Stack and Heap memory

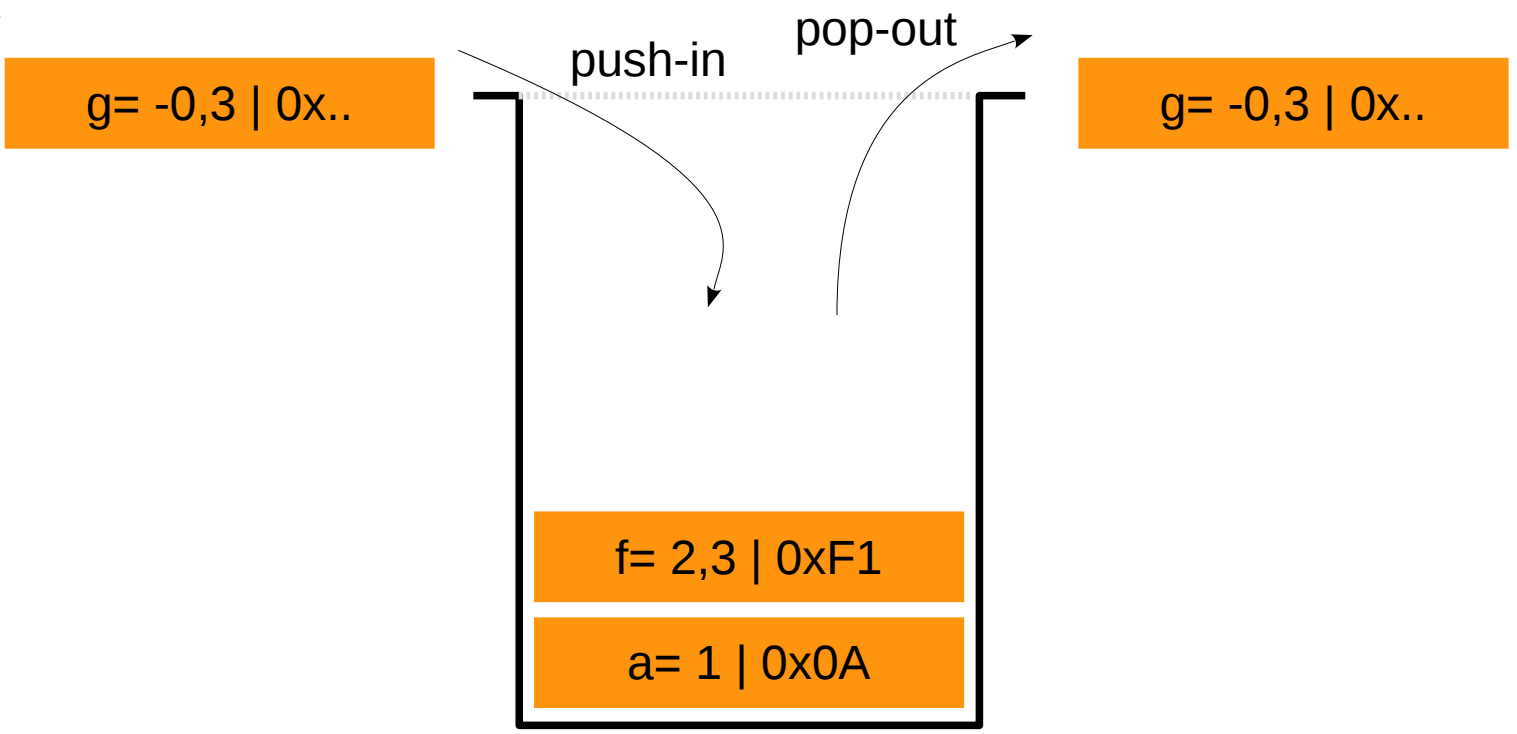
Stack and Heap memory

Disclaimer: VERY SIMPLIFIED AND NOT REAL (IT) DESCRIPTION!

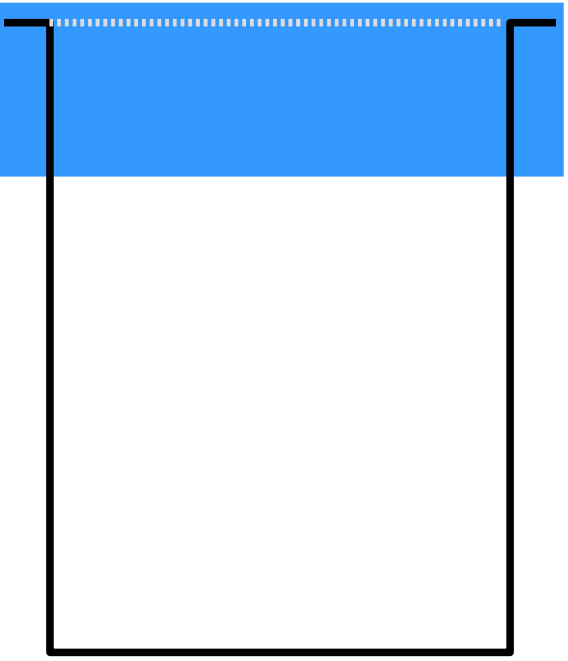
When a program is executed a certain RAM is assigned to it by the OS. This RAM is splitted into **STACK** memory and **HEAP** memory.

STACK MEMORY:

- data are added or removed in a last-in-first-out manner
- a variable in the stack lives inside the blocks and is automatically deleted when exiting the block



