Chapter 12 Topics

- **Meaning of an Abstract Data Type**
- **Declaring and Using a `class` Data Type**
- **Using Separate Specification and Implementation Files**
- **Invoking `class` Member Functions in Client Code**
- **C++ `class` Constructors**

Abstraction

- **Abstraction is the separation of the essential qualities of an object from the details of how it works or is composed**
  - **Focuses on what, not how**
  - **Necessary for managing large, complex software projects**

Control Abstraction

- **Control abstraction separates the logical properties of an action from its implementation:**

```
Search (list, item, length, where,
found);
```

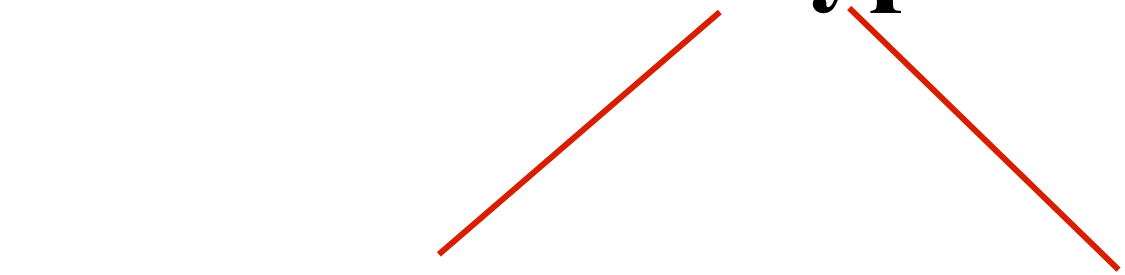
- **The function call depends on the function's specification (description), not its implementation (algorithm)**

Data Abstraction

- **Data abstraction** separates the logical properties of a data type from its implementation

LOGICAL PROPERTIES	IMPLEMENTATION
What are the possible values?	How can this be done in C++?
What operations will be needed?	How can data types be used?

Data Type



set of values (domain)

allowable operations on those values

FOR EXAMPLE, data type `int` has

domain	operations
-32768 . . . 32767	+, -, *, /, %, >>, <<

Abstract Data Type (ADT)

- An **abstract data type** is a data type whose properties (domain and operations) are specified (*what*) independently of any particular implementation (*how)*

For example . . .

ADT Specification Example

TYPE

Time

DOMAIN

Each Time value is a time in hours, minutes, and seconds.

OPERATIONS

Set the time

Print the time

Increment by one second

Compare 2 times for equality

Determine if one time is “less than” another

Another ADT Specification

TYPE

ComplexNumber

DOMAIN

Each value is an ordered pair of real numbers (a, b) representing a + b*i*

Another ADT Specification, cont...

OPERATIONS

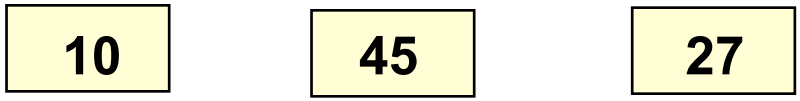
- Initialize the complex number
- Write the complex number
- Add
- Subtract
- Multiply
- Divide
- Determine the absolute value of a complex number

ADT Implementation

- **ADT implementation**
  - **Choose a specific data representation for the abstract data using data types that already exist (built-in or programmer-defined)**
  - **Write functions for each allowable operation**

Several Possible Representations of ADT `Time`

3 int variables



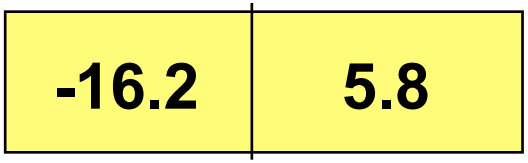
3 strings

3-element int array

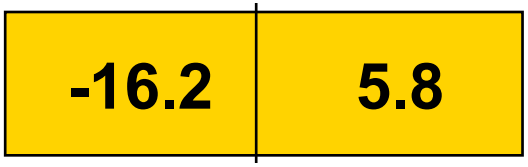
Choice of representation depends on time, space, and algorithms needed to implement operations

