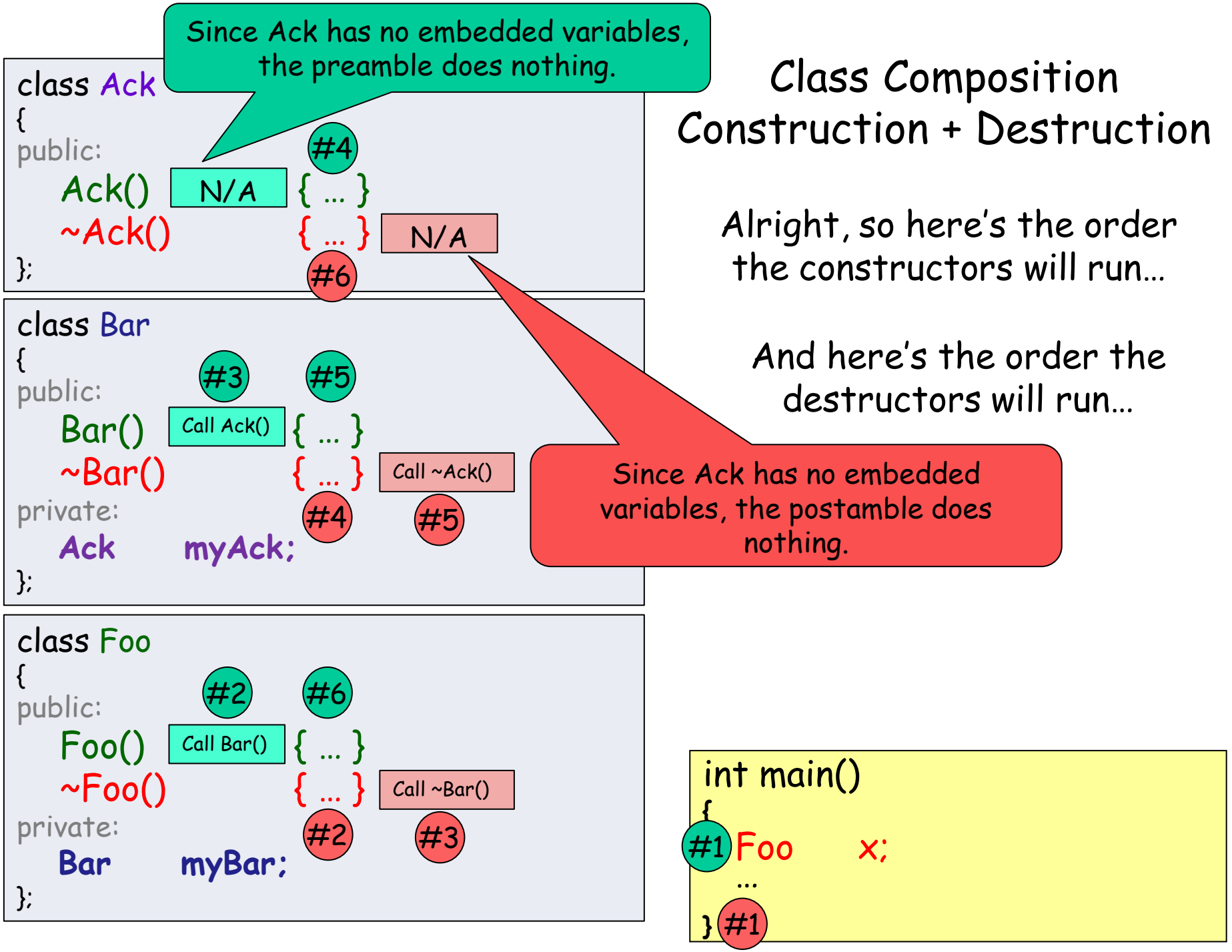
WON'T initialize your scalar member variables!

So if your class has any scalars (ints, bools, floats, doubles, etc.) you should define your own constructor and initialize them!

Class Composition
Construction + Destruction

Alright, so here's the order the constructors will run…

And here's the order the destructors will run…



Advanced Class Composition

Of course, things are never quite so simple…

Let's look at a slightly more complex class composition example.

Let's change the constructor of our Stomach class so it REQUIRES the user to specify the amount of gas each stomach starts with.

Advanced C[illegible]s...

```
class Stomach
{
public:
  Stomach(int startGas)
  {
     myGas = startGas;
  }

  ~Stomach() { cout << "Fart!\n";  }
  void eat()  { myGas ++; }
private:
  int myGas;
};
```

Ok, so now our new Stomach constructor REQUIRES us to pass in a value...

And here's how we create a new Stomach variable...

```
int main(void)
{
     Stomach  a(5); // 5 farts
     Stomach  b;    // ???

     a.eat();   // 6 farts
     ...
}
```

Now, what happens if we want to use our new Stomach class in our HungryNerd class?

Advanced Class Composition

```
class Stomach
{
public:
   Stomach(int startGas)
   {
       myGas = startGas;
   }
   ~Stomach() { cout << "Fart!\n";  }
   void eat()  { myGas ++; }
private:
  int myGas;
};
```

```
class HungryNerd
{
public:
   HungryNerd()
   {
       myBelly.eat();
       myBrain.think();
   }


   ...

private:
   Stomach myBelly;
   Brain myBrain;
};
```

Will our HungryNerd class still compile?

NO!

Advan mposition

```
class Stomach
{
public:
   Stomach(int startGas)
   {
      myGas = startGas;
   }
   ~Stomach() { cout << "Fart!\n";  }
   void eat()  { myGas ++; }
private:
  int myGas;
};
```

Because our new Stomach class REQUIRES you to pass a value in to its constructor.

But our Stomach class doesn't have a default (parameter-less) constructor anymore!

```
class HungryNerd
{
public:
   HungryNerd()
      Call myBelly's default constructor
      Call myBrain's default constructor
   {
      myBelly.eat();
      myBrain.think();
   }..

private:
   Stomach myBelly;
   Brain myBrain;
```

But our auto-generated C++ code always calls the default constructor, which takes NO parameters!

So this results in a C++ compilation error!

Advanced Class Composition

```
class Stomach
{
public:
   Stomach(int startGas)
   {
      myGas = startGas;
   }
   ~Stomach() { cout << "Fart!\n";  }
   void eat()  { myGas ++; }
private:
  int myGas;
};
```

Ok, so how can we fix our HungryNerd class so it works with our new Stomach class?

Answer: Our HungryNerd class MUST somehow explicitly call Stomach's constructor and pass in a valid parameter.

```
class HungryNerd
{
public:
   HungryNerd()
      Call myBelly's default constructor
      Call myBrain's default constructor
   {
      myBelly.eat();
      myBrain.think();
   }

private:
   Stomach myBelly(10); // Good?
   Brain myBrain;
};
```

Hmm… Perhaps we can do something like this?

Good thinking! But that's not the proper syntax!

Advanc mposition

```
class Stomach
{
public:
   Stomach(int startGas)
   {
      myGas = startGas;
   }
   ~Stomach() { cout << "Fart!\n";  }
   void eat()  { myGas ++; }
private:
  int myGas;
};
```

```
lass HungryNerd
{
public:
   HungryNerd()
   : myBelly(10)
   {
      myB   ly.eat();
      myB   in.think();
   }

private:
   Stom
   Brain
};
```

We're no longer going to let C++ call myBelly's default constructor for us…

"Initializer list"

Call myBrain's default constructor

Instead, we'll add our own C++ code to explicitly call myBelly's constructor with a parameter.

The initializer list calls the constructor(s) of the embedded object(s) with the values you pass in.

This is called an "initializer list" and it's the only way in C++ to initialize an embedded object whose constructor requires parameters!

Alright, let's see the correct syntax!

Advanced Class Composit

```
class Stomach
{
public:
   Sto
   {
      myGas = startGas;
   }
   ~Stomach() { cout << "Fart!\n";  }
   void eat()  { myGas ++; }
private:
  int myGas;
};
```

The initializer list sits between the constructor's prototype and its body.

```
class HungryNe
{
public:
   HungryNerd()
     : myBelly(10)
   {
      myBelly.eat();
      myBrain.think();
   }

private:
   Stomach myBelly;
   Brain myBrain;
};
```

You must add an initializer list to *all* of your outer class's constructor(s).

