CS-202

C++ Classes (Introduction)

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Course Week

Course , Projects , Labs:

Monday	Tuesday	Wednesday	Thursday	Friday		Sunday
			Lab (8 Sections)			
	CLASS		CLASS			
PASS Session	PASS Session	**Project DEADLINE**	NEW Project	PASS Session		PASS Session

Your 2nd Project Deadline is this Wednesday 2/6.

- PASS Sessions held Friday-Sunday-&-Monday-Tuesday, get all the help you need!
- 24-hrs delay after Project Deadline incurs 20% grade penalty.
- Past that, NO Project accepted. Better send what you have in time!

Today's Topics

C++ Classes

- Definitions
- Declaration, Implementation
- Members, Methods
- Usage, Coding Standards

Classes as Abstract Data Types

Protection Mechanisms

Abstraction

Programming Abstraction

All programming languages provide some form of Abstraction.

- In its most basic form also called "Information Hiding".
- Separates code use from code implementation.

In *Procedural* Programming:

- Data Abstraction: Data Structures. `struct somethingComplex{ … };`
- Control Abstraction: Functions. `void makeItHappen( … );`

In *Object-Oriented* Programming

- Data and Control Abstraction: Using Classes

Abstraction

Programming Abstraction

All programming languages provide some form of Abstraction.

Not to be confused with Abstract Types:

- A programming language-related implementation.
- Given a type system, an Abstract Type is one that cannot be *instantiated* directly (vs a Concrete Type).

```
<abstract_type> Vehicle ;
```

```
<concrete_type> Vehicle : Car ;
```

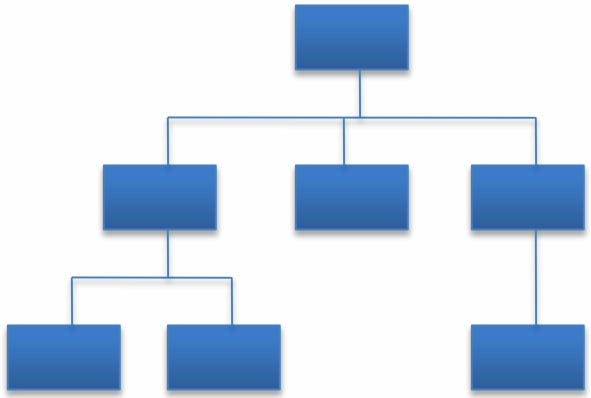
Remember: Procedural *vs* Object-Oriented

Procedural

Procedural Decomposition:

Divides the problem into more easily handled subtasks, until the functional modules (subproblems) can be coded.

Focus on: Processes.



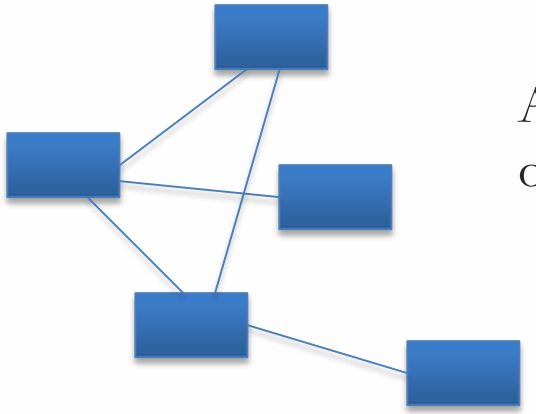
A hierarchy of functions

Object-Oriented (OO)

Object-Oriented Design:

Identifies various objects composed of data and operations, that can be used together to solve the problem.

Focus on: Data Objects.



A collection of Objects

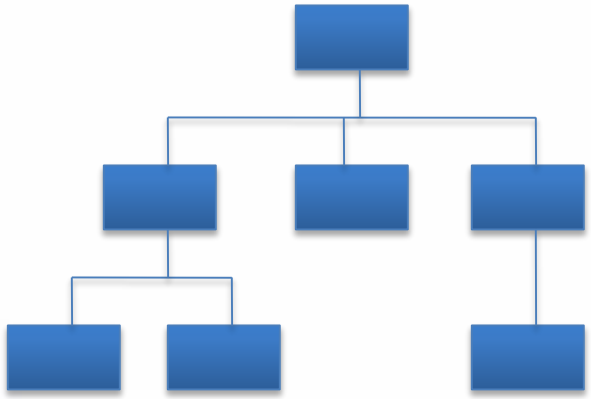
Remember: Procedural *vs* Object-Oriented

Procedural

Focused on the question: "What should the program do next?" Structure program by:

- Splitting into sets of tasks and subtasks.
- Make functions for tasks.

- Data and operations are not bound to each other



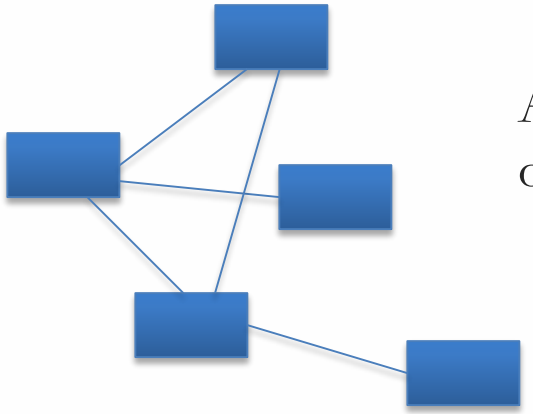
A hierarchy of functions

Object-Oriented (OO)

Package-up self-sufficient modular pieces of code. Pack away details into boxes (objects) keep them in mind in their abstract form.

- "The world is made up of interacting objects".

- Data and operations are bound to each other.



