4 Initializing and Finalizing Objects

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- Destructor

Initializing Objects: Constructors

- The class designer can guarantee initialization of every object by providing a special member function called the constructor.
- The constructor is invoked automatically each time an object of that class is created (instantiated).
- These functions are used to (for example) assign initial values to the data members, open files, establish connection to a remote computer etc.
- The constructor can take parameters as needed, but it cannot have a return value (even not void).

Initializing Objects: Constructors

- The constructor has the same name as the class itself.
- Constructors are generally public members of a class.
- There are different types of constructors.
- For example, a constructor that defaults all its arguments or requires no arguments, i.e. a constructor that can be invoked with no arguments is called default constructor.
- In this section we will discuss different kinds of constructors.

Default Constructors

- A constructor that <u>defaults all its arguments</u> or <u>requires no arguments</u>, i.e. a constructor that can be invoked with no arguments.

```
class Point{                          // Declaration Point Class
   int x,y;                           // Properties: x and y coordinates
 public:
   Point();                           // Declaration of the default constructor
   bool move(int, int);               // A function to move points
   void print();                      // to print coordinates on the screen
};

Point::Point() {        // Default Constructor
   cout << "Constructor is called..." << endl;
   x = 0;  // Assigns zero to coordinates
   y = 0;
}

int main() {
   Point p1, p2;                      // Default construct is called 2 times
   Point *pp = new Point;             // Default construct is called once
```

Constructors with Parameters

- Like other member functions, constructors may also have parameters.
- Users of the class (client programmer) must supply constructors with necessary arguments.

```
class Point{                          // Declaration Point Class
   int x,y;                           // Properties: x and y coordinates
 public:
   Point(int, int);                   // Declaration of the constructor
   bool move(int, int);               // A function to move points
   void print();                      // to print coordinates on the screen
};
```

- This declaration shows that the users of the Point class have to give two integer arguments while defining objects of that class.

Example: Constructors with Parameters


```
Point::Point(int x_first, int y_first) {
    cout << "Constructor is called..." << endl;
    if ( x_first < 0 )              // If the given value is negative
        x = 0;                      // Assigns zero to x
    else
        x = x_first;
    if ( y_first < 0 )              // If the given value is negative
        y = 0;                      // Assigns zero to x
    else
        y = y_first;
}
// -------- Main Program -------------
int main() {
    Point p1(20, 100), p2(-10, 45);      // Construct is called 2 times
    Point *pp = new Point(10, 50);       // Construct is called once
    Point p3;       // ERROR! There is not a default constructor
    :
}
```

Constructor Parameters with Default Values

- Constructors parameters may have default values

```
class Point{
  public:
     Point(int x_first = 0,  int y_first = 0);
     :
};
Point::Point(int x_first,  int y_first) {
    if ( x_first < 0 )          // If the given value is negative
       x = 0;                   // Assigns zero to x
    else           x = x_first;
    if ( y_first < 0 )          // If the given value is negative
       y = 0;                   // Assigns zero to x
    else    y = y_first;
}
```

- Now, client of the class can create objects

```
Point p1(15,75);          // x=15, y=75
Point p2(100);            // x=100, y=0
```

- This function can be also used as a default constructor

```
Point p3;    // x=0, y=0
```

Multiple Constructors

- The rules of function overloading is also valid for constructors. So, a class may have more than one constructor with different type of input parameters.

```
Point::Point() {                                   // Default constructor
    ...............                        // Body is not important
}

Point::Point(int x_first, int y_first) { // A constructor with parameters
    .................                      // Body is not important
}
```

- Now, the client programmer can define objects in different ways:

```
Point p1;                  // Default constructor is called
Point p2(30, 10);          // Constructor with parameters is called
```

- The following statement causes an compiler error, because the class does not include a constructor with only one parameter.

```
Point p3(10);              //ERROR! There isn't a constructor with one parameter
```

Initializing Arrays of Objects

► When an array of objects is created, the default constructor of the class is invoked for each element (object) of the array one time.

```
Point  array[10];  // Default constructor is called 10 times
```

► To invoke a constructor with arguments, a list of initial values should be used.

► To invoke a constructor with more than one arguments, its name must be given in the list of initial values, to make the program more readable.