It starts with a colon, followed by one or more member variables and their parameters in parentheses.

So here's what your revised C++ code looks like (without the C++ magic).

Any time you have a member variable (e.g., myBelly) that requires a parameter for construction…

Advanced Class Compos

```
class Stomach
{
public:
    class Brain
    {
    public:
        Brain()        { myIQ = 100; }
        void think() { myIQ += 10; }

    };

private:
    Brain myBrain;
};
```

```
class HungryNerd
{
public:
    HungryNerd()
      : myBelly(10)
    {
        myBelly.eat();
        myBrain.think();
    }

private:
    Stomach myBelly;
    Brain myBrain;
};
```

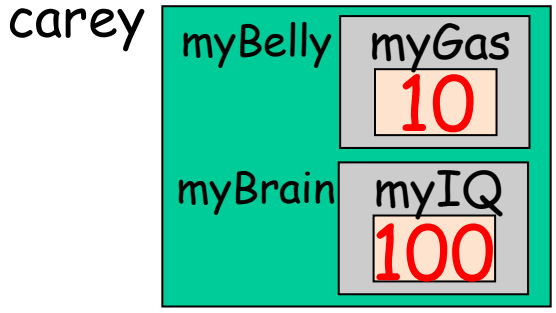
This line calls myBelly's constructor with a parameter value of 10!

Call myBrain's default constructor

Finally, once all of our embedded objects have been constructed, C++ will run the outer constructor's body!

Of course, C++ is still happy to implicitly construct any embedded objects with default constructors for us!

OK – let's see our new HungryNerd and Stomach classes in action!



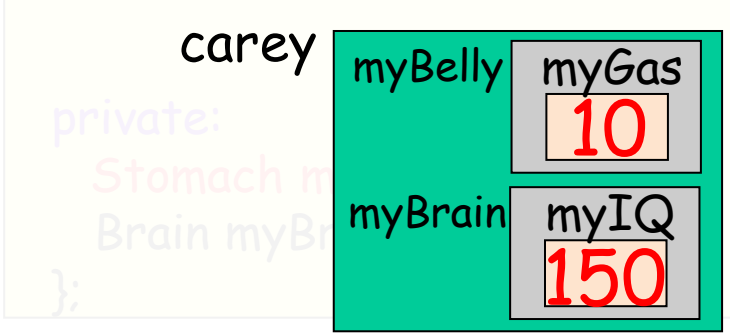

```
int main(void)
{
    HungryNerd  carey;

    ...
}
```

Advanced Class Composition

```
class Stomach
{
public:
   Stomach(int startGas)
   {
      myGas = startGas;
   }
   ~Stomach() { cout << "Fart!\n";  }
   void eat()  { myGas ++; }
private:
  int myGas;
};
```

```
class Brain
{
public:
    Brain(int startIQ)
    {
       myIQ = startIQ;
    }
    void think() { myIQ += 10; }
};
```

```
class HungryNerd
{
public:
   HungryNerd()
     : myBelly(10) , myBrain(150)
   {
      myBelly.eat();
      myBrain.think();
   }
private:
   Stomach myBelly;
   Brain myBrain;
};
```




```
int main(void)
{
   HungryNerd   carey;

   ...
}
```

Initializer Lists

You must always add your initializer list to your actual constructor definition (whether it's defined inside or outside your class).

```
class HungryNerd
{
public:

 HungryNerd()
  : myBelly(10), myBrain(150)
 {
   myBelly.eat();
   m_age = 19;
 }

private:
  Belly myBelly;
  Brain myBrain;
  int
};
```

Then you must have your initializer list here.

And NOT here.

```
class HungryNe
{
public:

 HungryNerd();

private:
  Belly myBelly;
  Brain myBrain;
  int   myAge;
};

HungryNerd::HungryNerd()
: myBelly(10), myBrain(150)
{
   myBelly.eat();
   m_age = 19;
}
```

So if you define the body of your constructor OUTSIDE of your class definition…

Initializer Lists

If you like, you may also use the initializer list to initialize your scalar member variables too.

```
class HungryNerd
{
public:

 HungryNerd()
  : myBelly(10), myBrain(150),myAge (19)
 {
   myBelly.eat();

 }

private:
  Belly myBelly;
  Brain myBrain;
  int   myAge;
};
```

You may do it here in your initializer list…

Feel free to use the initializer list for scalars if you like, but it's not required either way.

This will initialize your scalar variable(s) before the body of your constructor runs.

Instead of initializing your scalar variables here in your constructor body…

Advanced Class Compo

```
class Stomach
{
public:
   Stomach(int startGas)
   {
      myGas = startGas;
   }
   ~Stomach() { cout << "Fart!\n";  }
   void eat()  { myGas ++; }
private:
  int myGas;
};
```

```
class Hungry
{
public:
   HungryNerd( int startingGas)
     :myBelly( startingGas )
   {
      myBelly.eat
      myBrain.th
   }

private:
   Stomach myBelly;
   Brain myBrain;
};
```

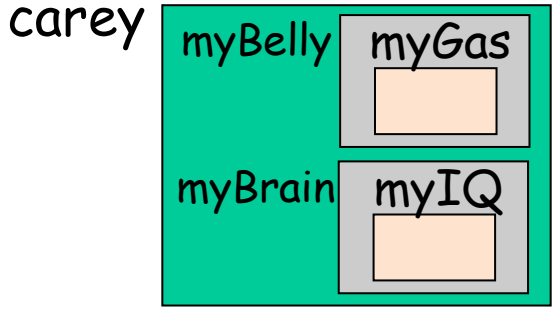
Call myBrain's default constructor

We don't need to have constants here!

Now we'll initialize our myBelly member with whatever the user passes in to the HungryNerd constructor!

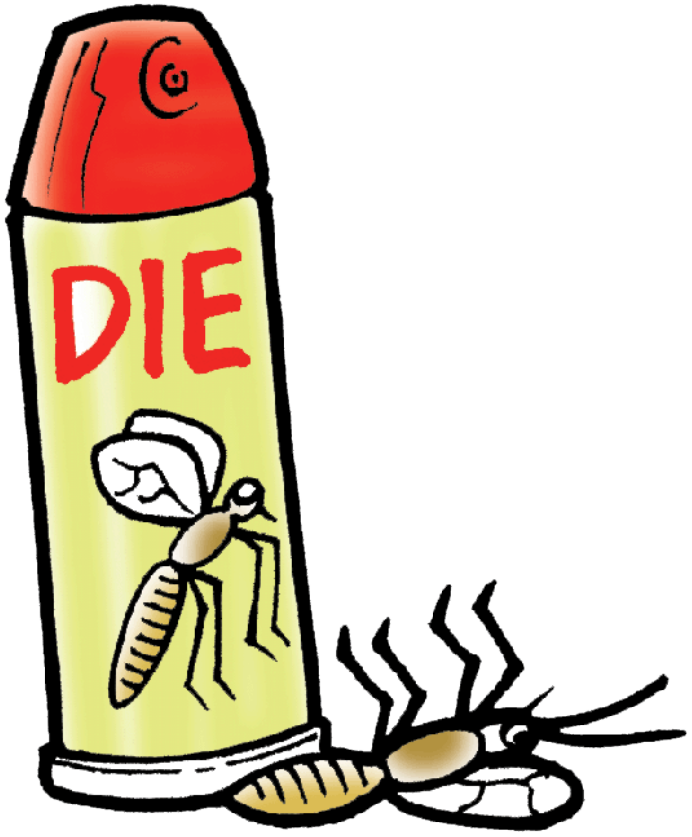
And these can even be more interesting expressions!