A collection of Objects

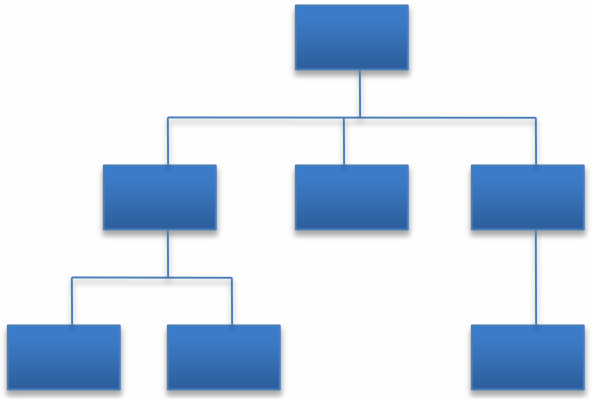
Remember: Procedural *vs* Object-Oriented

Procedural

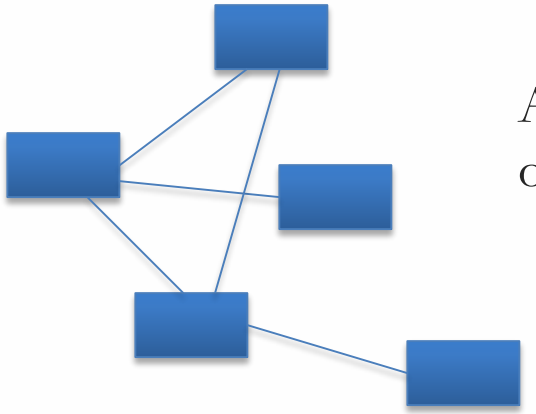
"What should the program do next?"

Object-Oriented (OO)

Self-sufficient, modular, interacting pieces of code.



A hierarchy of functions



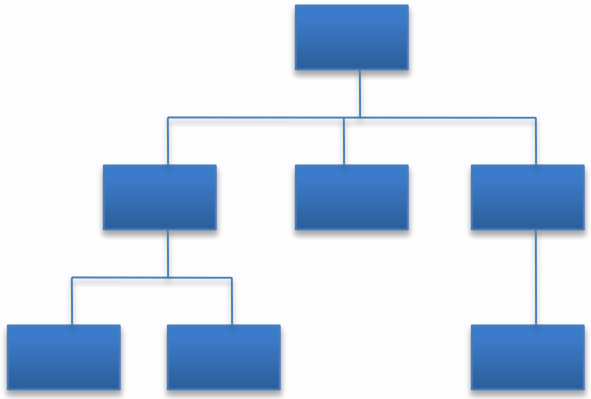
A collection of Objects

Remember: Procedural *vs* Object-Oriented

Procedural

"What should the program do next?"

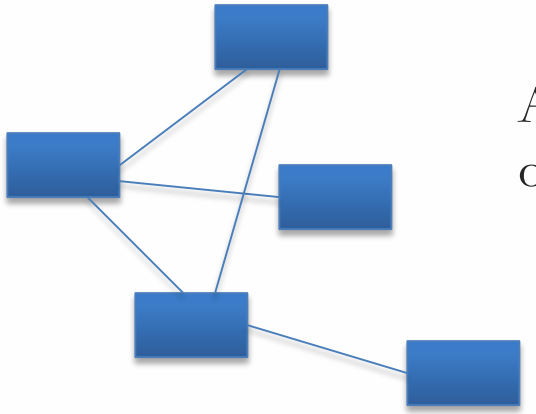
- Calculate the area of a circle given the specified radius.
- Sort this class list given an array of students.
- Calculate the car's expected mileage given its gas and road conditions.



A hierarchy of functions

Object-Oriented (OO)

Self-sufficient, modular, interacting pieces of code.



A collection of Objects

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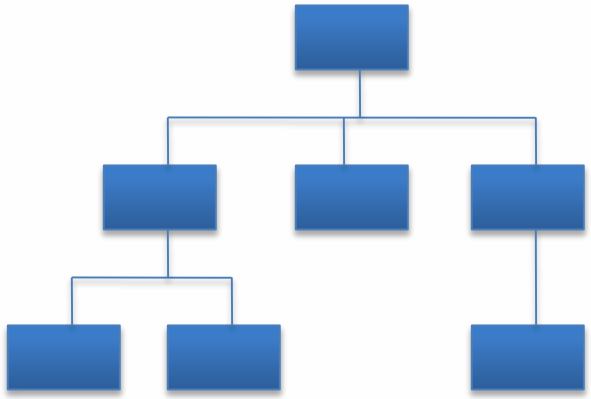
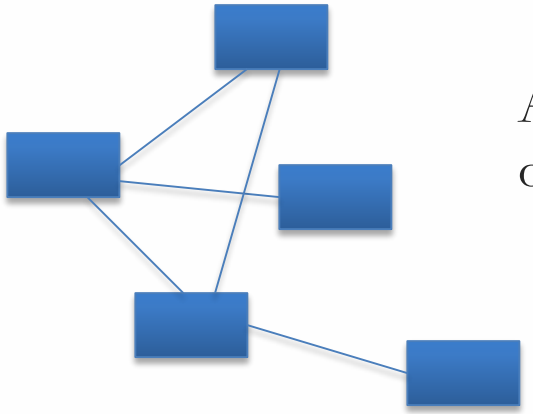


A hierarchy of functions

Object-Oriented (OO)

Self-sufficient, modular, interacting pieces of code.

- Circle, you know your radius, what is your area?
- Class list, sort your students.
- Car, when will you run out of gas on this trip?



A collection of Objects

Object-Oriented Programming

Principles

Information Hiding:

- Details of how operations (behaviors – functions) work are not known to the user of the Class.

Data Abstraction:

- Details of how attributes (data members) are manipulated within "Abstract Data Type (ADT)" / Class are not known to the user.

Encapsulation:

- Bring together data and operations, but keep details hidden.

