
Creative Software Design

6 – Class

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Fall 2021

Midterm Exam

- Time: Oct 26, 09:00 ~ 11:00 am
 - Actual exam time may be shorter than this, but you should have no other schedule from 9:00 to 11:00 am.
- Monitored online exam
- You must take the mock exam this Thursday (in the lab session).

Today's topics

- Class and Instance
- Class access control
- Member functions
- Constructor, Destructor
- *this* pointer
- Struct in C vs. Struct in C++, Struct vs. Class in C++

Class

- A *class* is a user-defined data type,
 - which holds its own *member variables* and *member functions*.
 - These members can be accessed by creating an *instance* of that class.

```
class ClassName
{
accessSpecifier:
    memberVariables;
    ...
    memberFunctions() {...}
    ...
...
};
```

```
class Point
{
private:
    int x;
    int y;
public:
    void setXY(int a, int b) {x=a; y=b;}
};
```

- C++ classes are similar to C structures,
 - except member functions and access control.

```
typedef struct _Point
{
    int x;
    int y;
} Point;
```

Class vs. Instance / Object

- Class - type vs. Instance (or Object) - variable
- Analogous to bread pan vs. bread.



```
class Point
{
private:
    int x;
    int y;
public:
    void setXY(int a, int b)
    {x=a; y=b;}
};

int main(void)
{
    Point P1;
    P1.setXY(3, 4);
    return 0;
}
```