Stack memory



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   int a = 1;
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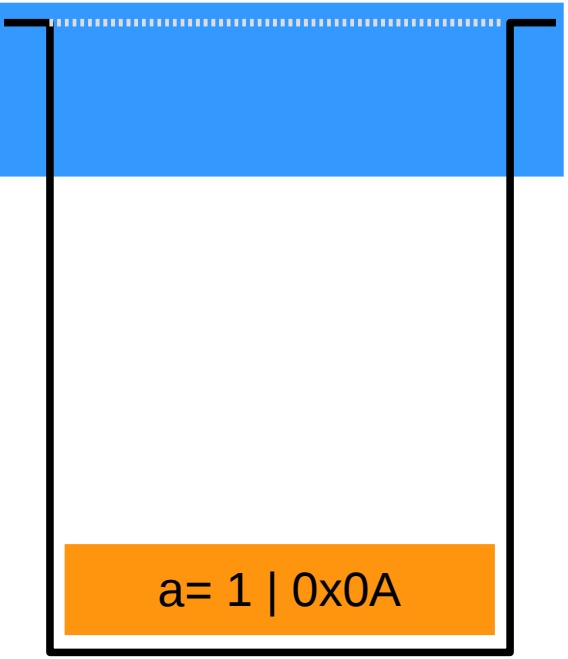
      float f = 2.3;
      int m = 4;
      float c = static_cast<float>(m) / f;
      for ( int j = 0 ; j < 2 ; j++){
         c += 0.12;
      }
      cout << "here c is" << c << "\n";
   }
   return 0;
}
```

Stack memory

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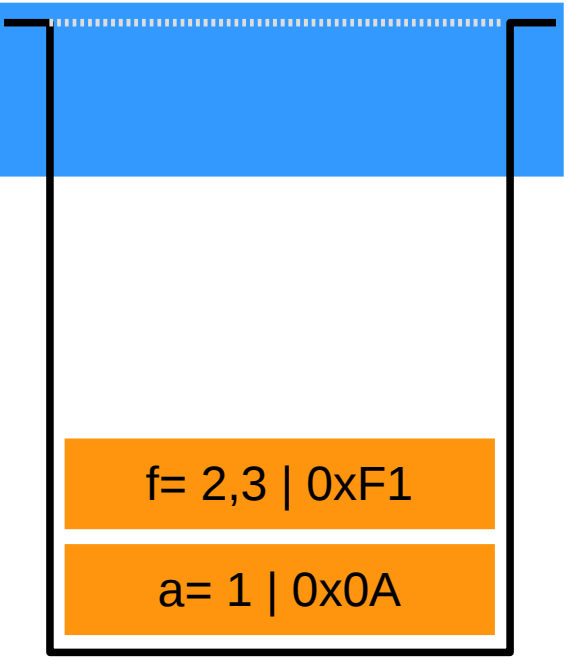


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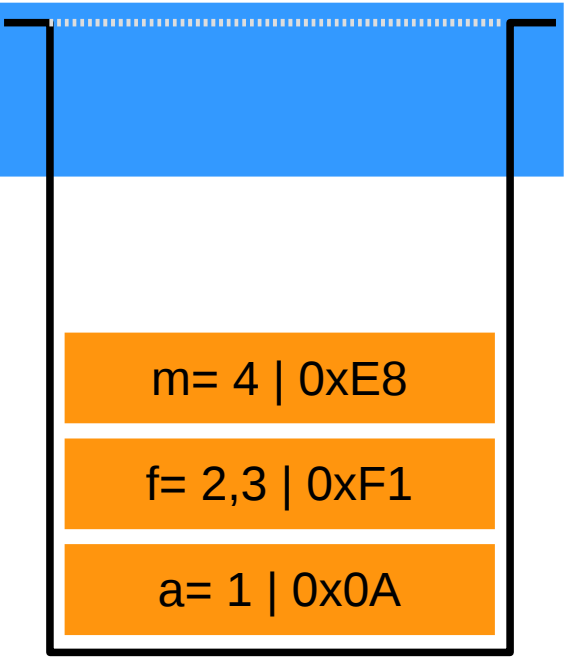


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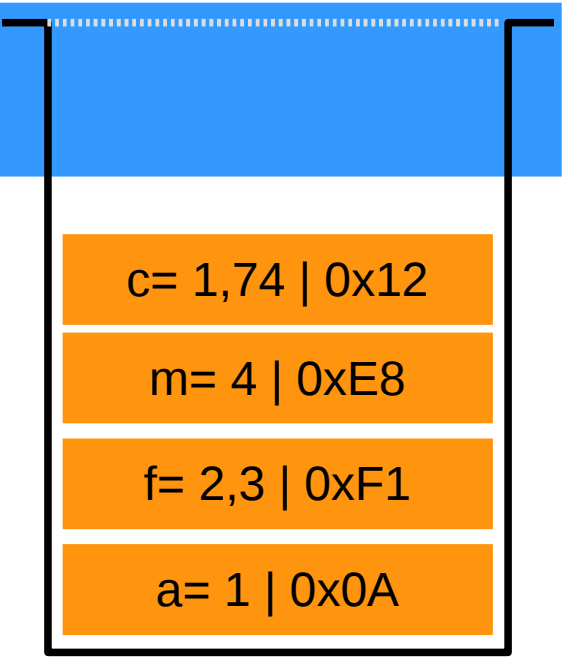


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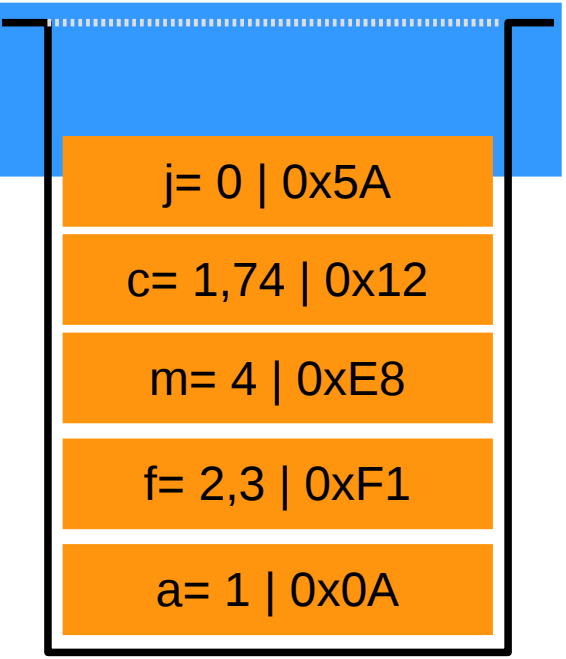


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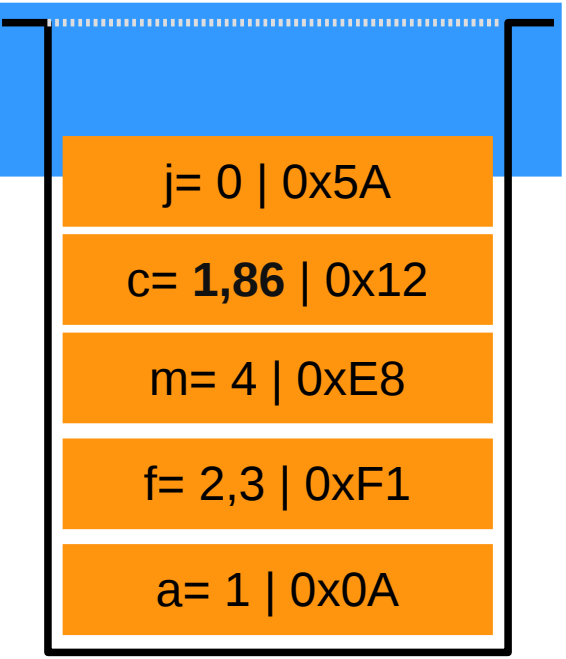


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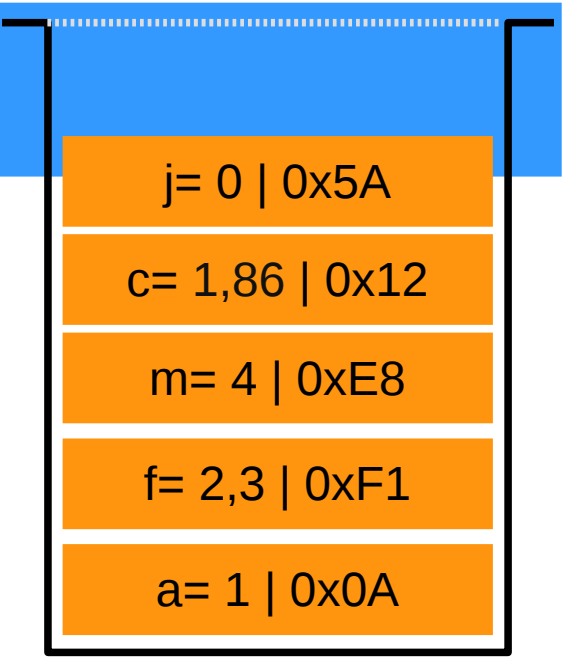


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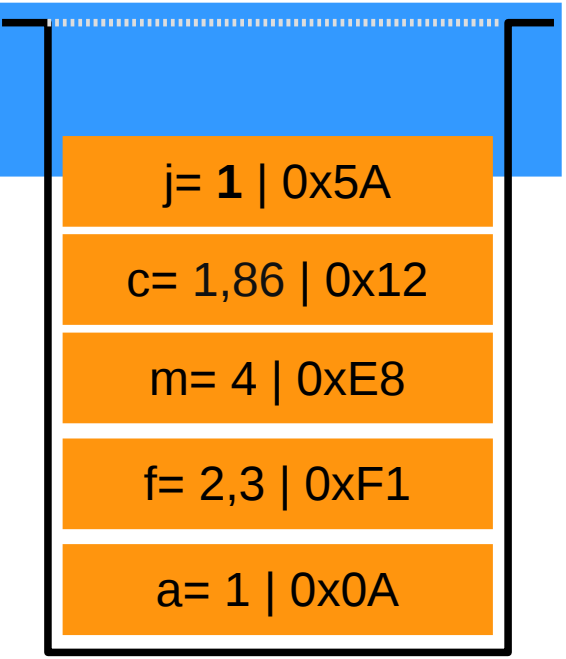


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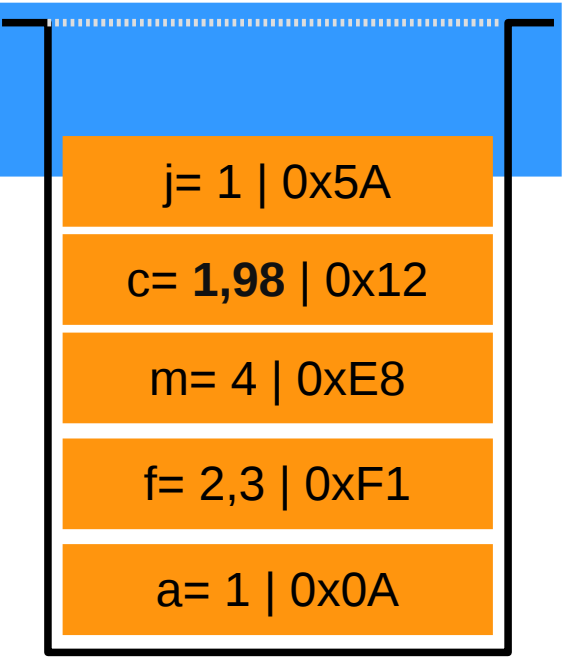


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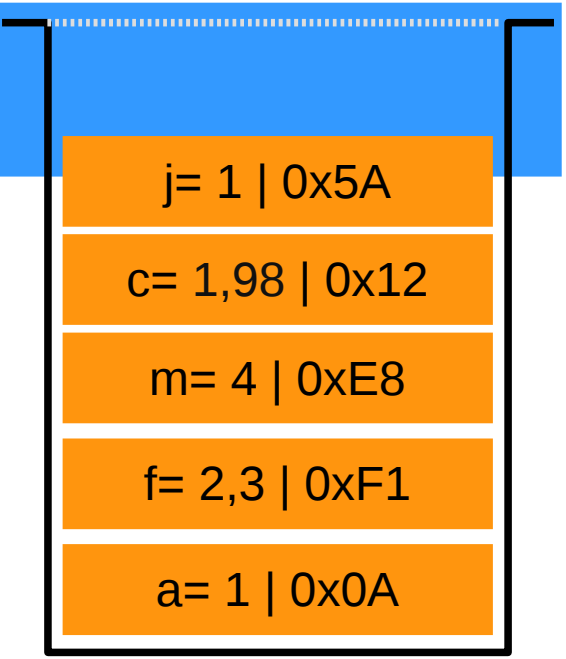


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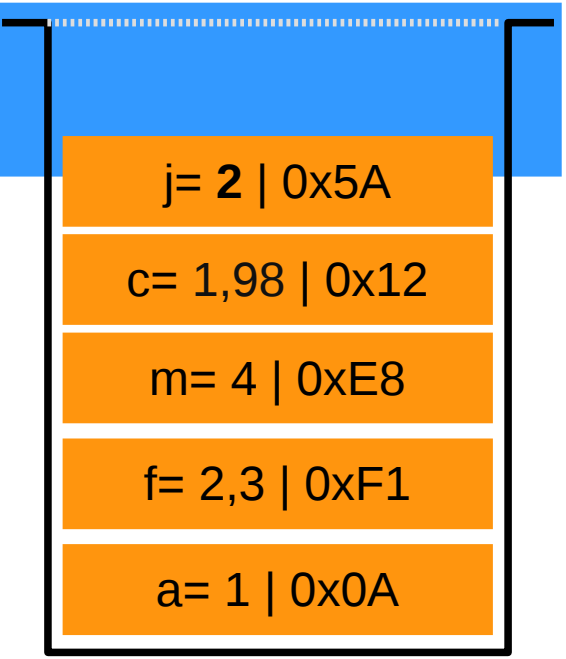


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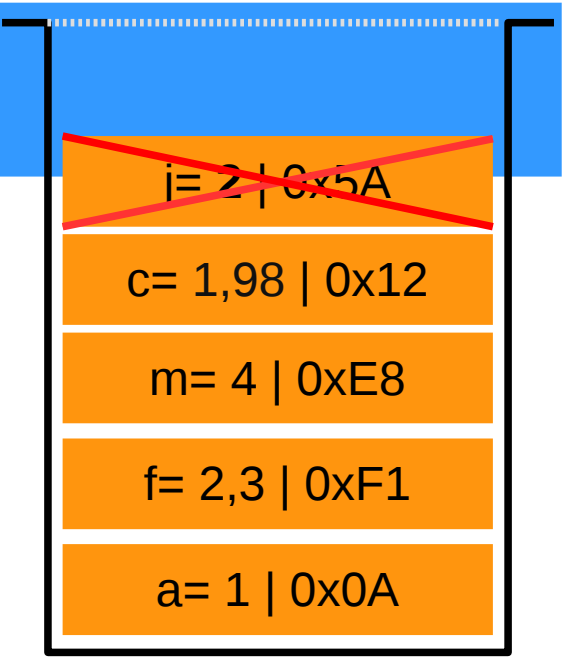


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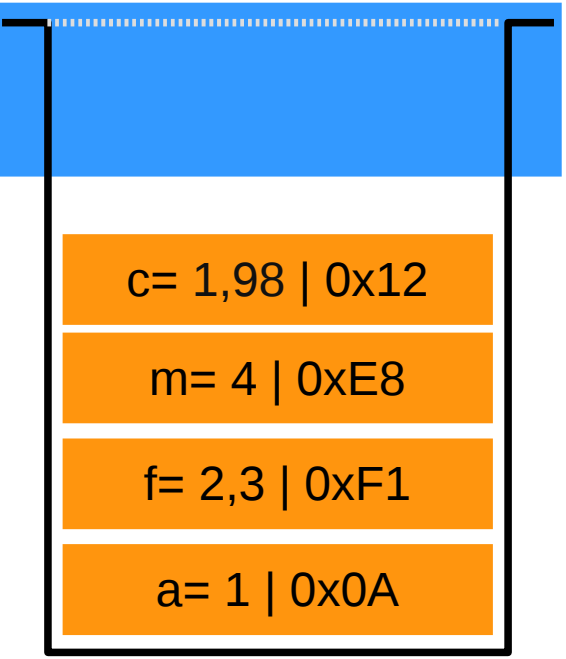


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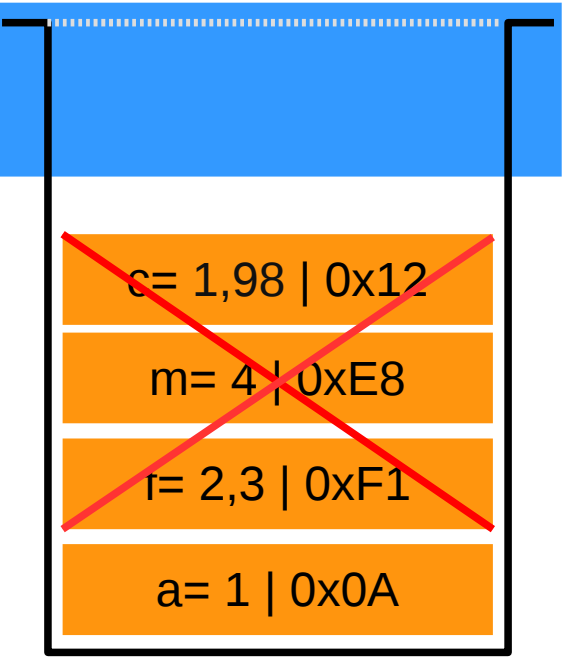


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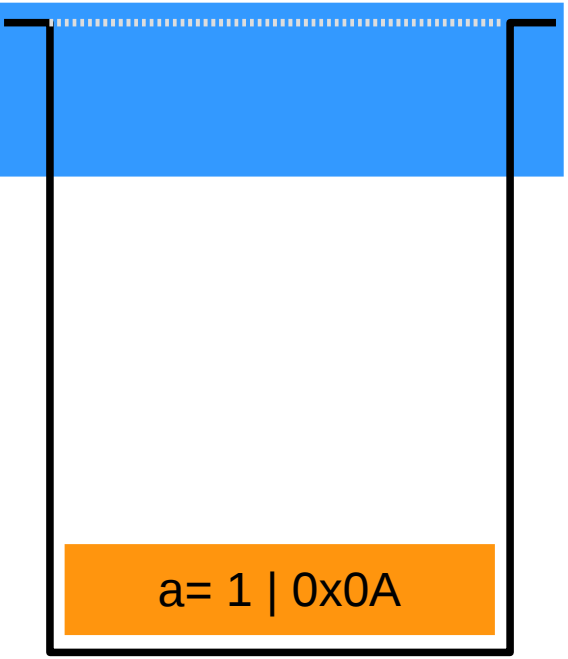


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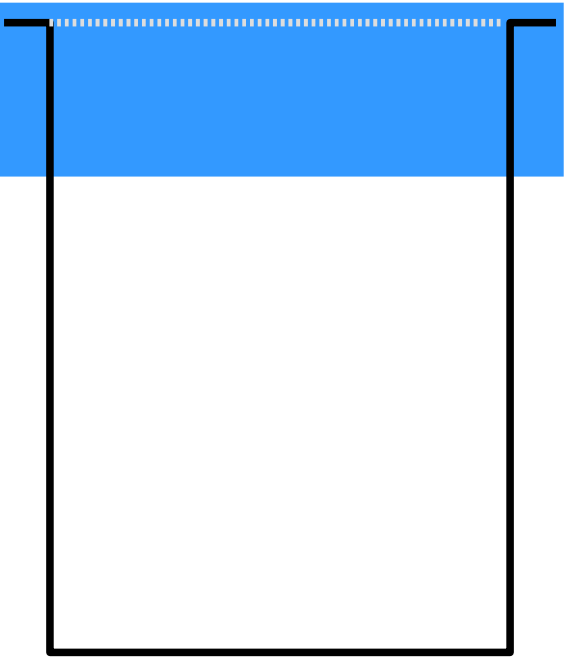

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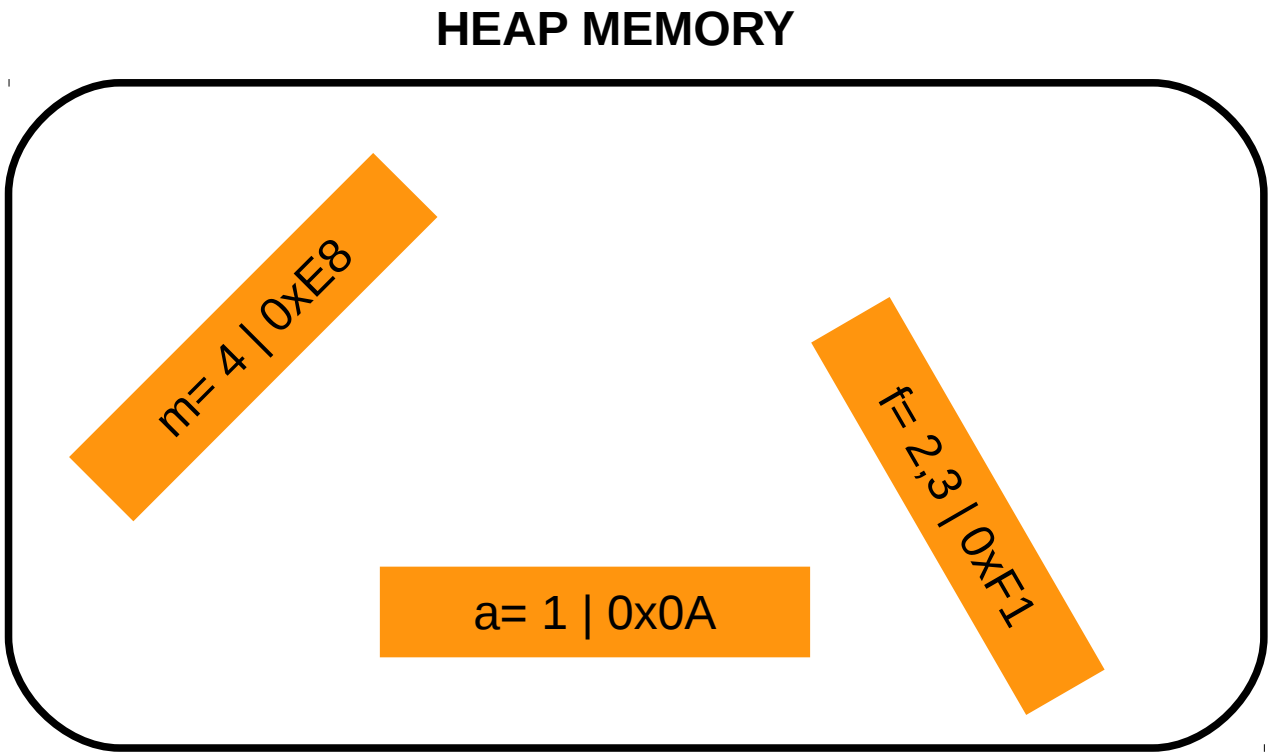
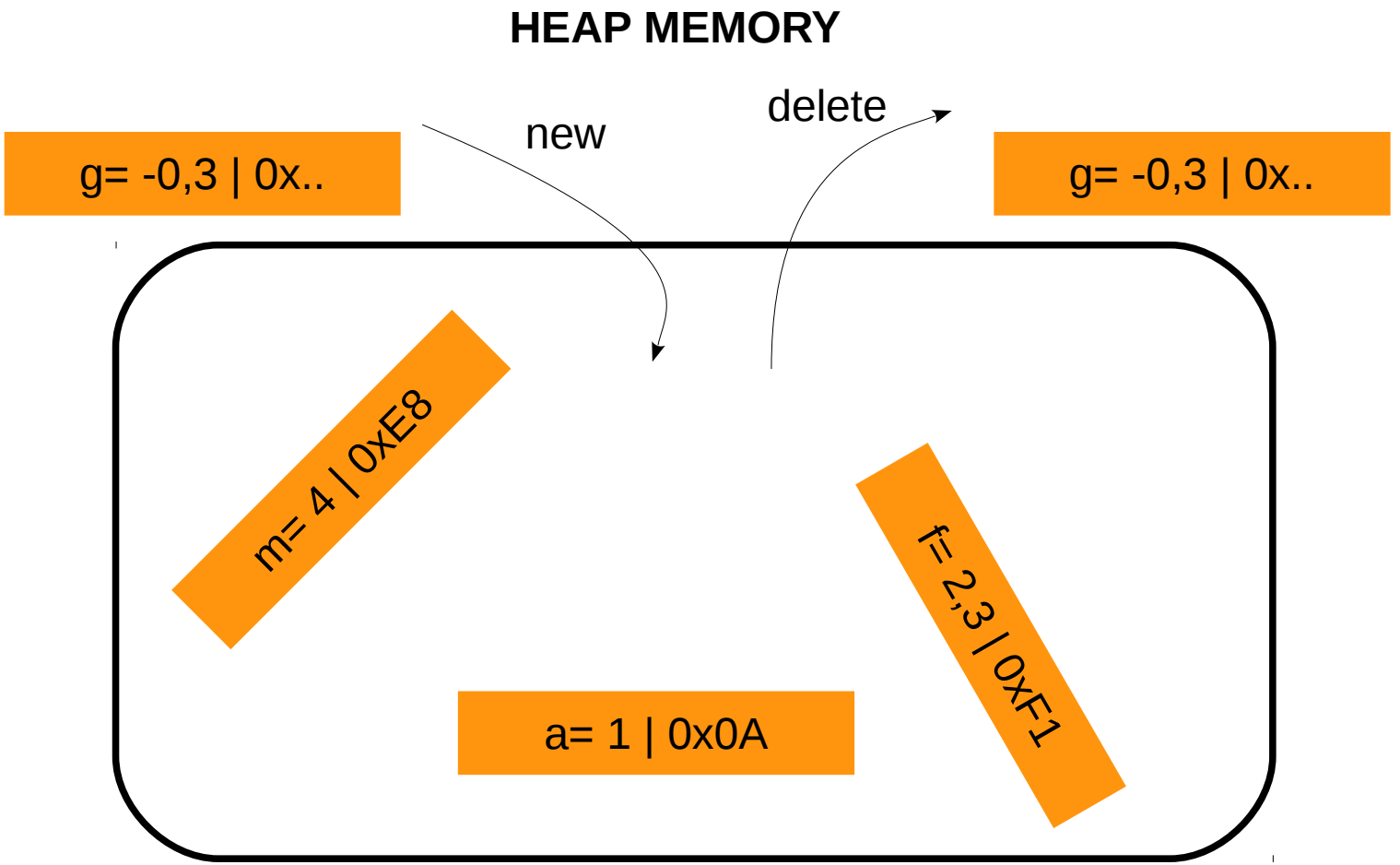
Heap memory

Big memory requests can be satisfied by allocating portions from a large pool of memory, the heap. At any given time, some parts of the heap are in use, while some are "free" (unused) and thus available for future allocations.



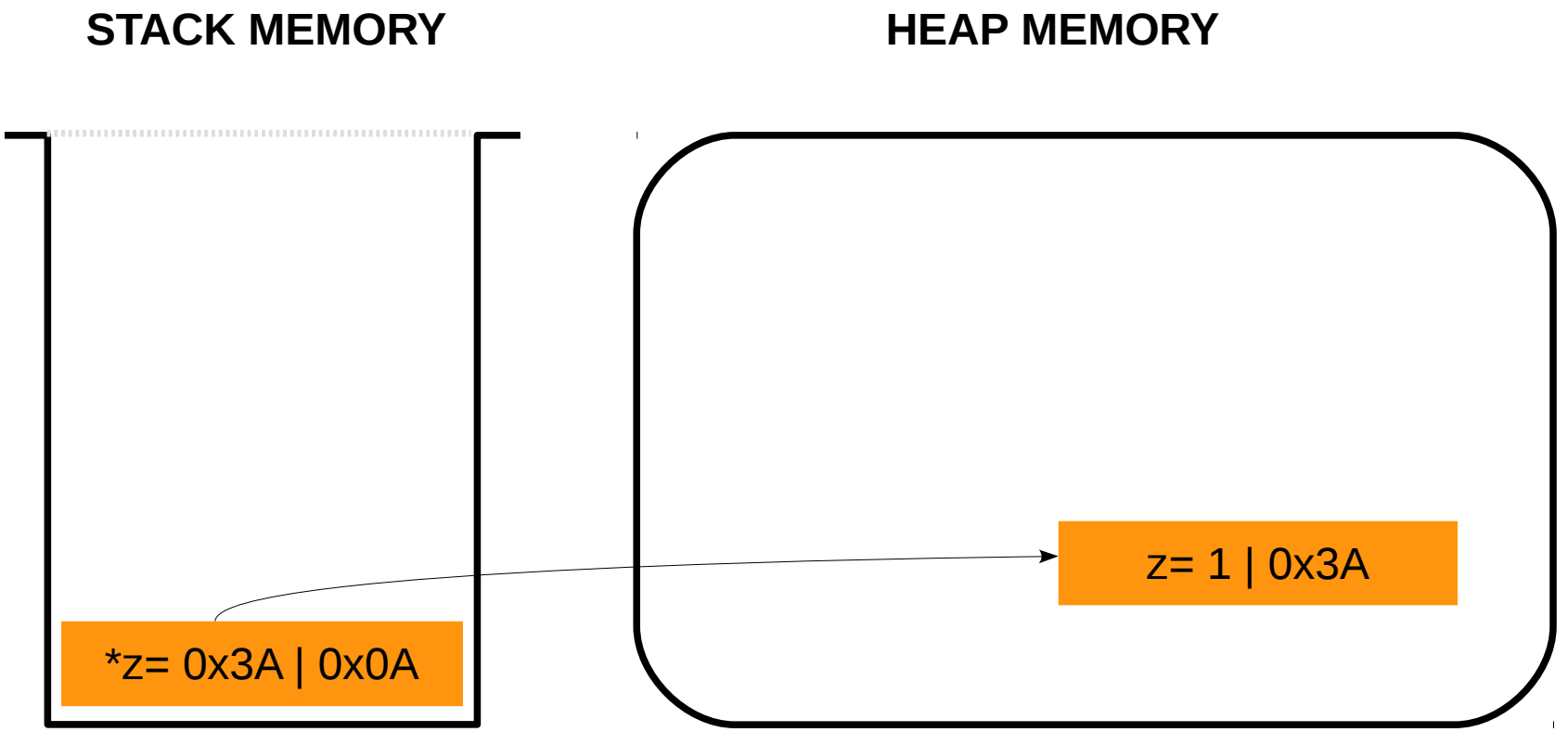
Heap memory – memory allocation

- To allocate heap memory we use the operator "`new`"
- To free heap memory we use the operator "`delete`"



Heap memory – need pointers

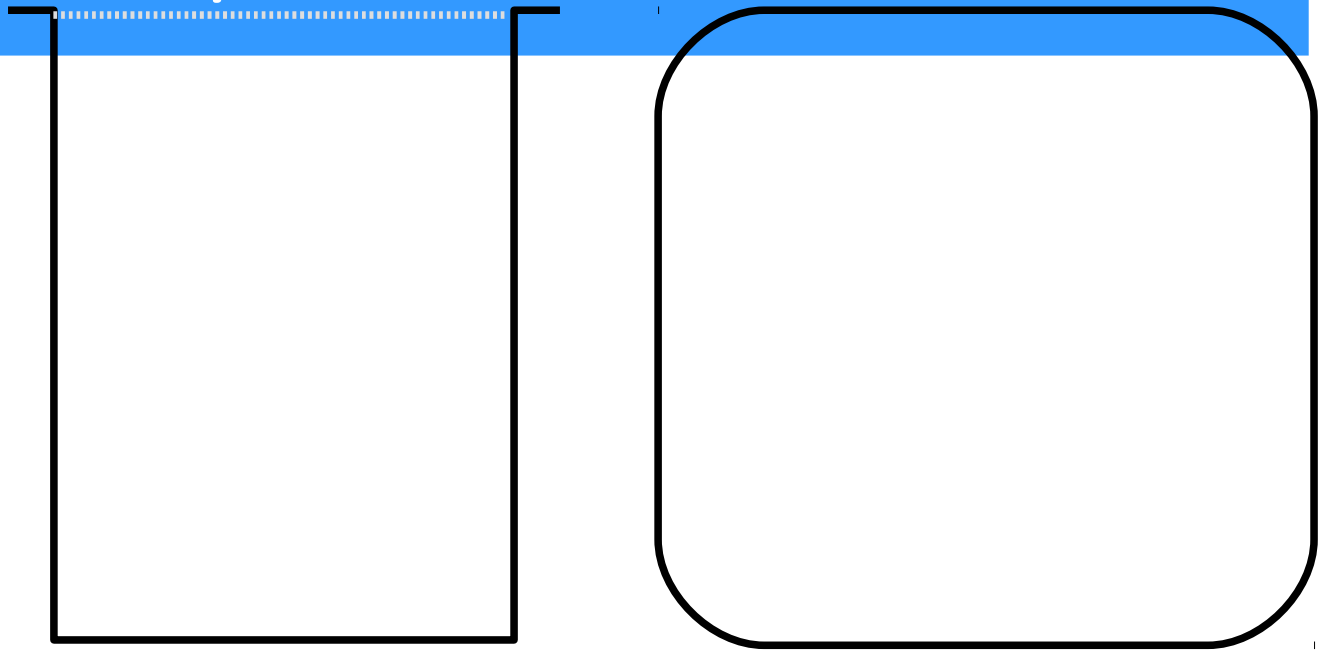
To access data in the heap we need a POINTER in the stack




