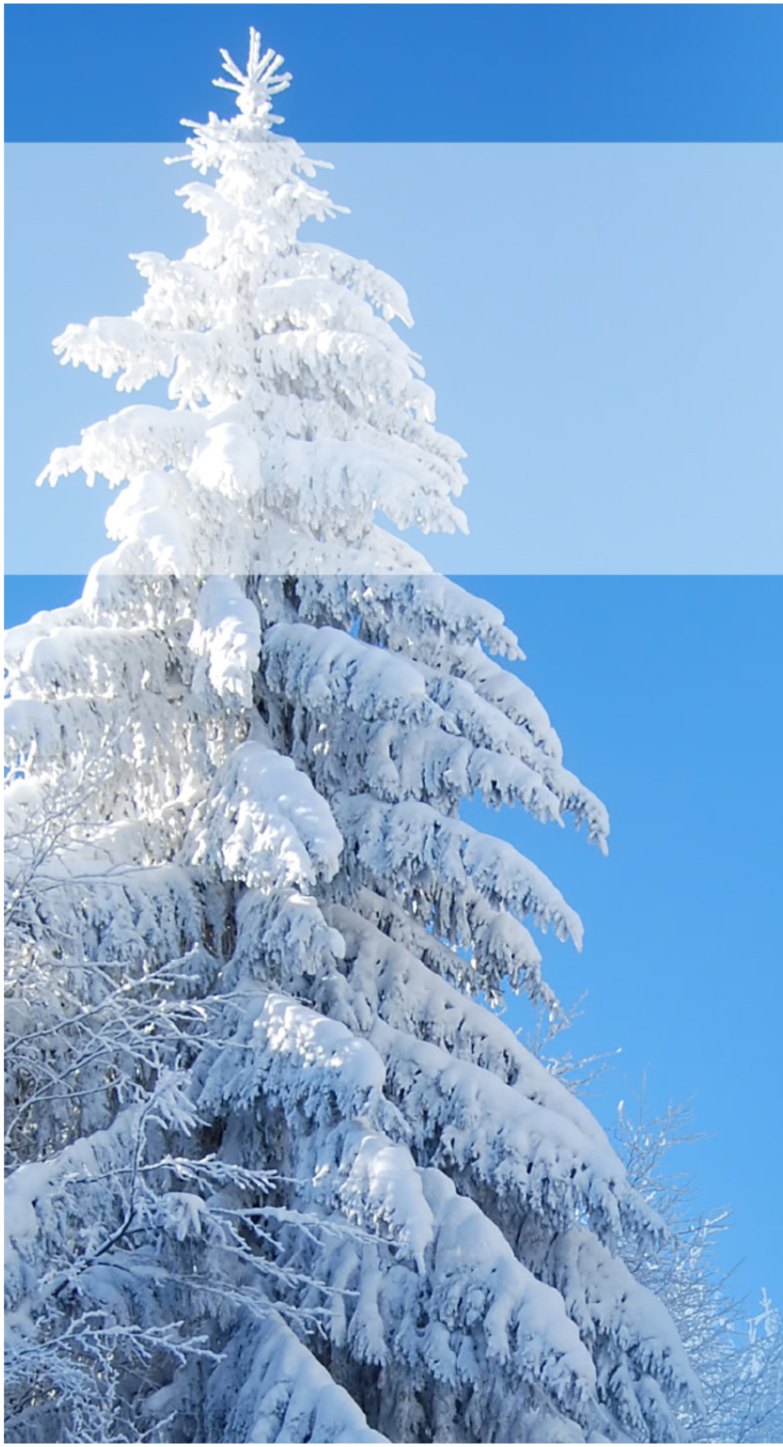

COMPREHENSIVE EDITION

PROGRAMMING AND PROBLEM SOLVING WITH C++

SIXTH EDITION

Nell Dale and Chip Weems

Chapter 15

Inheritance, Polymorphism and Object-Oriented Design

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