Some Possible Representations of ADT `ComplexNumber`

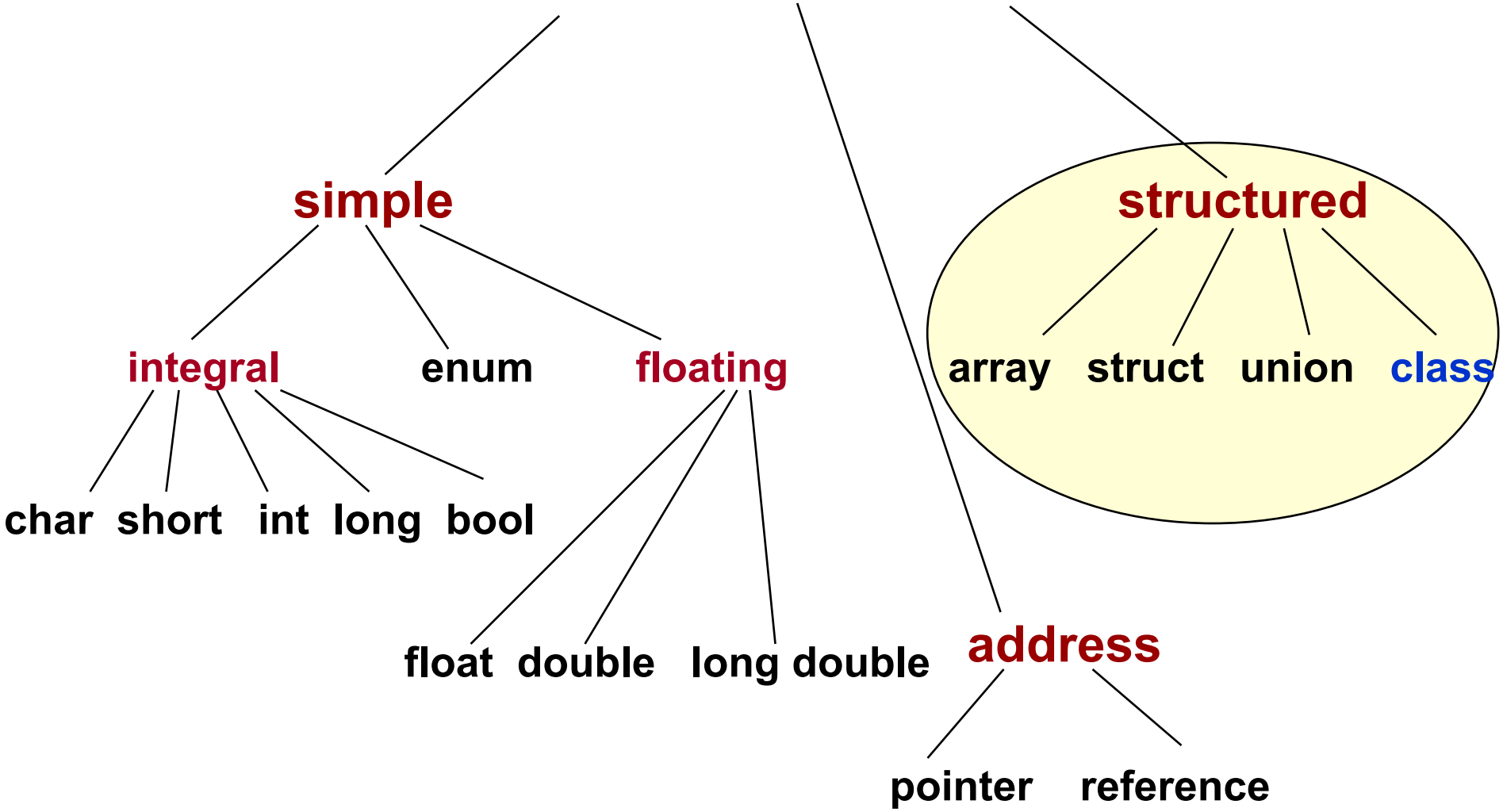
struct with 2 float members



2-element float array



C++ Data Types


simple
integral
enum
floating
char
short
int
long
bool
float
double
long double
structured
array
struct
union
class
address
pointer
reference

class Time Specification

```
class  Time      // Declares a  class data
  type
{                //  does not allocate memory
public :  // Five public function members

    void  Set (int  hours , int  mins , int
  secs);
    void  Increment ();
    void  Write ()  const;
    bool  Equal (Time   otherTime)  const;
    bool  LessThan (Time   otherTime)  const;

private :  // Three private data members

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

C++ `classType`

- Facilitates re-use of C++ code for an ADT
- Software that uses the class is called a client
- Variables of the class type are called class objects or class instances
- Client code uses class's public member functions to manipulate class objects

Client Code Using `Time`