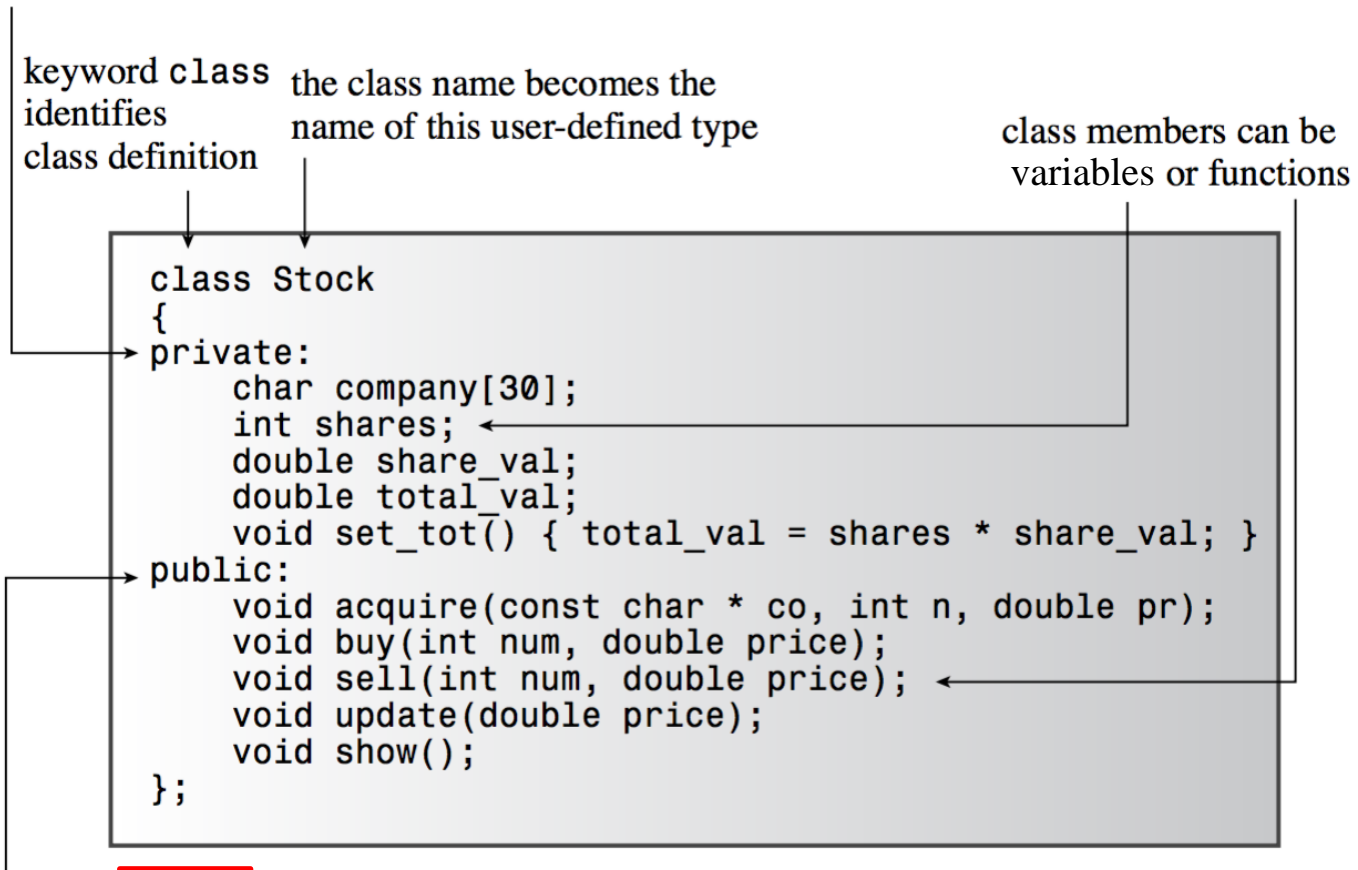
class

instance

- Creating an instance / object of a class is called *instantiation*.
- Instances have allocated memory to store specific data.
- There can be multiple identical instances of the same class type, but there cannot exist identical classes.

Class definition

keyword **private** identifies class members that can be accessed only through the member functions of the class (data hiding)



keyword **public** identifies class members that constitute the public interface for the class (abstraction)

Class access control

- Classes can have members with different **access control**.
 - The members are either **public**, **private**, or **protected** (*access specifiers*).
 - **public** members are accessible from anywhere.
 - **private** members are only accessible by its member functions.
 - **protected** members are accessible by its member functions and its derived classes' member functions - *will be covered in a later lecture (8-Inheritance)*.
- Any member *encountered after a specifier* will have the associated access *until another specifier is encountered*.

```
class Point {  
    private:  
private members { int x;  
                 int y;  
                 ...  
    public:  
public members { void setXY(int a, int b) {x=a; y=b;}  
                ...  
};
```

Class access control

- If member variables are **private**, they are **not accessible outside of the class**. They need **public access functions**.

```
class Point {
private:
    int x;
    int y;
public:
    void setXY(int a, int b) {x=a; y=b;}
};
int main(void){
    Point P1;
    P1.x = 3; // compile error!
    P1.setXY(3, 4);
    return 0;
}
```


Class access control : Stock example

```
class Stock // class declaration
{
private:
    std::string company;
    long shares;
    double share_val;
    double total_val;
    void set_tot() { total_val = shares * share_val; }
public:
    void acquire(const std::string & co, long n, double pr);
    void buy(long num, double price);
    void sell(long num, double price);
    void update(double price);
    void show();
}; // note semicolon at the end
```

Class access control : Student example

```
class Student {
private:
    string name_, id_, grade_;
    int midterm_, final_, hw1_, hw2_;

public:
    void SetInfo(string name, string id) { name_ = name, id_ = id; }
    void SetScores(int midterm, int final, int hw1, int hw2) {
        midterm_ = midterm, final_ = final, hw1_ = hw1, hw2_ = hw2;
    }
    void ProcessGrade() { ... }
    string GetGrade() { return grade_; }
};

int main() {
    Student a_student;
    a_student.SetInfo("gdhong", "13001");
    a_student.SetScores(99, 90, 85, 100);
    a_student.ProcessGrade(); // Call the member function ProcessGrade.

    a_student.grade_ = "D-"; // Compile error!
    string grade = a_student.GetGrade(); // Fine.
    ...
}
```

Member function

- A class can have member functions which work on the member variables of the class.
 - Member functions are **declared in the class definition**.
 - Member functions are **defined** either **in the class definition (in header files)** or **outside of the class definition (usually in source files)**.
 - Member functions are accessed by using **. operator**, like member variables.