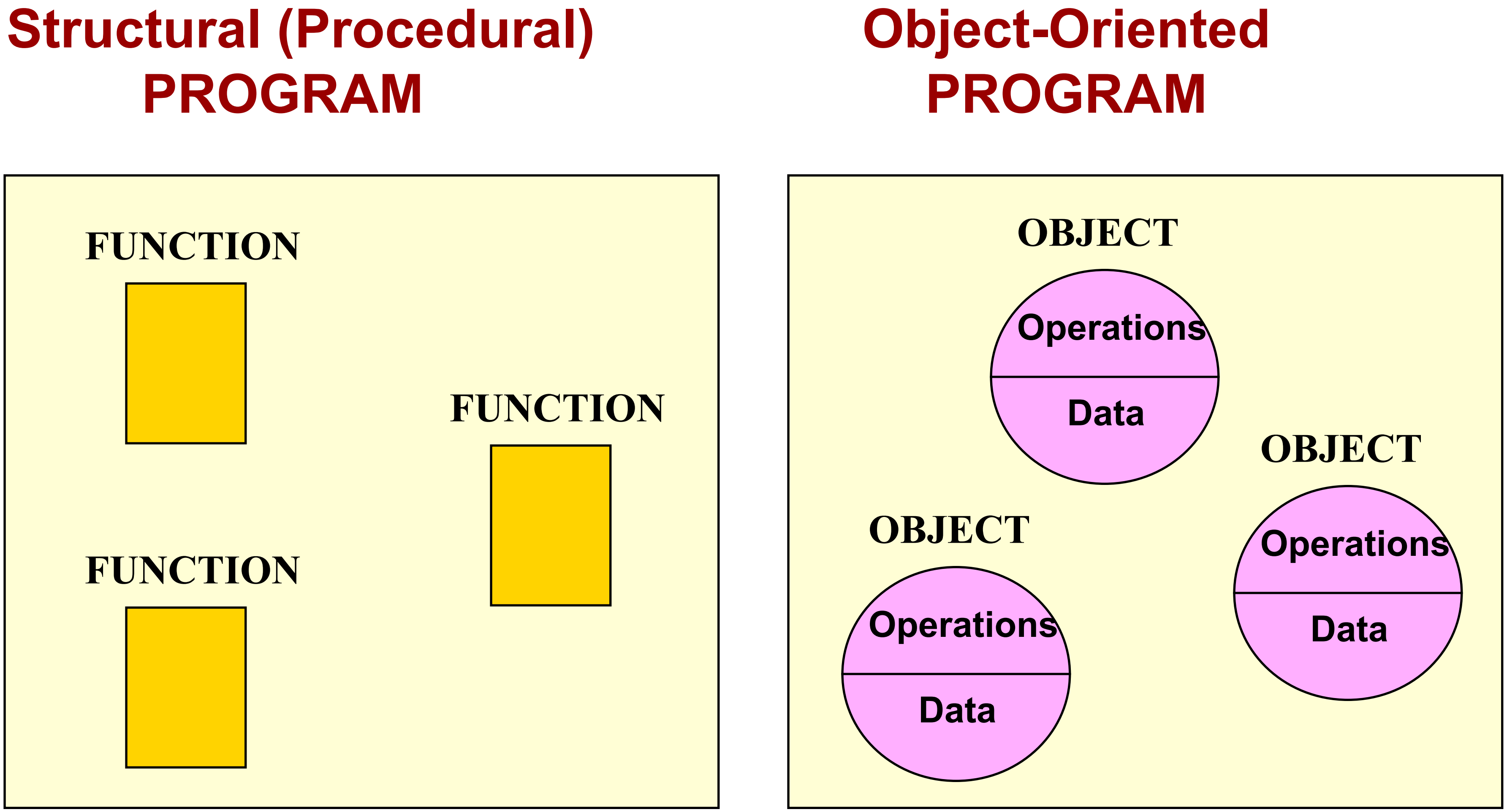
Chapter 15 Topics

- Structured Programming vs. Object-Oriented Programming
- Using Inheritance to Create a New C++ `class` Type
- Using Composition (Containment) to Create a New C++ `class` Type