```
// Includes specification of the class
#include   "time.h"

using  namespace  std;

int  main ()
{
   Time  currentTime; // Declares two objects of Time
   Time  endTime;
   bool  done  =  false;

   currentTime.Set (5, 30, 0);
   endTime.Set (18, 30, 0);
   while  (! done)    {
      .  .  .

      currentTime.Increment ();
      if  (currentTime.Equal (endTime))
         done  =  true;
   };
}
```

class type Declaration

- The class declaration creates a data type and names the members of the class
- It does not allocate memory for any variables of that type!
- Client code still needs to declare class variables

Remember …

- Two kinds of class members:

  1) data members and 2) function members

- Class members are private by default

Remember as well . . .

- Data members are generally private
- Function members are generally declared public
- Private class members can be accessed only by the class member functions (and friend functions), not by client code

Aggregate `class` Operations

- **Built-in operations valid on class objects are:**
  - **Member selection using dot (.) operator ,**
  - **Assignment to another class variable using (=),**
  - **Pass to a function as argument (by value or by reference),**

Aggregrate `class` Operations

- **Built-in operations valid on class objects a also:**
  - **Return as value of a function**

  Other operations can be defined as class member functions

Separate Specification and Implementation

```
// Specification file "time.h"
// Specifies the data and function members
class Time
{
  public:
                . . .

  private:
                . . .
 };
```

Separate Specification and Implementation

```
// Implementation file "time.cpp"
// Implements the Time member functions
 {
      ...
 }
```

Implementation File for `Time`

```
// Implementation file "time.cpp"
// Implements the Time member functions.
// Also must appear in client code:
#include "time.h"
#include  <iostream>

bool Time::Equal(/* in */  Time otherTime) const
// Postcondition:  Return value == true,
//      if this time equals otherTime,
//      otherwise == false
{
    return ((hrs == otherTime.hrs)
          && (mins == otherTime.mins)
          && (secs  == otherTime.secs));
}
```

Should be familiar …

- The member selection operator (.) selects either data members or function members
- Header files iostream and fstream declare the istream, ostream,and ifstream, ofstream I/O classes

Should be familiar. . .

- Both cin and cout are class objects and get and ignore are function members:

```
cin.get (someChar);
cin.ignore (100, '\n');
```

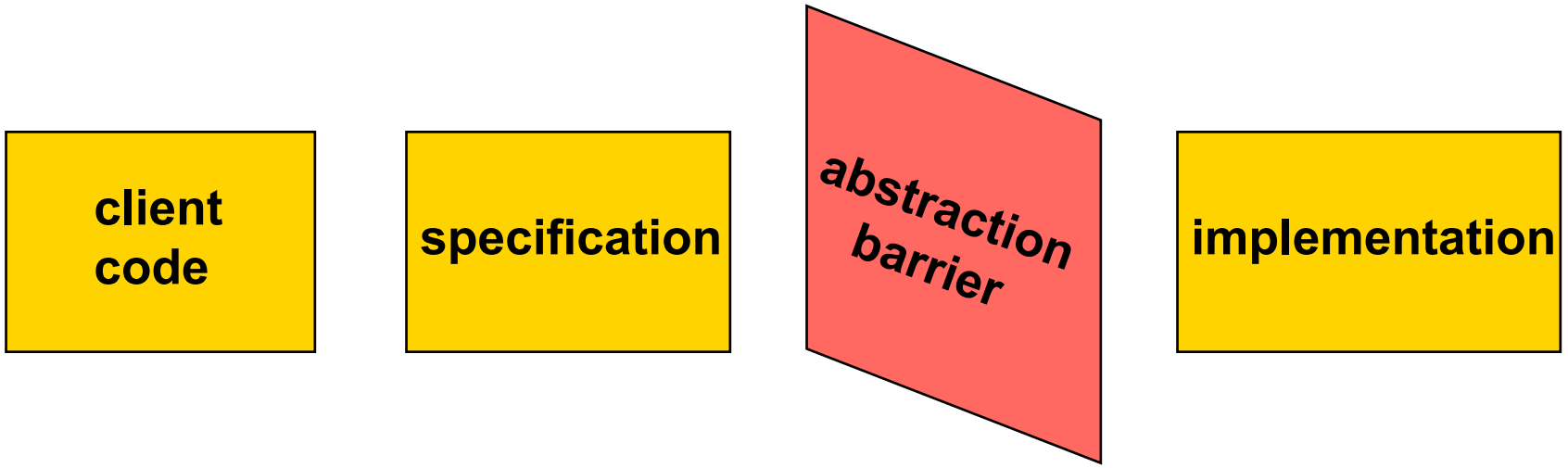
- These statements declare myInfile as an instance of class ifstream and invoke function member open :