```
int *z = new int(1);
```

WARNING: heap memory is not freed automatically!

Heap and stack memory



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int main(){
    int a = 1;
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        int *z = new int(1);
        // do something
        delete z;
        z = 0;
    }
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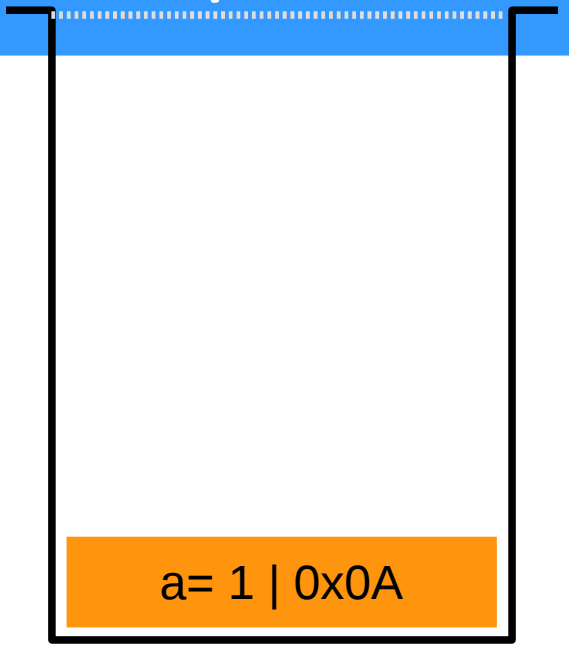

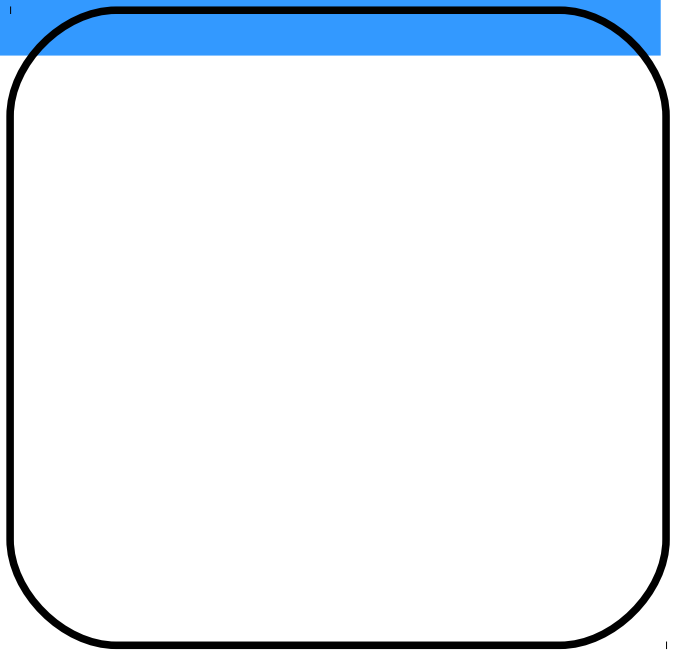

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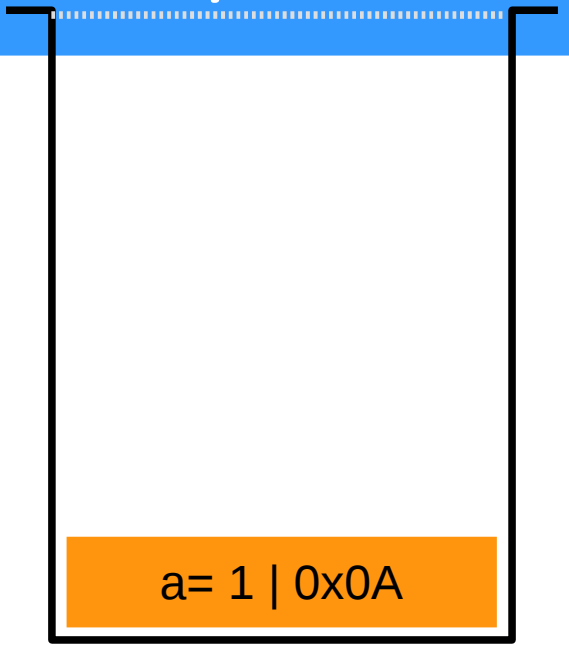

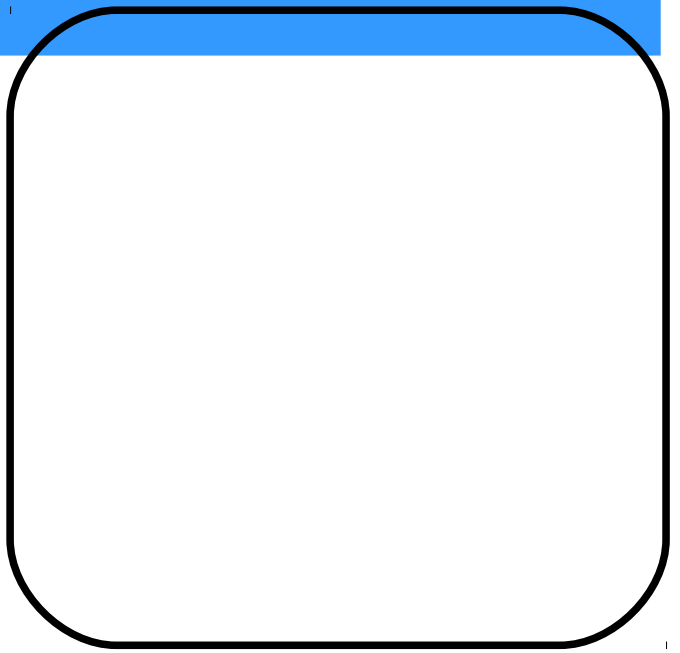

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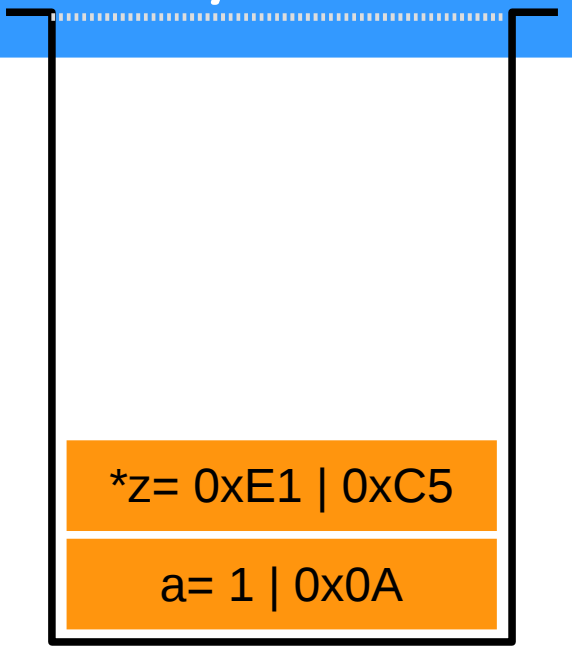

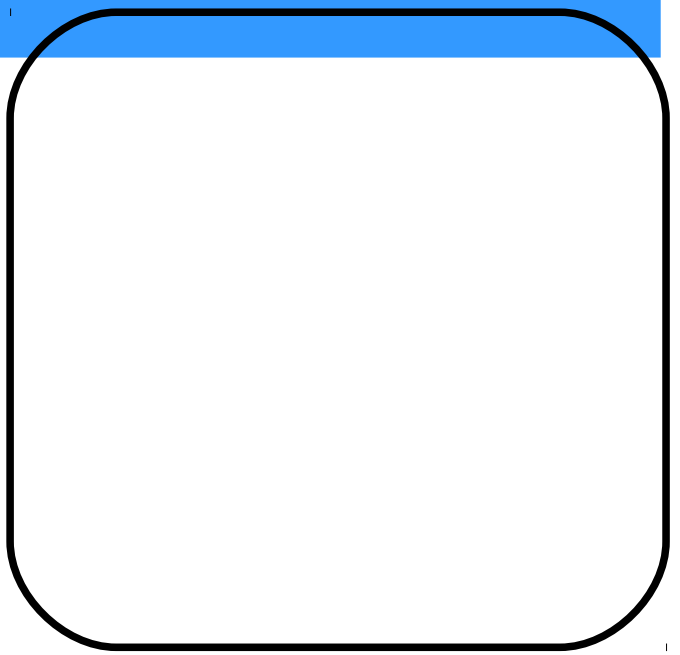

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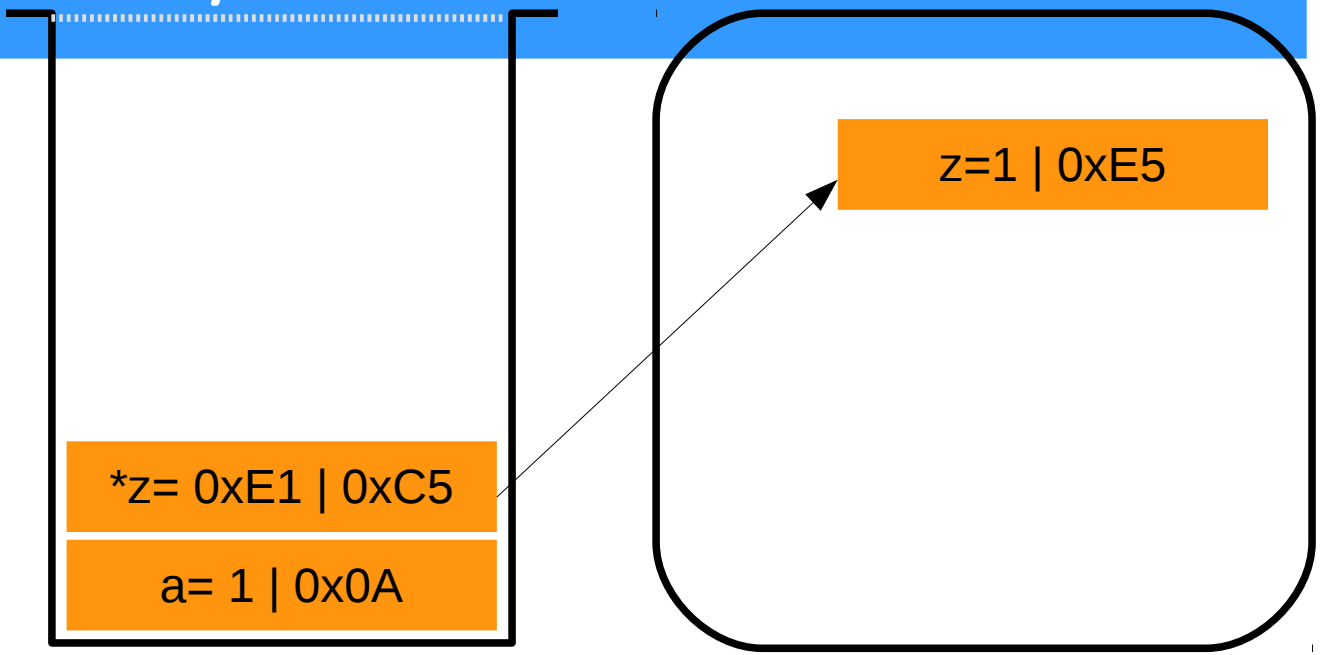


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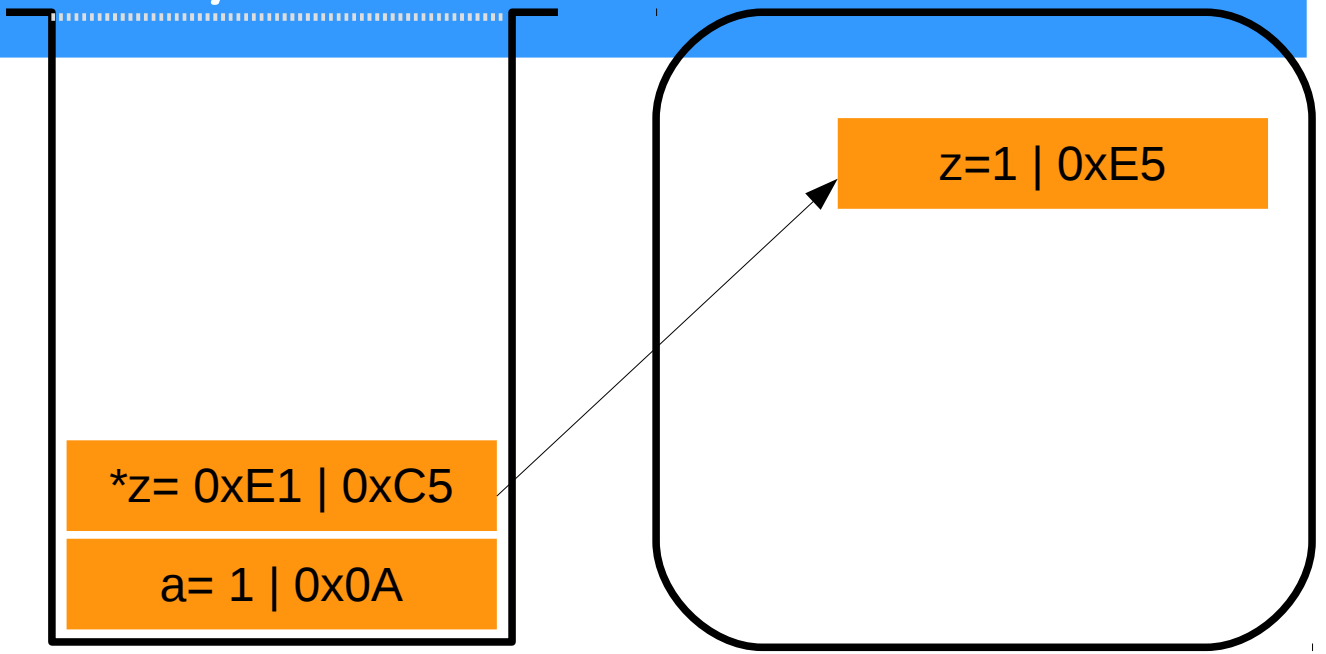


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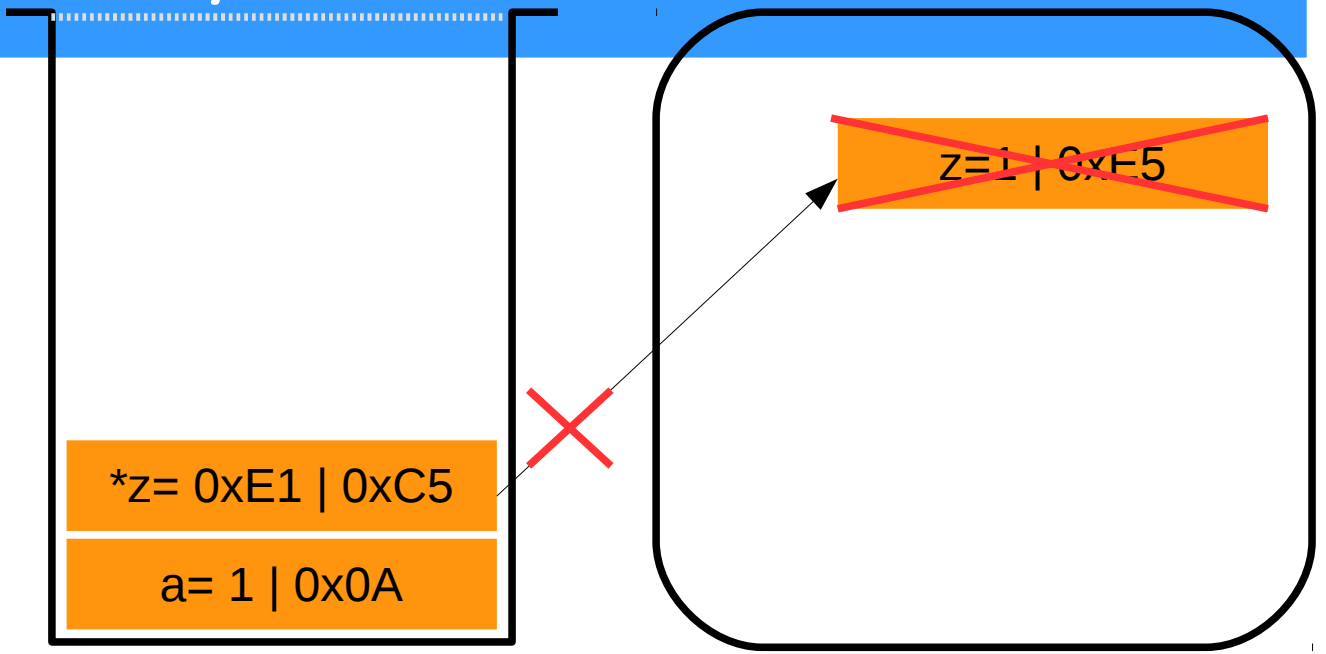


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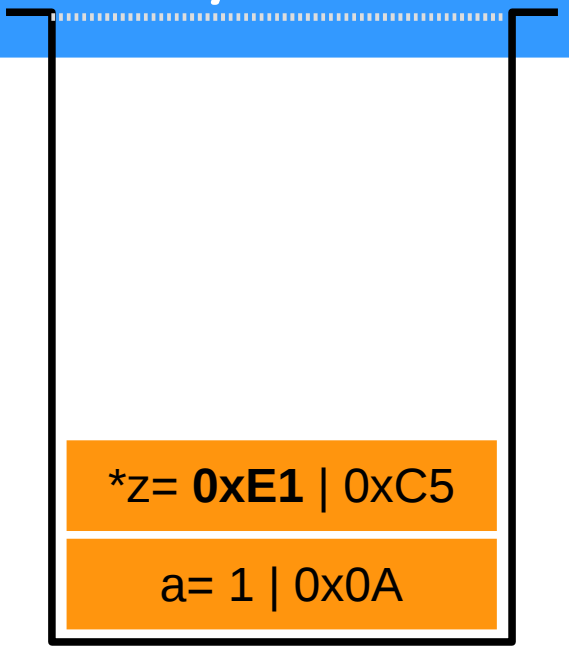