Initializing Arrays of Objects *Con't*

- *// Constructor*

```
Point(int x_first,  int y_first = 0)  { .... }
// Can be called with one or two args
```

- *// Array of Points*

```
Point array[]= { {10} , {20} , Point(30,40) };
```

- Three objects of type Point has been created and the constructor has been invoked three times with different arguments.

Objects:	Arguments:
array[0]	x_first = 10 , y_first = 0
array[1]	x_first = 20 , y_first = 0
array[2]	x_first = 30 , y_first = 40

Initializing Arrays of Objects *Con't*

- If the class has also a default constructor the programmer may define an array of objects as follows:

  Point array[5]= { {10} , {20} , Point(30,40) };

- Here, an array with 5 elements has been defined, but the list of initial values contains only 3 values, which are sent as arguments to the constructors of the first three elements. For the last two elements, the default constructor is called.
- To call the default constructor for an object, which is not at the end of the array

  Point array[5]= { {10} , {20}, Point() , Point(30,40) };

- Here, for objects array[2] and array[4] the default constructor is invoked.

  Point array[5]= { {10} , {20} , , Point(30,40) }; // ERROR!

Constructor Initializers

► Instead of assignment statements constructor initializers can be used to initialize data members of an object.

► Specially, to assign initial value to a constant member using the constructor initializer is the only way.

► Consider the class:

```
class C{
    const int CI;
    int x;
 public:
    C( ) {
        x = 0;
        CI = 0;
    }
};
```

```
class C{
    const int CI = 10 ;
    int x;
};
```

Solution

The solution is to use a constructor initializer.

```
class C{
    const int CI;
    int x;
  public:
    C() : CI(0) {
          x = -2;
    }
};
```

```
class C{
    const int CI;
    int x;
  public:
    C( int a ) : CI(0), x (a)
      { }
};
```

All data members of a class can be initialized by using constructor initializers.

Destructors

- The destructor is very similar to the constructor except that it is called automatically
  1. when each of the objects goes out of scope or
  2. a dynamic object is deleted from memory by using the delete operator.
- A destructor is characterized as having the same name as the class but with a tilde '~' preceded to the class name.
- A destructor has no return type and receives no parameters.
- A class may have only one destructor.

Example


```
class String{
   int size;           // Length (number of chars) of the string
   char *contents;     // Contents of the string
 public:
  String(const char *); // Constructor
  void print();           // An ordinary member function
 ~String();               // Destructor
};
```

- Actually, the standard library of C++ contains a **string** class. Programmers don't need to write their own string class. We write this class only to show some concepts.

```
// Constructor : copies the input character array that terminates with a null character
// to the contents of the string
String::String(const char *in_data) {
    cout<< "Constructor has been invoked" << endl;
    size = strlen(in_data);             // strlen is a function of the cstring library
    contents = new char[size +1];       // +1 for null ( '\0' ) character
    strcpy(contents, in_data);          // input_data is copied to the contents
 }
void String::print() {
    cout << contents << " " << size << endl;
}
// Destructor: Memory pointed by contents is given back
String::~String() {
    cout << "Destructor has been invoked" << endl;
    delete[] contents;
}
```

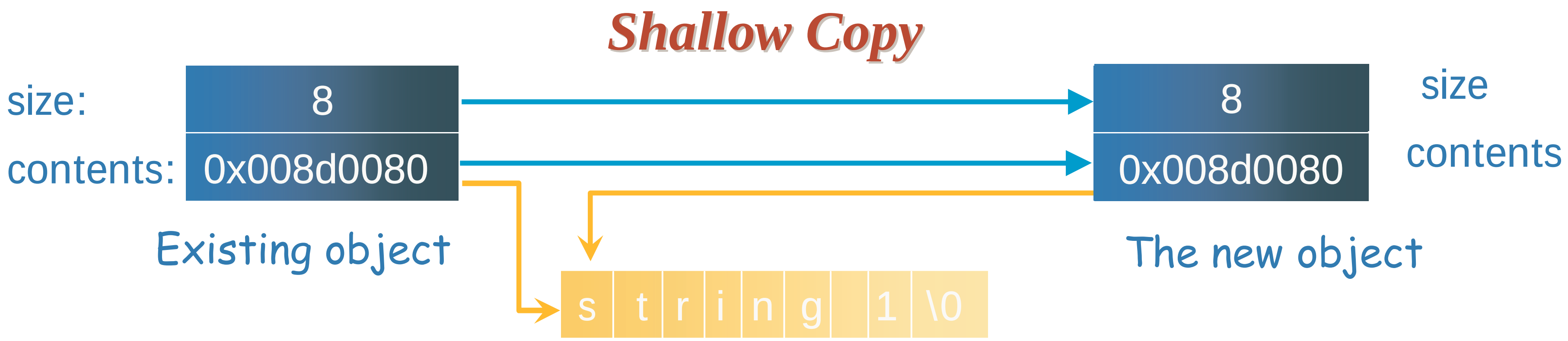
```
int main() {
    String string1("string 1");
    String string2("string 2");
    string1.print();
    string2.print();
    return 0; // destructor is called twice
}
```