```
ifstream  myInfile;
myInfile.open ("mydata.dat");
```

Information Hiding

Information hiding - Class implementation details are hidden from the client's view

Public functions of a class provide the interface between the client code and the class objects



Selection and Resolution

- C++ programs typically use several class types
- Different classes can have member functions with the same identifier, like Write()

Selection and Resolution

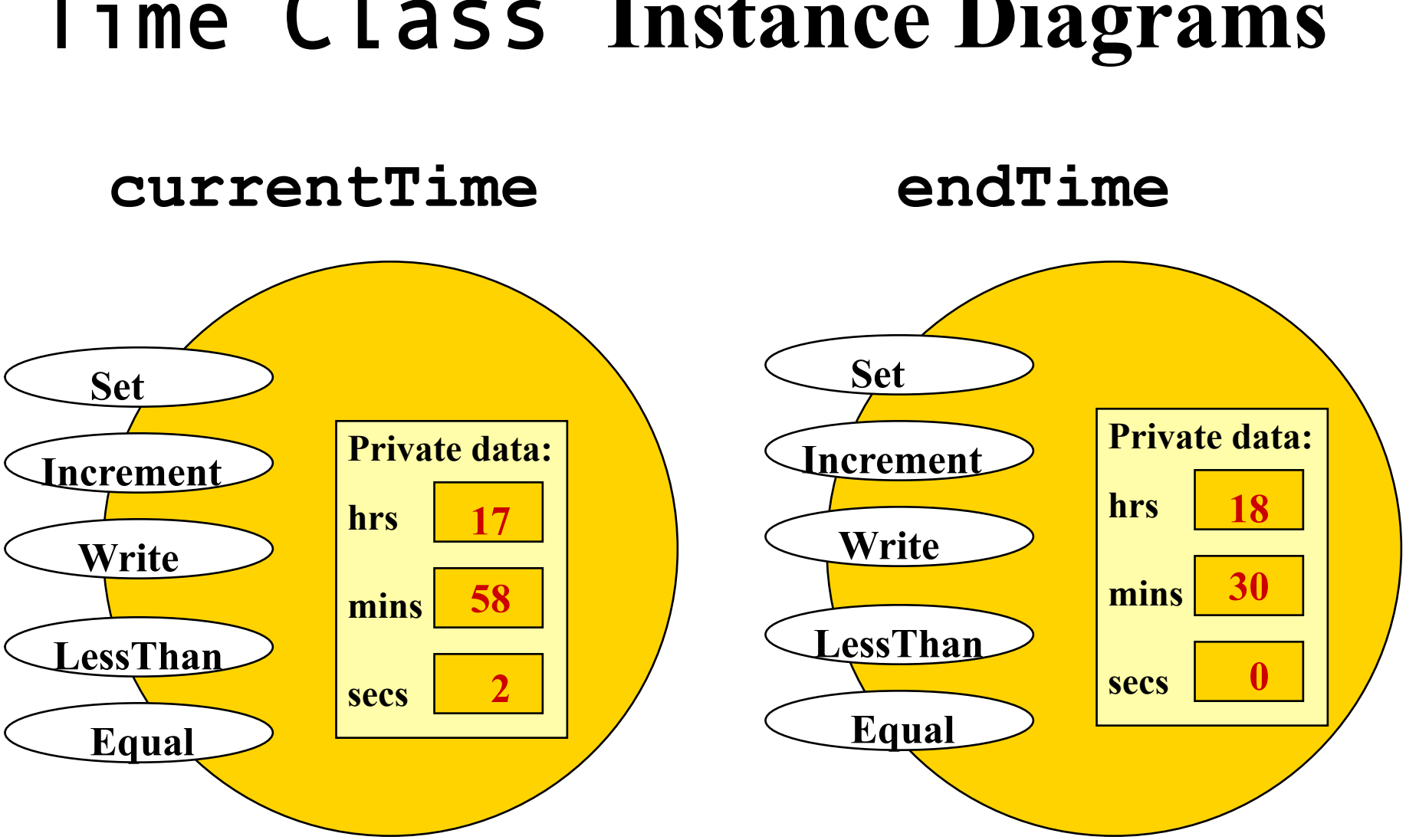
- Member **selection operator** is used to determine the object to whom member function Write() is applied