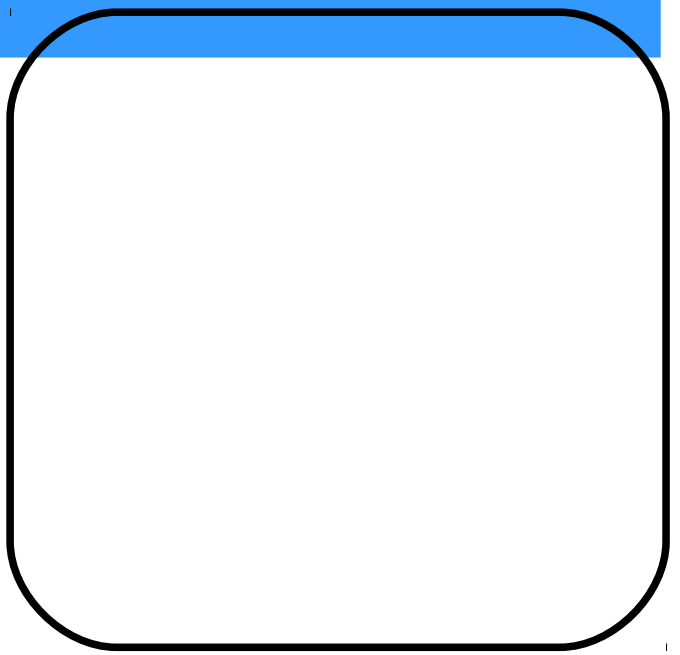

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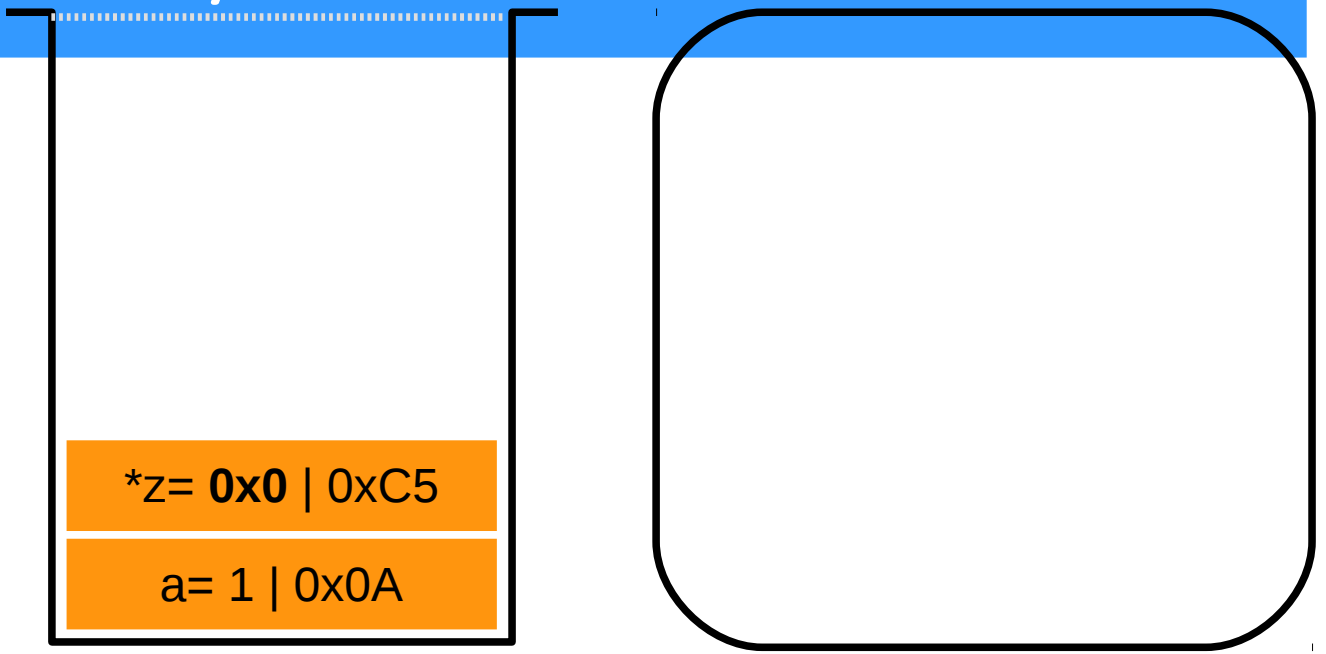


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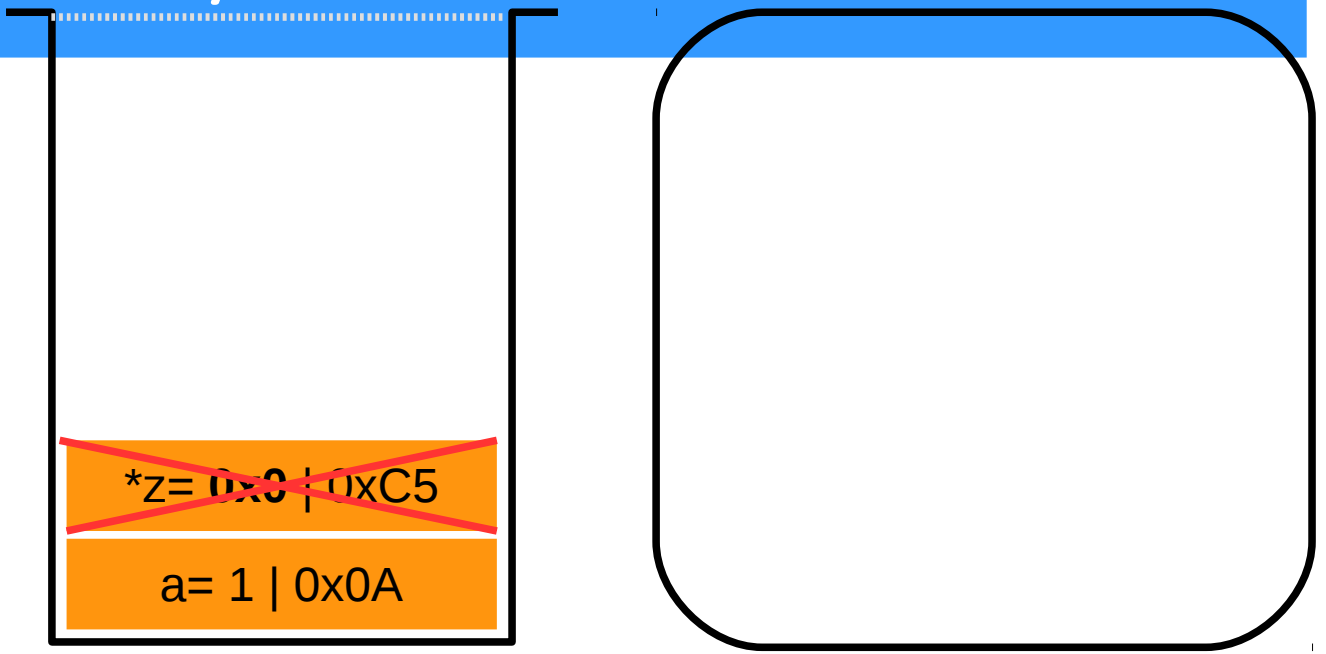


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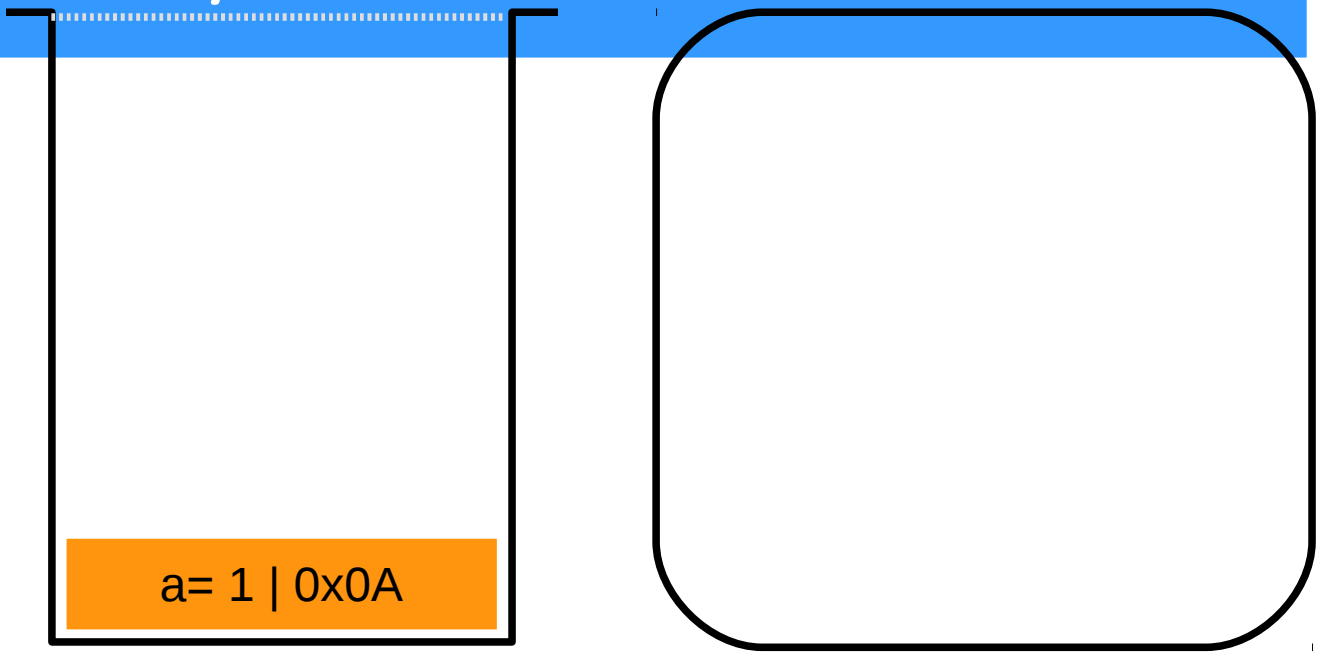


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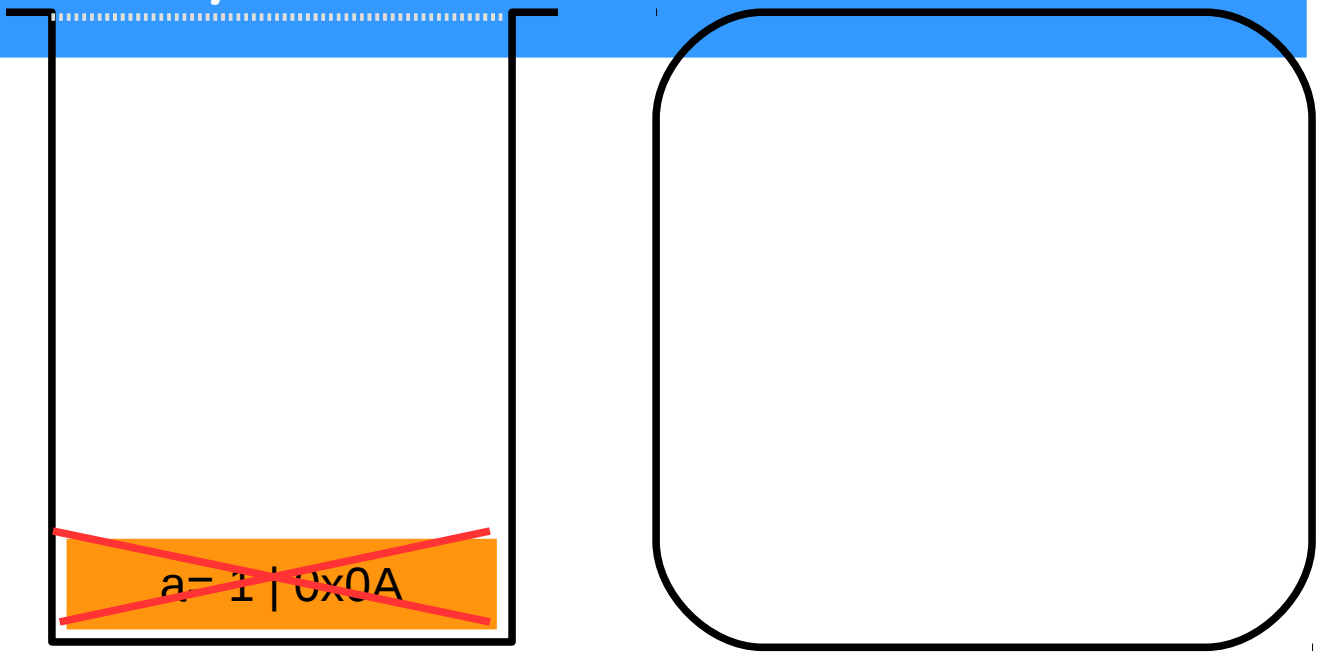


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```
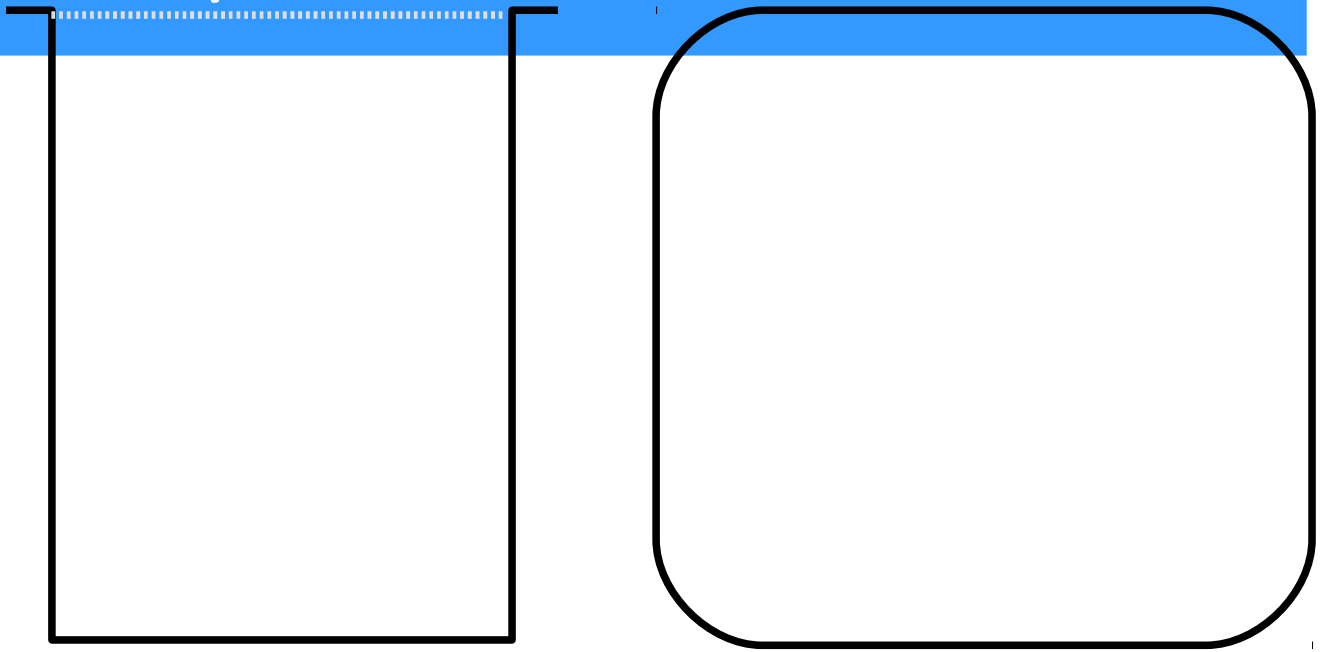
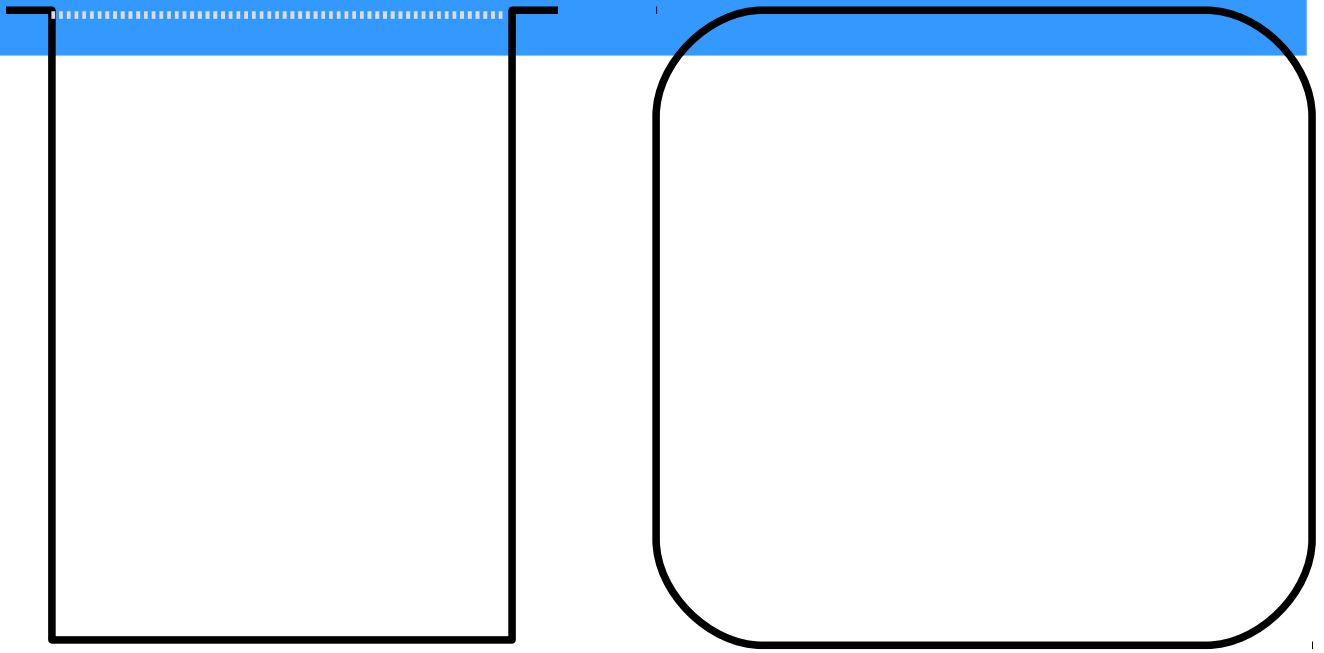

Heap and stack memory



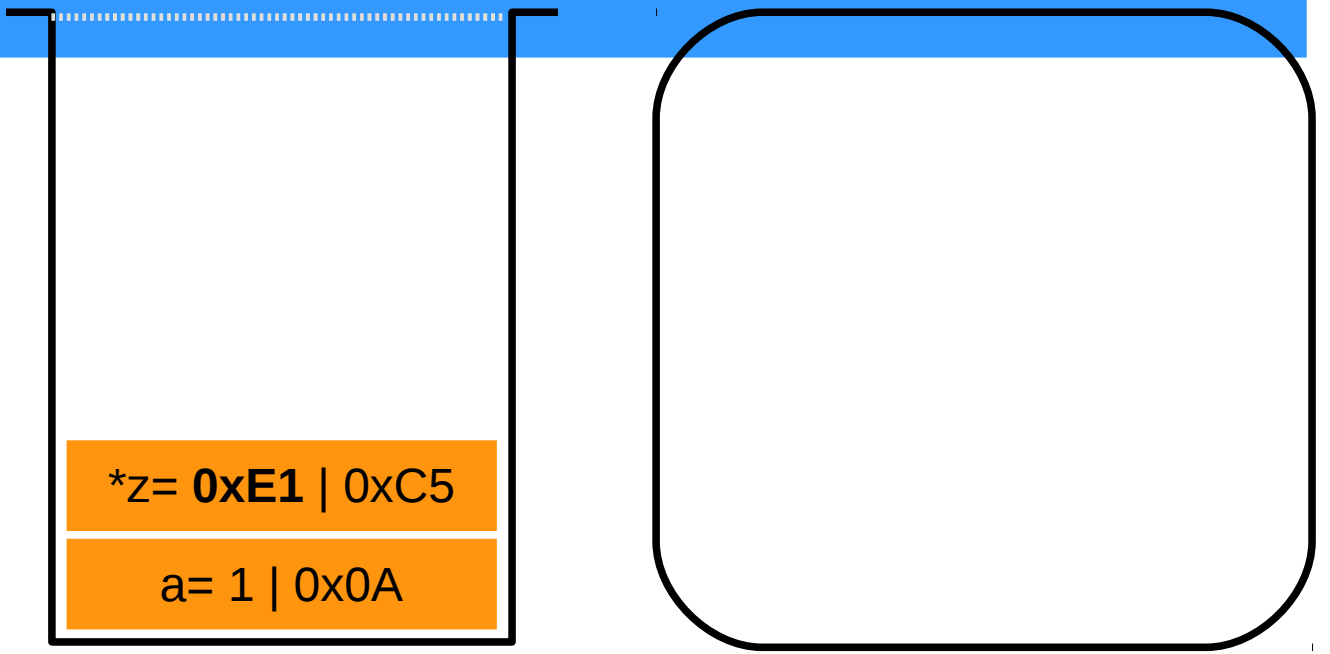
```
int main(){
   int a = 1;
   if ( a > 0 ){
      int *z = new int(1);
      // do something
      delete z;
      z = 0;
   }
   return 0;
}
```

Memory leak



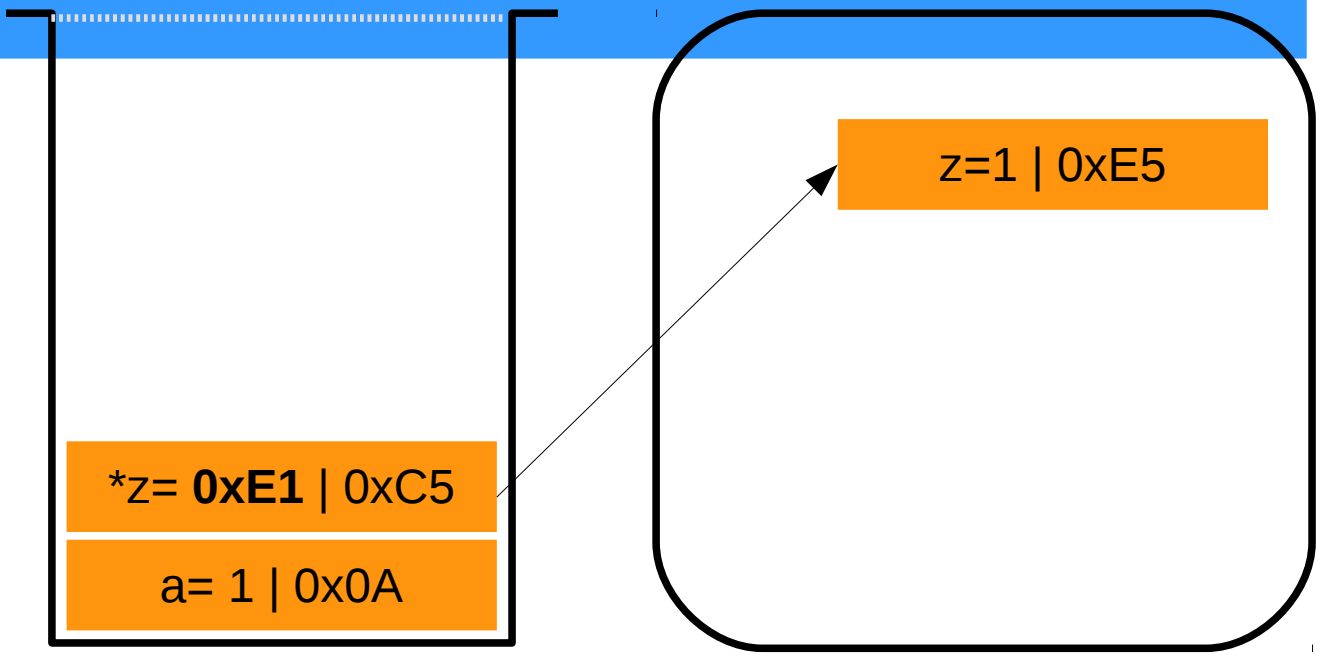
```
int main(){
   int a = 1;
   if ( a > 0 ){
      int *z = new int(1);
      // do something
      delete z;
      z = 0;
   }
   return 0;
}
```

Memory leak



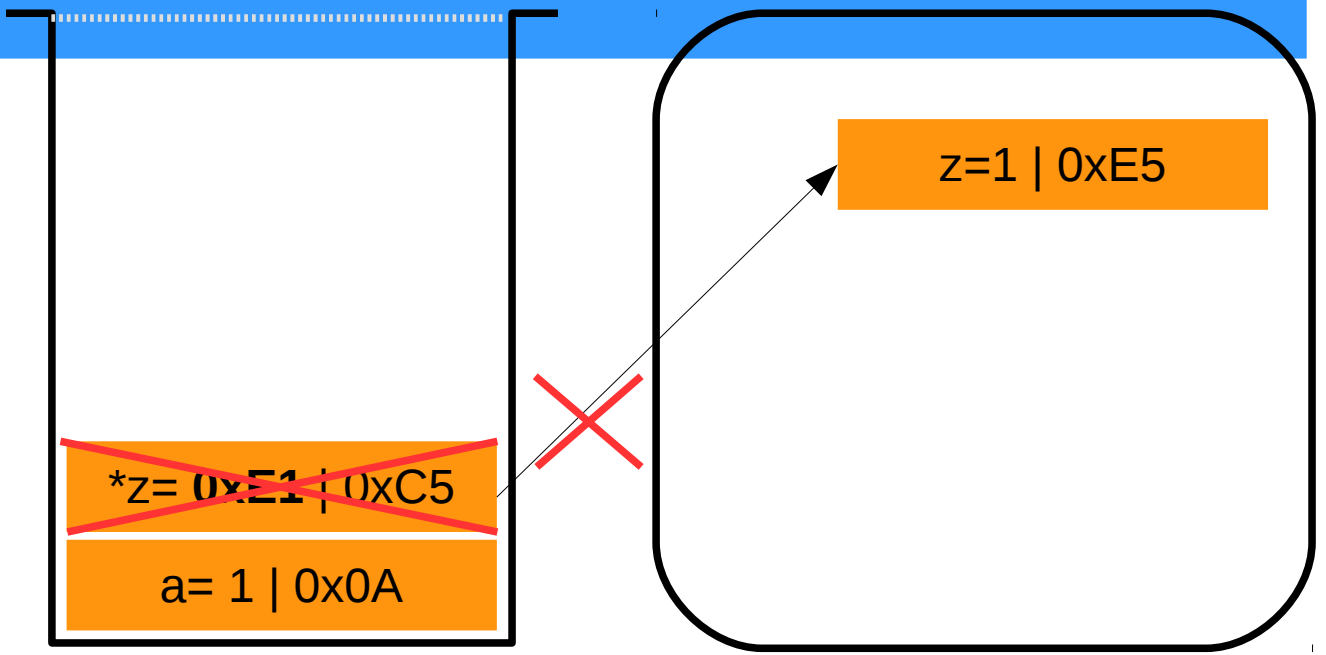