Finally, there's no reason why the parameters to your initializer list have to be constants…



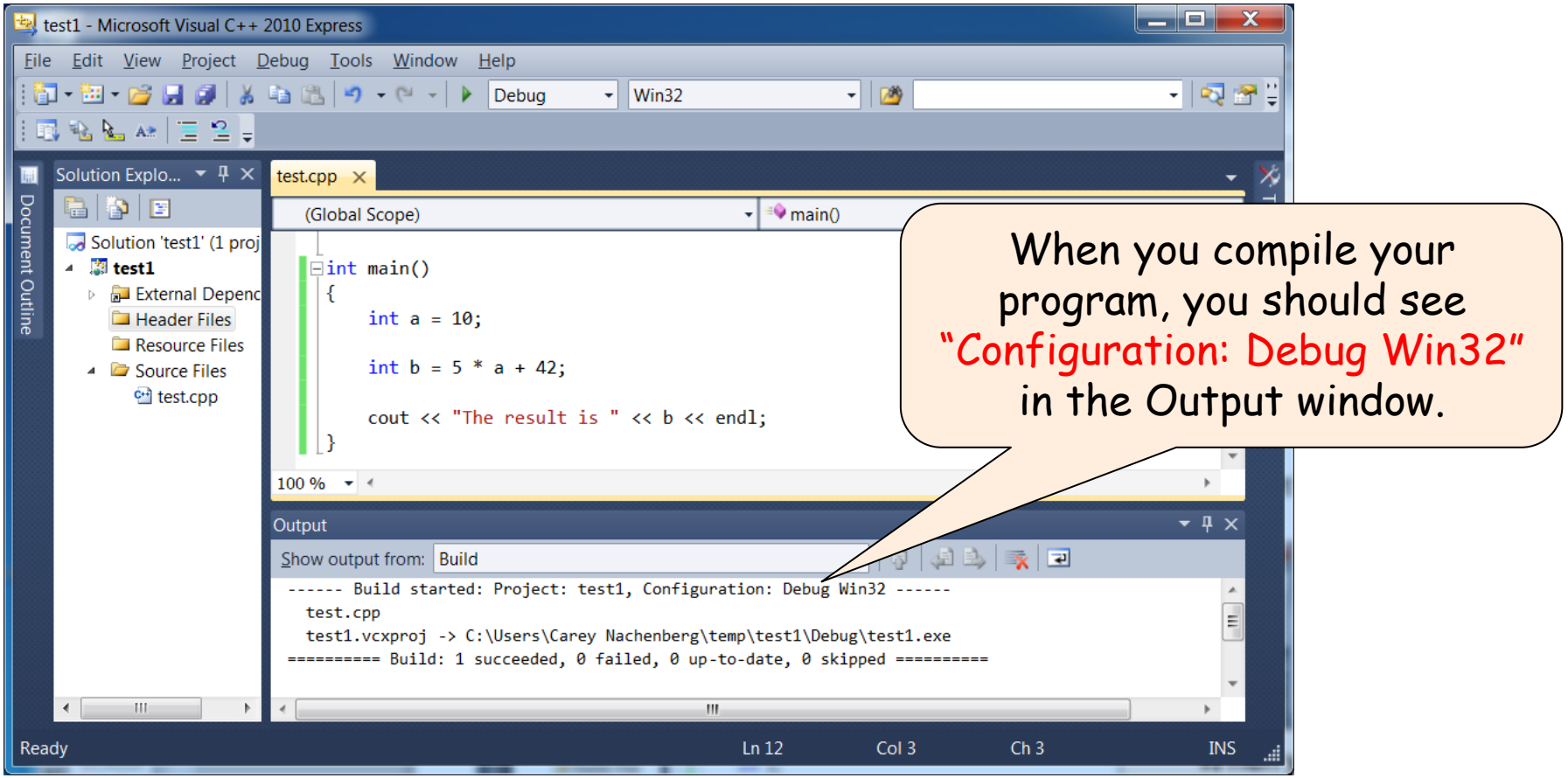

```
int main(void)
{
   HungryNerd   carey(75);

   ...
}
```

Final Topic: Debugging



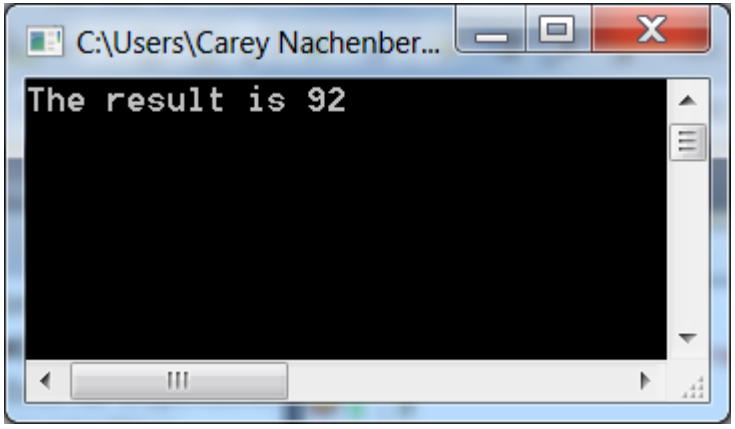
Debugging

By default, Visual Studio compiles all programs in "debug mode" so you can use the debugger with them right away.

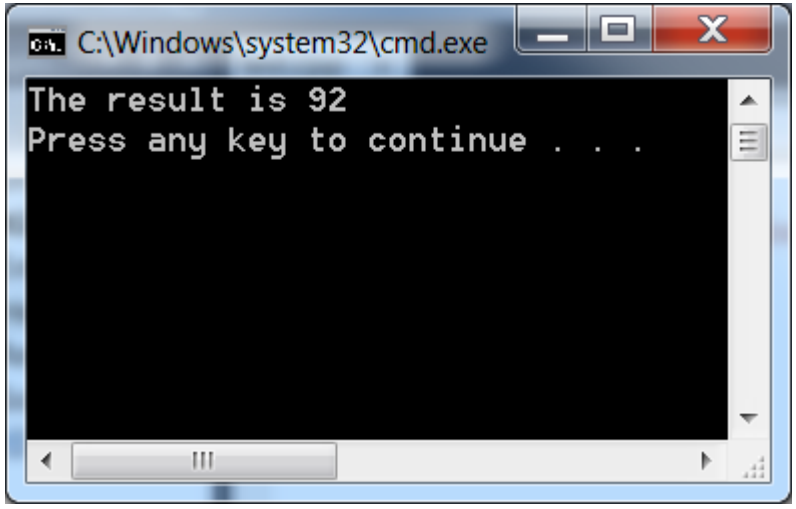


Debugging

You can run your program from start to finish by hitting either F5 or Ctrl-F5.



If you run your program by hitting F5, Visual Studio will immediately close the debug window after your program finishes.



If you run by hitting Ctrl-F5, Visual Studio will print "Press any key to continue..." and leave the debug window on the screen when your program completes.