Copy Constructor

- It is a special type of constructors and used to copy the contents of an object to a new object during construction of that new object.
- The type of its input parameter is a reference to objects of the same type. It takes as argument a reference to the object that will be copied into the new object.
- The copy constructor is generated automatically by the compiler if the class author fails to define one.
- If the compiler generates it, it will simply copy the contents of the original into the new object as a byte by byte copy.
- For simple classes with no pointers, that is usually sufficient, but if there is a pointer as a class member so a byte by byte copy would copy the pointer from one to the other and they would both be pointing to the same allocated member.

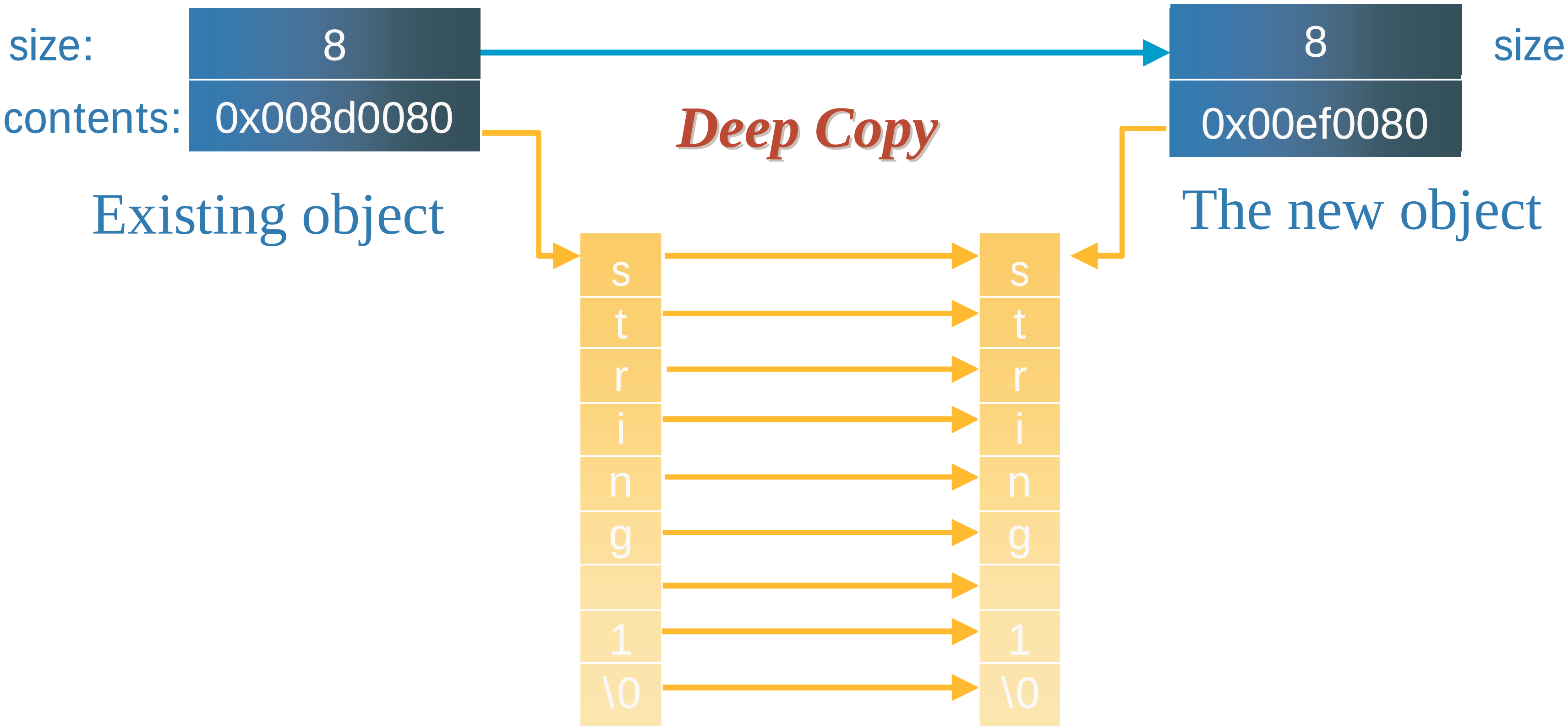
Copy Constructor *Con't*

- For example the copy constructor, generated by the compiler for the String class will do the following job:



Copy Constructor *Con't*

- The copy constructor, generated by the compiler can not copy the memory locations pointed by the member pointers.
- The programmer must write its own copy constructor to perform these operations.



Example: The copy constructor of the String class

```
class String {
    int size;
    char *contents;
 public:
    String(const char *);                    // Constructor
    String(const String &);                  // Copy Constructor
    void print();                            // Prints the string on the screen
    ~String();                               // Destructor
};

String::String(const String &object_in) {   // Copy Constructor
    cout<< "Copy Constructor has been invoked" << endl;
    size = object_in.size;
    contents = new char[size + 1];           //  +1 for null character
    strcpy(contents, object_in.contents);
}

int main() {
    String my_string("string 1");
    my_string.print();
    String other = my_string;                // Copy constructor is invoked
    String more(my_string);                  // Copy constructor is invoked
```

Constant Objects and Const Member Functions

- The programmer may use the keyword const to specify that an object is not modifiable.
- Any attempt to modify (to change the attributes) directly or indirectly (by calling a function) causes a compiler error.

```
const TComplex cz(0,1);    // constant object
```

- C++ compilers totally disallow any member function calls for const objects. The programmer may declare some functions as const, which do not modify any data of the object. Only const functions can operate on const objects.

```
void print() const     // constant method
{
  cout << “complex number= “ << real << “, “ << img;
}
```

```
// Constant function: It prints the coordinates on the screen
void Point::print() const
{
    cout << "X= " << x << ", Y= " << y << endl;
}

// -------- Main Program -------------
int main()
{
    const Point cp(10,20);        // constant point
    Point ncp(0,50);              // non-constant point
    cp.print();                   // OK. Const function operates on const object
    cp.move(30,15);               // ERROR! Non-const function on const object
    ncp.move(100,45);             // OK. ncp is non-const
    return 0;
}
```

- A const method can invoke only other const methods, because a const method is not allowed to alter an object's state either directly or indirectly, that is, by invoking some nonconst method.

```
class TComplex{
   float real,img;
 public:
   TComplex(float, float);    // constructor
   void print() const;            // const method
   void reset() {real=img=0;}   // non-const method
};

TComplex::TComplex(float r=0,float i=0){
     real=r;
     img=i;
}

void TComplex::print() const {     // const method
      std::cout << "complex number= " << real << ", " << img;
}
```

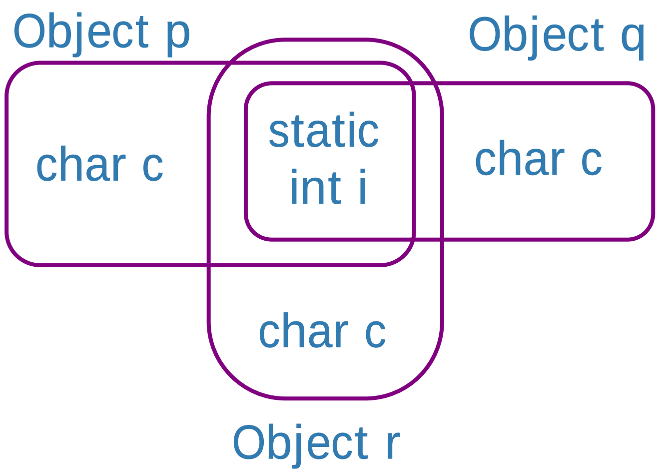
```
int main() {
 const TComplex cz(0,1);    // constant object
 TComplex ncz(1.2,0.5)        // non-constant object
 cz.print();  // OK
 cz.reset(); // Error !!!
 ncz.reset();  // OK
}
```

static Class Members

- Normally, each object of a class has its own copy of all data members of the class.
- In certain cases only one copy of a particular data member should be shared by all objects of a class. A static data member is used for this reason.

```
class A{
   char c;
   static int i;
};

int main()
{
    A   p, q, r;
    :
}
```



static Class Members

- Static data members exist even no objects of that class exist.
- Static data members can be public or private.
- To access public static data when no objects exist use the class name and binary scope resolution operator.

