

Classes and Objects in C++

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Today's Lecture

- **Classes**

- data members and member functions

- **Constructors**

- Special member functions

- **private and public members**

- **Helper and utility methods**

- setters
- getters
- accessors

Classes in C++

- A class is a set of data and functions that define the characteristics and behavior of an object
 - Characteristics also known as attributes
 - Behavior is what an object can do and is referred to also as its interface

Interface
or
Member Functions

Data members or
attributes

```
class Result {  
    public:  
  
    // constructors  
    Result() { }  
    Result(const double& mean, const double& stdDev) {  
        mean_ = mean;  
        stdDev_ = stdDev;  
    }  
  
    // accessors  
    double getMean() { return mean_; };  
    double getStdDev() { return stdDev_; };  
  
    private:  
    double mean_;  
    double stdDev_;  
};
```

Don't's forget ; at the end of definition!

Data Members (Attributes)

```
class Datum {  
    double value_;  
    double error_;  
};
```

- Data defined in the scope of a class are called data members of that class
- Data members are defined in the class and can be used by all member functions
- Contain the actual data that characterise the content of the class
- Can be public or private
 - public data members are generally bad and symptom of bad design
 - More on this topic later in the course

Interface: Member Functions

- Member functions are methods defined inside the scope of a class
 - Have access to all data members

`name_` is a datamember

No declaration of `name_` in member functions!

`name` is a local variable only within `setName()`

```
// Student
#include <iostream>
#include <string>

class Student {
    using namespace std;
public:
    // default constructor
    Student() { name_ = ""; }

    // another constructor
    Student(const string& name) { name_ = name; }

    // getter method: access to info from the class
    string name() { return name_; }

    // setter: set attribute of object
    void setName(const string& name) { name_ = name; }

    // utility method
    void print() {
        cout << "My name is: " << name_ << endl;
    }

private:
    string name_; // data member
};
```

Arguments of Member Functions

- All C++ rules discussed so far hold
- You can pass variables by value, pointer, or reference
- You can use the constant qualifier to protect input data and restrict the capabilities of the methods
 - This has implications on declaration of methods using constants
 - We will discuss constant methods and data members next week
- Member functions can return any type
 - Exceptions! Constructors and Destructor
 - Have no return type
 - More on this later

Access specifiers **public** and **private**

- Public functions and data members are available to anyone
- Private members and methods are available ONLY to other member functions

```
1 #include <iostream>
2 using std::cout;
3 using std::endl;
4
5 class Datum {
6     public:
7         Datum() { }
8         Datum(double val, double error) {
9             value_ = val;
10            error_ = error;
11        }
12
13        double value() { return value_; }
14        double error() { return error_; }
15
16        void setValue(double value) { value_ = value; }
17        void setError(double error) { error_ = error; }
18
19        double value_; // public data member!!!
20
21    private:
22        double error_; // private data member
23 };;
```

Access elements of an object through member selection operator “.”

```
25 int main() {
26
27     Datum d1(1.1223,0.23);
28
29     cout << "d1.value(): " << d1.value() ^
30         << " d1.error(): " << d1.error()
31         << endl;
32
33
34     cout << "d1.value_: " << d1.value_
35         << " d1.error_: " << d1.error_
36         << endl;
37
38     return 0;
39 }
```

Accessing private members
is a compilation error!

```
$ g++ -o class1 class1.cc
class1.cc: In function `int main()':
class1.cc:22: error: `double Datum::error_' is private
class1.cc:35: error: within this context
```

private members

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

class Datum {
public:
    Datum(double val, double error) {
        value_ = val;
        error_ = error;
    }

    double value() { return value_; }
    double error() { return error_; }

    void setValue(double value)
    { value_ = value; }
    void setError(double error)
    { error_ = error; }

    void print() {
        cout << "datum: " << value_
              << " +/- " << error_
              << endl;
    }

private:
    double value_; // private data member!!!
    double error_; // private data member
};
```

```
int main() {

    Datum d1(1.1223,0.23);
    // setter with no return value
    d1.setValue( 8.563 );

    // getter to access private data
    double x = d1.value();

    cout << "d1.value(): " << d1.value()
          << " d1.error(): " << d1.error()
          << endl;

    d1.print();

    return 0;
}
```

```
$ g++ -o class2 class2.cc
$ ./class2
d1.value(): 8.563 d1.error(): 0.23
datum: 8.563 +/- 0.23
```


private methods

- Can be used only inside other methods but not from outside