Object-Oriented Programming

Classes ⟵ Etymology:  (ἡ) **κλάσις**

According to the dictionary:

- "A kind or category."
- "A set, collection, group, or configuration containing members regarded as having certain attributes or traits in common."

A "*Class*" according to OOP principles:

- A group of objects with similar properties, common behavior, common relationships with other objects, and common semantics.
- We use *Classes* for Abstraction purposes.

Classes

Blueprints

Classes are "*blueprints*" for "*instantiating*" (creating) Objects.

- A **`Dog`** Class to instantiate **`dog1`** , **`dog2`**, … **`dogN`** Objects.
- A **`Shoe`** Class to instantiate **`shoe1`** , **`shoe2`**, … **`shoeN`** Objects.
- A **`Car`** Class to instantiate **`car1`** , **`car2`**, … **`carN`** Objects.

The blueprint defines:

- The Class's state/attributes as *class member variables*.
- The Class's behaviors as *class methods*.

Objects

Variables of Class types may be created just like variables of built-in types:

- Each instance of a class is called an "*Object*" of that Class type.
- Using a set of **`Car`** blueprints we can create a "***`my_car`***" Object.

We can create as many instances of a Class as needed:

- Just like a regular data type, **`int`**, **`float`**, etc.
- There can be more than one ***`dog`***, ***`car`***, ***`shoe`*** (and might differ a lot)!

The challenge is to define Classes and create Objects that satisfy the problem:

- Do we need a **`Car`** class?

1. Class Interface

The requests you can make of an Object are determined by its interface.

Do we need to know?

- *How* the **`Car`** *manufacturing* chain works in order to buy one?
- *How* the **`car`** operates *internally* in order to drive one?

All we need to know is:

- How the **`Car`** dealership works with financing.
  How to *get* one?
- How the **`car`** pedals, signals, switches, and steering wheel work.
  How to *operate* one?

1. Class Interface

The requests you can make of an Object are determined by its interface.

- *How* to *acquire* one?
- *How* to *operate* one?

Car Class
Dealership price/scheme
Operate steering wheel
Operate gas pedal
Operate brake pedal
Operate clutch
Operate transmission
Switch lights
…

Type

Interface

2. Class Implementation

What actually lies inside the Class. It is the:

- Code,
- Hidden Data,

that satisfy requests made to it (and/or its Objects).

Every request made of an Object must have associated *Method* (i.e. Function) that will be called.

- When dealing with OO content, we say that the user is sending a message to the object, which responds to the message by executing the appropriate code.
- "The world is made up of interacting objects".

Class Declaration

```
class Car
{
   public:
    bool addGas(float gallons);
    float getMileage();
    // other operations
   private:
    float m_currGallons;
    float m_currMileage;
    // other data
};
```

Class (Type) Name

Class Declaration

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class Car
{
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Protection Mechanism

Protection Mechanism

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Protection Mechanism

Data

Class Declaration

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  private:
    float m_currGallons;
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    // other data
};
```

Class (Type) Name

Protection Mechanism

Operations

Protection Mechanism

Data

Class Conventions

Standards for coding with Classes:

```
class Car
```

This is already *Italicized* !

Integrated Development Environments (IDEs) can sometimes save the day with their smart features:

- Real-time search for Declaration.
- Auto-completion, Function alternatives.

But:

- Learn to adopt a set of conventions (not rules), same as with every other language.

Class Conventions

Class names:

- Always begin with capital letter.
- Use **`CamelCase`** for phrases.
- General word for Class (Type) of Objects.

  Examples: **`Car`**, **`Shoe`**, **`Dog`**, **`StudyBook`**, **`BoxOfDVDs`**, …

```
class Car
{
        …
};
```

Class Conventions

Class data (member variables):

- Always begin names with **`m_`** (stands for "member").
  Examples: **`float m_fuel`**, **`char* m_title`**, …
- Use **`camelCase`** (alternatively also **`CamelCase`**).

```
class Car
{
        …
        float m_currGallons;
        float m_currMileage;
};
```

Class Conventions

Class operations/methods:

- Use **`camelCase`** (alternatively also **`CamelCase`**).
  Examples: **`addGas()`**, **`accelerate()`**, **`modifyTitle()`**, **`removeDVD()`**, …

```
class Car
{
        …
        bool addGas(float gallons);
        float getMileage();
};
```

Encapsulation

Main principle in Object-Oriented Design / Programming.

- A form of "Information Hiding" and Abstraction.

How:

- Data and Functions that act on *that* data are located in the same place.
- Encapsulated inside the Class.

Goal:

- Separate *Interface* from *Implementation*.
  Someone can still use the code without any knowledge of how it works!

Encapsulation

Classes encapsulate both Data and Functions.

- Class definitions must contain both!

Member Variables are the Data of a Class.

- Its attributes, characteristics, an Object's state.

(e.g. **`breed`** of ***`Dog`***, **`size`** of ***`Shoe`***, **`make`** of ***`Car`*** …)

Class Methods are used to act on that Data.

(e.g., **`play()`** with ***`Dog`***, **`inspect()`** a ***`Car`***, …)

BankAccount
Member Vars:
`m_accountNr`
`m_ownerName`
`m_balance`
Class Methods:
`depositMoney()`
`withdrawMoney()`
`checkBalance()`

Class Components – 4 Crucial Questions

Member variables:

- What data must be stored?

Class Methods/Member Functions:

- How does the user need to interact with the stored data?

Constructor(s):

- How do you build an instance (create an Object)?

Destructor:

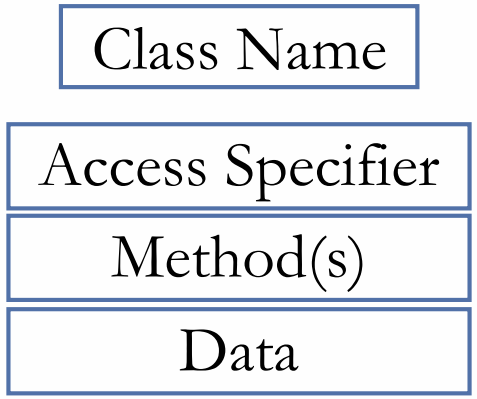
- How do you clean up an after an instance (after Object is destroyed)?

Classes by-Example

Class Method(s) Declaration & Implementation