Debugging

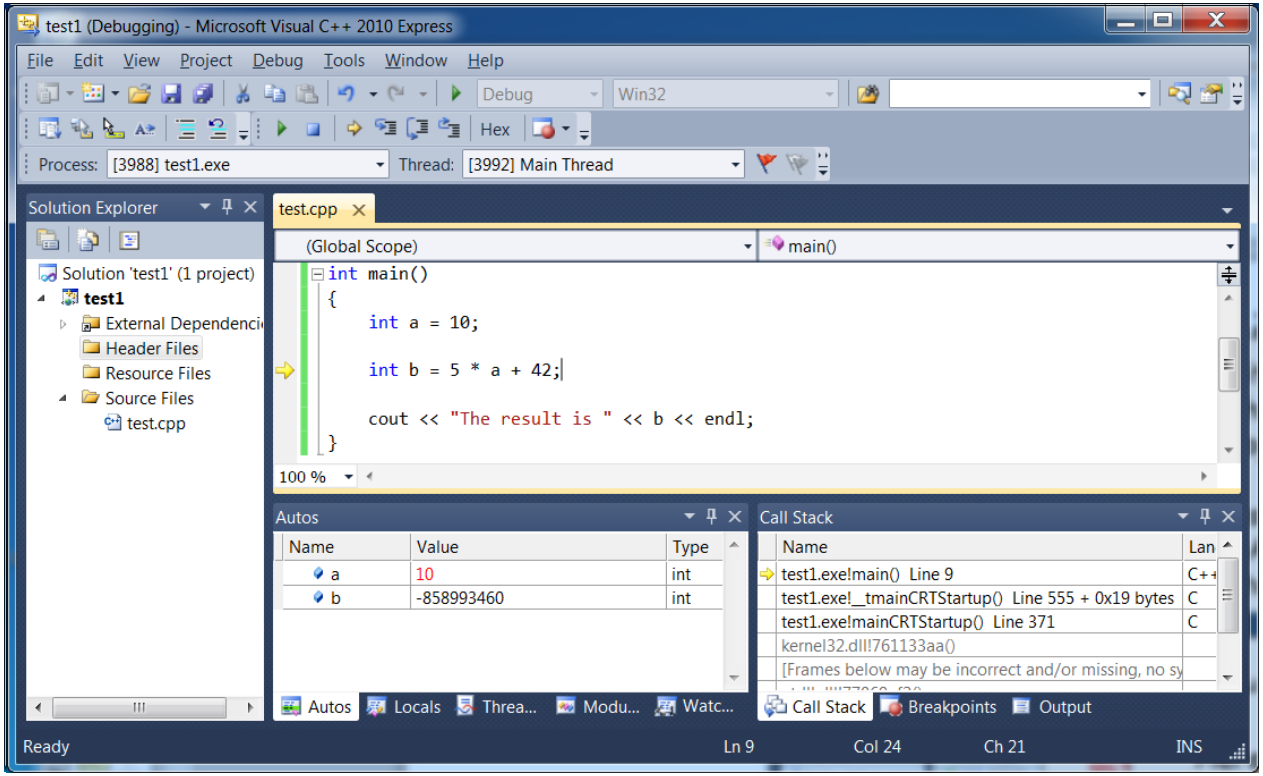
You can step through your program one line at a time using the F10 and F11 keys.

To start your program and debug one line at a time, hit F10 after you finish compiling it.

To run the current line of code, hit F10 or F11.

Let's do that now.

Let's hit F10 again and trace over another line.

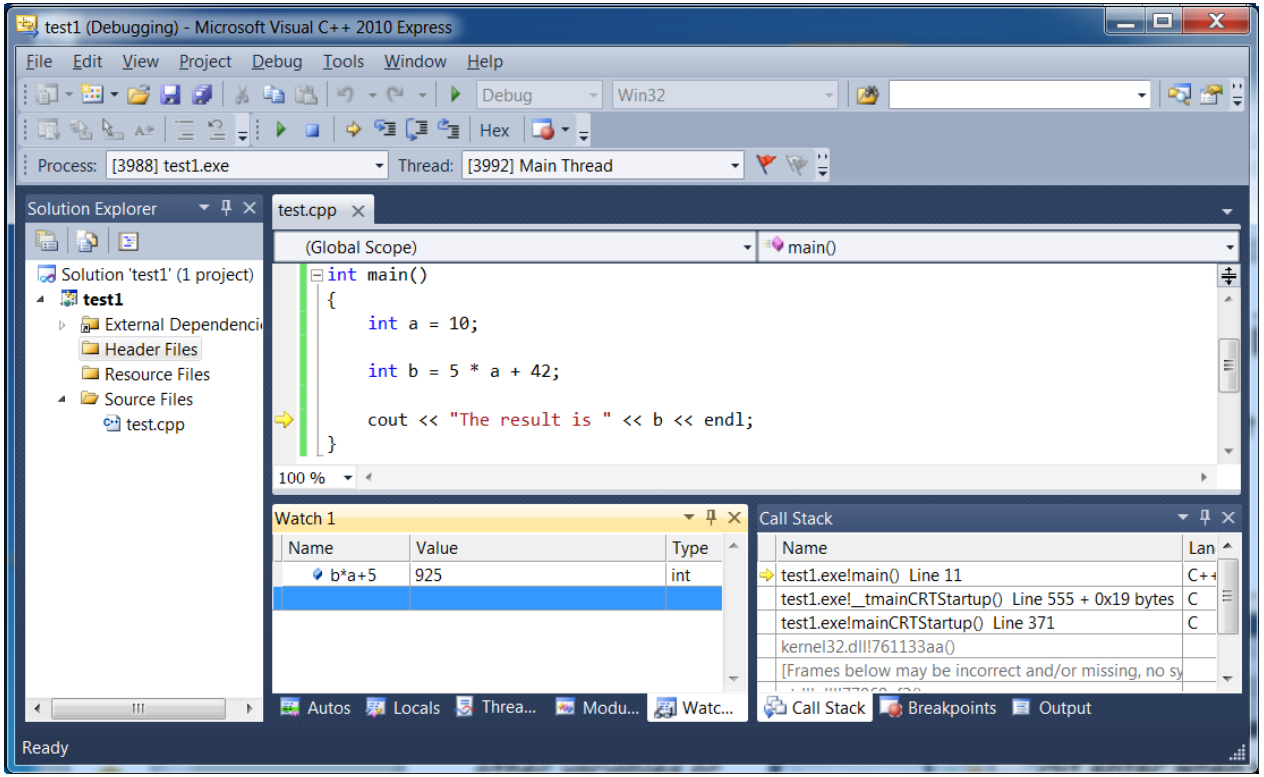


Debugging

You can step through your program one line at a time using the F10 and F11 keys.

Let's hit F10 again and trace over another line.

If you want to watch other variables or expressions, you can do that in the "watch" sub-window.

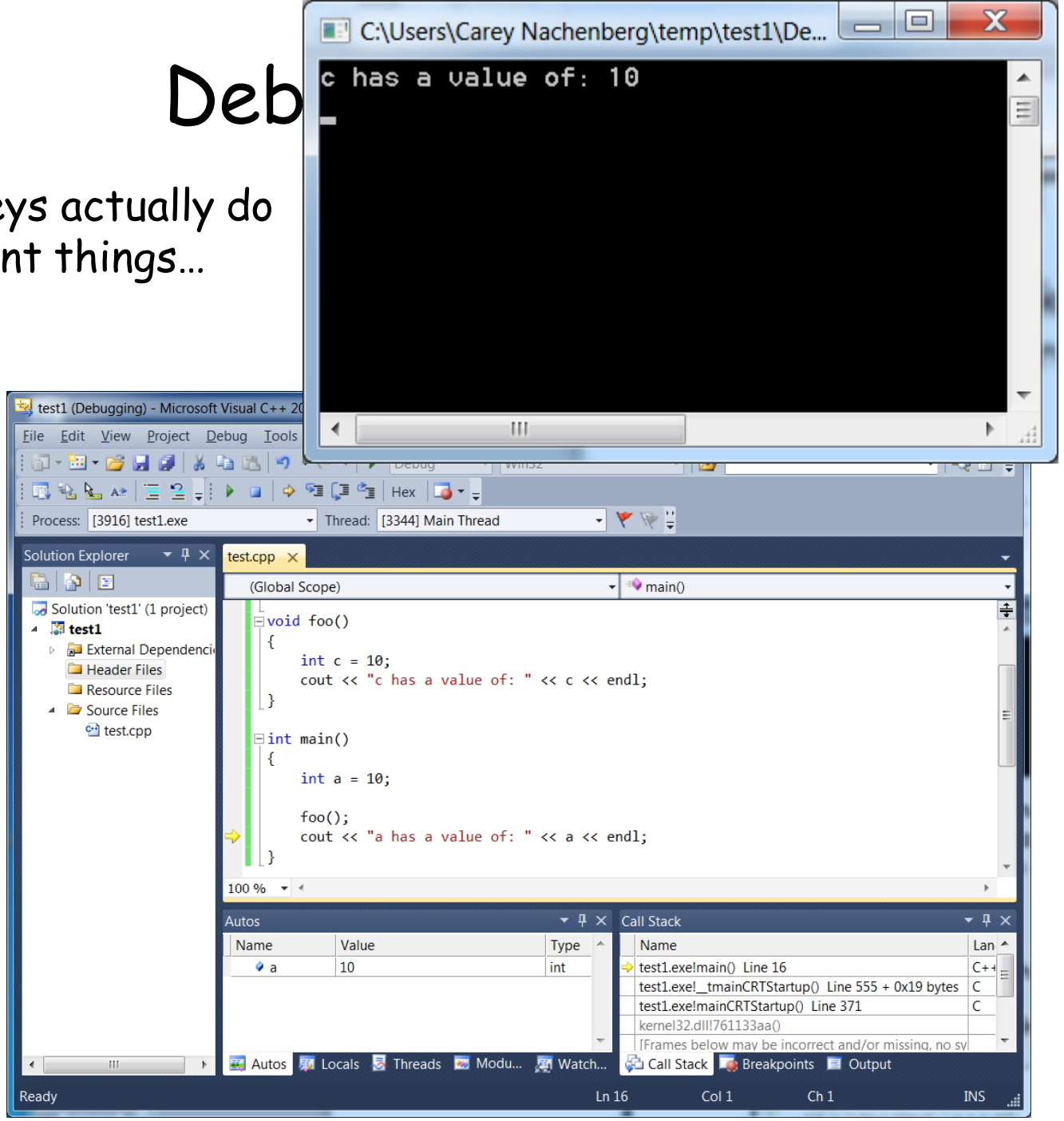


Deb

The F10 and F11 keys actually do slightly different things…

If you hit F10 while on a function call line, Visual Studio will run the entire function in one step. You won't be able to trace line-by-line through it.