Member function definition in the class definition : Student example

```
// student.h
class Student {
private:
    string name_, id_, grade_;
    int midterm_, final_, hw1_, hw2_;

public:
    void SetInfo(string name, string id)
    { name_ = name, id_ = id; }

    void SetScores(int midterm, int final, int hw1, int hw2)
    {
        midterm_ = midterm, final_ = final, hw1_ = hw1, hw2_ = hw2;
    }

    string GetGrade() { return grade_; }
};
```

Member function definition outside of the class definition : Student example

```
// student.h
class Student {
private:
    string name_, id_, grade_;
    int midterm_, final_, hw1_, hw2_;

public:
    void SetInfo(string name, string id);
    void SetScores(int midterm, int final, int hw1, int hw2);
    string GetGrade();
};
```

```
// student.cpp
#include "student.h"

void Student::SetInfo(string name, string id)
{ name_ = name, id_ = id; }

void Student::SetScores(int midterm, int final, int hw1, int hw2)
{
    midterm_ = midterm, final_ = final, hw1_ = hw1, hw2_ = hw2;
}

string Student::GetGrade()
{ return grade_; }
```

Member function: Scope resolution operator (::)

- `::` is used to specify the namespace or the class membership.
- `A::B` means `B` is in a namespace/class `A`.
- `::B` means `B` belongs the global namespace (most C library functions).

```
#include <math.h>
namespace my_namespace {

class MyClass {
    void FunctionA(int i);
    // ...
};

void MyClass::FunctionA(int i) { /* ... */ }
void FunctionB(double v, MyClass* a) { /* ... */ }

} // namespace my_namespace

int main() {
    my_namespace::MyClass a;
    my_namespace::FunctionB(1.25, &a);
    double v = ::cos(0.0);
    return 0;
}
```

Member function: Stock example

stock.cpp

```
void Stock::acquire(const std::string & co, long n, double pr)
{
    company = co;
    if (n < 0)
    {
        std::cout << "Number of shares can't be negative; "
                  << company << " shares set to 0.\n";
        shares = 0;
    }
    else
        shares = n;
    share_val = pr;
    set_tot();
}
```

stock.h

```
class Stock // class declaration
{
private:
    std::string company;
    long shares;
    double share_val;
    double total_val;
    void set_tot() { total_val = shares * share_val; }
public:
    void acquire(const std::string & co, long n, double pr);
    void buy(long num, double price);
    void sell(long num, double price);
    void update(double price);
    void show();
}; // note semicolon at the end
```

Member function: Stock example

stock.cpp

```
void Stock::sell(long num, double price)
{
    using std::cout;
    if (num < 0)
    {
        cout << "Number of shares sold can't be negative. "
              << "Transaction is aborted.\n";
    }
    else if (num > shares)
    {
        cout << "You can't sell more than you have! "
              << "Transaction is aborted.\n";
    }
    else
    {
        shares -= num;
        share_val = price;
        set_tot();
    }
}
```

stock.h

```
class Stock // class declaration
{
private:
    std::string company;
    long shares;
    double share_val;
    double total_val;
    void set_tot() { total_val = shares * share_val; }
public:
    void acquire(const std::string & co, long n, double pr);
    void buy(long num, double price);
    void sell(long num, double price);
    void update(double price);
    void show();
}; // note semicolon at the end
```


Quiz #1

- Go to <https://www.slido.com/>
- Join #csd-ys
- Click "Polls"

- Submit your answer in the following format:
 - **Student ID: Your answer**
 - e.g. **2017123456: 4)**

- Note that you must submit all quiz answers **in this format** to be counted as attendance.

Inline member functions

- To make a member function inline, you can define a member function in the class definition (in header file)
- Or you can define a member function outside the class definition (BUT IN header file) and use the *inline* qualifier.
- DO NOT define inline functions in source files.
 - If an inline function defined in a source file is called from another source file, you'll get 'unresolved external' error (<https://isocpp.org/wiki/faq/inline-functions#inline-member-fns>).

```
class Stock {
private:
    ...
    void set_tot(){
        total_val = shares * share_val;
    }
public:
    ...
};
```

```
class Stock {
private:
    ...
    void set_tot();
public:
    ...
};

inline void Stock::set_tot(){
    total_val = shares * share_val;
}
```