```
// Represents a Day of the Year
class DayOfYear
{
   public:
      void output();
      int m_month;
      int m_day;
};

// Output method - displays a DayOfYear
void DayOfYear::output( )
{
   cout << m_month << "/" << m_day;
}
```



Classes by-Example

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// Output method - displays a DayOfYear
void DayOfYear::output( )
{
   cout << m_month << "/" << m_day;
}
```

Method Prototype *inside* Class Declaration

Class Name

Access Specifier

Method(s)

Data

Method Implementation *outside* of Class Declaration

Classes by-Example

Class Method Implementation

The Method Implementation:

```
class DayOfYear
{
  public:
    void output();
    int m_month;
    int m_day;
};
```

```
// Output method - displays a DayOfYear
void DayOfYear::output( )
{
    cout << m_month << "/" << m_day;
}
```

`return` type

Method Name & Parameters List

Classes by-Example

Class Method Implementation

The Method Implementation:

```
// Output method - displays a DayOfYear
void DayOfYear::output( )
{
    cout << m_month << "/" << m_day;
}
```

Scope Resolution Operator (::)
Indicates which Class Method this definition implements.
Simpler: Which Class is it from?

Class Name

```
class DayOfYear
{
  public:
    void output();
    int m_month;
    int m_day;
};
```

Classes by-Example

Class Method Implementation

The Method Implementation:

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Class Name

```
class DayOfYear
{
  public:
    void output();
    int m_month;
    int m_day;
};
```

Method Body
has direct access to
Class Member Variables

Classes by-Example

Class Separation into Files

```
// Represents a Day of the Year
class DayOfYear
{
   public:
      void output();
      int m_month;
      int m_day;
};

// Output method - displays a DayOfYear
void DayOfYear::output( )
{
   cout << m_month << "/" << m_day;
}
```

Class Declaration:

- Goes into Class header file.

<ClassName.h>

<DayOfYear.h>

Class Definition:

- Goes into Class source file.

<ClassName.cpp>

<DayOfYear.cpp>

Class Usage

Simple Instantiation and Member-access:

```
// Inside a main() somewhere
DayOfYear july4th;



july4th.m_month = 7;
july4th.m_day = 4;
july4th.output();
```

(Default) Constructor-based Instantiation

Class Usage

Simple Instantiation and Member-access:

```
// Inside a main() somewhere
DayOfYear july4th;
```

Dot Operator (.) – Member-Access
Indicates which Object this Class Member references.
Simpler: The Member-of which Object?

Object Name

```
july4th.m_month = 7;
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Classes by-Example

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july4th.output();
```

Class Member Variables
&
Class Methods

Class Usage

Member-access through Pointer:

```
// Inside a main() somewhere

DayOfYear july4th;
DayOfYear * july4th_Pt = &july4th;
```

Pointer to Class Type

```
july4th_Pt->m_month = 7;
july4th_Pt->m_day = 4;
july4th_Pt->output();
```

Classes by-Example

Class Usage

Member-access through Pointer:

```
// Inside a main() somewhere

DayOfYear july4th;
DayOfYear * july4th_Pt = &july4th;
```

Pointer to Class Type

Arrow Operator (**->**) – Pointer to Member-access

Class Pointer Dereference Operator (The C++ standard just calls it "arrow" (§**5.2.5**)).

Simpler: "Works out" similarly to Member-access (**.**), just through a Pointer !

Object Pointer

```
july4th_Pt->m_month = 7;
july4th_Pt->m_day = 4;
july4th_Pt->output();
```

Class, by-Example (one more)

```
1  //Program to demonstrate a very simple example of a class.
2  //A better version of the class DayOfYear will be given in Display 6.4.
3  #include <iostream>
4  using namespace std;

5  class DayOfYear
6  {
7  public:
8      void output( );
9      int month;
10     int day;
11 };

12 int main( )
13 {
14     DayOfYear today, birthday;
15     cout << "Enter today's date:\n";
16     cout << "Enter month as a number: ";
17     cin >> today.month;
18     cout << "Enter the day of the month: ";
19     cin >> today.day;
20     cout << "Enter your birthday:\n";
21     cout << "Enter month as a number: ";
22     cin >> birthday.month;
23     cout << "Enter the day of the month: ";
24     cin >> birthday.day;
25     cout << "Today's date is ";
26     today.output( );
27     cout << endl;
28     cout << "Your birthday is ";
29     birthday.output( );
30     cout << endl;

31     if (today.month == birthday.month && today.day == birthday.day)
32         cout << "Happy Birthday!\n";
33     else
34         cout << "Happy Unbirthday!\n";
35     return 0;
36 }
```

Normally, member variables are `private` *and not* `public`*, as in this example. This is discussed a bit later in this chapter.*

Member function declaration

Calls to the member function `output`

Classes by-Example

Class, by-Example (one more)

```
37  //Uses iostream:
38  void DayOfYear::output( )
39  {
40      switch (month)
41      {
42          case 1:
43              cout << "January "; break;
44          case 2:
45              cout << "February "; break;
46          case 3:
47              cout << "March "; break;
48          case 4:
49              cout << "April "; break;
50          case 5:
51              cout << "May "; break;
52          case 6:
53              cout << "June "; break;
54          case 7:
55              cout << "July "; break;
56          case 8:
57              cout << "August "; break;
58          case 9:
59              cout << "September "; break;
60          case 10:
61              cout << "October "; break;
62          case 11:
63              cout << "November "; break;
64          case 12:
65              cout << "December "; break;
66          default:
67              cout << "Error in DayOfYear::output. Contact software vendor.";
68      }
69
70      cout << day;
71  }
```