Chapter 15 Topics

- Static vs. Dynamic Binding of Operations to Objects
- Virtual Member Functions

Two Programming Paradigms



Structural (Procedural) PROGRAM

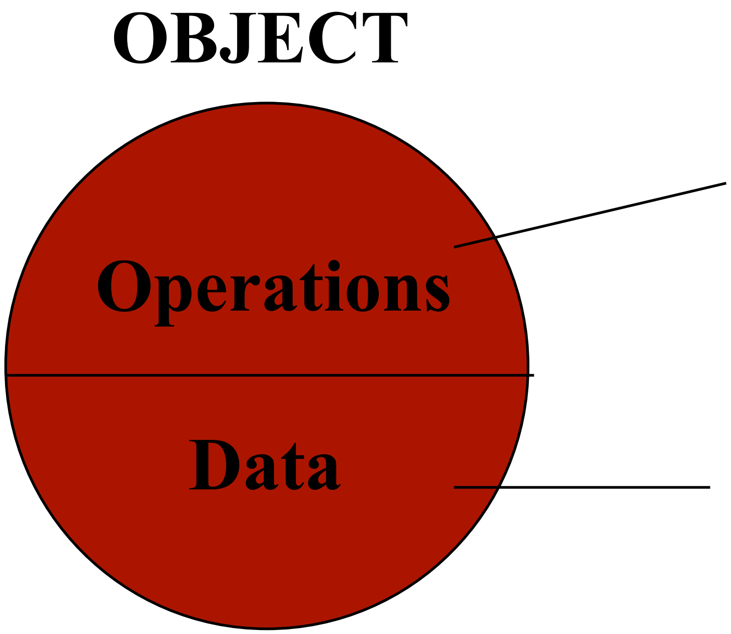
Object-Oriented PROGRAM

Object-Oriented Programming Language Features

1. Data abstraction
2. Inheritance of properties
3. Dynamic binding of operations to objects

OOP Terms	C++ Equivalents
Object	Class object or class instance
Instance variable	Private data member
Method	Public member function
Message passing	Function call (to a public member function)

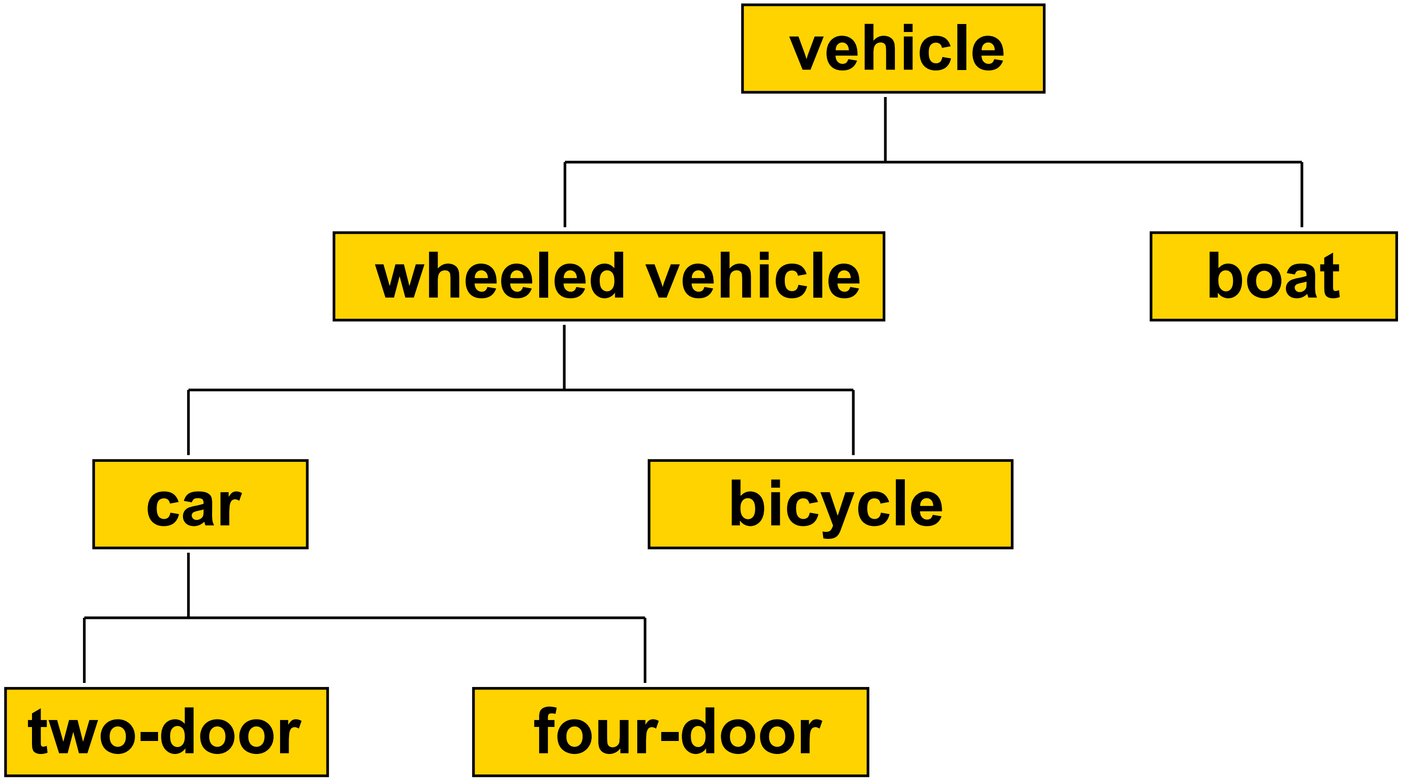
What is an object?