Inline member functions

- Question: Can I define a non-inline member function in a header file (outside the class definition)?
 - Let's say main.cpp and test.cpp include one of the following header files:

```
#include <string>

class Student {
private:
    std::string name_;
public:
    std::string getName();
};

std::string Student::getName()
{
    return name_;
}
```

link error: multiple definition of
Student::getName()

```
#include <string>

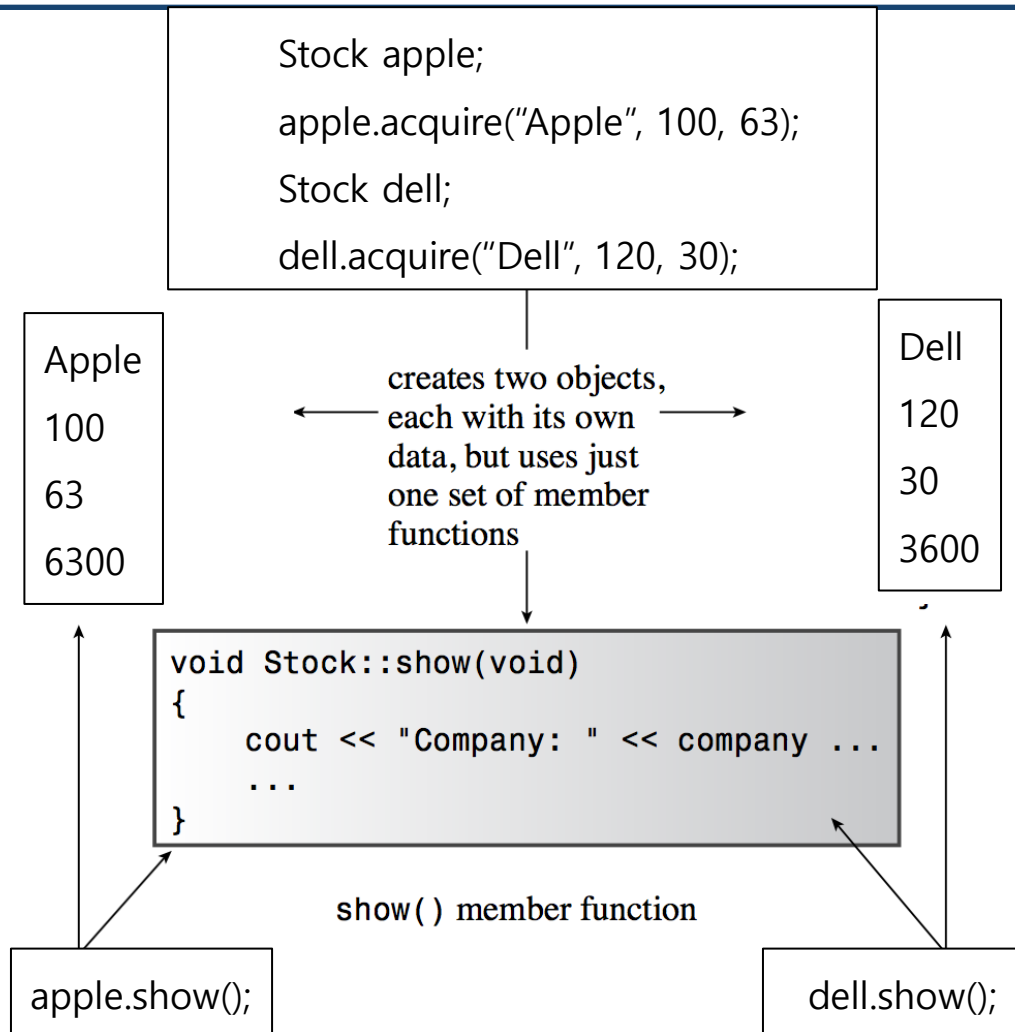
class Student {
private:
    std::string name_;
public:
    std::string getName();
};

inline std::string Student::getName()
{
    return name_;
}
```

Ok

→ Functions defined in a header file must be inline,
otherwise you'll get multiple definitions error.