```
1 // class3.cc
2 #include <iostream>
3 using namespace std;
4
5 class Datum {
6     public:
7         Datum() { reset(); } // reset data members
8
9         double value() { return value_; }
10        double error() { return error_; }
11
12        void setValue(double value) { value_ = value; }
13        void setError(double error) { error_ = error; }
14
15        void print() {
16            cout << "datum: " << value_ << " +/- "
17                << error_ << endl;
18        }
19    private:
20        void reset() {
21            value_ = 0.0;
22            error_ = 0.0;
23        }
24
25        double value_;
26        double error_;
27 };
```

```
int main() {

    Datum d1;
    d1.setValue( 8.563 );
    d1.print();

    return 0;
}
```

```
$ g++ -o class3 class3.cc
$ ./class3
datum: 8.563 +/- 0
```

```
30 int main() {
31
32     Datum d1;
33     d1.setValue( 8.563 );
34     d1.print();
35     d1.reset();
36
37     return 0;
38 }
```

```
$ g++ -o class4 class4.cc
class4.cc: In function `int main()':
class4.cc:20: error: `void Datum::reset()' is private
class4.cc:35: error: within this context
```

Hiding Implementation from Users/Clients

- How to decide what to make public or private?
- Principle of Least Privilege
 - elements of a class, data or functions, must be private unless proven to be needed as public!
- Users should rely solely on the interface of a class
- They should never use the internal details of the class
- ***That's why having public data members is a VERY bad idea!***
 - name and characteristics of data members can change
 - Functionalities and methods remain the same
 - You must be able to change internal structure of the class without affecting the clients!

Bad Example of Public Data Members

```
class Datum {
public:
    Datum(double val, double error) {
        value_ = val;
        error_ = error;
    }

    double value() { return value_; }
    double error() { return error_; }

    void setValue(double value) { value_ = value; }
    void setError(double error) { error_ = error; }

    void print() {
        cout << "datum: " << value_ << " +/- " << error_ << endl;
    }

//private:          // all data are public!
    double value_;
    double error_;
};
```

```
int main() {

    Datum d1(1.1223,0.23);
    double x = d1.value();
    double y = d1.error_;
    cout << "x: " << x << "\t y: " << y << endl;

    return 0;
}
```

application uses directly
the data member!

```
$ g++ -o class6 class6.cc
$ ./class6
x: 1.1223          y: 0.23
```

Bad Example of Public Data Members

Same Application as before

Change the names of data members

No change of functionality so no one should be affected!

```
class Datum {
public:
    Datum(double val, double error) {
        val_ = val;
        err_ = error;
    }

    double value() { return val_; }
    double error() { return err_; }

    void setValue(double value) { val_ = value; }
    void setError(double error) { err_ = error; }

    void print() {
        cout << "datum: " << val_ << " +/- " << err_ << endl;
    }

//private:          // alla data are public!
    double val_;    // value_ → val_
    double err_;    // error_ → err_
};
```

```
28 int main() {
29
30     Datum d1(1.1223,0.23);
31     double x = d1.value();
32     double y = d1.error_;
33
34     cout << "x: " << x << "\t y: " << y << endl;
35
36     return 0;
37 }
```

Our application is now broken!

But Datum has not changed its behavior!

Bad programming!

Only use the interface of an object not its internal data!

Private data members prevent this

```
$ g++ -o class7 class7.cc
class7.cc: In function `int main()':
class7.cc:32: error: 'class Datum' has no member named 'error_'
```

Constructors

```
class Datum {  
    public:  
        Datum() { }  
        Datum(double val, double error) {  
            value_ = val;  
            error_ = error;  
        }  
  
    private:  
        double value_; // public data member!!!  
        double error_; // private data member  
};
```

- Special member functions
 - Required by C++ to create a new object
 - MUST have the same name of the class
 - Used to initialize data members of an instance of the class
 - Can accept any number of arguments
 - Same rules as any other C++ function applies
- Constructors have no return type!
- There can be several constructors for a class
 - Different ways to declare and an object of a given type

Different Types of Constructors

- Default constructor
 - Has no argument
 - On most machines the default values for data members are assigned
- Copy Constructor
 - Make a new object from an existing one
- Regular constructor
 - Provide sufficient arguments to initialize data members