set of methods
(public member functions)

internal state
(values of private data members)

Inheritance Hierarchy Among Vehicles



Every car **is a** wheeled vehicle.

Inheritance

- Inheritance is a mechanism by which one class acquires (inherits) the properties (both data and operations) of another class

- The class being inherited from is the Base Class (Superclass)

Inheritance, cont...

- The class that inherits is the **Derived Class** (Subclass)
- The derived class is specialized by adding properties specific to it

class Time Specification

```
// Specification file (“time.h”)

class  Time
{

public:
    void Set ( int hours, int minutes, int seconds);
    void Increment ();
    void Write ()  const;
    Time ( int initHrs, int initMins, int initSecs);
    // Constructor
    Time ();             // Default constructor
```

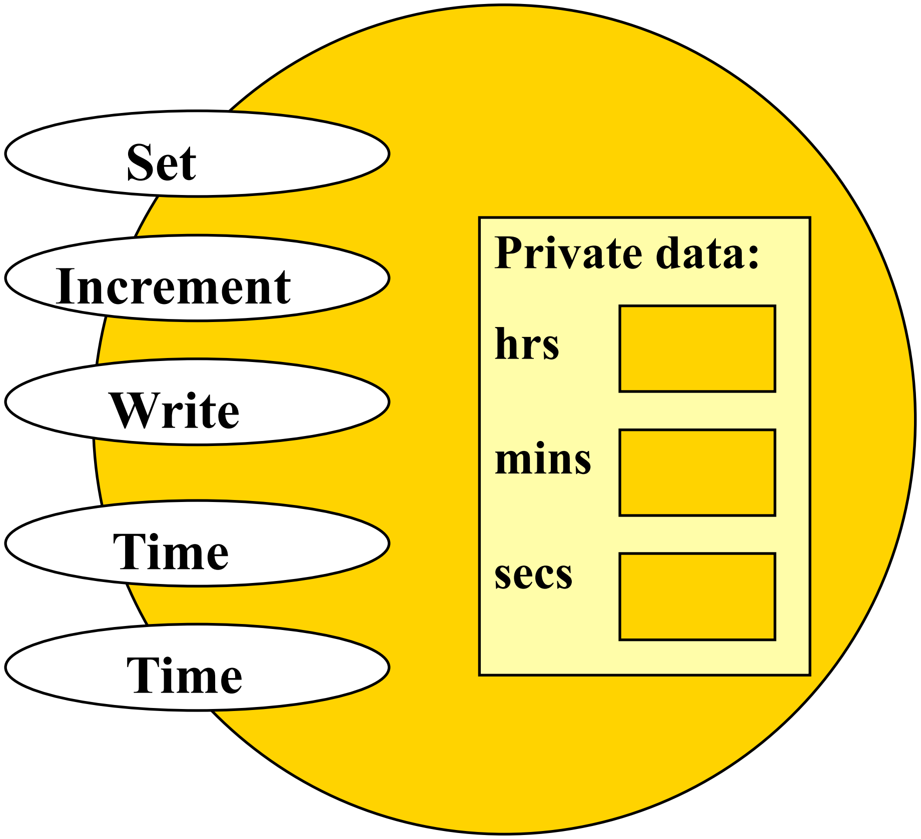
`class Time` Specification

```
private:

    int hrs;
    int mins;
    int secs;
};
```