Class vs. Instance : Stock example 1



Class vs. Instance : Stock example 2

```
int main() {  
  
    Stock apple;  
    apple.acquire("Apple", 20, 12.50);  
    apple.show();  
    apple.buy(15, 18.125);  
    apple.show();  
    apple.sell(400, 20.00);  
    apple.show();  
    apple.buy(300000, 40.125);  
    apple.show();  
    apple.sell(300000, 0.125);  
    apple.show();  
    return 0;  
}
```

Constructor

- Constructors are special member functions that **initialize the object** and is **called when the object is created**.
- They have the same name as the class and no return type.
- They are automatically called when the object of its class type is defined.

```
class Student {
public:
    string name_, id_, grade_;
    ...
public:
    Student() { name_="noname"; id_="noid"; }
    ...
};

int main()
{
    Student st; // Student::Student() is called!
    cout << st.name_ << endl;
}
```

Constructor Overloading

- A class can have multiple constructors.

```
class Student {
public:
    string name_, id_, grade_;
    ...
public:
    Student() { name_="noname"; id_="noid"; }
    Student(string name, string id) { name_=name; id_=id; }
    ...
};

int main()
{
    Student st1; // Student::Student() is called!
    Student st2("Tom", "2016123456"); // Student::Student(string,
string) is called!
}
```

Default constructor

- A default constructor is a constructor which is called with no argument.

```
class Student {
public:
    string name_, id_, grade_;
    int midterm_, final_, hw1_, hw2_;
    ...
public:
    Student() // default constructor
    { name_="noname"; id_="noid"; }

    Student(string name, string id) // this is not a default constructor
    { name_=name; id_=id; }
};
```


Default constructor

- **A default constructor is implicitly created by compiler if there is no user-defined constructor.**

```
class Stock
{
public:
    string company;
    long shares;
    double share_val;
};

int main()
{
    Stock stock; // implicitly declared
default constructor is called!

    cout << stock.company << endl;
    cout << stock.shares << endl;
    cout << stock.share_val << endl;
    return 0;
}
```

```
class Stock
{
public:
    string company;
    long shares;
    double share_val;

    Stock(const string& co, long n, double pr)
    {}
};

int main()
{
    Stock stock; // compile error!

    cout << stock.company << endl;
    cout << stock.shares << endl;
    cout << stock.share_val << endl;
    return 0;
}
```

Constructor : Stock example

stock.cpp

```
Stock::Stock(const string & co, long n, double pr)
{
    company = co;

    if (n < 0)
    {
        std::cerr << "Number of shares can't be negative; "
                  << company << " shares set to 0.\n";
        shares = 0;
    }
    else
        shares = n;
    share_val = pr;
    set_tot();
}
```

Quiz #2

- Go to <https://www.slido.com/>
- Join #**csd-ys**
- Click "Polls"

- Submit your answer in the following format:
 - **Student ID: Your answer**
 - e.g. **2017123456: 4)**

- Note that you must submit all quiz answers **in this format** to be counted as attendance.

Member initializer list

- Member initializer list is the place where non-default initialization of member variables can be specified.
 - Members of primitive type (such as int) are initialized with the parameter.
 - Members of class type is initialized **by calling the proper constructor taking the arguments.**

```
class Stock
{
public:
    string company;
    long shares;
    double share_val;

    Stock(const string& co, long n, double pr)
        : company(co), shares(n), share_val(pr)
    {}
};
```

Member initializer list & default constructor

- For member variables that are not initialized in a constructor,
 - Members of primitive type (such as int) remain uninitialized.
 - Members of class type initialized by calling their classes' **default constructor**.

```
class Student {
public:
    string name_, id_, grade_;
    int midterm_, final_, hw1_, hw2_;
    ...
public:
    Student(string name, string id)
        : name_(name), id_(id)
    {}
    // member variables other than name_ & id_ remain
    // uninitialized (for primitive types, e.g., midterm_)
    // or initialized by their classes' default constructor (for class type,
    // e.g., grade_ will be initialized by calling std::string::string() )
    ...
};
```

Operator new and class constructor

- $T^* p = \text{new } T;$
 - If T is a primitive type: Allocates memory space to store data of type T
 - If T is a class: Allocates memory space and initialize it **by calling default constructor of T**
- $T^* p = \text{new } T(\textit{arguments});$
 - If T is a primitive type: Allocates memory space and initialize it with the *arguments*
 - If T is a class: Allocates memory space and initialize it **by calling the proper constructor that takes *arguments***

```
#include <iostream>
#include <string>
using namespace std;

class Stock
{
public:
    string company;
    long shares;
    double share_val;

    Stock() { cout << "Stock::Stock()" << endl; }

    Stock(const string& co, long n, double pr)
    : company(co), shares(n), share_val(pr)
    { cout << "Stock::Stock(const string&, long, double)" << endl; }
};

int main()
{
    int* i1 = new int;
    int* i2 = new int(10);

    Stock* s1 = new Stock;
    Stock* s2 = new Stock("Apple", 10, 125.0);

    delete i1;
    delete i2;
    delete s1;
    delete s2;

    return 0;
}
```