```
currentTime.Write(); // Class Time
numberZ.Write(); // Class ComplexNumber
```

- In the implementation file, the **scope resolution** operator is used in the heading before the function member's name to specify its class

```
void  Time::Write () const
{          . . .
}
```

Time Class Instance Diagrams



Use of `const` with Member Functions

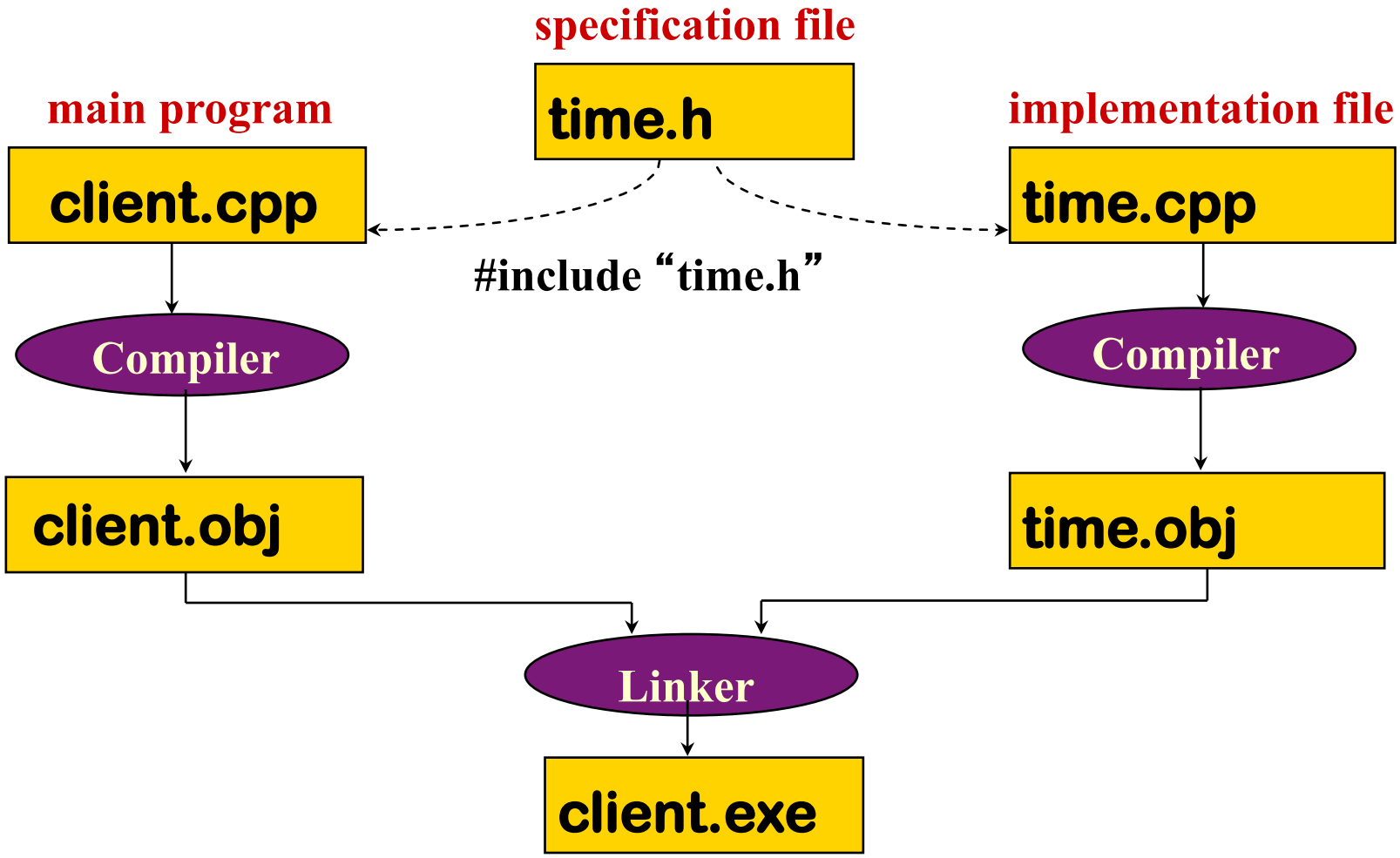
- When a member function does not modify the private data members:

- Use `const` in both the function prototype (in specification file) and the heading of the function definition (in implementation file)

Example Using `const` with a Member Function