Classes by-Example

Class, by-Example (one more)

```
1  //Program to demonstrate a very simple example of a class.
2  //A better version of the class DayOfYear will be given in Display 6.4.
3  #include <iostream>
4  using namespace std;

5  class DayOfYear
6  {
7  public:
8      void output( );
9      int month;
10     int day;
11 };

12 int main( )
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19     cin >> today.day;
20     cout << "Enter your birthday:\n";
21     cout << "Enter month as a number: ";
22     cin >> birthday.month;
23     cout << "Enter the day of the month: ";
24     cin >> birthday.day;
25     cout << "Today's date is ";
26     today.output( );
27     cout << endl;
28     cout << "Your birthday is ";
29     birthday.output( );
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31     if (today.month == birthday.month && today.day == birthday.day)
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```

Normally, member variables are **private** *and not* **public**, *as in this example. This is discussed a bit later in this chapter.*

Member function declaration

Note:
Properly, this is placed in
<DayofYear.h>

Calls to the member function **output**

Classes by-Example

Class, by-Example (one more)

```
37  //Uses iostream:
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49              cout << "April "; break;
50          case 5:
51              cout << "May "; break;
52          case 6:
53              cout << "June "; break;
54          case 7:
55              cout << "July "; break;
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Note:
Properly, this is placed in
<DayofYear.cpp>

A Class' Place

A Class is full-fledged *Type* (it is just a *User-Defined* one) !

- Almost like primitive (e.g. built-in) data types `int`, `double`, etc.

Hence, we can have *Variables* of a *Class Type*:

- We simply call them "*Objects*".

Therefore, we can have Function Parameters of a *Class Type* !

- Pass-by-Value.
- Pass-by-Reference.
- Pass-by-Address.

Pass-by-Value

Hence, we can also have Function Parameters of a Class derivatives:

- Function Parameter by-Value.

```
DayOfYear july4th;
july4th.m_month = 7; july4th.m_day = 4;
printNextDay(july4th);

void printNextDay(DayOfYear date){
    date.m_day++;
    if(date.m_day … && date.m_month …){
      date.m_day = …;
      date.m_month = …;
    }
    date.output();
}
```

```
class DayOfYear{
  public:
    void output();
    int m_month;
    int m_day;
};
```

Pass-by-Value

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    if(date.m_day … && date.m_month …){
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      date.m_month = …;
    }
    date.output();
}
```

```
class DayOfYear{
  public:
    void output();
    int m_month;
    int m_day;
};
```

Note:
Will work with Local Object Copy !

Pass-by-Reference

Hence, we can also have Function Parameters of a Class derivatives:

- Function Parameter by-Reference.

```
DayOfYear july4th;
july4th.m_month = 7; july4th.m_day = 4;
shiftNextDay(july4th);
july4th.output();

void shiftNextDay(DayOfYear & date){
    date.m_day++;
    if(date.m_day … && date.m_month …){
      date.m_day = …;
      date.m_month = …;
    }
}
```

```
class DayOfYear{
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class DayOfYear{
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    void output();
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```

Note:
Will modify Object Data !

Pass-by-Address

Hence, we can also have Function Parameters of a Class derivatives:

- Function Parameter by-Address.

```
DayOfYear july4th;
DayOfYear* july4th_Pt = &july4th;
shiftNextDay_Pt(july4th_Pt);
july4th.output();

void shiftNextDay_Pt(DayOfYear * date_p){
    date_p->m_day++;
    if(date_p->m_day … && date_p->m_month …){
      date_p->m_day = …;
      date_p->m_month = …;
    }
}
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class DayOfYear{
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class DayOfYear{
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};
```

Note:
Will modify Object Data !

Abstract *(User-Defined)* Data Types

The concept of "Programming Abstraction" :

- *Programmers* don't (need to) know the details!

Abbreviated "ADT" :

- An ADT is a collection of data values together with set of basic operations defined for the values, ADTs are often language-independent.
- In C++ we ADTs are implemented with Classes.
  A C++ Class "defines" the ADT.