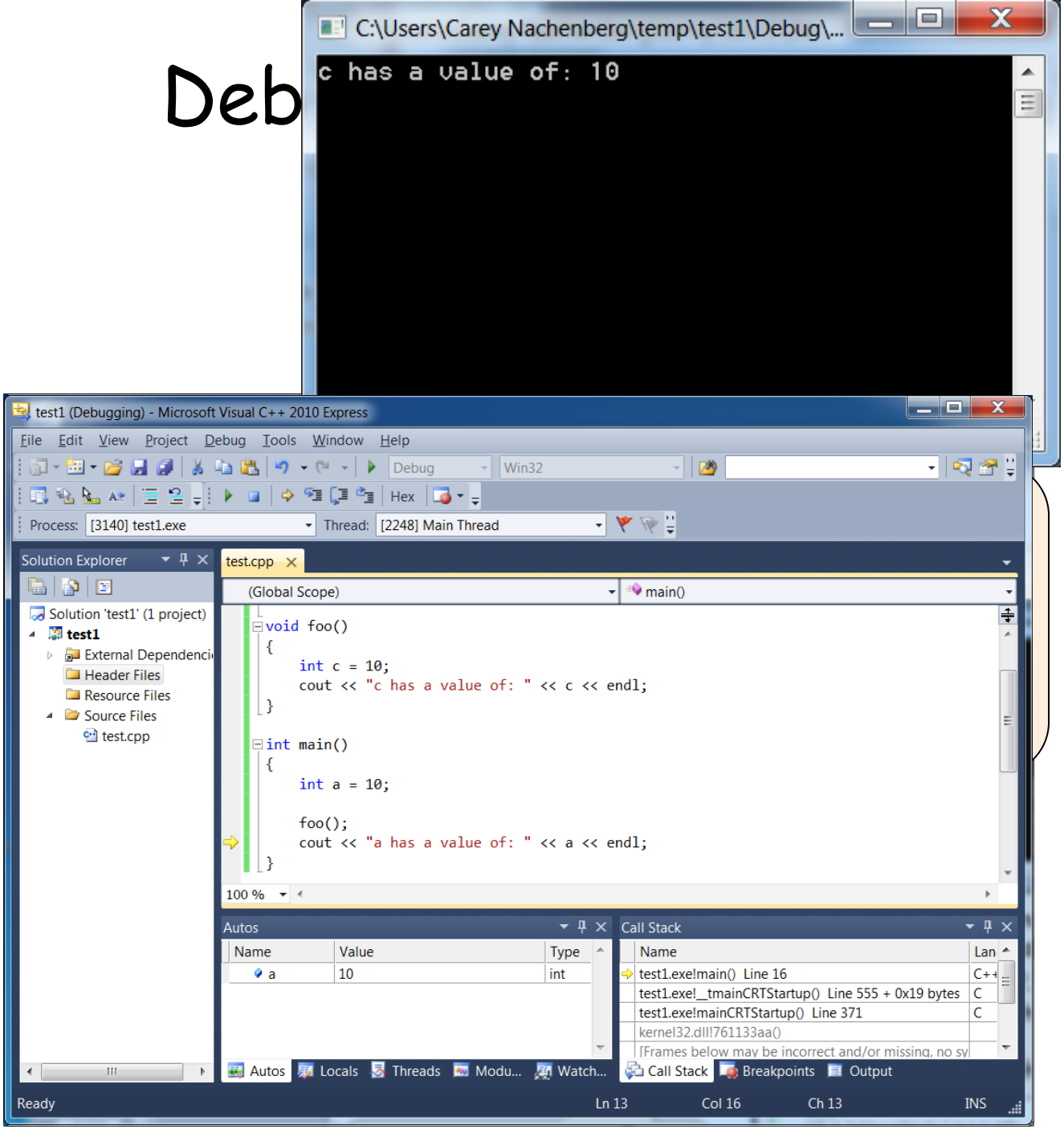
So F10 lets you quickly run a line of code without delving into the details.



Deb

If you hit F11 while on a function call line, Visual Studio will let you step into that function and trace through it a line at a time.

So F11 lets you dive into a function call and trace through it line by line as well.

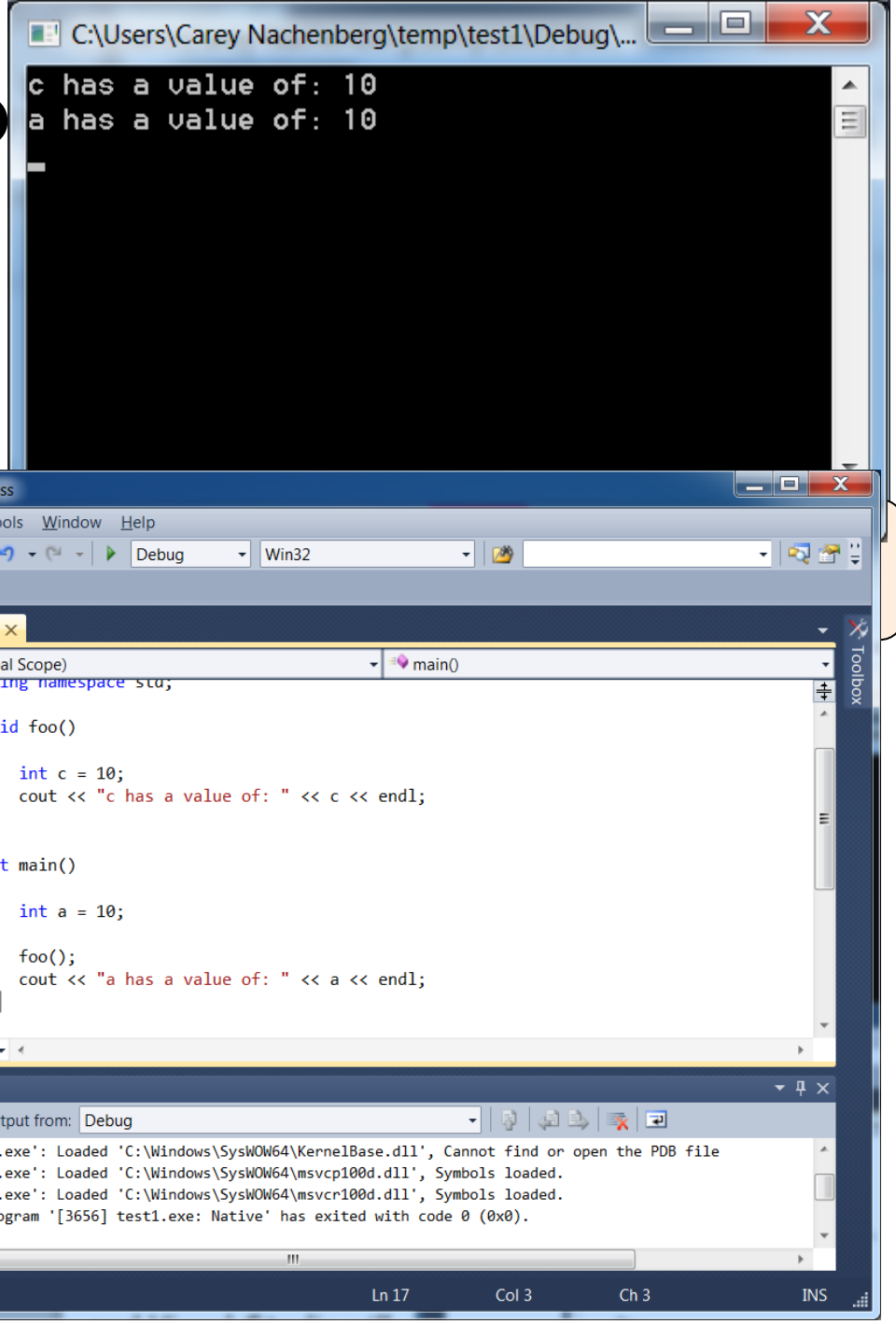


Deb

If at any time while you're tracing line-by-line you want to stop tracing line-by-line…

And simply let the rest of your program run normally…

Just hit F5 and Visual Studio will run your program until completion!