```
void Time::Write ()   const
// Postcondition: Time has been output in form
//   HH:MM:SS
{
    if  (hrs < 10)
        cout << '0';
    cout  << hrs  <<  ':';
    if  (mins < 10)
        cout << '0';
    cout  << mins  <<  ':';
    if  (secs < 10)
        cout << '0';
    cout  << secs;
}
```

Separate Compilation and Linking of Files



Avoiding Multiple Inclusion of Header Files

- Often several program files use the same header file containing typedef statements, constants, or class type declarations
- But, it is a compile-time error to define the same identifier twice within the same namespace

Avoiding Multiple Inclusion of Header Files

- This preprocessor directive syntax is used to avoid the compilation error that would otherwise occur from multiple uses of #include for the same header file

```
#ifndef   Preprocessor_Identifier
#define   Preprocessor_Identifier
    .
    .
    .
#endif
```

Example Using Preprocessor Directive `#ifndef`

```
// time .h
// Specification file

#ifndef   TIME_H
#define  TIME_H

class Time
{
    public:
     . . .

    private:
     . . .
};
#endif
```

For compilation the class declaration in File time.h will be included only once

```
// time .cpp
// IMPLEMENTATION FILE

#include "time.h"

          . . .
```

```
// client.cpp
// Appointment program

#include "time.h"

 int   main (void)
 {
      . . .
 }
```

Class Constructors

- A **class constructor** – a member function whose purpose is to initialize the private data members of a class object

- The name of a constructor is always the name of the class, and there is no return type for the constructor

Class Constructors

- A class may have several constructors with different parameter lists
- A constructor with no parameters is the default constructor
- A constructor is implicitly invoked when a class object is declared
- If there are parameters, their values are listed in parentheses in the declaration

Specification of `Time` Class Constructors

```
class  Time      // Time.h
{
public :   //  7 function members
     void Set(int hours, int minutes, int seconds);
     void Increment();
     void Write()  const;
     bool Equal(Time otherTime)  const;
     bool LessThan(Time otherTime)  const;

     // Parameterized constructor
     Time (int initHrs, int initMins, int initSecs);
     // Default constructor
     Time();
private :  //  3 data members
     int hrs;
     int mins;
     int secs;
};
```

Implementation of `Time` Default Constructor

```
Time::Time ()
// Default  Constructor
// Postcondition:
// hrs == 0 && mins == 0 &&  secs == 0
{
    hrs  = 0;
    mins = 0;
    secs = 0;
}
```

Parameterized Constructor

```
Time::Time( /* in */   int   initHrs,
            /* in */   int   initMins,
            /* in */   int   initSecs)
//  Constructor
//  Precondition:
//    0 <= initHrs <= 23 && 0 <= initMins <= 59
//    0 <= initSecs <= 59
//  Postcondition:
//     hrs == initHrs && mins == initMins
//    && secs == initSecs
{
    hrs  =  initHrs;
    mins =  initMins;
    secs =  initSecs;
}
```

Automatic invocation of constructors occurs

```
Time departureTime;  // Default constructor invoked

Time movieTime (19, 30, 0); // Parameterized constructor
```