  for example **A::i= 5;**
- To access private static data when no objects exist, a public **static member function** must be provided.
- They must be initialized **once** (and only once) at file scope.

```
class A {
  char c;
  static int count; //  Number of created objects (static data)
 public:
  static void GetCount(){return count;}
  A(){count ++; std::cout<< std::endl << "Constructor " << count;}
 ~A(){count--; std::cout<< std::endl << "Destructor " << count;}
};
int A::count=0;     // Allocating memory for number
```

```
int main(){
 std::cout<<"\n Entering 1. BLOCK...........";
 A a,b,c;
  {
   std::cout<<"\n Entering 2. BLOCK...........";
   A d,e;
   std::cout<<"\n Exiting 2. BLOCK...........";
  }
  std::cout<<"\n Exiting 1. BLOCK...........";
}
```

Entering 1. BLOCK...........
Constructor 1
Constructor 2
Constructor 3
Entering 2. BLOCK...........
Constructor 4
Constructor 5
Exiting 2. BLOCK...........
Destructor 5
Destructor 4
Exiting 1. BLOCK...........
Destructor 3
Destructor 2
Destructor 1

Passing Objects to Functions as Arguments

- Objects should be passed or returned by reference unless there are compelling reasons to pass or return them by value.
- Passing or returning by value can be especially inefficient in the case of objects. Recall that the object passed or returned by value must be copied into stack and the data may be large, which thus wastes storage. The copying itself takes time.
- If the class contains a copy constructor the compiler uses this function to copy the object into stack.
- We should pass the argument by reference because we don't want an unnecessary copy of it to be created. Then, to prevent the function from accidentally modifying the original object, we make the parameter a const reference.

```
ComplexT & ComplexT::add(const ComplexT& z) {
    ComplexT  result;          // local object
    result.re = re + z.re;
    result.im = im + z.im;
    return result;             // ERROR!
}
```

Remember, local variables can not be returned by reference.

Avoiding Temporary Objects

- In the previous example, within the add function a temporary object is defined to add two complex numbers.
- Because of this object, constructor and destructor are called.
- Avoiding the creation of a temporary object within add() saves time and memory space.

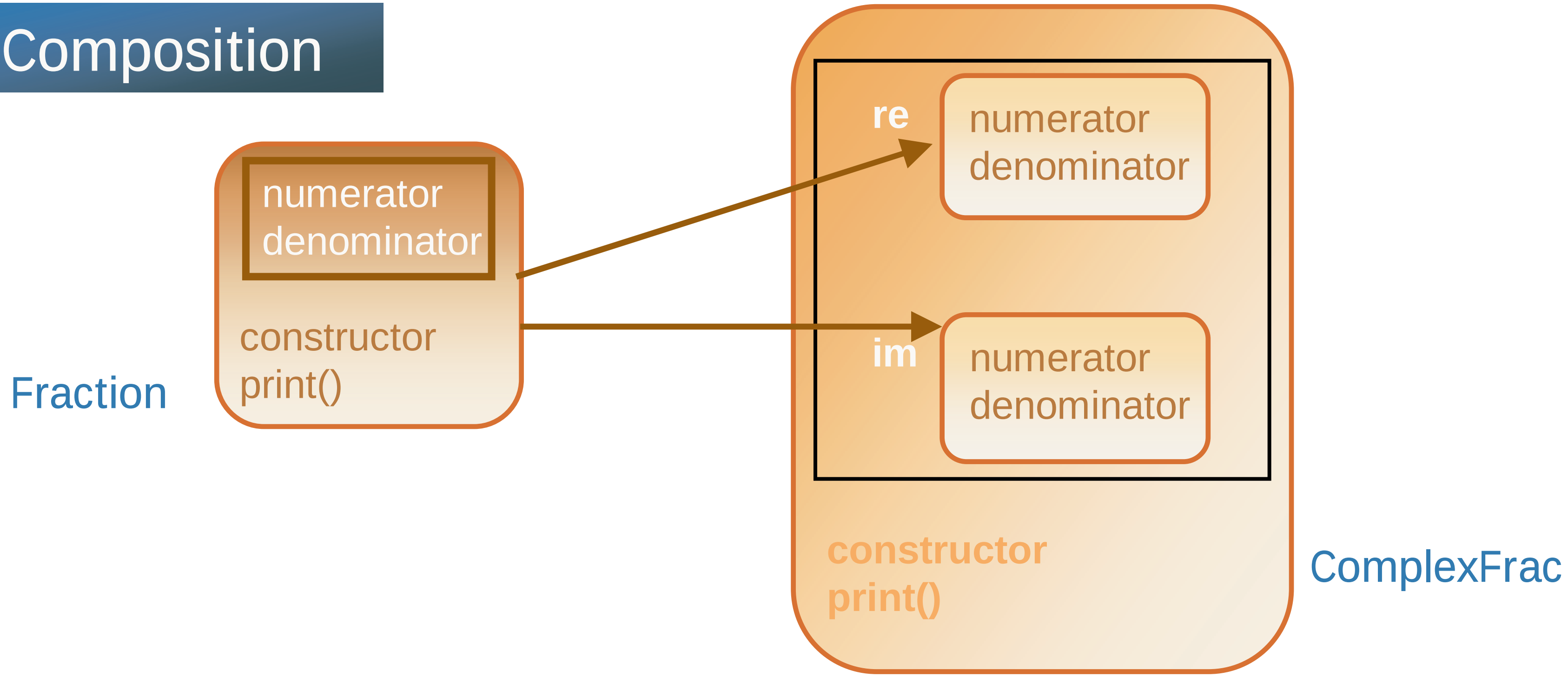
```
ComplexT ComplexT::add(const ComplexT& c)  {
    double  re_new,im_new;
    re_new = re + c.re;
    im_new = im + c.im;
    return ComplexT(re_new,im_new);  // Constructor is called
}
```