Class Interface Diagram

`Time` class



Using Inheritance to Add Features

```
// Specification file (“exttime.h”)
#include   “time.h”
enum ZoneType{EST, CST, MST, PST, EDT, CDT, MDT, PDT};

class ExtTime : public Time // Time is the base class
```

Using Inheritance to Add Features

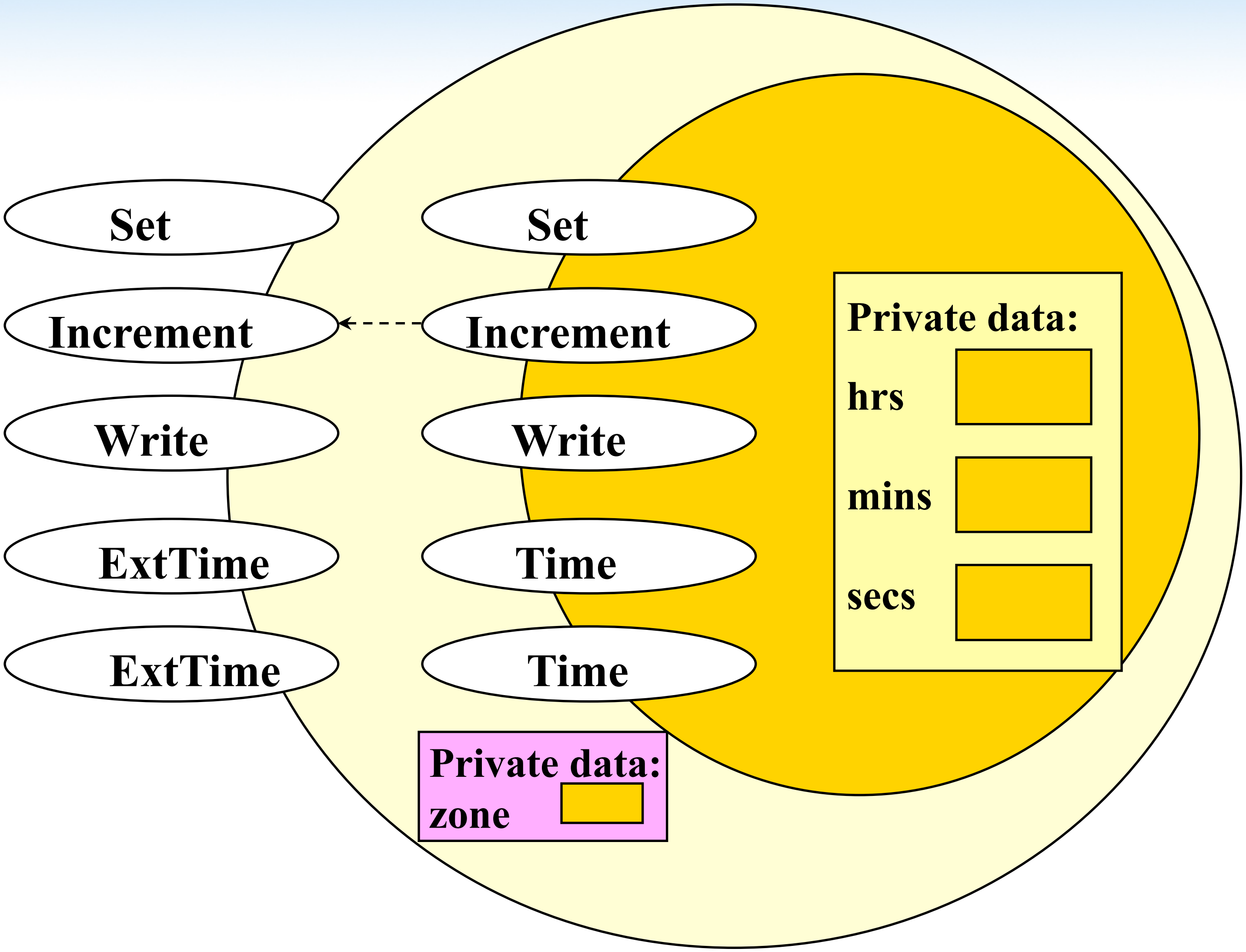
```
{
public:
    void Set(int hours, int minutes, int seconds,
            ZoneType  timeZone);
    void Write ()  const;
    ExtTime ( int  initHrs,  int  initMins,
              int  initSecs, ZoneType  initZone);
    ExtTime ();
private:
    ZoneType  zone; // Additional data member
};
```