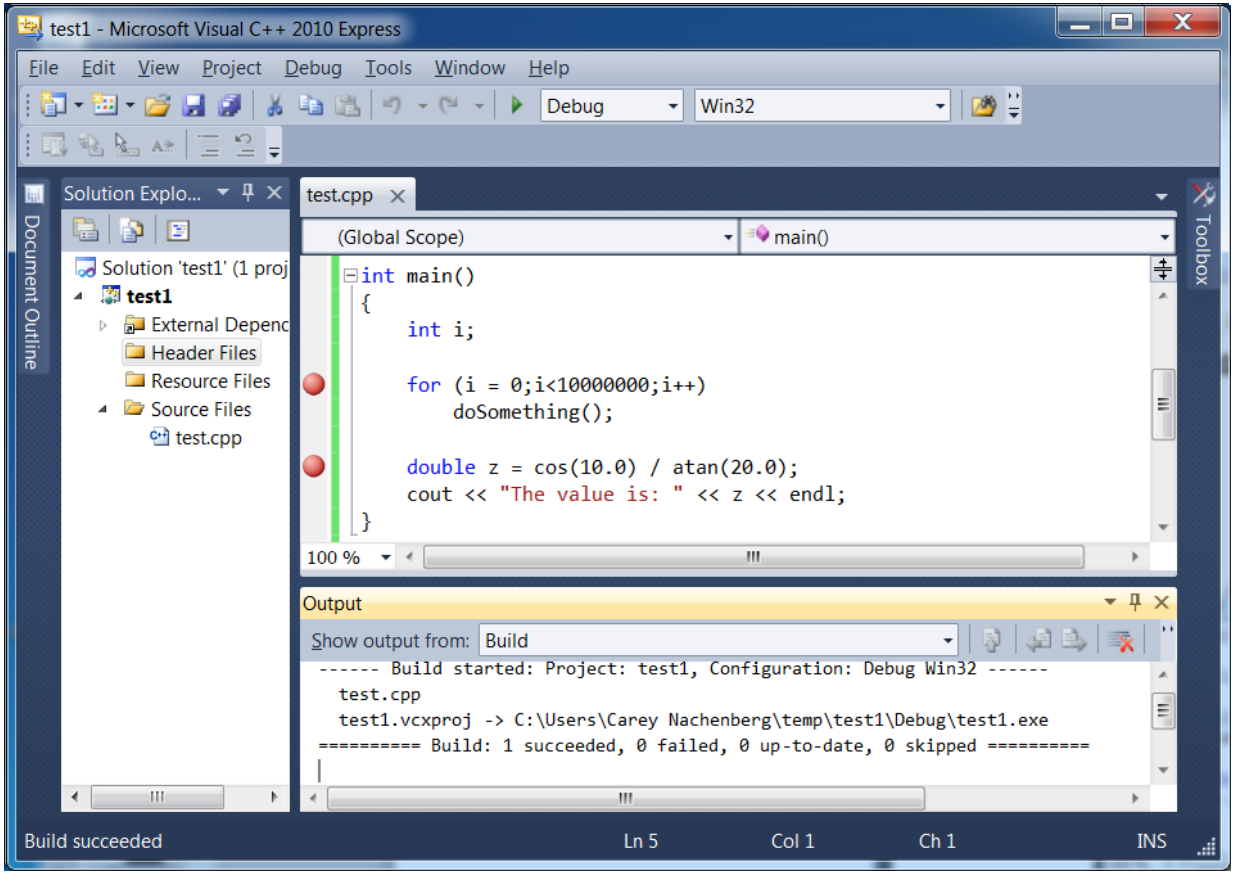
Debugging

Sometimes you'll want to start debugging deep within your program.

You don't want to trace through millions of lines to reach the likely location of a bug.

What should you do?

Answer:
Create a breakpoint!



Go to the line where you'd like to start debugging and hit the F9 key.

Then just hit the F5 key (not Ctrl-F5) to run your program until it reaches that line!

Debugging

Learn how to use the debugger!

It can drastically speed up the programming process!

Which means less frustration

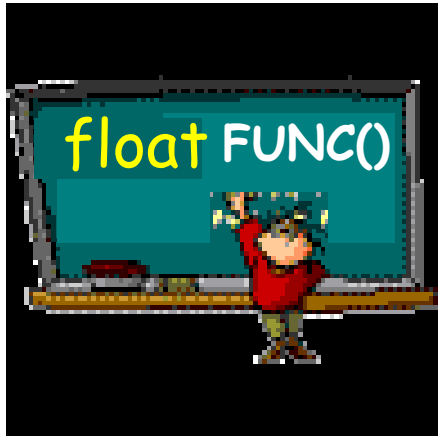
and more time doing the things you love!

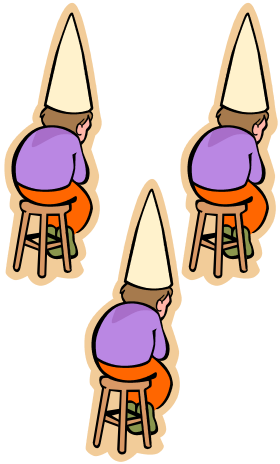
Class Challenge

RULES

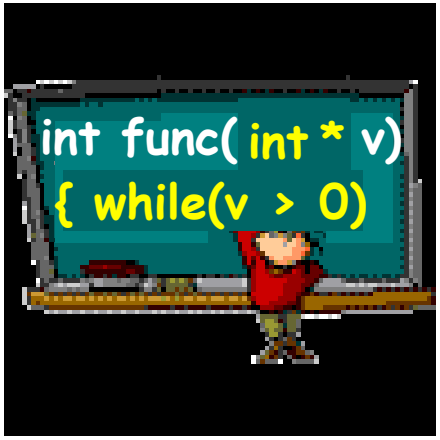
- The class will split into left and right teams
- One student from each team will come up to the board
- Each student can either
  - write one new line of code to solve the problem OR
  - fix a single error in the code their teammates have already written
- Then the next two people come up, etc.
- The team that completes their program first wins!

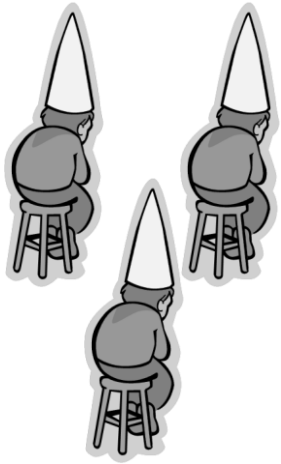
Team #1





Team #2





Challenge #1

Write a class called quadratic which represents a second-order quadratic equation, e.g.: $4x^2+3x+5$

When you construct a quadratic class, you pass in the three coefficients (e.g., 4, 3, and 5) for the equation.

The class also has an evaluate method which allows you pass in a value for x. The function will return the value of f(x).

The class has a destructor which prints out "goodbye"

Challenge #2

Write a class called MathNerd which represents a math nerd. Every MathNerd has his own special quadratic equation!