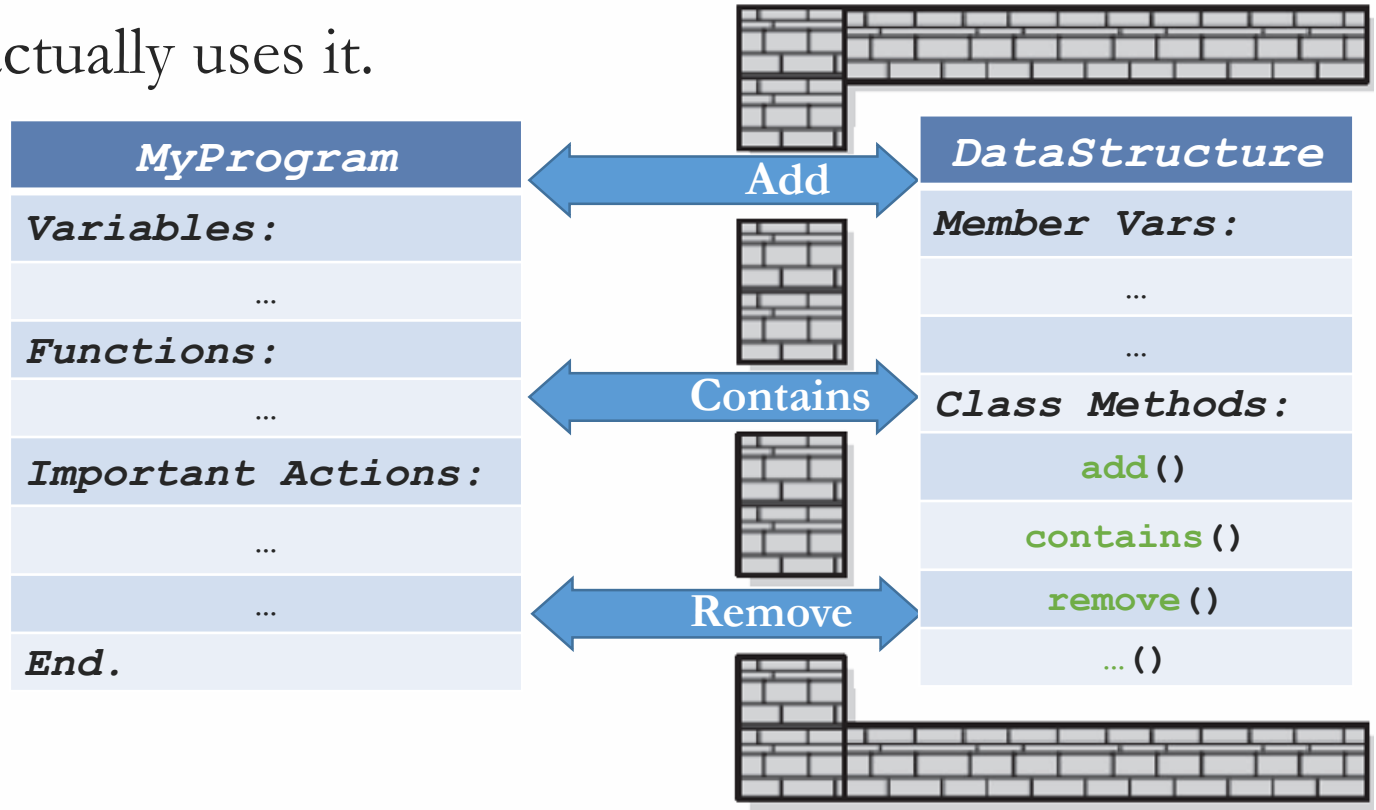
A Data Structure :

- An ADT implementation within a programming language.

Abstract Data Types

A wall of ADT operations isolates a Data Structure:

- from the program that actually uses it.



Coupling (more on Abstraction)

"Coupling" refers to how much components depend on each other's implementation details (i.e. how much work it is to remove one component and drop-in a new implementation of it)

- Placing a new battery in a car *vs* a new engine.
- Adding a USB device *vs* a new video card to a laptop.

Object-Oriented Design seeks to reduce Coupling as much as possible by:

- Well-defined Interfaces to change (*write*) or access (*read*) the state of an Object.
- Enforcing those interfaces are adhered to (`private` *vs* `public`).
- Alternate implementations that may be more appropriate for different cases.

Encapsulation (*Reminder*)

Main principle in Object-Oriented Design / Programming.

- A form of "Information Hiding" and Abstraction.

How:

- Data and Functions acting on *that* data are placed in same code unit.
- Encapsulated inside the Class.

Goal:

- Separate *Interface* from *Implementation*.
  Keep state separate from users via `private` Data, `public` Member Functions.
  Someone can still use the code without any knowledge of how it works!

Classes

Encapsulation (a correlation to Classes)

Any data type includes:

- Data (range of Data).
- Operations (that can be performed on Data).

Example: The `int` data type.

Data: `-2147483648` to `2147483647` (for 32-bit `int` – a.k.a. `int32_t`)
Operations: `+`, `-`, `*`, `/`, `%`, logical, etc.

The same holds with Classes:

- But Data & their Ranges are specified by user/programmer/you(!), and operations to be allowed on that Data (and their implementation) by you(!) as well.

Encapsulation (a correlation to Classes)

In one sense, it means "bringing together as one":

- Declare & Define a Class.

```
class DayOfYear
{
   public:
      void output();
      int m_month;
      int m_day;
};
```

```
void DayOfYear::output(){
   cout << m_month << "/" << m_day;
}
```

```
DayOfYear july4th;
july4th.m_month = 7;
july4th.m_day = 4;
july4th.output();
```

Encapsulation (a correlation to Classes)

In one sense, it means "bringing together as one":

- Declare & Define a Class → Get an Object.

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```

Encapsulation (a correlation to Classes)

In one sense, it means "bringing together as one":

- Declare & Define a Class → Get an Object.
- The Object is an "Encapsulation" of: a) Data values, b) Data operations.

```
class DayOfYear
{
   public:
      void output();
      int m_month;
      int m_day;
};

void DayOfYear::output(){
   cout << m_month << "/" << m_day;
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Encapsulation (a correlation to Classes)

Class Methods do not need to be passed information about that Class Object!

- Remember how the `DayOfYear::output()` Method has no parameters?

```
void DayOfYear::output(){
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Encapsulation (a correlation to Classes)

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- Remember how the `DayOfYear::output()` Method has no parameters?

```
void DayOfYear::output(){
    cout << m_month << "/" << m_day;
}
```

```
DayOfYear july4th, november19th;
july4th.output();
november19th.output();
```

Member Functions are called *on* a Class Object.

- They know everything about that object already. Why?
- It is the Object itself that applies the Data operations (Method).
  It is the one that contains the Data, and its class contains the code.