`class ExtTime:public Time`

- Says class Time is a public base class of the derived class ExtTime
- As a result, all public members of Time (except constructors) are also public members of ExtTime
- In this example, new constructors are provided, new data member zone added, and member functions Set and Write overridden

Class Interface Diagram

`ExtTime` class



Client Code Using `ExtTime`

```
#include  “exttime.h”
         .
         .
         .
ExtTime  thisTime ( 8, 35, 0, PST);
ExtTime  thatTime; // Default constructor called

thatTime.Write(); // Outputs 00:00:00  EST
cout  <<  endl;
```

Client Code Using `ExtTime`

```
thatTime.Set (16, 49, 23, CDT);
thatTime.Write(); // Outputs 16:49:23  CDT
cout  << endl;

thisTime.Increment ();
thisTime.Increment ();
thisTime.Write (); // Outputs 08:35:02  PST
cout  << endl;
```

Constructor Rules for Derived Classes

- At run time, the base class constructor is implicitly called first, before the body of the derived class' s constructor executes

- If the base class constructor requires parameters, they must be passed by the derived class' s constructor

Implementation of ExtTime Default Constructor

```
ExtTime::ExtTime ( )
// Default  Constructor
// Postcondition:

//    hrs == 0   &&   mins == 0   &&  secs == 0

//     (via an implicit call to base class default
//      constructor)

//     &&  zone == EST
```

Implementation of ExtTime Default Constructor

```
{
     zone  =  EST;
}
```

Implementation of Another ExtTime Class Constructor

```
ExtTime::ExtTime  ( /* in */ int initHrs,
                    /* in */ int initMins,
                    /* in */ int initSecs,
                    /* in */ ZoneType initZone)

           : Time (initHrs, initMins, initSecs)
```

Implementation of Another `ExtTime` Class Constructor

```
// Constructor initializer
// Pre: 0 <= initHrs <= 23 && 0 <= initMins <= 59
//      0 <= initSecs <= 59 && initZone is
//      assigned
// Post: zone == initZone && Time set by base
//      class constructor

{
    zone  = initZone;
}
```

Implementation of `ExtTime::Set` function

```
void  ExtTime::Set  ( /* in */ int initHrs,
                      /* in */ int initMins,
                      /* in */ int initSecs,
                      /* in */ ZoneType initZone)

// Pre: 0 <= initHrs <= 23 && 0 <= initMins <= 59
//      0 <= initSecs <= 59 && initZone is assigned
// Post: zone == timeZone  && Time set by base
//      class function
```

Implementation of `ExtTime::Set` function

```
{
    Time::Set (hours, minutes, seconds);
    zone  = timeZone;
}
```

Implementation of ExtTime::Write Function

```
void ExtTime::Write (   )   const

//   Postcondition:
//  Time has been output in form HH:MM:SS   ZZZ
//       where  ZZZ is the time zone abbreviation
```

Implementation of ExtTime::Write Function

```
{
    static string zoneString[8] = { “EST”, CST”,
        MST”, “PST”, “EDT”, “CDT”, “MDT”, “PDT” };
    Time::Write ();
    cout  << ‘ ‘ <<  zoneString[zone];
}
```

Responsibilities

- **Responsibilities** are operations implemented as C++ functions
- **Action responsibilities** are operations that perform an action
- **Knowledge responsibilities** are operations that return the state of private data variables

What responsibilities are Missing?