- The only object that's created is the return value in stack, which is always necessary when returning by value.
- This could be a better approach, if creating and destroying individual member data items is faster than creating and destroying a complete object.

Nesting Objects: Classes as Members of Other Classes

- A class may include objects of other classes as its data members.
- In the example, a class is designed (ComplexFrac) to define complex numbers. The data members of this class are fractions which are objects of another class (Fraction).

Composition



Composition & Aggregation

- The relation between Fraction and ComplexFrac is called "**has a relation**". Here, ComplexFrac has a Fraction (actually two Fractions).
- Here, the author of the class ComplexFrac has to supply the constructors of its object members (re , im) with necessary arguments.
- Member objects are constructed in the order in which they are declared and before their enclosing class objects are constructed.

Example: A class to define fractions

```
class Fraction{                                     // A class to define fractions
    int numerator, denominator;
 public:
    Fraction(int, int);                             // CONSTRUCTOR
    void print() const;
};

Fraction::Fraction(int num, int denom)              // CONSTRUCTOR
{
    numerator = num;
    if (denom==0) denominator = 1;
    else denominator = denom;
            cout << "Constructor of Fraction" << endl;
}

void Fraction::print() const
{
    cout << numerator << "/" << denominator << endl;
}
```

Example: A class to define complex numbers. It contains two objects as members

```
class ComplexFrac {   //  Complex numbers, real and imag. parts are fractions
   Fraction re, im;  //  objects as data members of another class
 public:
   ComplexFrac(int,int);     // Constructor
   void print() const;
 };

ComplexFrac::ComplexFrac(int re_in, int im_in) : re(re_in, 1) , im(im_in, 1)
{
      :
}
void ComplexFrac::print() const  {
    re.print();
    im.print();
}
int main()  {
     ComplexFrac cf(2,5);
     cf.print();
     return 0;
}
```