```
class Datum {  
    public:  
        Datum() { }  
  
        Datum(double x, double y) {  
            value_ = x;  
            error_ = y;  
        }  
  
        Datum(const Datum& datum) {  
            value_ = datum.value_;  
            error_ = datum.error_;  
        }  
  
    private:  
        double value_;  
        double error_;  
};
```

Using Constructors

```
// class5.cc
#include <iostream>
using namespace std;

class Datum {
public:
    Datum() { }

    Datum(double x, double y) {
        value_ = x;
        error_ = y;
    }

    Datum(const Datum& datum) {
        value_ = datum.value_;
        error_ = datum.error_;
    }

    void print() {
        cout << "datum: " << value_
              << " +/- " << error_
              << endl;
    }

private:
    double value_;
    double error_;
};
```

```
int main() {

    Datum d1;
    d1.print();

    Datum d2(0.23,0.212);
    d2.print();

    Datum d3( d2 );
    d3.print();

    return 0;
}
```

```
$ g++ -o class5 class5.cc
$ ./class5
datum: NaN +/- 8.48798e-314
datum: 0.23 +/- 0.212
datum: 0.23 +/- 0.212
```

Default Constructors on Different Architectures

```
$ uname -a
CYGWIN_NT-5.1 lajolla 1.5.18(0.132/4/2) 2005-07-02 20:30 i686 unknown
unknown Cygwin
$ gcc -v
Reading specs from /usr/lib/gcc/i686-pc-cygwin/3.4.4/specs
...
gcc version 3.4.4 (cygming special) (gdc 0.12, using dmd 0.125)

$ g++ -o class5 class5.cc
$ ./class5
datum: NaN +/- 8.48798e-314
datum: 0.23 +/- 0.212
datum: 0.23 +/- 0.212
```

Windows XP with CygWin

```
$ uname -a
Linux pccms02.roma1.infn.it 2.6.14-1.1656_FC4smp #1 SMP Thu Jan 5 22:24:06 EST
2006 i686 i686 i386 GNU/Linux
$ gcc -v
Using built-in specs.
Target: i386-redhat-linux
...
gcc version 4.0.2 20051125 (Red Hat 4.0.2-8)
$ g++ -o class5 class5.cc
$ ./class5
datum: 6.3275e-308 +/- 4.85825e-270
datum: 0.23 +/- 0.212
datum: 0.23 +/- 0.212
```

Fedora Core4

Default Assignment

```
// ctor.cc
#include <iostream>
using std::cout;
using std::endl;

class Datum {
public:
    Datum(double x) { x_ = x; }
    double value() { return x_; }
    void setValue(double x) { x_ = x; }
    void print() {
        cout << "x: " << x_ << endl;
    }

private:
    double x_;
};
```

d3.x_ = d1.x_
done by compiler

```
int main() {

    Datum d1(1.2);
    d1.print();

    // no default ctor. compiler error if uncommented
    //Datum d2;
    //d2.print();

    Datum d3 = d1; // default assignment by compiler
    d3.print();
    cout << "&d1: " << &d1
         << "\t &d3: " << &d3 << endl;
    return 0;
}
```

```
$ g++ -o ctor ctor.cc
$ ./ctor
x: 1.2
x: 1.2
&d1: 0x23ef10      &d3: 0x23ef08
```

Question

- Can a constructor be private?
 - Is it allowed by the compiler?
 - How to instantiate an object with no public constructor?

- *Find a working example of a very simple class for next week*

Accessors and Helper/Utility Methods

- Methods that allow read access to data members
- Can also provide functionalities commonly needed by users to elaborate information from the class
 - for example formatted printing of data
- Usually they do not modify the objects, i.e. do not change the value of its attributes

```
class Student {
public:

    // getter method: access to data members
    string name() { return name_; }

    // utility method
    void print() {
        cout << "My name is: " << name_ << endl;
    }

private:
    string name_; // data member
};
```

```
class Datum {
public:

    double value() { return value_; }
    double error() { return error_; }

    void print() {
        cout << "datum: " << value_
            << " +/- " << error_
            << endl;
    }

private:
    double value_; // public data member!!!
    double error_; // private data member
};
```

Getter Methods

- getters are helpers methods with explicit names returning individual data members
 - Do not modify the data members simply return them
 - Good practice: call these methods as getFoo() or foo() for member foo_
- Return value of a getter method should be that of the data member