When you construct a MathNerd, he always wants you to specify the first two coefficients (for the x^2 and x) for his equation. The MathNerd always selects a value of PI for his final coefficient.

The MathNerd has a getMyValue function which accepts a value for x and should return f(x) for the nerd's QE.

A Few Final Topics

Let's talk about three final topics that you'll need in order to solve your Project #1…

Topic #1: Include Etiquette

A. Never include a CPP file in another .CPP or .H file.

file1.cpp

```
void someFunc(void)
{
    cout << "I'm cool!"
}
```

file2.cpp

```
#include "file1.cpp" // bad!

void otherFunc(void)
{
    cout << "So am I!"
    someFunc();
}
```

You'll get linker errors.

Only include .H files within a .CPP file.

Topic #1: Include Etiquette

B. Never put a "using namespace" command in a header file.

someHeader.h

```
#include <iostream>

using namespace std;
```

hello.cpp

```
#include "someHeader.h"

// BUT I DON'T WANT THAT
// NAMESPACE! YOU BASTARD!

int main()
{
   cout << "Hello world!";
}
```

So this is bad…

This is called "Namespace Pollution"

Why? The .H file is forcing CPP files that include it to use its namespace.

And that's just selfish.

Instead, just move the "using" commands into your C++ files.

Topic #1: Include Etiquette

C. Never assume that a header file will include some other header file for you.

alcohol.h

```
class Alcohol
{
   ...
};
```

student.h

```
#include "alcohol.h"

class Student
{
   ...
private:
   Alcohol bottles[5];
};
```

main.cpp

```
#include "student.h"

int main()
{
   Student larry;
   Alcohol vodka;

   cout << larry << " is drinking " << vodka;
}
```

What can you do?
Always DIRECTLY include the header files you need RIGHT where you need them. In this case, main.cpp has a Student variable and an Alcohol variable. So it should include both of their header files.

main.cpp defines an Alcohol variable but it doesn't #include"alcohol.h".

Why? It assumes that student.h will just include alcohol.h for it.

Topic #2: Preprocessor Directives

C++ has several special commands which you sometimes need in your programs.

Command 1: #define

You can use the #define command to define new constants:

file.cpp

```
#define PI 3.14159

#define FOOBAR

void someFunc(void)
{
    cout << PI;
}
```

You can also use #define to define a new constant without specifying a value! Why you ask? We'll see!

Preprocessor Directives

Command 2: #ifdef and #endif

You can use the #ifdef command to check if a constant has been defined already…

The compiler
only compiles the code
between the
#ifdef and the #endif
if the constant was defined.

file.cpp

```
#ifdef FOOBAR
void someFunc(void)
{
    cout << PI;
}
#endif
```

Preprocessor Directives

Command 2: #ifndef and #endif

You can use the #ifndef command to check if a constant has NOT been defined already…

The compiler
only compiles the code
between the
#ifndef and the #endif
if the constant was NOT defined.

file.cpp

```
#ifndef FOOBAR
void someFunc(void)
{
    cout << PI;
}
#endif
```

Separate Compilation

When using class composition, it helps to define each class in a separate pair of .cpp/.h files.

Then you can use them like this in your main program…

Now – something interesting (and bad) happens if I use both classes in my main program. Let's see!

Can anyone see what the problem is?

calc.h

```
class Calculator
{
public:
   int compute();
   ...
};
```

calc.cpp

```
#include "calc.h"

int Calculator::compute()
{
   ...
}
```

student.h

```
#include "calc.h"

class Student
{
public:
   void study()
   ...
private:
   Calculator myCalc;
};
```

student.cpp

```
#include "student.h"

int Student::study()
{
 cout << myCalc.compute();
}
```

main.cpp

```
#include "student.h"
#include "calc.h"

int main()
{
   Student grace;
   Calculator hp;
   ...
   grace.study();
   hp.compute();
}
```

Separate Compilation

Your main program first includes student.h…

Then student.h then includes calc.h!

…and finally, main.cpp includes calc.h… again!

So what's the problem?
Well, since main.cpp and student.h both included calc.h, we ended up with two definitions of Calc! That's bad!

This can result in a compiler error!

So how do we fix it, you ask?

Here's how…

main.cpp

```
class Calculator
{
public:
  void compute();
  ...
};

class Student
{
public:
  void study()
  ...
private:
  Calculator myCalc;
};
class Calculator
{
public:
  void compute();
  ...
};
int main()
{
  Student grace;
  Calculator hp;
  ...
  grace.study();
  hp.compute();
}
```

Separate Compilation

calc.h

```
#ifndef CALC_H

#define CALC_H


class Calculator
{
public:
   void compute();
   ...
};

#endif // for CALC_H
```

Add "include guards" to each header file.

An include guard is a special check that prevents duplicate header inclusions.

Now, when the compiler compiles this code, it will ignore the redefined definitions!

student.h

```
#ifndef STUDENT_H

#define STUDENT_H

#include "calc.h"


class Student
{
public:
   void study()
   ...
private:
   Calculator myCalc;
};
#endif // for STUDENT_H
```

Last Topic: Knowing *WHEN* to Include .H Files

alcohol.h

```
class Alcohol
{
public:
    void drink() { cout << "glug!"; }
};
```

student.h

```
#include "alcohol.h"

class Student
{
public:
  void beIrresponsible();
  ...
private:
  Alcohol *myBottle;
};
```

So I need to include alcohol.h, right?

I use the Alcohol class (which is defined in alcohol.h) to define a member variable

You might think that any time you refer to a class, you should include it's .h file first… Right?

Well, not so fast!

A.h

```
class FirstClass
{
public:
    void someFunc() { ... }
};
```

B.h

```
#include "A.h"

class SecondClass
{
public:
   void otherFunc()
   {
     FirstClass y;
     FirstClass b[10];
     y.someFunc();
     return(y);
   }

private:
   FirstClass x;
   FirstClass a[10];
};
```

Why? Because C++ needs to know the class's details in order to define actual variables with it or to let you call methods from it!

Last Topic: Knowing *WHEN* to Include .H Files

Here are the rules…

You must include the header file (containing the full definition of a class)

Any time…

1. You define a regular variable of that class's type, OR
2. You use the variable in any way (call a method on it, return it, etc).

On the other hand…

Last Topic: Knowing WHEN to Include .H Files

A.h

```
class FirstClass
{
public:
    void someFunc() ;
};
```

This line tells C++ that your class exists, but doesn't actually define all the gory details.

B.h

```
class FirstClass;

class SecondClass
{
public:
   void goober(FirstClass p1);
   FirstClass hoober(int a);
   void joober(FirstClass &p1);
   void koober(FirstClass *p1);

   void loober()
   {
      FirstClass *ptr;
   }

private:
  FirstClass *ptr1, *z[10];
};
```

Since none of this code actually uses the "guts" of the class (as the code did on the previous slide), this is all C++ needs to know!

If you do NONE of the previous items, but you…

Use the class to define a parameter to a function, OR

2. Use the class as the return type for a func, OR
3. Use the class to define a pointer or reference variable

Then you DON'T need to include the class's .H file.
(You may do so, but you don't need to)

Instead, all you need to do is give C++ a hint that your class exists (and is defined elsewhere).

Here's how you do that:

A.h

```
class FirstClass
{
public:
  // thousands of lines
  …void someFunc();…
};
```

B.h

```
#include "A.h" // really slow!

class SecondClass
{
public:




private:

};
```

Last Topic: Knowing *WHEN* to Include .H Files

Wow – so confusing!

Why not just always use #include to avoid the confusion?