```
int main(){
   int a = 1;
   if ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak



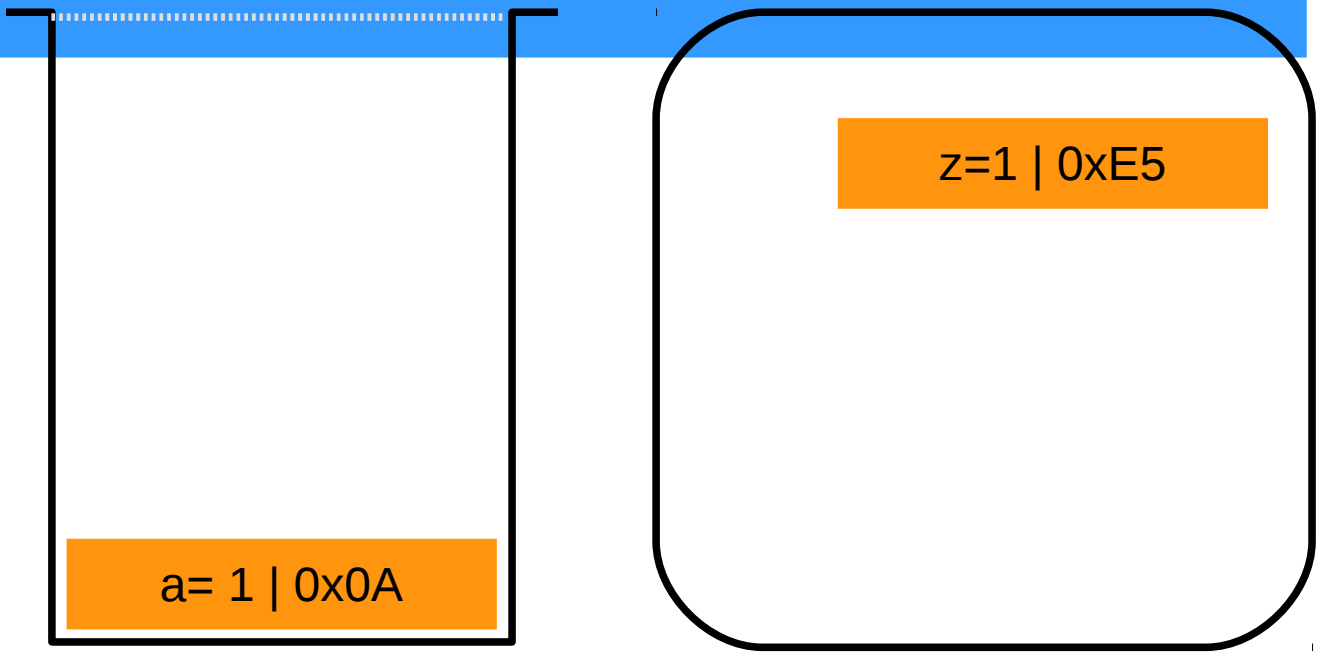

```
int main(){
   int a = 1;
   if ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak



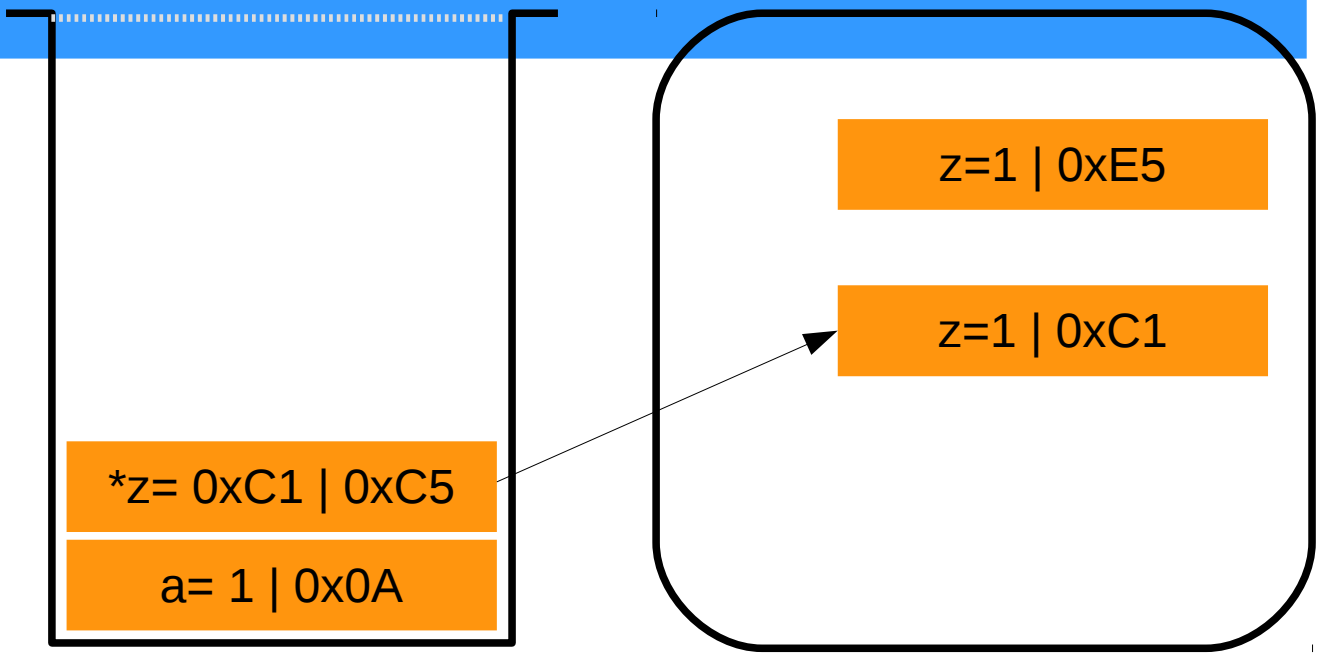

```
int main(){
   int a = 1;
   if ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak



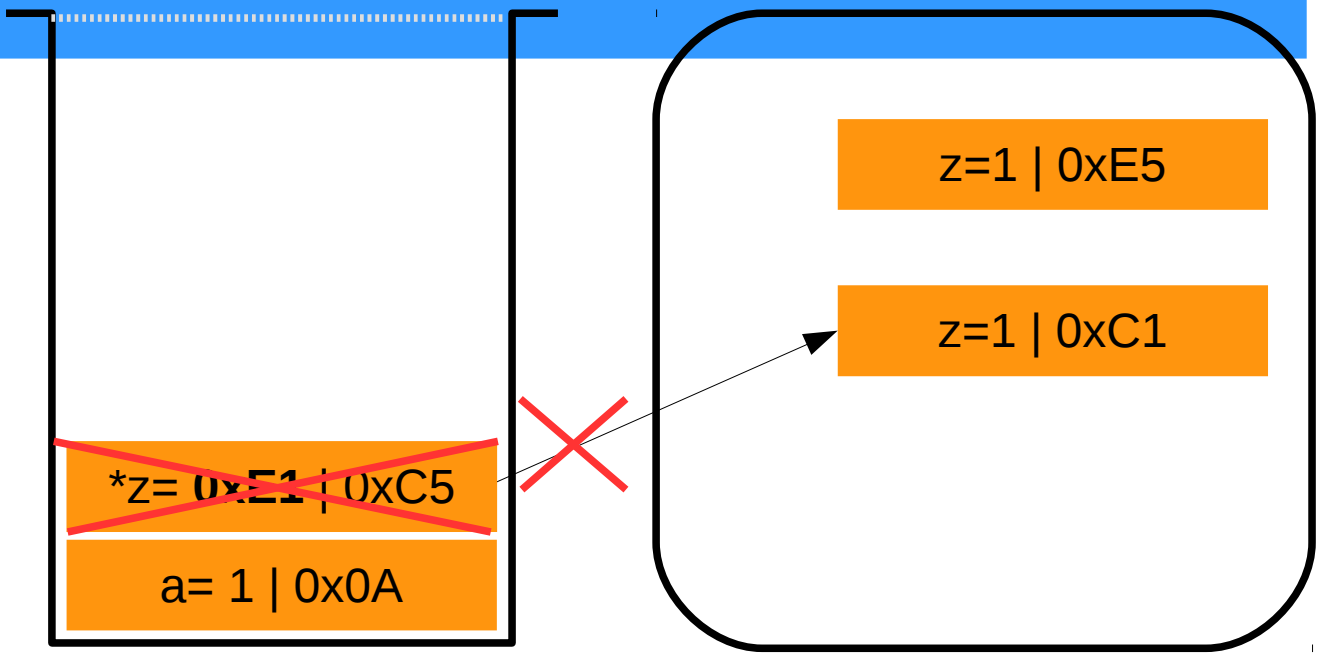

```
int main(){
   int a = 1;
   if ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak



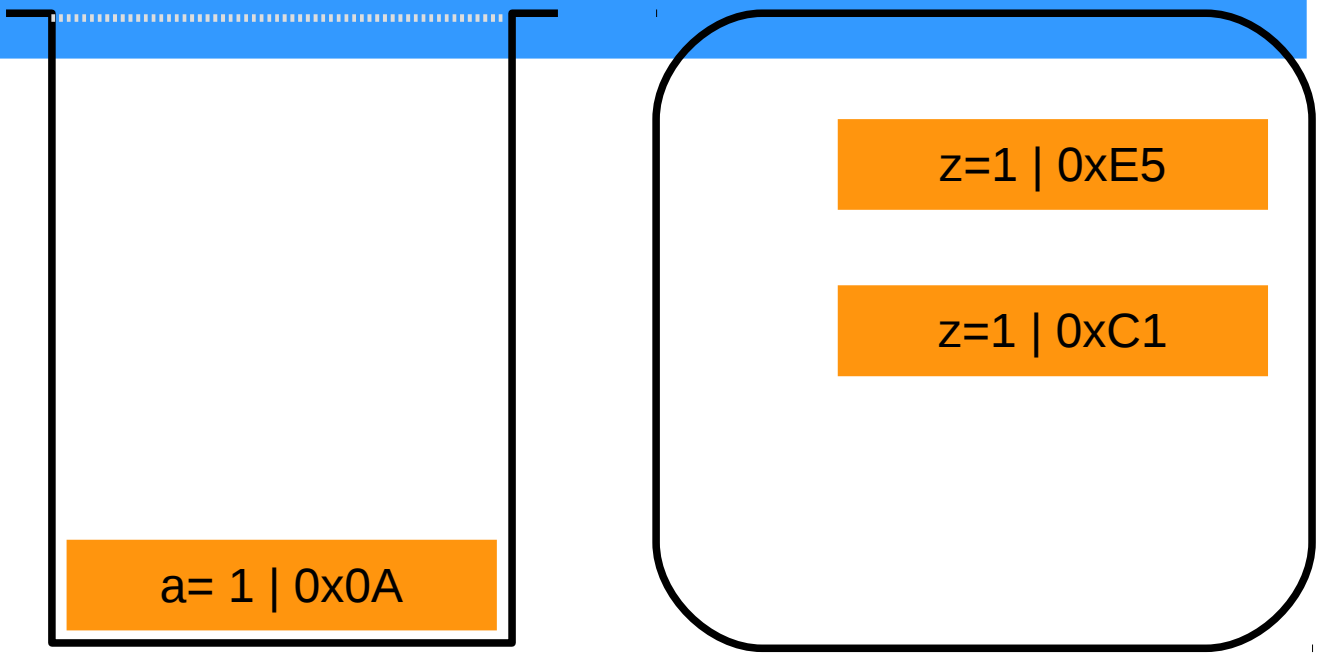

```
int main(){
   int a = 1;
   while ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak



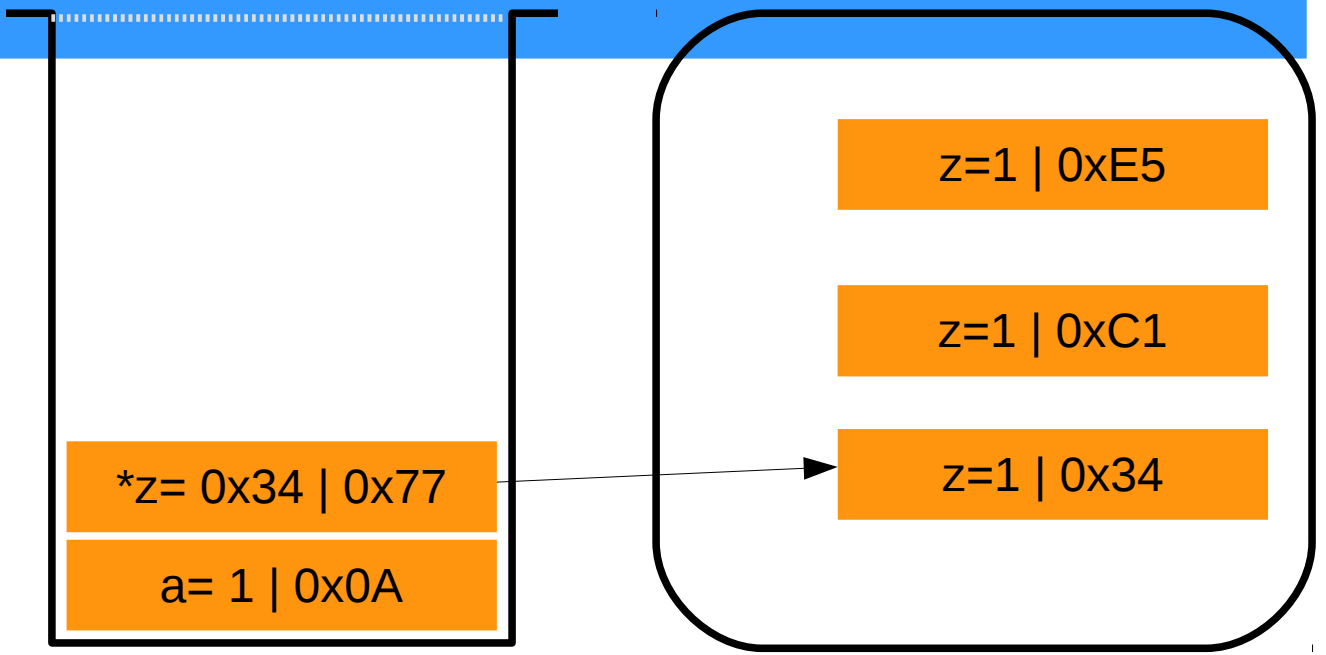

```
int main(){
   int a = 1;
   while ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak



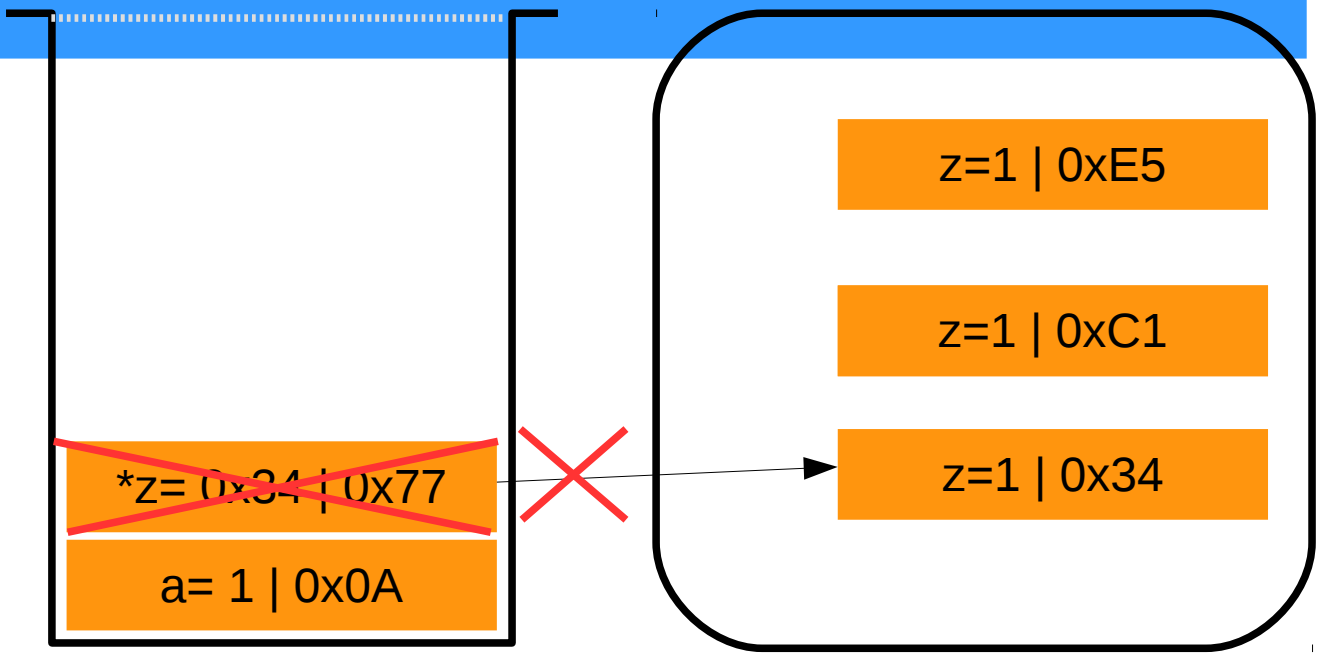

```
int main(){
   int a = 1;
   while ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak



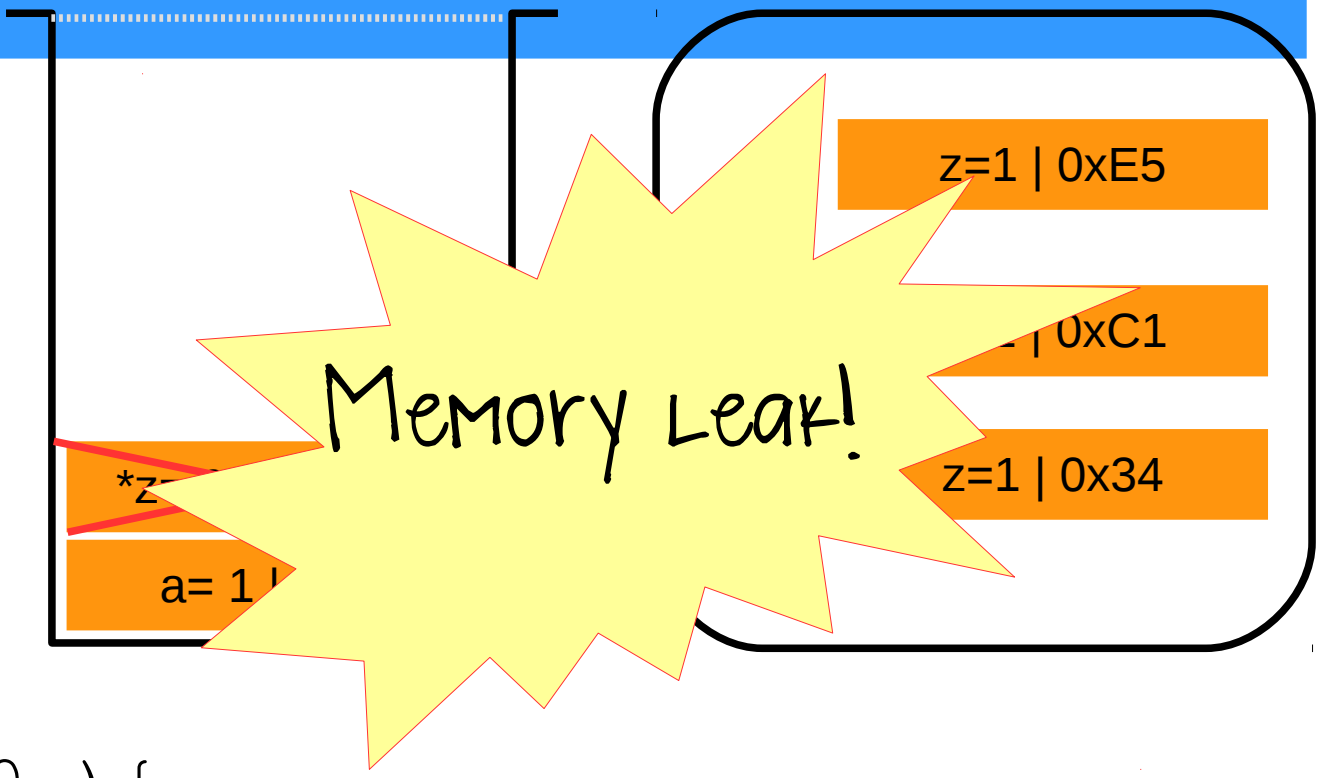

```
int main(){
   int a = 1;
   while ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak




```
int main(){
   int a = 1;
   while ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Memory leak




```
int main(){
   int a = 1;
   while ( a > 0 ){
      int *z = new int(1);
      // do something
    }
   return 0;
}
```

Classes and Data Abstraction

Introduction

- Object-oriented programming (OOP)
  - Encapsulates data (attributes) and functions (behavior) into packages called classes
- Information hiding
  - Class objects communicate across well-defined interfaces
- Implementation details hidden within classes themselves
  - User-defined (programmer-defined) types: classes
  - Data (data members)
- Functions (member functions or methods)
  - Similar to blueprints – reusable
  - Class instance: object

Structure Definitions

- C++ allows us to create our own user-defined aggregate data types. An aggregate data type is a data type that groups multiple individual variables together. One of the simplest aggregate data type is the **structure**.
- A structure allows us to group variables of mixed data types together into a single unit.
- How to define a structure:

```
struct Time {
    int hour;
    int minute;
    int second;
    };
```

Structure tag

Structure members

- Structure member naming

  In same **`struct`**: must have unique names

  In different **`struct`**s: can share name

- **`struct`** definition must end with semicolon

Structure Definitions

- Self-referential structure
  - Structure member cannot be instance of enclosing **`struct`**
  - Structure member can be pointer to instance of enclosing **`struct`** (self-referential structure)
    - Used for linked lists, queues, stacks and trees
- **`struct`** definition
  - Creates new data type used to declare variables
  - Structure variables declared like variables of other types
  - Examples:
    - `Time timeObject;`
    - `Time timeArray[ 10 ];`
    - `Time *timePtr;`
    - `Time &timeRef = timeObject;`

Accessing Structure Members

- Member access operators

  Dot operator (**.**) for structure and class members

  Arrow operator (→) for structure and class members via pointer to object

  Print member **hour** of **timeObject**:

```
cout << timeObject.hour;
```

OR

```
timePtr = &timeObject;
cout << timePtr->hour;
```

  - **timePtr->hour** same as **(*timePtr).hour**

    Parentheses required

    - ***** lower precedence than **.**

Implementing a User-Defined Type `Time` with a `struct`

- Default: structures passed by value
  - Pass structure by reference
    - Avoid overhead of copying structure
- C-style structures
  - No “interface”
    - If implementation changes, all programs using that **`struct`** must change accordingly
  - Cannot print as unit
    - Must print/format member by member
  - Cannot compare in entirety
    - Must compare member by member

Implementing a User-Defined Type Time with a `struct`

```
1     // Fig. 6.1: fig06_01.cpp
2     // Create a structure, set its members, and print it.
3     #include <iostream>
4
5     using std::cout;
6     using std::endl;
7
8     #include <iomanip>
9
10    using std::setfill;
11    using std::setw;
12
13    // structure definition
14    struct Time {
15       int hour;      // 0-23 (24-hour clock format)
16       int minute;    // 0-59
17       int second;    // 0-59
18
19    }; // end struct Time
20
21    void printUniversal( const Time & );  // prototype
22    void printStandard( const Time & );   // prototype
23
```

Define structure type **`Time`** with three integer members.

Pass references to constant **`Time`** objects to eliminate copying overhead.

Implementing a User-Defined Type Time with a `struct`

```
24    int main()
25    {
26       Time dinnerTime;          // variable of
27
28       dinnerTime.hour = 18;    // set hour member of dinnerTime
29       dinnerTime.minute = 30;  // set minute member of dinnerTime
30       dinnerTime.second = 0;   // set second member of dinnerTime
31
32       cout << "Dinner will be held at ";
33       printUniversal( dinnerTime );
34       cout << " universal time,\nwhich is ";
35       printStandard( dinnerTime );
36       cout << " standard time.\n";
37
38       dinnerTime.hour = 29;    // set hour to invalid value
39       dinnerTime.minute = 73;  // set minute to invalid value
40
41       cout << "\nTime with invalid values: ";
42       printUniversal( dinnerTime );
43       cout << endl;
44
45       return 0;
46
47    } // end main
48
```

Use dot operator to initialize structure members.

Direct access to data allows assignment of bad values.

Implementing a User-Defined Type Time with a `struct`

```
49    // print time in universal-time format
50    void printUniversal( const Time &t )
51    {
52       cout << setfill( '0' ) << setw( 2 ) << t.hour << ":"
53            << setw( 2 ) << t.minute << ":"
54            << setw( 2 ) << t.second;
55
56    } // end function printUniversal
57
58    // print time in standard-time format
59    void printStandard( const Time &t )
60    {
61       cout << ( ( t.hour == 0 || t.hour == 12 ) ?
62                 12 : t.hour % 12 ) << ":" << setfill( '0' )
63            << setw( 2 ) << t.minute << ":"
64            << setw( 2 ) << t.second
65            << ( t.hour < 12 ? " AM" : " PM" );
66
67    } // end function printStandard
```

Use parameterized stream manipulator **`setfill`**.

```
Dinner will be held at 18:30:00 universal time,
which is 6:30:00 PM standard time.

Time with invalid values: 29:73:00
```

Implementing a User-Defined Type Time with a `struct`

```
49    // print time in universal-time format
50    void printUniversal( const Time &t )
51    {
52       cout << setfill( '0' ) << setw( 2 ) << t.hour << ":"
53            << setw( 2 ) << t.minute << ":"
54            << setw( 2 ) << t.second;
55
56    } // end function printUniversal
57
58    // print time in standard-time format
59    void printStandard( const Time &t )
60    {
61       cout << ( ( t.hour == 0 || t.hour == 12 ) ?
62                 12 : t.hour % 12 ) << ":" << setfill( '0' )
63            << setw( 2 ) << t.minute << ":"
64            << setw( 2 ) << t.second
65            << ( t.hour < 12 ? " AM" : " PM" );
66
67    } // end function printStandard
```

Use dot operator to access data members.

```
Dinner will be held at 18:30:00 universal time,
which is 6:30:00 PM standard time.

Time with invalid values: 29:73:00
```

Implementing a `Time` Abstract Data Type with a `class`

- **Classes** : part of the system, it describes "something"
- **objects** : class declaration in the program
  - Attributes (data members)
  - Behaviors (member functions)
  - Defined using keyword **`class`**
- Member functions: Methods function of the class, it describes what the class can do (action)

  Invoked in response to messages
- Member access specifiers
  - **`public:`**

  Accessible wherever object of class in scope
  - **`private:`**

  Accessible only to member functions of class
  - **`protected:`**

Implementing a `Time` Abstract Data Type with a `class`

- **Constructor function**
  - Special member function
    - Initializes data members
    - Same name as class
  - Called when object instantiated
  - Several constructors
    - Function overloading
    - No return type

Class Time definition

```
1       class Time {
2
3       public:
4          Time();                           // constructor
5          void setTime( int, int, int );    // set hour, minute, second
6          void printUniversal();            // print universal-time format
7          void printStandard();             // print standard-time format
8
9       private:
10        int hour;      // 0 - 23 (24-hour clock format)
11        int minute;    // 0 - 59
12        int second;    // 0 - 59
13
14     }; // end class Time
```

Class Time definition

Definition of class begins with keyword **class**.

```
1       class Time {
2
3       public:
4          Time();
5          void setTime( int, int, int ); // set hour, minute, second
6          void printUniversal();         // print universal-time format
7          void printStandard();          // print standard-time format
8
9       private:
10         int hour;
11         int minute;
12         int second;    // 0 - 59
13
14      }; // end class Time
```

Class body starts with left brace.

Class body ends with right brace.

Definition terminates with semicolon.

Class Time definition

```
1       class Time {
2
3       public:
4          Time();                          // constructor
5          void setTime( int, int, int ); // set hour, minute, second
6          void printUniversal();           // print universal-time format
7          void printStandard();            // print standard-time format
8
9       private:
10        int hour;      // 0 - 23 (24-hour clock format)
11        int minute;    // 0 - 59
12        int second;    // 0 - 59
13
14     }; // end class Time
```

Member access specifiers.

Class Time definition

```
1     class Time {
2
3     public:
4        Time();                          // const
5        void setTime( int, int, int );   // set h
6        void printUniversal();           // print universal-time format
7        void printStandard();            // print standard-time format
8
9     private:
10       int hour;     // 0 - 23 (24-
11       int minute;   // 0 - 59
12       int second;   // 0 - 59
13
14    }; // end class Time
```

Constructor has same name as class, **Time**, and no return type.

Function prototypes for **public** member functions.

private data members accessible only to member functions.

Implementing a `Time` Abstract Data Type with a `class`

Objects of class

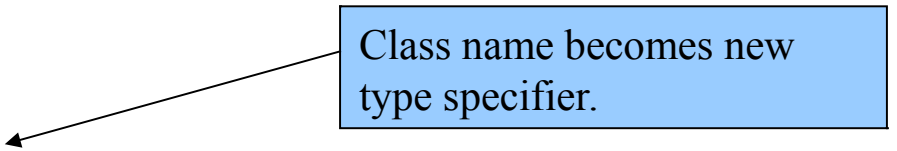
After class definition

Class name new type specifier

C++ extensible language

Object, array, pointer and reference declarations

Example:




```
Time sunset;                    // object of type Time
Time arrayOfTimes[ 5 ];         // array of Time objects
Time *pointerToTime;            // pointer to a Time object
Time &dinnerTime = sunset;      // reference to a Time object
```

Implementing a `Time` Abstract Data Type with a `class`

- Member functions defined outside class
  - Binary scope resolution operator (`::`)
  - "Ties" member name to class name
  - Uniquely identify functions of particular class
  - Different classes can have member functions with same name
  - Format for defining member functions

```
ReturnType ClassName::MemberFunctionName( ){
   ...
}
```

  - Does not change whether function **`public`** or **`private`**
- Member functions defined inside class
  - Do not need scope resolution operator, class name
  - Compiler attempts **`inline`**
    - Outside class, inline explicitly with keyword **`inline`**

Class Time definition

```
1       // Fig. 6.3: fig06_03.cpp
2       // Time class.
3       #include <iostream>
4
5       using std::cout;
6       using std::endl;
7
8       #include <iomanip>
9
10    using std::setfill;
11    using std::setw;
12
13    // Time abstract data type (ADT) definition
14    class Time {
15
16    public:
17       Time();                           // constructor
18       void setTime( int, int, int ); // set hour, minute, second
19       void printUniversal();            // print universal-time format
20       void printStandard();             // print standard-time format
21
```

Define class **Time**.

Class Time definition

```
22    private:
23       int hour;      // 0 - 23 (24-hour clock format)
24       int minute;    // 0 - 59
25       int second;    // 0 - 59
26
27    }; // end class Time
28
29    // Time constructor initializes each data member to zero and
30    // ensures all Time objects start in a consistent state
31    Time::Time()
32    {
33       hour = minute = second = 0;
34
35    } // end Time constructor
36
37    // set new Time value using universal time, perform validity
38    // checks on the data values and set invalid values to zero
39    void Time::setTime( int h, int m, int s )
40    {
41       hour = ( h >= 0 && h < 24 ) ? h : 0;
42       minute = ( m >= 0 && m < 60 ) ? m : 0;
43       second = ( s >= 0 && s < 60 ) ? s : 0;
44
45    } // end function setTime
46
```

Constructor initializes **private** data members to **0**.

public member function checks parameter values for validity before setting **private** data members.

Class Time definition

```
47    // print Time in universal format
48    void Time::printUniversal()
49    {
50       cout << setfill( '0' ) << setw( 2 ) << hour << ":"
51            << setw( 2 ) << minute << ":"
52            << setw( 2 ) << second;
53
54    } // end function printUniversal
55
56    // print Time in standard format
57    void Time::printStandard()
58    {
59       cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
60            << ":" << setfill( '0' ) << setw( 2 ) << minute
61            << ":" << setw( 2 ) << second
62            << ( hour < 12 ? " AM" : " PM" );
63
64    } // end function printStandard
65
66    int main()
67    {
68       Time t;  // instantiate object t of class Time
69
```

No arguments (implicitly "know" purpose is to print data members); member function calls more concise.

Declare variable **t** to be object of class **Time**.

Class Time definition

```
70        // output Time object t's initial values
71        cout << "The initial universal time is ";
72        t.printUniversal();   // 00:00:00
73
74        cout << "\nThe initial standard time is
75        t.printStandard();    // 12:00:00 AM
76
77        t.setTime( 13, 27, 6 );   // change time
78
79        // output Time object t's new values
80        cout << "\n\nUniversal time after setTi
81        t.printUniversal();   // 13:27:06
82
83        cout << "\nStandard time after setTime is ";
84        t.printStandard();    // 1:27:06 PM
85
86        t.setTime( 99, 99, 99 );  // attempt invalid settings
87
88        // output t's values after specifying invalid values
89        cout << "\n\nAfter attempting invalid settings:"
90             << "\nUniversal time: ";
91        t.printUniversal();   // 00:00:00
92
```

Invoke **public** member functions to print time.

Set data members using **public** member function.

Attempt to set data members to invalid values using **public** member function.

Class Time definition

```
93        cout << "\nStandard time: ";
94        t.printStandard();     // 12:00:00 AM
95        cout << endl;
96
97        return 0;
98
99     } // end main
```

```
The initial universal time is 00:00:00
The initial standard time is 12:00:00 AM

Universal time after setTime is 13:27:06
Standard time after setTime is 1:27:06 PM

After attempting invalid settings:
Universal time: 00:00:00
Standard time: 12:00:00 AM
```

Data members set to **0** after attempting invalid settings.

Implementing a `Time` Abstract Data Type with a `class`

- Advantages of using classes
  - Simplify programming
  - Interfaces
- Hide implementation
- Software reuse
- Composition (aggregation)
  - Class objects included as members of other classes
  - Inheritance : New classes derived from old

Class Scope and Accessing Class Members

- Class scope
  - Data members, member functions
  - Within class scope
    - Class members
      - Immediately accessible by all member functions
      - Referenced by name
  - Outside class scope
    - Referenced through handles
    - Object name, reference to object, pointer to object
- File scope
  - Nonmember functions

Class Scope and Accessing Class Members

- Function scope
  - Variables declared in member function
  - Only known to function
  - Variables with same name as class-scope variables

Class-scope variable “hidden”

Access with scope resolution operator (`::`)

`ClassName::classVariableName`

Variables only known to function they are defined in

Variables are destroyed after function completion

Class Scope and Accessing Class Members

- Operators to access class members

  Identical to those for **`struct`**s
  - Dot member selection operator (**`.`**)

    Object

    Reference to object
  - Arrow member selection operator (**`->`**)

    Pointers

Class Count definition

```
1      // Fig. 6.4: fig06_04.cpp
2      // Demonstrating the class member access operators . and ->
3      //
4      // CAUTION: IN FUTURE EXAMPLES WE AVOID PUBLIC DATA!
5      #include <iostream>
6
7      using std::cout;
8      using std::endl;
9
10     // class Count definition
11     class Count {
12
13     public:
14        int x;
15
16        void print()
17        {
18           cout << x << endl;
19        }
20
21     }; // end class Count
22
```

Data member **`x public`** to illustrate class member access operators; typically data members **`private`**.

Class Count definition

```
23    int main()
24    {
25       Count counter;                 // create counter object
26       Count *counterPtr = &counter; // create pointer to counter
27       Count &counterRef = counter;  // create reference to counter
28
29       cout << "Assign 1 to x and print using the object's name: ";
30       counter.x = 1;          // assign 1 to data member x
31       counter.print();        // call member function print
32
33       cout << "Assign 2 to x and print using a reference: ";
34       counterRef.x = 2;       // assign 2 to data member x
35       counterRef.print();     // call member function print
36
37       cout << "Assign 3 to x and print using a pointer: ";
38       counterPtr->x = 3;      // assign 3 to data member x
39       counterPtr->print(); // call member function print
40
41       return 0;
42
43    } // end main
```

```
Assign 1 to x and print using the object's name: 1
Assign 2 to x and print using a reference: 2
Assign 3 to x and print using a pointer: 3
```

Class Count definition

```
23    int main()
24    {
25       Count counter;                 // create counter object
26       Count *counterPtr = &counter; // create pointer to counter
27       Count &counterRef = counter;  // create reference to counter
28
29       cout << "Assign 1 to x and print using the object's name: ";
30       counter.x = 1;          // assign 1 to data member x
31       counter.print();        // call member function print
32
33       cout << "Assign 2 to x and print using a reference: ";
34       counterRef.x = 2;       // assign 2 to data member x
35       counterRef.print();     // call member function print
36
37       cout << "Assign 3 to x and print using a pointer: ";
38       counterPtr->x = 3;      // assign 3 to data member x
39       counterPtr->print(); // call member function print
40
41       return 0;
42
43    } // end main
```

Use dot member selection operator for **counter** object.

Use dot member selection operator for **counterRef** reference to object.

Use arrow member selection operator for **counterPtr** pointer to object.

```
Assign 1 to x and print using the object's name: 1
Assign 2 to x and print using a reference: 2
Assign 3 to x and print using a pointer: 3
```

Separating Interface from Implementation

- Separating interface from implementation
  - Advantage
    - Easier to modify programs
  - Disadvantage
    - Header files
      - Portions of implementation
        - Inline member functions
        - Hints about other implementation
        - private members

Separating Interface from Implementation

- Header files
  - Class definitions and function prototypes
  - Included in each file using class

    `#include`
  - File extension **`.h`**
  - Source-code files
  - Member function definitions
  - Same base name
  - Convention
  - Compiled and linked

Class time1 declaration

```
1      // Fig. 6.5: time1.h
2      // Declaration of class Time.
3      // Member functions are defined in time1.cpp
4
5      // prevent multiple inclusions of header file
6      #ifndef TIME1_H
7      #define TIME1_H
8
9      // Time abstract data type definition
10     class Time {
11
12     public:
13        Time();                           // constructor
14        void setTime( int, int, int ); // set hour, minute, second
15        void printUniversal();            // print universal-time format
16        void printStandard();             // print standard-time format
17
18     private:
19        int hour;     // 0 - 23 (24-hour clock format)
20        int minute;   // 0 - 59
21        int second;   // 0 - 59
22
23     }; // end class Time
24
25     #endif
```

Class time1 declaration

```
1   // Fig. 6.5: time1.h
2   // Declaration of class Time.
3   // Member functions are defined i
4
5   // prevent multiple inclusions of header file
6   #ifndef TIME1_H
7   #define TIME1_H
8
9   // Time abstract data type defi
10
11
12  public:
13     Time();                                  /
14     void setTime( int, int, int );           /
15     void printUniversal();                   // print universal-time format
16     void printStandard();                    // print standard-time format
17
18  private:
19     int hour;      // 0 - 23 (24-hour c
20     int minute;    // 0 - 59
21     int second;    // 0 - 59
22
23  }; // end class Time
24
25  #endif
```

Preprocessor code to prevent multiple inclusions.

"If not defined"

Code between these directives not included if name **TIME1_H** already defined.

Preprocessor directive defines name **TIME1_H**.

Naming convention: header file name with underscore replacing period.

Class time1 definition

```
1   // Fig. 6.6: time1.cpp
2   // Member-function definitions for class Time.
3   #include <iostream>
4
5   using std::cout;
6
7   #include <iomanip>
8
9   using std::setfill;
10  using std::setw;
11
12  // include definition of class Time from time1.h
13  #include "time1.h"
14
15  // Time constructor initializes each data member to zero.
16  // Ensures all Time objects s
17  Time::Time()
18  {
19     hour = minute = second = 0;
20
21  } // end Time constructor
22
```

Include header file **time1.h**.

Name of header file enclosed in quotes; angle brackets cause preprocessor to assume header part of C++ Standard Library.