```
class Datum {
public:
    Datum(double val, double error) {
        val_ = val;
        err_ = error;
    }

    double value() { return val_; }
    double error() { return err_; }

    void setValue(double value) { val_ = value; }
    void setError(double error) { err_ = error; }

    void print() {
        cout << "datum: " << val_ << " +/- " << err_
            << endl;
    }

private:
    double val_;
    double err_;
};
```

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

class Student {
public:
    // default constructor
    Student() { name_ = ""; }

    // another constructor
    Student(const string& name) { name_ = name; }

    // getter method: access to info from the class
    string name() { return name_; }

    // setter: set attribute of object
    void setName(const string& name) { name_ = name; }

    // utility method
    void print() {
        cout << "My name is: " << name_ << endl;
    }

private:
    string name_; // data member
};
```

Setter Methods

- Setters are member functions that modify attributes of an object after it is created
 - Typically defined as void
 - Could return other values for error handling purposes
 - Very useful to assign correct attributes to an object in algorithms
 - As usual abusing setter methods can cause unexpected problems

```
// class8.cc
#include <iostream>
using namespace std;

class Datum {
public:
    Datum(double val, double error) {
        value_ = val;
        error_ = error;
    }

    double value() { return value_; }
    double error() { return error_; }

    void setValue(double value) { value_ = value; }
    void setError(double error) { error_ = error; }

    void print() {
        cout << "datum: " << value_ << " +/- "
              << error_ << endl;
    }

private:
    double value_;
    double error_;
};
```

```
int main() {

    Datum d1(23.4,7.5);
    d1.print();

    d1.setValue( 8.563 );
    d1.setError( 0.45 );
    d1.print();

    return 0;
}
```

```
$ g++ -o class8 class8.cc
$ ./class8
datum: 23.4 +/- 7.5
datum: 8.563 +/- 0.45
```

Pointers and References to Objects

```
// app2.cpp
#include <iostream>
using std::cout; // use using only for specific
classes
using std::endl; // not for entire namespace

class Counter {
public:
    Counter() { count_ = 0; x_=0.0; };
    int value() { return count_; }
    void reset() { count_ = 0; x_=0.0; }
    void increment() { count_++; }
    void increment(int step)
        { count_ = count_+step; }
    void print() {
        cout << "---- Counter::print() ----" << endl;
        cout << "my count_: " << count_ << endl;
        // this is special pointer
        cout << "my address: " << this << endl;
        cout << "&x_ : " << &x_ << " sizeof(x_): "
            << sizeof(x_) << endl;
        cout << "&count_ : " << &count_
            << " sizeof(count_): "
            << sizeof(count_) << endl;
        cout << "---- Counter::print() ----" << endl;
    }

private:
    int count_;
    double x_; // dummy variable
};
```

```
void printCounter(Counter& counter) {
    cout << "counter value: " << counter.value() << endl;
}

void printByPtr(Counter* counter) {
    cout << "counter value: " << counter->value() << endl;
}
```

```
int main() {
    Counter counter;
    counter.increment(7);

    // ptr is a pointer to a Counter Object
    Counter* ptr = &counter;
    cout << "ptr = &counter: " << &counter << endl;

    // use . to access member of objects
    cout << "counter.value(): " << counter.value() << endl;

    // use -> with pointer to objects
    cout << "ptr->value(): " << ptr->value() << endl;

    printCounter( counter );
    printByPtr( ptr );

    ptr->print();

    cout << "sizeof(ptr): " << sizeof(ptr) << "\t"
        << "sizeof(counter): " << sizeof(counter)
        << endl;

    return 0;
}
```