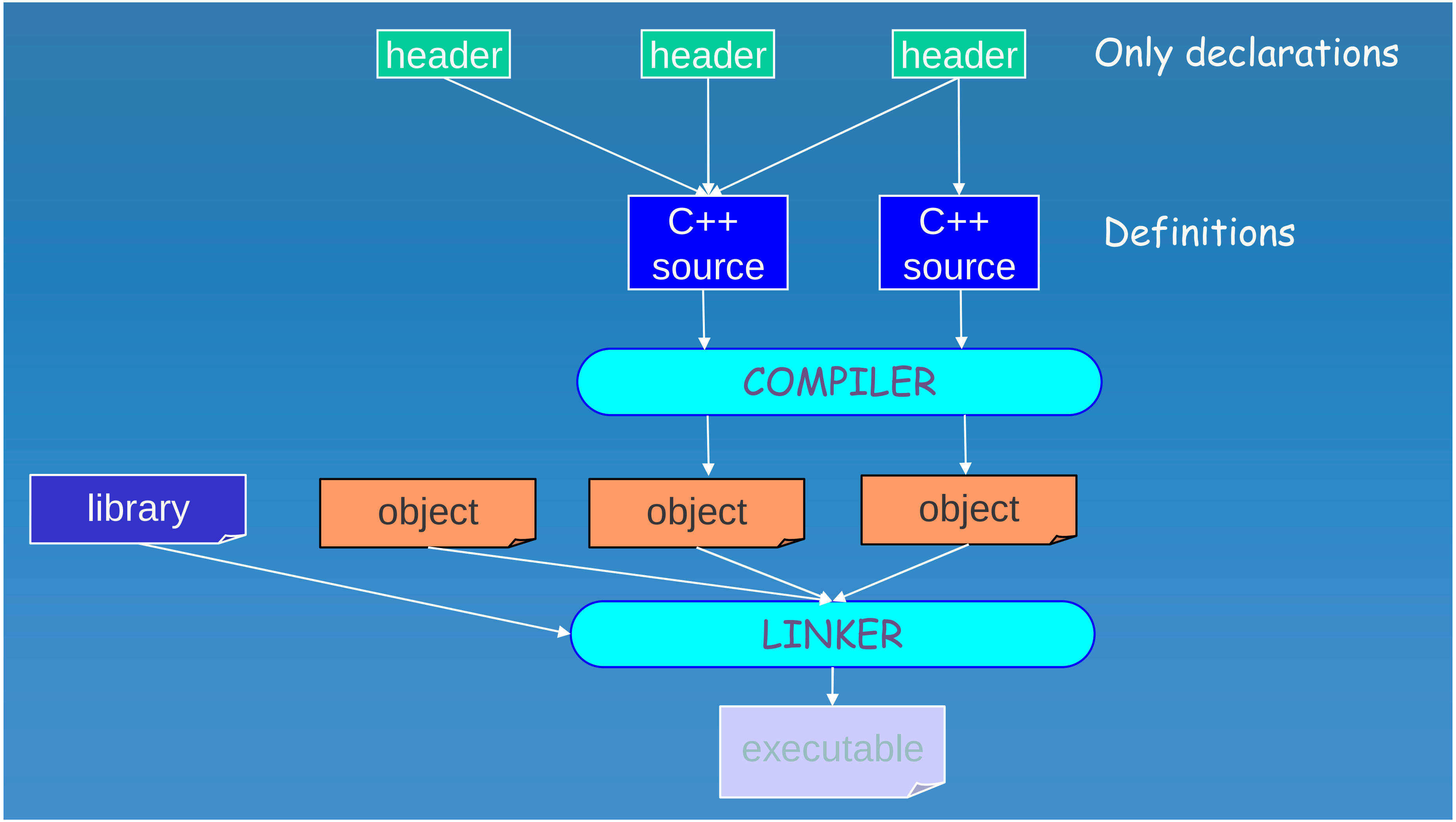
Data members are initialized

When an object goes out of scope, the destructors are called in reverse order: The enclosing object is destroyed first, then the member (inner) object.

Working with Multiple Files (Separate Compilation)

- It is a good way to write each class or a collection of related classes in separate files.
- It provides managing the complexity of the software and reusability of classes in new projects.

Working with Multiple Files



- When using separate compilation you need some way to automatically compile each file and to tell the linker to build all the pieces along with the appropriate libraries and startup code into an executable file.
- The solution, developed on Unix but available everywhere in some form, is a program called ***make***.
- Compiler vendors have also created their own project building tools. These tools ask you which files are in your project and determine all the relationships themselves. These tools use something similar to a makefile, generally called a project file, but the programming environment maintains this file so you don't have to worry about it.
- The configuration and use of project files varies from one development environment to another, so you must find the appropriate documentation on how to use them (although project file tools provided by compiler vendors are usually so simple to use that you can learn them by playing around).
- We will write the example e410.cpp about fractions and complex numbers again. Now we will put the class for fractions and complex numbers in separate files.