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7 / 4

11 / 19

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Protection Mechanisms

The keyword **const** for Member Function(s):

- Member Functions have access to all Member Variables.
- Use **const** function signature to "promise" it won't change Member Data.

```
class DayOfYear{
  public:
    void printDay() const;
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    int m_day;
};
```

```
void DayOfYear::printDay() const{
        cout << m_month <<
              "/" << m_day;
}

void DayOfYear::shiftNextDay(){
        m_day++;
        if(m_day … && m_month …){
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        }
}
```

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"Promises" to leave Data untouched

```
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"Promises" to leave Data untouched

Makes no such "promise".

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void DayOfYear::printDay() const{
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```

```
void DayOfYear::printDay() const{
        cout << m_month <<
              "/" << m_day;
}
```

Note (more on this later in CS-202) :
In the body of a **cv**-qualified function, the **this** pointer is **cv**-qualified, e.g. in a **const** member function, only other **const** member functions may be called normally.

Protection Mechanisms

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DayOfYear july4th;
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july4th.shiftNextDay();
july4th.printDay();

july4th_Pt->shiftNextDay();
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```

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class DayOfYear{
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class DayOfYear{
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Protection Mechanisms

Access Specifiers:

```
class DayOfYear{
  public:
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  private:
    int m_month;
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};
```
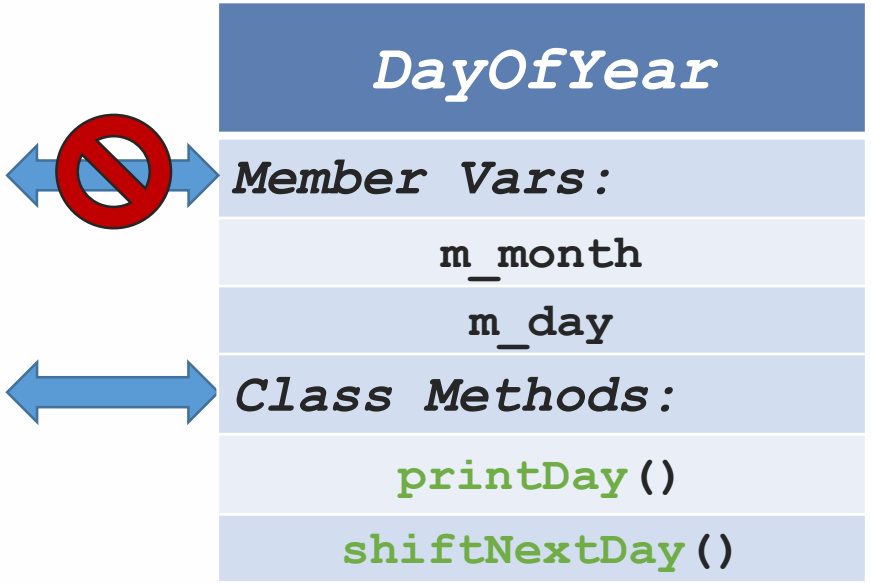

The CHANGE:
Data are now **private**.
Direct Object Interface to Member Data is broken!



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```
DayOfYear july4th;
```

Impossible

```
july4th.m_month = 7;
july4th.m_day = 4;
```

```
july4th.shiftNextDay();
july4th.output();
```

Impossible

```
cout << july4th.m_day;
```

Protection Mechanisms

Access Specifiers style:

Can mix & match **`public`** & **`private`**:

- More typically place **`public`** first
- Allows easy viewing of portions that actually can be used by programmers using the Class.

`private` data is "hidden", so irrelevant to users of Class.

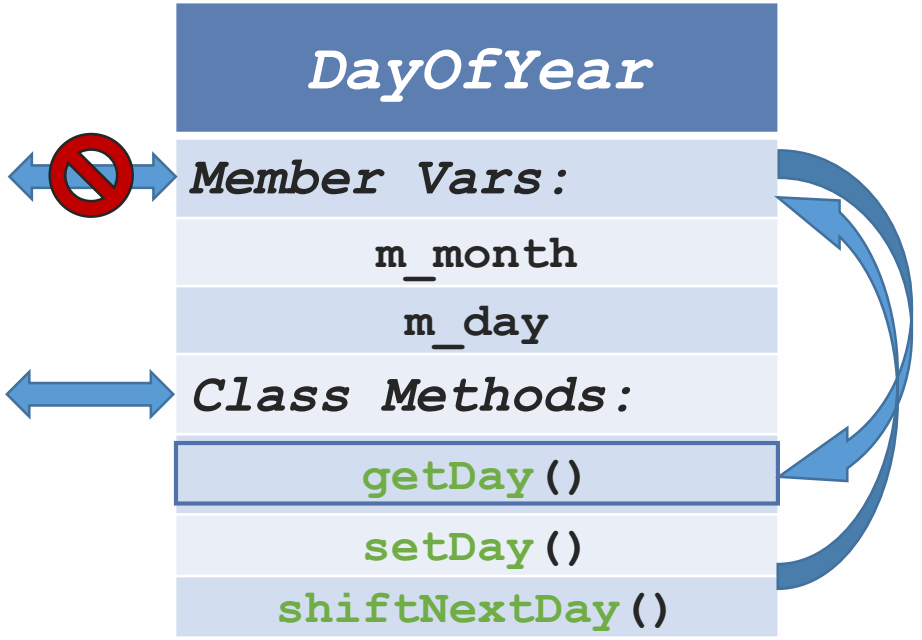
- Outside of Class definition, cannot change (or access) **`private`** data.

Protection Mechanisms

Accessor & Mutator Functions:

Object needs to "do something" with its data !

- *Accessor* Member Functions.
  An Object-Interface to read Member Data.
  Typically: "`getMember`" Functions.