-> instead of . When using pointers to objects

Size and Address of Objects

gcc 3.4.4 on cygwin

```
$ g++ -o app2 app2.cpp
$ ./app2
ptr = &counter: 0x22ccd0
counter.value(): 7
ptr->value(): 7
printCounter: counter value: 7
printByPtr: counter value: 7
---- Counter::print() : begin ----
my count_: 7
my address: 0x22ccd0
&count_ : 0x22ccd0  sizeof(count_): 4
&x_ : 0x22ccd8  sizeof(x_): 8
---- Counter::print() : end ----
&i: 0x22ccc8
sizeof(ptr): 4  sizeof(counter): 16
sizeof(int): 4  sizeof(double): 8
```

gcc 4.1.1 on fedora core 6

```
$ g++ -o app2 app2.cpp
$ ./app2
ptr = &counter: 0xbf841e20
counter.value(): 7
ptr->value(): 7
printCounter: counter value: 7
printByPtr: counter value: 7
---- Counter::print() : begin ----
my count_: 7
my address: 0xbf841e20
&count_ : 0xbf841e20  sizeof(count_): 4
&x_ : 0xbf841e24  sizeof(x_): 8
---- Counter::print() : end ----
&i: 0xbf841e1c
sizeof(ptr): 4  sizeof(counter): 12
sizeof(int): 4  sizeof(double): 8
```

- Different size of objects on different platform!
 - Different configuration of compiler
 - Optimization for access to memory
- Address of object is address of first data member in the object

Classes and Applications

- So far we have always included the definition of classes together with the main application in one file
- The advantage is that we have only one file to modify
- Disadvantage are many
 - There is always ONE file to modify no matter what kind of modification you want to make
 - This file becomes VERY long after a very short time
 - Hard to maintain everything in only one place
 - We compile everything even after very simple changes

Example of Typical Application So Far

```
// app3.cpp
#include <iostream>
using std::cout;
using std::endl;

#include "Counter.h"

Counter makeCounter() {
    Counter c;
    return c;
}

void printCounter(Counter& counter) {
    cout << "counter value: " << counter.value() << endl;
}

void printByPtr(Counter* counter) {
    cout << "counter value: " << counter->value() << endl;
}
```

```
int main() {
    Counter counter;
    counter.increment(7);

    Counter* ptr = &counter;

    cout << "counter.value(): " << counter.value()
         << endl;
    cout << "ptr = &counter: " << &counter << endl;
    cout << "ptr->value(): " << ptr->value() << endl;

    Counter c2 = makeCounter();
    c2.increment();

    printCounter( c2 );

    cout << "sizeof(ptr): " << sizeof(ptr)
         << " sizeof(c2): " << sizeof(c2)
         << endl;

    return 0;
}
```

Separating Classes and Applications

- It's good practice to separate classes from applications
- Create one file with only your application
 - Use `#include` directive to add all classes needed in your application
 - Keep a separate file for each class
- Compile your classes separately
- Include compiled classes (or libraries) when linking your application

First Attempt at Improving Code Management

```
// Datum1.cc
// include all header files needed
#include <iostream>
using namespace std;

class Datum {
public:
    Datum() { }

    Datum(double x, double y) {
        value_ = x;
        error_ = y;
    }

    Datum(const Datum& datum) {
        value_ = datum.value_;
        error_ = datum.error_;
    }

    void print() {
        cout << "datum: " << value_
              << " +/- " << error_
              << endl;
    }

private:
    double value_;
    double error_;
};
```

```
// app1.cpp
#include "Datum1.cc"

int main() {

    Datum d1;
    d1.print();

    Datum d2(0.23, 0.212);
    d2.print();

    Datum d3( d2 );
    d3.print();

    return 0;
}
```

```
$ g++ -o app1 app1.cpp
$ ./app1
datum: NaN +/- 8.48798e-314
datum: 0.23 +/- 0.212
datum: 0.23 +/- 0.212
```

Problems with Previous Example

- Although we have two files it is basically if we had just one!
- Datum1.cc includes not only the declaration but also the definition of class Datum
 - Implementation of all methods exposed to user
- When compiling app1.cpp we also compile class Datum every time!
 - We do not need any library because app1.cpp includes all source code!
 - When compiling and linking app1.cpp we also create compiled code for Datum to be used in our application
 - *Remember what #include does!*

Pre-Compiled version of Datum1.cc

- Our source file is only a few lines long

```
$ wc -l Datum1.cc
30 Datum1.cc
```

```
$ wc -l app1.cpp
16 app1.cpp
```

```
$ g++ -E -c Datum1.cc > Datum1.cc-precompiled
```

```
$ wc -l Datum1.cc-precompiled
23740 Datum1.cc-precompiled
```