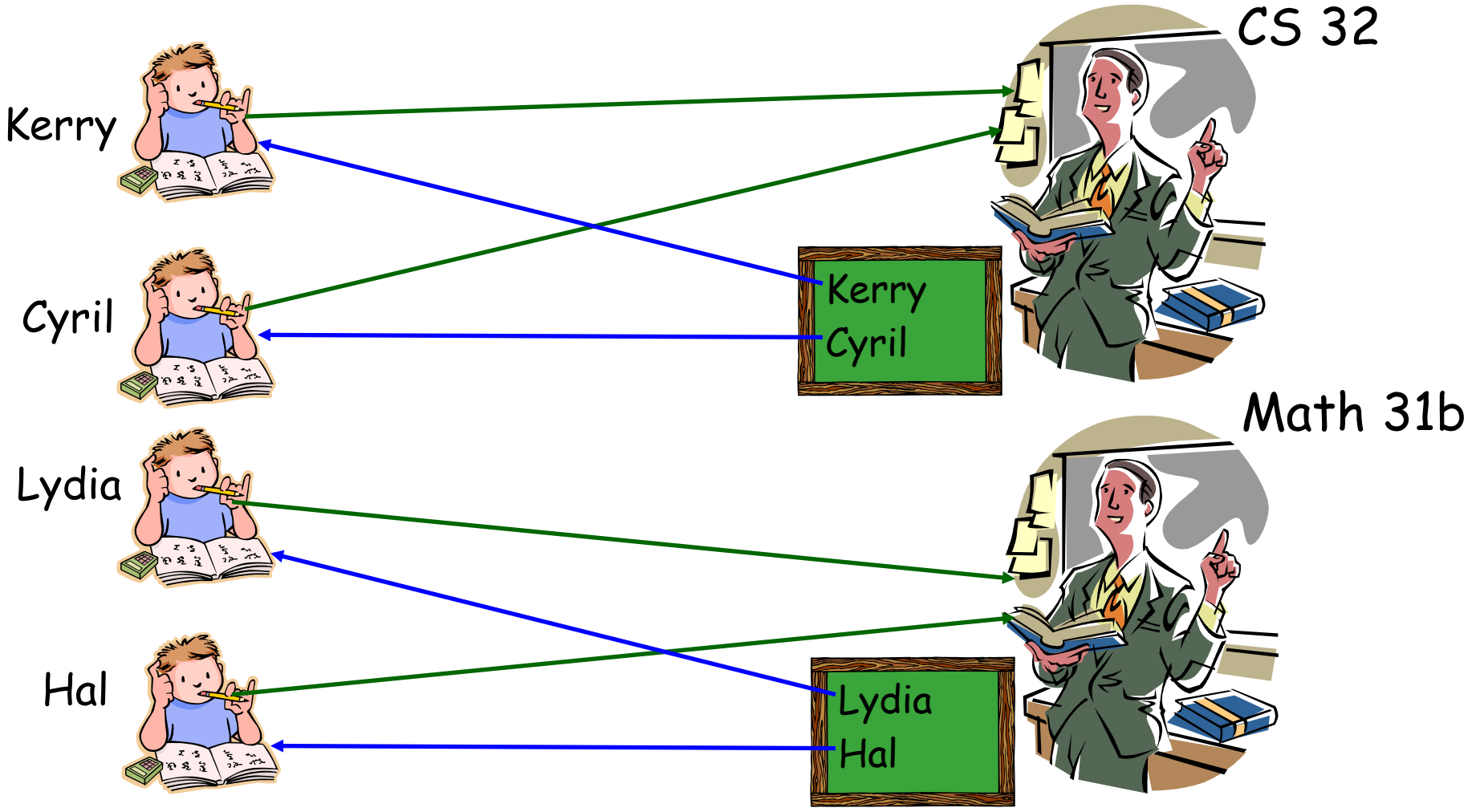
There are two reasons:

1. If a .h file is large (thousands of lines), #including it when you don't strictly need to slows down your compilation!
2. If two classes refer to each other, and both classes try to #include the other's .H file, you'll get a compile error.

Students and Classrooms

Every student knows what class he/she is in…

Every class has a roster of its students…



These type of cyclical relationships cause #include problems!

Last Topic: Self-referential Classes

Here we have a ClassRoom class that holds a bunch of Students…

And here we have the Student class. Each Student knows which classroom he or she is in…

Since our ClassRoom class refers to the Student class it includes Student.h

Since our Student class refers to the classroom class, it includes ClassRoom.h…

Do you see the problem?

Student.h

```
#include "ClassRoom.h"

class Student
{
public:
  ...

private:
   ClassRoom *m_myRoom;
};
```

ClassRoom.h

```
#include "Student.h"

class ClassRoom
{
public:
  ...

private:
    Student m_studs[100];
};
```

Student.cpp

```
#include "Student.h"

void Student::printMyClassRoom()
{
 cout <<"I'm in Boelter #" <<
     m_myRoom->getRmNum();
}
```

ClassRoom.cpp

```
#include "ClassRoom.h"

void ClassRoom::printRoster()
{
 for (int i=0;i<100;i++)
   cout << m_studs[i].getName();
}
```

Last Topic: Self-referential Classes

main.cpp

```
#include "Student.h"
```

Student.h

```
#include "ClassRoom.h"
```

```
public:
  ...

private:
    Student m_studs[100];
};
```

The compiler will keep going forever!!!!!

(oh, and adding Include Guards doesn't solve the underlying problem either!)

So how do we solve this cyclical nightmare?

Step #1:

Look at the two class definitions in your .h files. At least one of them should NOT need the full #include.

Question:

Which of our two classes doesn't need the full #include? Why?

This class JUST defines a pointer to a ClassRoom. It does NOT hold a full ClassRoom variable and therefore doesn't require the full class definition here!!!

This class defines actual Student variables… It therefore requires the full class definition to work!

Student.h

```
#include "ClassRoo

class Student
{
public:
    ...

private:
    ClassRoom *m_myRoom;
};
```

ClassRoom.h

```
#include "Stude      "

class ClassRoom
{
public:
    ...

private:
    Student m_studs[100];
};
```

So how do we solve this cyclical nightmare?

Step #2:

Take the class that does NOT require the full #include (forget the other one) and update its header file:

Replace the #include "XXXX.h" statement with the following: class YYY;
Where YYY is the other class name (e.g., ClassRoom).

Student.h

```
class ClassRoom;

class Student
{
public:
    ...

private:
    ClassRoom *m_myRoom;
};
```

ClassRoom.h

```
#include "Student.h"

class ClassRoom
{
public:
    ...

private:
    Student m_studs[100];
};
```

So how do we solve this cyclical nightmare?

Student.h

```
class ClassRoom;

class Student
{
public:
   ...

private:
  ClassRoom *m_myRoom;
};
```

Student.cpp

```
#include "Student.h"
#include "ClassRoom.h"
void Student::printMyClassRoom()
{
 cout <<"I'm in Boelter #" <<
    m_myRoom->getRmNum();
}
```

Step #3:
Almost done. Now update the CPP file for this class by #including the other header file normally.

This line tells the compiler:

"Hey Compiler, since my CPP file is going to actually use class's functionality, I'll now tell you all the details about the class."

The compiler is happy as long as you #include the class definition before you actually use the class in your functions…

So how do we solve this cyclical nightmare?

Student.h

```
class ClassRoom;

class Student
{
public:
  void beObnoxious();

private:
   ClassRoom *m_myRoom;
};
```

Student.cpp

```
#include "Student.h"
#include "ClassRoom.h"

 void Student::beObnoxious() {
    cout << m_myRoom->getRmNum() << " sucks!"; }


}
```

Step #4:

Finally, make sure that your class doesn't have any other member functions that violate our #include vs class rules…

If you have defined one or more functions DIRECTLY in your class definition AND they use your other class in a significant way, then you must MOVE them to the CPP file.

So how do we solve this cyclical nightmare?

Now let's look at both of our classes… Notice, we no longer have a cyclical reference! Woohoo!

Student.h

```
class ClassRoom;

class Student
{
public:
   ...

private:
  ClassRoom *m_myRoom;
};
```

ClassRoom.h

```
#include "Student.h"

class ClassRoom
{
public:
  ...

private:
    Student m_studs[100];
};
```

Student.cpp

```
#include "Student.h"
#include "ClassRoom.h"
void Student::printMyClassRoom()
{
 cout <<"I'm in Boelter #" <<
     m_myRoom->getRmNum();
}
```

ClassRoom.cpp

```
#include "ClassRoom.h"

void ClassRoom::printRoster()
{
 for (int i=0;i<100;i++)
   cout << m_studs[i].getName();
}
```