The Time class needs

int Hours()

int Minutes()

int Seconds()

The ExtTime class needs

ZoneType zone()

Composition (or Containment)

- **Composition (containment)** is a mechanism by which the internal data (the state) of one class includes an object of another class

An Entry Object

```
#include "Time.h"
#include "Name.h"
#include <string>
class Entry
{
public:
    string NameStr() const;
    // Returns a string made up of first
    // name and last name
    string TimeStr() const;
    // Returns a string made up of hour,
    // colon, minutes
```

An Entry Object

```
Entry();
    // Default constructor
    Entry(……)
    // Parameterized constructor

private:
    Name name;
    Time time;
}
```

Implementation of `ExtTime::Write` Function

```
void ExtTime::Write (   )  const

//  Postcondition:
//Time has been output in form HH:MM:SS  ZZZ
//      where  ZZZ is the time zone abbreviation
```

Implementation of ExtTime::Write Function

```
{
    static string zoneString[8] = { “EST”, CST”,
        MST”, “PST”, “EDT”, “CDT”, “MDT”, “PDT” };
    Time::Write ();
    cout  << ‘ ‘ <<  zoneString[zone];
}
```

Order in Which Constructors are Executed

Given a class X:

- If X is a derived class its base class constructor is executed first
- Next, constructors for member objects, if any, are executed (using their own default constructors if none is specified)
- Finally, the body of X's constructor is executed

In C++ . . .

When the type of a formal parameter is a parent class, the argument used can be

- **the same type as the formal parameter or,**
- **any descendant class type**

Static Binding

- Static binding is the compile-time determination of which function to call for a particular object based on the type of the formal parameter(s)

- When pass-by-value is used, static binding occurs

Static Binding Is Based on Formal Parameter Type

```
void  Print ( /* in */ Time someTime)
{
 cout  <<  “Time is “;
 someTime.Write ( );
 cout  <<  endl;
}
```

CLIENT CODE

```
Time startTime(8, 30, 0);
ExtTime endTime(10,45,0,CST);
Print ( startTime);

Print ( endTime);
```

OUTPUT

```
Time is 08:30:00

Time is 10:45:00 CST
```

Dynamic Binding

- **Dynamic binding** is the **run-time determination** of which function to call for a particular object of a descendant class based on the type of the argument

- Declaring a member function to be **virtual** instructs the compiler to generate code that guarantees dynamic binding

Virtual Member Function

```
// Specification file ( “time.h”)

class  Time
{

public:

      .   .   .

      virtual void Write () const;
      // Forces dynamic binding

      .   .   .
```

Virtual Member Function

```
private:
    int  hrs;
    int  mins;
    int  secs;
};
```

Dynamic binding requires pass-by-reference

```
void Print  ( /* in */ Time& someTime)
{
 cout  <<  “Time is  “;
 someTime.Write ( );
 cout  <<  endl;
}
```

CLIENT CODE

```
Time startTime ( 8, 30, 0);
ExtTime endTime (10,45,0,CST);
Print ( startTime);
Print ( endTime);
```

OUTPUT

```
Time is 08:30:00

Time is 10:45:00 CST
```

Using virtual functions in C++

- Dynamic binding requires **pass-by-reference** when passing a class object to a function

- In the declaration for a virtual function, the word **virtual appears only in the base class**

Using virtual functions in C++

- If a base class declares a virtual function, it must implement that function, even if the body is empty

- A derived class is not required to re-implement a virtual function; if it does not, the base class version is used

Object-Oriented Design

- Identify the Objects and Operations
- Determine the relationship among objects
- Design and Implement the driver

Implementation of the Design

- Choose a suitable data representation
  - Built-in data type
  - Existing ADT
  - Create a new ADT
- Create algorithms for the abstract operations
  - Top-down design is often the best technique to create algorithms for the function tasks

Case Study

- Beginning of the Appointment Calendar Program
- Class Entry composed of a Name class and a Time class
- Current Time class represents active time (seconds with Increment)
- Need a static Time class for time in the appointment calendar

Is inheritance appropriate?