Class time1 definition

```
23    // Set new Time value using universal time. Perform validity
24    // checks on the data values. Set invalid values to zero.
25    void Time::setTime( int h, int m, int s )
26    {
27       hour = ( h >= 0 && h < 24 ) ? h : 0;
28       minute = ( m >= 0 && m < 60 ) ? m : 0;
29       second = ( s >= 0 && s < 60 ) ? s : 0;
30
31    } // end function setTime
32
33    // print Time in universal format
34    void Time::printUniversal()
35    {
36       cout << setfill( '0' ) << setw( 2 ) << hour << ":"
37            << setw( 2 ) << minute << ":"
38            << setw( 2 ) << second;
39
40    } // end function printUniversal
41
42    // print Time in standard format
43    void Time::printStandard()
44    {
45       cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
46            << ":" << setfill( '0' ) << setw( 2 ) << minute
47            << ":" << setw( 2 ) << second
48            << ( hour < 12 ? " AM" : " PM" );
49
50    } // end function printStandard
```

Class time1 : main program

```
1     // Fig. 6.7: fig06_07.cpp
2     // Program to test class Time.
3     // NOTE: This file must be compiled with time1.cpp.
4     #include <iostream>
5
6     using std::cout;
7     using std::endl;
8
9     // include definition of class Ti
10    #include "time1.h"
11
12    int main()
13    {
14       Time t;  // instantiate object t of class Time
15
16       // output Time object t's initial values
17       cout << "The initial universal time is ";
18       t.printUniversal();   // 00:00:00
19       cout << "\nThe initial standard time is ";
20       t.printStandard();    // 12:00:00 AM
21
22       t.setTime( 13, 27, 6 );   // change time
23
```

Include header file **time1.h** to ensure correct creation/manipulation and determine size of **Time** class object.

Class time1 : main program

```
24        // output Time object t's new values
25        cout << "\n\nUniversal time after setTime is ";
26        t.printUniversal();   // 13:27:06
27        cout << "\nStandard time after setTime is ";
28        t.printStandard();    // 1:27:06 PM
29
30        t.setTime( 99, 99, 99 );  // attempt invalid settings
31
32        // output t's values after specifying invalid values
33        cout << "\n\nAfter attempting invalid settings:"
34             << "\nUniversal time: ";
35        t.printUniversal();   // 00:00:00
36        cout << "\nStandard time: ";
37        t.printStandard();    // 12:00:00 AM
38        cout << endl;
39
40        return 0;
41
42     } // end main
```

```
The initial universal time is 00:00:00
The initial standard time is 12:00:00 AM

Universal time after setTime is 13:27:06
Standard time after setTime is 1:27:06 PM
```

Controlling Access to Members

Access modes

- **`private`**

  Default access mode

  Accessible to member functions and **`friend`**s

- **`public`**

  Accessible to any function in program with handle to class object

- **`protected`**

Controlling Access to Members

```
1       // Fig. 6.8: fig06_08.cpp
2       // Demonstrate errors resulting from attempts
3       // to access private class members.
4       #include <iostream>
5
6       using std::cout;
7
8       // include definition of class Time from time1.h
9       #include "time1.h"
10
11      int main()
12      {
13         Time t;  // create Time object
14
15
16         t.hour = 7;  // error: 'Time::hour' is not accessible
17
18         // error: 'Time::minute' is not accessible
19         cout << "minute = " << t.minute;
20
21         return 0;
22
23      } // end main
```

```
D:\cpphtp4_examples\ch06\Fig6_06\Fig06_06.cpp(16) : error C2248:
   'hour' : cannot access private member declared in class 'Time'
D:\cpphtp4_examples\ch06\Fig6_06\Fig06_06.cpp(19) : error C2248:
   'minute' : cannot access private member declared in class 'Time'
```

Controlling Access to Members

```
1      // Fig. 6.8: fig06_08.cpp
2      // Demonstrate errors resulting from attempts
3      // to access private class members.
4      #include <iostream>
5
6      using std::cout;
7
8      // include definition of class Time from time1.h
9      #include "time1.h"
10
11     int main()
12     {
13        Time t;  // create Time object
14
15
16        t.hour = 7;  // error: 'Time::hour' is not accessible
17
18        // error: 'Time::minute' is not accessible
19        cout << "minute = " << t.minute;
20
21        return 0;
22
23     } // end main
```

Recall data member **hour** is **private**; attempts to access **private** members results in error.

Data member **minute** also **private**; attempts to access **private** members produces error.

```
D:\cpphtp4_examples\ch06\Fig6_06\Fig06_06.cpp(16) : error C22
   'hour' : cannot access private member declared in class 'T
D:\cpphtp4_examples\ch06\Fig6_06\Fig06_06.cpp(19) : error C2248:
   'minute' : cannot access private member declared in class 'Time'
```

Errors produced by attempting to access **private** members.

Controlling Access to Members

Class member access

- Default **`private`**
- Explicitly set to **`private`**, **`public`**, **`protected`**

- **`struct`** member access
  - Default **`public`**
  - Explicitly set to **`private`**, **`public`**, **`protected`**

Access to class's **`private`** data

- Controlled with **access functions** (accessor methods)
  - Get function: Read **`private`** data
  - Set function: Modify **`private`** data

Access Functions and Utility Functions

Access functions

- **`public`**

Read/display data

Predicate functions

Check conditions

Utility functions (helper functions)

- **`private`**

Support operation of **`public`** member functions

Not intended for direct client use

Access Functions and Utility Functions

```
1     // Fig. 6.9: salesp.h
2     // SalesPerson class definition.
3     // Member functions defined in salesp.cpp.
4     #ifndef SALESP_H
5     #define SALESP_H
6
7     class SalesPerson {
8
9     public:
10       SalesPerson();                    // constructor
11       void getSalesFromUser();          // input sales from keyboard
12       void setSales( int, double );     // set sales for a month
13       void printAnnualSales();          // summarize a
14
15    private:
16       double totalAnnualSales();        // utility function
17       double sales[ 12 ];               // 12 monthly sales figures
18
19    }; // end class SalesPerson
20
21    #endif
```

Set access function performs validity checks.

private utility function.

Access Functions and Utility Functions

```
1      // Fig. 6.10: salesp.cpp
2      // Member functions for class SalesPerson.
3      #include <iostream>
4
5      using std::cout;
6      using std::cin;
7      using std::endl;
8      using std::fixed;
9
10     #include <iomanip>
11
12     using std::setprecision;
13
14     // include SalesPerson class definition from salesp.h
15     #include "salesp.h"
16
17     // initialize elements of array sales to 0.0
18     SalesPerson::SalesPerson()
19     {
20        for ( int i = 0; i < 12; i++ )
21           sales[ i ] = 0.0;
22
23     } // end SalesPerson constructor
24
```

Access Functions and Utility Functions

```
25    // get 12 sales figures from the user at the keyboard
26    void SalesPerson::getSalesFromUser()
27    {
28       double salesFigure;
29
30       for ( int i = 1; i <= 12; i++ ) {
31          cout << "Enter sales amount for month " << i << ": ";
32          cin >> salesFigure;
33          setSales( i, salesFigure );
34
35       } // end for
36
37    } // end function getSalesFromUser
38
39    // set one of the 12 monthly sales figures; function subtracts
40    // one from month value for proper subscript in sales array
41    void SalesPerson::setSales( int month, double amount )
42    {
43       // test for valid month and amount values
44       if ( month >= 1 && month <= 12 && amount > 0 )
45          sales[ month - 1 ] = amount; // adjust for subscripts 0-11
46
47       else // invalid month or amount value
48          cout << "Invalid month or sales figure" << endl;
```

Set access function performs validity checks.

Access Functions and Utility Functions

```
49
50    } // end function setSales
51
52    // print total annual sales (with help of utility function)
53    void SalesPerson::printAnnualSales()
54    {
55       cout << setprecision( 2 ) << fixed
56            << "\nThe total annual sales are: $"
57            << totalAnnualSales() << endl; // call utility function
58
59    } // end function printAnnualSales
60
61    // private utility function to total annual sales
62    double SalesPerson::totalAnnualSales()
63    {
64       double total = 0.0;              // initialize total
65
66       for ( int i = 0; i < 12; i++ )  // summarize sales results
67          total += sales[ i ];
68
69       return total;
70
71    } // end function totalAnnualSales
```

private utility function to help function **printAnnualSales**; encapsulates logic of manipulating **sales** array.

```
1      // Fig. 6.11: fig06_11.cpp
2      // Demonstrating a utility function.
3      // Compile this program with salesp.cpp
4
5      // include SalesPerson class definition from salesp.h
6      #include "salesp.h"
7
8      int main()
9      {
10       SalesPerson s;          // create SalesPerson object s
11
12       s.getSalesFromUser();  // note simple sequential code; n
13       s.printAnnualSales();  // control structures in main
14
15       return 0;
16
17     } // end main
```

Simple sequence of member function calls; logic encapsulated in member functions.

```
Enter sales amount for month 1: 5314.76
Enter sales amount for month 2: 4292.38
Enter sales amount for month 3: 4589.83
Enter sales amount for month 4: 5534.03
Enter sales amount for month 5: 4376.34
Enter sales amount for month 6: 5698.45
Enter sales amount for month 7: 4439.22
Enter sales amount for month 8: 5893.57
Enter sales amount for month 9: 4909.67
Enter sales amount for month 10: 5123.45
Enter sales amount for month 11: 4024.97
Enter sales amount for month 12: 5923.92

The total annual sales are: $60120.59
```

Initializing Class Objects: Constructors

- Constructors
  - Initialize data members
    - Or can set later
  - Same name as class
  - No return type
- Initializers
  - Passed as arguments to constructor
  - In parentheses to right of class name before semicolon

```
Class-type ObjectName( value1,value2,…);
```

Using Default Arguments with Constructors

Constructors:

- Can specify default arguments
- Default constructors
- Defaults all arguments

  OR

  - Explicitly requires no arguments
  - Can be invoked with no arguments
  - Only one per class

Using Default Arguments with Constructors

```
1   // Fig. 6.12: time2.h
2   // Declaration of class Time.
3   // Member functions defined in time2.cpp.
4
5   // prevent multiple inclusions of header file
6   #ifndef TIME2_H
7   #define TIME2_H
8
9   // Time abstract data type definiti
10  class Time {
11
12  public:
13     Time( int = 0, int = 0, int = 0); // default constructor
14     void setTime( int, int, int ); // set hour, minute, second
15     void printUniversal();         // print universal-time format
16     void printStandard();          // print standard-time format
17
18  private:
19     int hour;     // 0 - 23 (24-hour clock format)
20     int minute;   // 0 - 59
21     int second;   // 0 - 59
22
23  }; // end class Time
24
25  #endif
```

Default constructor specifying all arguments.

Using Default Arguments with Constructors

```
1       // Fig. 6.13: time2.cpp
2       // Member-function definitions for class Time.
3       #include <iostream>
4
5       using std::cout;
6
7       #include <iomanip>
8
9       using std::setfill;
10    using std::setw;
11
12    // include definition of class Time from time2.h
13    #include "time2.h"
14
15    // Time constructor initializes each data member to zero
16    // ensures all Time objects start in a consistent state
17    Time::Time( int hr, int min, int sec )
18    {
19       setTime( hr, min, sec );  // validate and set time
20
21    } // end Time constructor
22
```

Constructor calls **`setTime`** to validate passed (or default) values.

Using Default Arguments with Constructors

```
23    // set new Time value using universal time, perform validity
24    // checks on the data values and set invalid values to zero
25    void Time::setTime( int h, int m, int s )
26    {
27       hour = ( h >= 0 && h < 24 ) ? h : 0;
28       minute = ( m >= 0 && m < 60 ) ? m : 0;
29       second = ( s >= 0 && s < 60 ) ? s : 0;
30
31    } // end function setTime
32
33    // print Time in universal format
34    void Time::printUniversal()
35    {
36       cout << setfill( '0' ) << setw( 2 ) << hour << ":"
37            << setw( 2 ) << minute << ":"
38            << setw( 2 ) << second;
39
40    } // end function printUniversal
41
42    // print Time in standard format
43    void Time::printStandard()
44    {
45       cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
46            << ":" << setfill( '0' ) << setw( 2 ) << minute
47            << ":" << setw( 2 ) << second
48            << ( hour < 12 ? " AM" : " PM" );
49
50    } // end function printStandard
```

Using Default Arguments with Constructors

```
1   // Fig. 6.14: fig06_14.cpp
2   // Demonstrating a default constructor for class Time.
3   #include <iostream>
4
5   using std::cout;
6   using std::endl;
7
8   // include definition of class Time from time2.h
9   #include "time2.h"
10
11  int main()
12  {
13     Time t1;                // all arguments defaulted
14     Time t2( 2 );           // minute and second defaulted
15     Time t3( 21, 34 );      // second defaulted
16     Time t4( 12, 25, 42 ); // all values specified
17     Time t5( 27, 74, 99 ); // all bad values specified
18
19     cout << "Constructed with:\n\n"
20          << "all default arguments:\n  ";
21     t1.printUniversal();  // 00:00:00
22     cout << "\n  ";
23     t1.printStandard();   // 12:00:00 AM
24
```

Initialize **`Time`** objects using default arguments.

Initialize **`Time`** object with invalid values; validity checking will set values to **0**.

Using Default Arguments with Constructors

```
25        cout << "\n\nhour specified; default minute and second:\n  ";
26        t2.printUniversal();  // 02:00:00
27        cout << "\n  ";
28        t2.printStandard();   // 2:00:00 AM
29
30        cout << "\n\nhour and minute specified; default second:\n  ";
31        t3.printUniversal();  // 21:34:00
32        cout << "\n  ";
33        t3.printStandard();   // 9:34:00 PM
34
35        cout << "\n\nhour, minute, and second specified:\n  ";
36        t4.printUniversal();  // 12:25:42
37        cout << "\n  ";
38        t4.printStandard();   // 12:25:42 PM
39
40        cout << "\n\nall invalid values specified:\n  ";
41        t5.printUniversal();  // 00:00:00
42        cout << "\n  ";
43        t5.printStandard();   // 12:00:00 AM
44        cout << endl;
45
46        return 0;
47
48     } // end main
```

t5 constructed with invalid arguments; values set to **0**.

Using Default Arguments with Constructors

```
Constructed with:

all default arguments:
  00:00:00
  12:00:00 AM

hour specified; default minute and second:
  02:00:00
  2:00:00 AM

hour and minute specified; default second:
  21:34:00
  9:34:00 PM

hour, minute, and second specified:
  12:25:42
  12:25:42 PM

all invalid values specified:
  00:00:00
  12:00:00 AM
```

Destructors

- Destructors
  - Special member function
  - Same name as class
    - Preceded with tilde (**~**)
  - No arguments
  - No return value
  - Cannot be overloaded
  - Performs “termination housekeeping”
  - Before system reclaims object’s memory
    - Reuse memory for new objects
  - If No explicit destructor : Compiler creates “empty” destructor”

When Constructors and Destructors Are Called

- Constructors and destructors
  - Called implicitly by compiler
- Order of function calls
  - Depends on order of execution
    - When execution enters and exits scope of objects
  - Generally, destructor calls reverse order of constructor calls

When Constructors and Destructors Are Called

- Order of constructor, destructor function calls
  - Global scope objects
    - Constructors
      - Before any other function (including **`main`**)
    - Destructors
      - When **`main`** terminates (or **`exit`** function called)
      - Not called if program terminates with **`abort`**
  - Automatic local objects
    - Constructors
      - When objects defined
        - Each time execution enters scope
    - Destructors
      - When objects leave scope
        - Execution exits block in which object defined
      - Not called if program ends with **`exit`** or **`abort`**

When Constructors and Destructors Are Called

Order of constructor, destructor function calls

- **`static`** local objects

Constructors

Exactly once

When execution reaches point where object defined

Destructors

When **`main`** terminates or **`exit`** function called

Not called if program ends with **`abort`**

Using `Set` and `Get` Functions

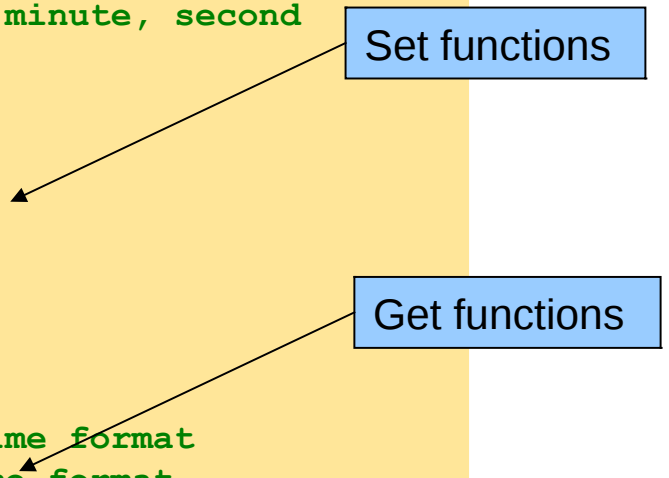
Set functions

- Perform validity checks before modifying **`private`** data
- Notify if invalid values
- Indicate with return values

Get functions

- “Query” functions
- Control format of data returned

```
1   // Fig. 6.18: time3.h
2   // Declaration of class Time.
3   // Member functions defined in time3.cpp
4
5   // prevent multiple inclusions of header file
6   #ifndef TIME3_H
7   #define TIME3_H
8
9   class Time {
10
11  public:
12     Time( int = 0, int = 0, int = 0 );  // default constructor
13
14     // set functions
15     void setTime( int, int, int );  // set hour, minute, second
16     void setHour( int );    // set hour
17     void setMinute( int ); // set minute
18     void setSecond( int ); // set second
19
20     // get functions
21     int getHour();          // return hour
22     int getMinute();        // return minute
23     int getSecond();        // return second
24
25     void printUniversal(); // output universal-time format
26     void printStandard();  // output standard-time format
27
28  private:
29     int hour;               // 0 - 23 (24-hour clock format)
30     int minute;             // 0 - 59
31     int second;             // 0 - 59
32
33  }; // end clas Time
34
35  #endif
```



Using Set and Get Functions

```
1      // Fig. 6.19: time3.cpp
2      // Member-function definitions for Time class.
3      #include <iostream>
4
5      using std::cout;
6
7      #include <iomanip>
8
9      using std::setfill;
10    using std::setw;
11
12    // include definition of class Time from time3.h
13    #include "time3.h"
14
15    // constructor function to initialize private data;
16    // calls member function setTime to set variables;
17    // default values are 0 (see class definition)
18    Time::Time( int hr, int min, int sec )
19    {
20       setTime( hr, min, sec );
21
22    } // end Time constructor
23
```

Using Set and Get Functions

```
24    // set hour, minute and second values
25    void Time::setTime( int h, int m, int s )
26    {
27       setHour( h );
28       setMinute( m );
29       setSecond( s );
30
31    } // end function setTime
32
33    // set hour value
34    void Time::setHour( int h )
35    {
36       hour = ( h >= 0 && h < 24 ) ? h : 0;
37
38    } // end function setHour
39
40    // set minute value
41    void Time::setMinute( int m )
42    {
43       minute = ( m >= 0 && m < 60 ) ? m : 0;
44
45    } // end function setMinute
46
```

Call set functions to perform validity checking.

Set functions perform validity checks before modifying data.

Using Set and Get Functions

```
47    // set second value
48    void Time::setSecond( int s )
49    {
50       second = ( s >= 0 && s < 60 ) ? s : 0;
51
52    } // end function setSecond
53
54    // return hour value
55    int Time::getHour()
56    {
57       return hour;
58
59    } // end function getHour
60
61    // return minute value
62    int Time::getMinute()
63    {
64       return minute;
65
66    } // end function getMinute
67
```

Set function performs validity checks before modifying data.

Get functions allow client to read data.

Using Set and Get Functions

```
68    // return second value
69    int Time::getSecond()
70    {
71       return second;
72
73    } // end function getSecond
74
75    // print Time in universal format
76    void Time::printUniversal()
77    {
78       cout << setfill( '0' ) << setw( 2 ) << hour << ":"
79            << setw( 2 ) << minute << ":"
80            << setw( 2 ) << second;
81
82    } // end function printUniversal
83
84    // print Time in standard format
85    void Time::printStandard()
86    {
87       cout << ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 )
88            << ":" << setfill( '0' ) << setw( 2 ) << minute
89            << ":" << setw( 2 ) << second
90            << ( hour < 12 ? " AM" : " PM" );
91
92    } // end function printStandard
```

Get function allows client to read data.

Using Set and Get Functions

```
1     // Fig. 6.20: fig06_20.cpp
2     // Demonstrating the Time class set and get functions
3     #include <iostream>
4
5     using std::cout;
6     using std::endl;
7
8     // include definition of class Time from time3.h
9     #include "time3.h"
10
11    void incrementMinutes( Time &, const int );  // prototype
12
13    int main()
14    {
15       Time t;              // create Time object
16
17       // set time using individual set functions
18       t.setHour( 17 );     // set hour to valid value
19       t.setMinute( 34 );   // set minute to valid value
20       t.setSecond( 25 );   // set second to valid value
21
```

Invoke set functions to set valid values.