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  An Object-Interface to change Member Data.
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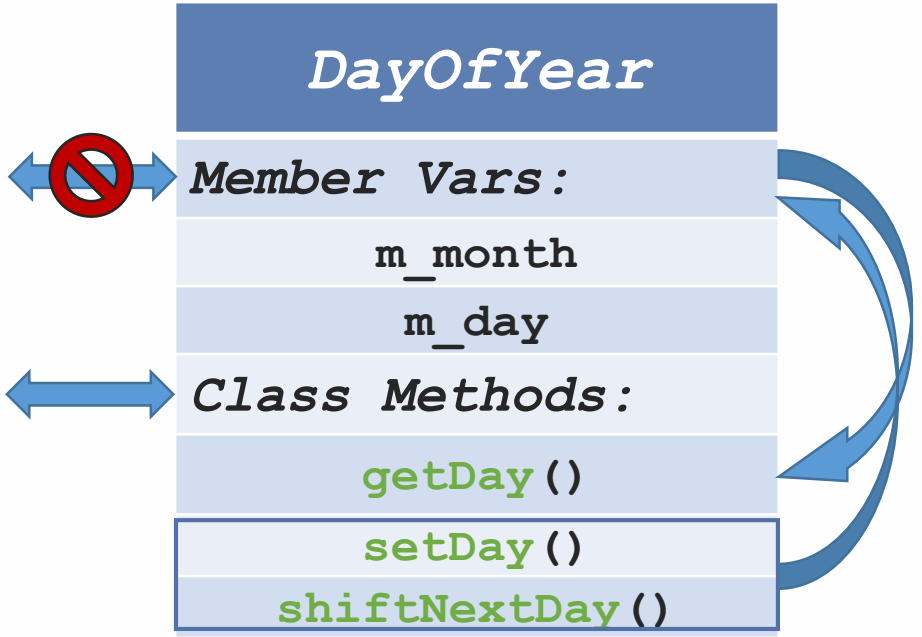

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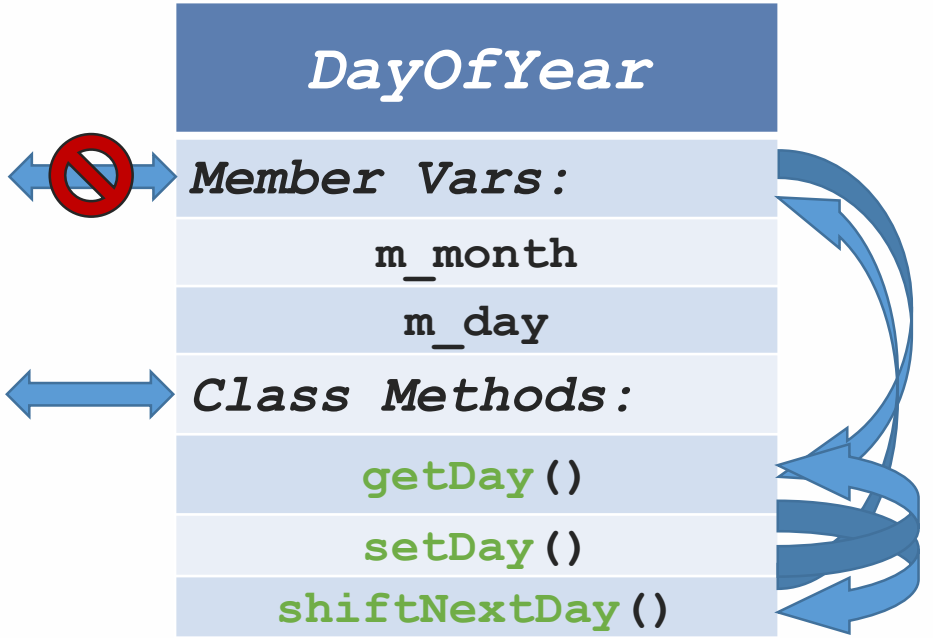


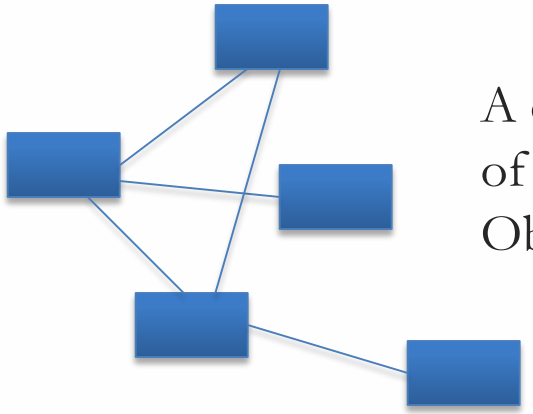
Classes

Object-Oriented Design (a correlation to Classes)

Thinking Objects / thinking with Objects:

- Focus on programming-style changes.
  - Before ➡ Algorithms at center stage.
  - OOP ➡ Data is the focal point.

A new type of Program Structure



A collection of interacting Objects

Algorithms still exist (of course):

- They focus on their data.
- Are "made" to "fit" the data.

Designing software solutions:

- Define variety of objects and how they interact.

Classes

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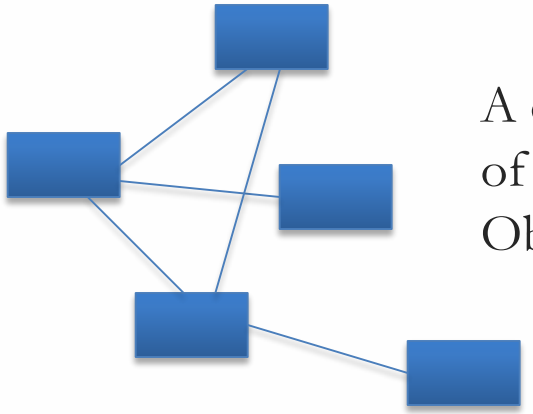

A collection of interacting Objects

Create large and powerful software systems from tiny components.

- Split things up into manageable pieces.
- Somewhat of a bottom up approach
  (define little pieces that can be used to compose larger pieces).

CS-202

Time for Questions !