- The precompiled version is almost 24000 lines!
 - This is all code included in and by iostream

```
$ grep "#include" /usr/lib/gcc/i686-pc-cygwin//3.4.4/include/c++/
iostream
```

```
* This is a Standard C++ Library header. You should @c #include
this header
```

```
#include <bits/c++config.h>
```

```
#include <ostream>
```

```
#include <istream>
```

iostream

```
#ifndef _GLIBCXX_IOSTREAM
#define _GLIBCXX_IOSTREAM 1

#pragma GCC system_header

#include <bits/c++config.h>
#include <ostream>
#include <istream>

namespace std
{
    /**
     * @name Standard Stream Objects
     */
    /*
     //@{
     extern istream cin;      ///< Linked to standard input
     extern ostream cout;    ///< Linked to standard output
     extern ostream cerr;    ///< Linked to standard error (unbuffered)
     extern ostream clog;    ///< Linked to standard error (buffered)

#ifdef _GLIBCXX_USE_WCHAR_T
     extern wistream wcin;   ///< Linked to standard input
     extern wostream wcout;  ///< Linked to standard output
     extern wostream wcerr;  ///< Linked to standard error (unbuffered)
     extern wostream wclog;  ///< Linked to standard error (buffered)
#endif
     //@}

    // For construction of filebuffers for cout, cin, cerr, clog et. al.
    static ios_base::Init __ioinit;
} // namespace std

#endif /* _GLIBCXX_IOSTREAM */
```

I have removed all comments from the file to make it fit in this slide

Additional code included by the header files in this file

How do you find **iostream** file on your computer?

Separating Interface from Implementation

- Clients of your classes only need to know the interface of your classes
- Remember:
 - Users should only rely on public members of your class
 - Internal data structure must be hidden and not needed in applications
- Compiler needs only the declaration of your classes, its functions and their signature to compile the application
 - Signature of a function is the exact set of arguments passed to a function and its return type
- The compiled class code (definition) is needed only at link time
 - Libraries are needed to link not to compile!

Header and Source Files

- We can separate the declaration of a class from its implementation
 - Declaration tells the compiler about data members and member functions of a class
 - We know how many and what type of arguments a function has by looking at the declaration but we don't know how the function is implemented
- Declaration of a class Counter goes into a file usually called Counter.h or Counter.hh suffix
- Implementation of methods goes into the source file usually called Counter.cc

Counter.h and Counter.cc

```
// Counter.h
// Counter Class: simple counter class.
// Allows simple or step
// increments and also a reset function

// include header files for types
// and classes used in the declaration

class Counter {
public:
    Counter();
    int value();
    void reset();
    void increment();
    void increment(int step);

private:
    int count_;
};
```

```
// Counter.cc
// include class header files
#include "Counter.h"

// include any additional header files
// needed in the class
// definition
#include <iostream>
using std::cout;
using std::endl;

Counter::Counter() {
    count_ = 0;
};

int Counter::value() {
    return count_;
}

void Counter::reset() {
    count_ = 0;
}

void Counter::increment() {
    count_++;
}

void Counter::increment(int step) {
    count_ = count_ + step;
}
```

Scope operator :: is used to tell methods belong to Class Counter

What is included in header files?

- Declaration of the class
 - Public and data members
- All header files for types and classes used in the header
 - data members, arguments or return types of member functions
- Sometimes when we have very simple methods these are directly implemented in the header file
- Methods implemented in the header file are referred to as inline functions
 - For example getter methods are a good candidate to become inline functions

What is included in source file?

- Header file of the class being implemented
 - Compiler needs the prototype (declaration) of the methods
- Implementation of methods declared in the header file
 - Scope operator `::` must be used to tell the compiler methods belong to a class
- Header files for all additional types used in the implementation but not needed in the header!
 - Nota bene: header files include in the header file of the class are automatically included in the source file

Compiling Source Files of a Class

```
$ g++ Counter.cc  
/usr/lib/gcc/i686-pc-cygwin/3.4.4/../../../../libcygwin.a(libcmain.o) : :  
undefined reference to `__WinMain@16'  
collect2: ld returned 1 exit status
```

WinXP+
cygwin

```
$ g++ Counter.cc  
/usr/lib/gcc/i386-redhat-linux/4.0.2/../../../../crt1.o(.text+0x18) :  
In function `__start': : undefined reference to `main'  
collect2: ld returned 1 exit status
```

Linux

- Do you understand the error?
- What does undefined symbol usually mean?
- Why we did not encounter this error earlier?