Using Set and Get Functions

```
22       // use get functions to obtain hour, minute and second
23       cout << "Result of setting all valid values:\n"
24            << "  Hour: " << t.getHour()
25            << "  Minute: " << t.getMinute()
26            << "  Second: " << t.getSecond();
27
28       // set time using individual set functions
29       t.setHour( 234 );    // invalid hour set to 0
30       t.setMinute( 43 );   // set minute to valid value
31       t.setSecond( 6373 ); // invalid second set to 0
32
33       // display hour, minute and second after setting
34       // invalid hour and second values
35       cout << "\n\nResult of attempting to set invalid hour and"
36            << " second:\n  Hour: " << t.getHour()
37            << "  Minute: " << t.getMinute()
38            << "  Second: " << t.getSecond() << "\n\n";
39
40       t.setTime( 11, 58, 0 );    // set time
41       incrementMinutes( t, 3 );  // increment t's minute by 3
42
43       return 0;
44
45    } // end main
46
```

Attempt to set invalid values using set functions.

Invalid values result in setting data members to **0**.

Modify data members using function **setTime**.

Using Set and Get Functions

```
47    // add specified number of minutes to a Time object
48    void incrementMinutes( Time &tt, const int count )
49    {
50       cout << "Incrementing minute " << count
51            << " times:\nStart time: ";
52       tt.printStandard();
53
54       for ( int i = 0; i < count; i++ ) {
55          tt.setMinute( ( tt.getMinute() + 1 ) % 60 );
56
57          if ( tt.getMinute() == 0 )
58             tt.setHour( ( tt.getHour() + 1 ) % 24);
59
60          cout << "\nminute + 1: ";
61          tt.printStandard();
62
63       } // end for
64
65       cout << endl;
66
67    } // end function incrementMinutes
```

Using get functions to read data and set functions to modify data.

Using Set and Get Functions

```
Result of setting all valid values:
  Hour: 17  Minute: 34  Second: 25

Result of attempting to set invalid hour and second:
  Hour: 0  Minute: 43  Second: 0

Incrementing minute 3 times:
Start time: 11:58:00 AM
minute + 1: 11:59:00 AM
minute + 1: 12:00:00 PM
minute + 1: 12:01:00 PM
```

Attempting to set data members with invalid values results in error message and members set to **0**.

Default Memberwise Assignment

- Assigning objects
  - Assignment operator (=)
    - Can assign one object to another of same type
    - Default: memberwise assignment
      - Each right member assigned individually to left member
- Passing, returning objects
  - Objects passed as function arguments
  - Objects returned from functions
  - Default: pass-by-value
    - Copy of object passed, returned
      - Copy constructor
        - Copy original values into new object

Default Memberwise Assignment

```
1       // Fig. 6.24: fig06_24.cpp
2       // Demonstrating that class objects can be assigned
3       // to each other using default memberwise assignment.
4       #include <iostream>
5
6       using std::cout;
7       using std::endl;
8
9       // class Date definition
10    class Date {
11
12    public:
13       Date( int = 1, int = 1, int = 1990 ); // default constructor
14       void print();
15
16    private:
17       int month;
18       int day;
19       int year;
20
21    }; // end class Date
22
```

Default Memberwise Assignment

```
23    // Date constructor with no range checking
24    Date::Date( int m, int d, int y )
25    {
26       month = m;
27       day = d;
28       year = y;
29
30    } // end Date constructor
31
32    // print Date in the format mm-dd-yyyy
33    void Date::print()
34    {
35       cout << month << '-' << day << '-' << year;
36
37    } // end function print
38
39    int main()
40    {
41       Date date1( 7, 4, 2002 );
42       Date date2;  // date2 defaults to 1/1/1990
43
```

Default Memberwise Assignment

```
44        cout << "date1 = ";
45        date1.print();
46        cout << "\ndate2 = ";
47        date2.print();
48
49        date2 = date1;    // default m
50
51        cout << "\n\nAfter default memberwise assignment, date2 = ";
52        date2.print();
53        cout << endl;
54
55        return 0;
56
57     } // end main
```

Default memberwise assignment assigns each member of **date1** individually to each member of **date2**.

```
date1 = 7-4-2002
date2 = 1-1-1990

After default memberwise assignment, date2 = 7-4-2002
```

Software Reusability

- Software reusability
  - Class libraries
    - Well-defined
    - Carefully tested
    - Well-documented
    - Portable
    - Widely available
  - Speeds development of powerful, high-quality software
    - Rapid applications development (RAD)
  - Resulting problems
    - Cataloging schemes
    - Licensing schemes
    - Protection mechanisms

Esercitazione 7

Copy the files Cane.cpp, Cane.h, Sfera.cpp, Sfera.h

Exercise 1

Write a program that uses the "Cane" class:

- create two dogs
- print their age and weight
- change the weight of one of the dogs
- makes the second dog the same as the first
- use the “parla” function for the two dogs

```
Execution example:
./usaCane.exe

Constructor Dog
Constructor Dog
Bobi is 4 years old.
It weighs 30 Kg.

We change the weight of Bobi
Bobi is 4 years old.
It weighs 10 Kg.

Fido is 2 years old.
It weighs 15 Kg.

Fido becomes a clone of Bobi
Fido is 4 years old.
It weighs 10 Kg.

BAU !!
BAU !!
Destructor Dog
Destructor Dog
```

Esercitazione 7

Exercise 2

Write a program that uses the "Sfera" class:

- create a Sphere s and a pointer to the Sphere created sPtr
- print the center, the surface and the volume of the sphere using the object s
- print the center, the surface and the volume of the sphere using the sPtr pointer

```
Execution example:
./usaSfera.exe
Sphere: Center: (1, 2, 3) radius = 4 Surface: 201.024; Volume: 268.032
  We access the sphere via a pointer
Sphere: Center: (1, 2, 3) radius = 4 Surface: 201.024; Volume: 268.032
```

Exercise 3

Write a program that uses the "Sfera" class:
- create an array of spheres
- print the center, the surface and the volume of each sphere of the iterating array along the elements of the array

```
Execution example:
./usaSfera2.exe
Sphere: Center: (1, 2, 3)    radius = 4 Surface: 201.024; Volume: 268.032
Sphere: Center: (11, 12, 13) radius = 14 Surface: 2462.54; Volume: 11491.9
Sphere: Center: (21, 22, 23) radius = 24 Surface: 7236.86; Volume: 57894.9
Sphere: Center: (31, 32, 33) radius = 34 Surface: 14524; Volume: 164605
```

Esercitazione 7

Exercise 4

Write a program that uses the "Sfera" class:

- create an array of pointers to spheres
- center print, surface and volume of each sphere of the iterating array along the elements of the array

```
./usaSfera3.exe
Sphere: Center: (1, 2, 3) radius = 4 Surface: 201.024; Volume: 268.032
Sphere: Center: (11, 12, 13) radius = 14 Surface: 2462.54; Volume: 11491.9
Sphere: Center: (21, 22, 23) radius = 24 Surface: 7236.86; Volume: 57894.9
Sphere: Center: (31, 32, 33) radius = 34 Surface: 14524; Volume: 164605
```

Exercise 5

Write a "Cubo" class and a program that uses it.
The data members are the 3 coordinates of the center of the cube and its side
There must be functions: `getX(), setX(double), getY(), setY(double), getZ(), setZ(double), getLato(), setLato(double), print(),getArea () and getVolume ()`

Hint: this class is very similar to the Sphere class: start from there.

```
Execution example:
./usaCubo.exe
Cube: Center: (1, 2, 3) Side = 4 Surface: 96; Volume: 64
```

Esercitazione 7

Exercise 6

- Write a "Punto" class in 3 dimensions and a program that uses it.
- The data members are the 3 coordinates of the "point".
- There must be functions: `getX()`, `setX(double)`, `getY()`, `setY(double)`, `getZ()`, `setZ(double)`, `print()`, `distance(Point &)`
- The function `distance(Point &)` belongs to an object of the Point class, let's call it `p1`, and its argument is another object of the class Point, `p2`. By writing **`double dist = p1.distance(p2)`** the function must return the distance between `p1` and `p2`.

```
Execution example:
./usaPunto.exe
  Point p1: [1, 2, 3]
  Point p2: [4, 5, 6]
  The distance between p1 and p2: 5.19615
  We access the points via pointer
  Point p1: [1, 2, 3]
  Point p2: [4, 5, 6]
  The distance between p1 and p2: 5.19615
```

Esercitazione 7

Exercise 7

- Implement a "Sfera" class whose data members are:
  - the Center, an object of the Punto class, and the radius (a double)
- There must be:
  - a constructor with arguments "Punto" and a double
  - `set` and `get` functions for the datamembers "center" (i.e. Point) and "radius"
  - functions `getArea()`, `getVolume()`, `getName()`, `print()`
  - a **bool function** that returns true if two spheres overlap, false if they do not overlap (N.B .: two spheres overlap if the distance between the centers is less than the sum of their radii)
- Hint: the Point class can be reused as equal. Start from the class "Sfera" and make the (few) necessary changes.

```
Execution example:
./usaSfera.exe
 Sfera1
 center: [1, 2, 3]
 radius: 4; Surface area: 201.024; Volume: 268.032
 Sfera2
 center: [10, 20, 30]
 radius: 40; Surface area: 20102.4; Volume: 268032
 the spheres overlap
```

Constructors and Destructors

```
1   // Fig. 6.15: create.h
2   // Definition of class CreateAndDestroy.
3   // Member functions defined in create.cpp.
4   #ifndef CREATE_H
5   #define CREATE_H
6
7   class CreateAndDestroy {
8
9   public:
10    CreateAndDestroy( int, char * );  // constructor
11    ~CreateAndDestroy();              // destructor
12
13  private:
14    int objectID;
15    char *message;
16
17  }; // end class CreateAndDestroy
18
19  #endif
```

Constructor and destructor member functions.

private members to show order of constructor, destructor function calls.

```
1   // Fig. 6.16: create.cpp
2   // Member-function definitions for class CreateAndDestroy
3   #include <iostream>
4
5   using std::cout;
6   using std::endl;
7
8   // include CreateAndDestroy class definition from create.h
9   #include "create.h"
10
11  // constructor
12  CreateAndDestroy::CreateAndDestroy(
13     int objectNumber, char *messagePtr )
14  {
15     objectID = objectNumber;
16     message = messagePtr;
17
18     cout << "Object " << objectID << "   constructor runs   "
19          << message << endl;
20
21  } // end CreateAndDestroy constructor
22
23  // destructor
24  CreateAndDestroy::~CreateAndDestroy()
25  {
26     // the following line is for pedagogic purposes only
27     cout << ( objectID == 1 || objectID == 6 ? "\n" : "" );
28
29     cout << "Object " << objectID << "   destructor runs    "
30          << message << endl;
31
32  } // end ~CreateAndDestroy destructor
```

Output message to demonstrate timing of constructor function calls.

Constructors and Destructors

```
1   // Fig. 6.17: fig06_17.cpp
2   // Demonstrating the order in which constructors and
3   // destructors are called.
4   #include <iostream>
5
6   using std::cout;
7   using std::endl;
8
9   // include CreateAndDestroy class definition from create.h
10  #include "create.h"
11
12  void create( void );    // prototype
13
14  // global object
15  CreateAndDestroy first( 1, "(global before main)" );
16
17  int main()
18  {
19     cout << "\nMAIN FUNCTION: EXECUTION BEGINS" << endl;
20
21     CreateAndDestroy second( 2, "(local automatic in main)" );
22
23     static CreateAndDestroy third(
24        3, "(local static in main)" );
25
```

Create variable with global scope.

Create local automatic object.

Create **static** local object.

Constructors and Destructors

```
26       create();  // call function to create objects
27
28       cout << "\nMAIN FUNCTION: EXECUTION RESUMES" << endl;
29
30       CreateAndDestroy fourth
31
32       cout << "\nMAIN FUNCTION: EXECUTION ENDS" << endl;
33
34       return 0;
35
36    } // end main
37
38    // function to create objects
39    void create( void )
40    {
41       cout << "\nCREATE FUNCTION: EXECUTION BEGINS" << endl;
42
43       CreateAndDestroy fifth(
44
45       static CreateAndDestroy
46          6, "(local static in
47
48       CreateAndDestroy sevent
49          7, "(local automatic
50
51       cout << "\nCREATE FUNCTION: EXECUTION ENDS\" << endl;
52
53    } // end function create
```

Create local automatic objects.

Create local automatic object.

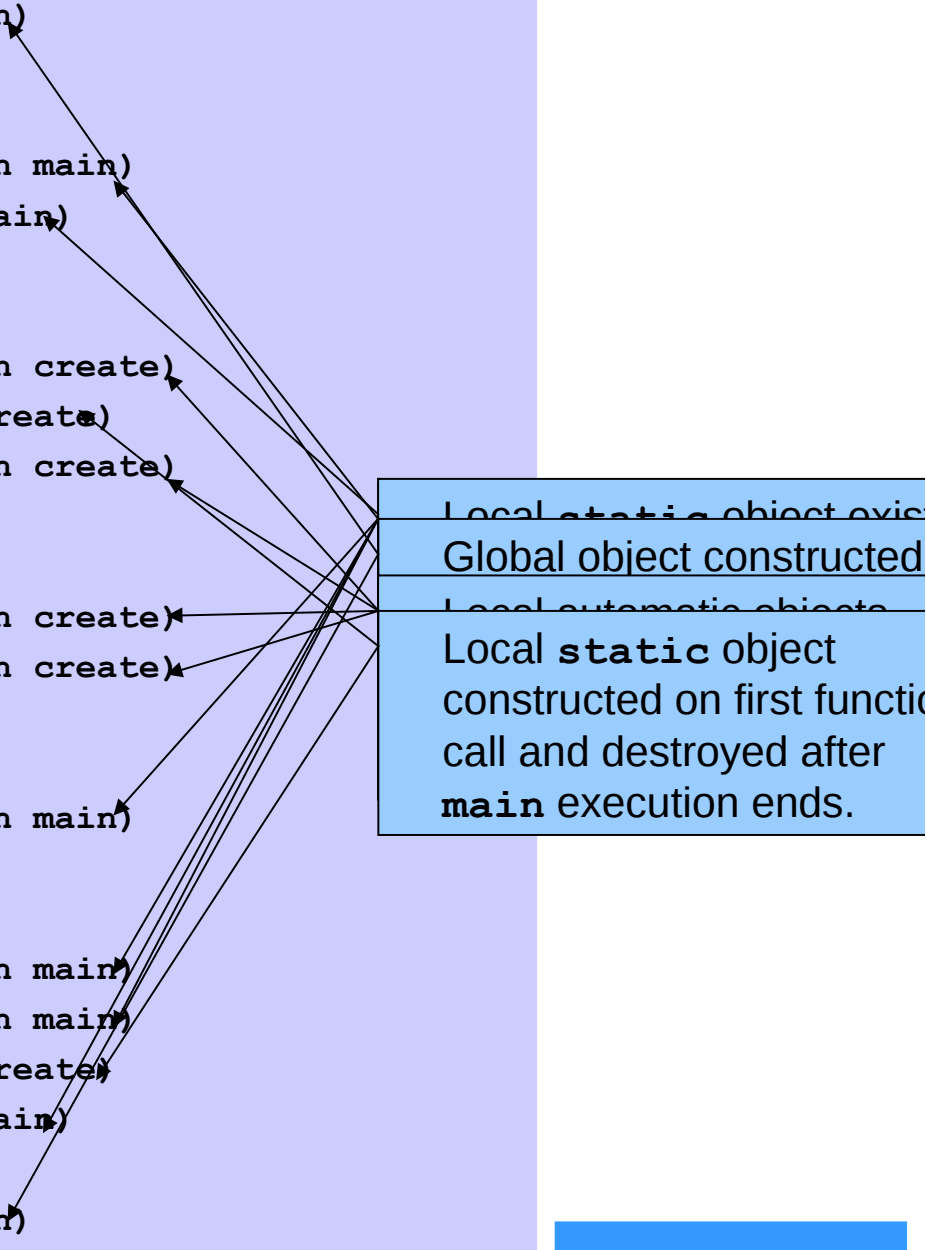
Create local automatic object in function.

Create **static** local object in function.

Create local automatic object in function.

Constructors and Destructors

```
Object 1   constructor runs   (global before main)

MAIN FUNCTION: EXECUTION BEGINS
Object 2   constructor runs   (local automatic in main)
Object 3   constructor runs   (local static in main)

CREATE FUNCTION: EXECUTION BEGINS
Object 5   constructor runs   (local automatic in create)
Object 6   constructor runs   (local static in create)
Object 7   constructor runs   (local automatic in create)

CREATE FUNCTION: EXECUTION ENDS
Object 7   destructor runs    (local automatic in create)
Object 5   destructor runs    (local automatic in create)

MAIN FUNCTION: EXECUTION RESUMES
Object 4   constructor runs   (local automatic in main)

MAIN FUNCTION: EXECUTION ENDS
Object 4   destructor runs    (local automatic in main)
Object 2   destructor runs    (local automatic in main)
Object 6   destructor runs    (local static in create)
Object 3   destructor runs    (local static in main)

Object 1   destructor runs    (global before main)
```



Subtle Trap: Returning a Reference to a `private` Data Member

- Reference to object
  - Alias for name of object
  - Lvalue
    - Can receive value in assignment statement
      - Changes original object
- Returning references
  - **`public`** member functions can return non-**`const`** references to **`private`** data members
    - Client able to modify **`private`** data members

Returning a Reference to a `private` Data Member

```
1      // Fig. 6.21: time4.h
2      // Declaration of class Time.
3      // Member functions defined in time4.cpp
4
5      // prevent multiple inclusions of header file
6      #ifndef TIME4_H
7      #define TIME4_H
8
9      class Time {
10
11     public:
12        Time( int = 0, int = 0, int = 0 );
13        void setTime( int, int, int );
14        int getHour();
15
16        int &badSetHour( int );  // DANGEROUS
17
18     private:
19        int hour;
20        int minute;
21        int second;
22
23     }; // end class Time
24
25     #endif
```

Function to demonstrate effects of returning reference to **`private`** data member.

Returning a Reference to a `private` Data Member

```
1      // Fig. 6.22: time4.cpp
2      // Member-function definitions for Time class.
3
4      // include definition of class Time from time4.h
5      #include "time4.h"
6
7      // constructor function to initialize private data;
8      // calls member function setTime to set variables;
9      // default values are 0 (see class definition)
10     Time::Time( int hr, int min, int sec )
11     {
12        setTime( hr, min, sec );
13
14     } // end Time constructor
15
16     // set values of hour, minute and second
17     void Time::setTime( int h, int m, int s )
18     {
19        hour = ( h >= 0 && h < 24 ) ? h : 0;
20        minute = ( m >= 0 && m < 60 ) ? m : 0;
21        second = ( s >= 0 && s < 60 ) ? s : 0;
22
23     } // end function setTime
24
```

Returning a Reference to a `private` Data Member

```
25    // return hour value
26    int Time::getHour()
27    {
28       return hour;
29
30    } // end function getHour
31
32    // POOR PROGRAMMING PRACTICE:
33    // Returning a reference to a private data member.
34    int &Time::badSetHour( int hh
35    {
36       hour = ( hh >= 0 && hh < 24
37
38       return hour;  // DANGEROUS reference return
39
40    } // end function badSetHour
```

Return reference to **`private`** data member **`hour`**.

Returning a Reference to a `private` Data Member

```
1   // Fig. 6.23: fig06_23.cpp
2   // Demonstrating a public member function that
3   // returns a reference to a private data member.
4   #include <iostream>
5
6   using std::cout;
7   using std::endl;
8
9   // include definition of class Time from time4.h
10  #include "time4.h"
11
12  int main()
13  {
14     Time t;
15
16     // store in hourRef the reference returned by badS
17     int &hourRef = t.badSetHour( 20 );
18
19     cout << "Hour before modifica
20
21     // use hourRef to set invalic
22     hourRef = 30;
23
24     cout << "\nHour after modification: " << t.getHour();
25
```

`badSetHour` returns reference to **`private`** data member **`hour`**.

Reference allows setting of **`private`** data member **`hour`**.

Returning a Reference to a `private` Data Member

```
26       // Dangerous: Function call that returns
27       // a reference can be used as an lvalue!
28       t.badSetHour( 12 ) = 74;
29
30       cout << "\n\n*********************************\n"
31            << "POOR PROGRAMMING PRACT
32            << "badSetHour as an lvalu
33            << t.getHour()
34            << "\n*********************************" << endl;
35
36       return 0;
37
38    } // end main
```

Can use function call as lvalue to set invalid value.

```
Hour before modification: 20
Hour after modification: 30

*********************************
POOR PROGRAMMING PRACTICE!!!!!!!
badSetHour as an lvalue, Hour: 74
*********************************
```

Returning reference allowed invalid setting of **`private`** data member **`hour`**.