Destructor

- A destructor is a special member function **for clean-up** that is **called when the object is destructed**.
- Its name is '~' + the class name.
- It has no arguments and no return type.

```
Stock::~~Stock()  
{  
}
```

```
Stock::~~Stock()    // class destructor  
{  
    cout << "Bye, " << company << "!\n";  
}
```


Destructor example

(Focus on ~DoubleArray() destructor!)

```
class DoubleArray {
public:
    DoubleArray() : ptr_(NULL), size_(0) {}
    DoubleArray(size_t size) : ptr_(NULL), size_(0) { Resize(size); }

    ~DoubleArray() { if (ptr_) delete[] ptr_; }

    void Resize(size_t size);

    int size() const { return size_; }
    double* ptr() { return ptr_; }
    const double* ptr() const { return ptr_; }

private:
    double* ptr_;
    size_t size_; // size_t is unsigned int.
};

void DoubleArray::Resize(size_t size) {
    double* new_ptr = new double[size];
    if (ptr_) {
        for (int i = 0; i < size_ && i < size; ++i) new_ptr[i] = ptr_[i];
        delete[] ptr_;
    }
    ptr_ = new_ptr;
    size_ = size;
}
```

Stock class example

Listing 10.4 `stock10.h`

```
// stock10.h -- Stock class declaration with constructors, destructor added
#ifndef STOCK10_H_
#define STOCK10_H_
#include <string>

class Stock
{
private:
    std::string company;
    long shares;
    double share_val;
    double total_val;
    void set_tot() { total_val = shares * share_val; }
public:
    // two constructors
    Stock();           // default constructor
    Stock(const std::string & co, long n = 0, double pr = 0.0);
    ~Stock();         // noisy destructor
    void buy(long num, double price);
    void sell(long num, double price);
    void update(double price);
    void show();
};

#endif
```

Stock class example

Listing 10.5 `stock10.cpp`

```
// stock10.cpp -- Stock class with constructors, destructor added
#include <iostream>
#include "stock10.h"

// constructors (verbose versions)
Stock::Stock()          // default constructor
{
    std::cout << "Default constructor called\n";
    company = "no name";
    shares = 0;
    share_val = 0.0;
    total_val = 0.0;
}

Stock::Stock(const std::string & co, long n, double pr)
{
    std::cout << "Constructor using " << co << " called\n";
    company = co;

    if (n < 0)
    {
        std::cout << "Number of shares can't be negative; "
                  << company << " shares set to 0.\n";
        shares = 0;
    }
    else
        shares = n;
    share_val = pr;
    set_tot();
}

// class destructor
Stock::~Stock()        // verbose class destructor
{
    std::cout << "Bye, " << company << "!\n";
}
```

Stock class example

Listing 10.6 usestok1.cpp

```
// usestok1.cpp -- using the Stock class
// compile with stock10.cpp
#include <iostream>
#include "stock10.h"

int main()
{
    {
        using std::cout;
        cout << "Using constructors to create new objects\n";
        Stock stock1("NanoSmart", 12, 20.0);           // syntax 1
        stock1.show();
        Stock stock2 = Stock ("Boffo Objects", 2, 2.0); // syntax 2
        stock2.show();

        cout << "Assigning stock1 to stock2:\n";
        stock2 = stock1;
        cout << "Listing stock1 and stock2:\n";
        stock1.show();
        stock2.show();

        cout << "Using a constructor to reset an object\n";
        stock1 = Stock("Nifty Foods", 10, 50.0);     // temp object
        cout << "Revised stock1:\n";
        stock1.show();
        cout << "Done\n";
    }
    return 0;
}
```

Quiz #3

- Go to <https://www.slido.com/>
- Join #csd-ys
- Click "Polls"

- Submit your answer in the following format:
 - **Student ID: Your answer**
 - e.g. 2017123456: 4)

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this pointer

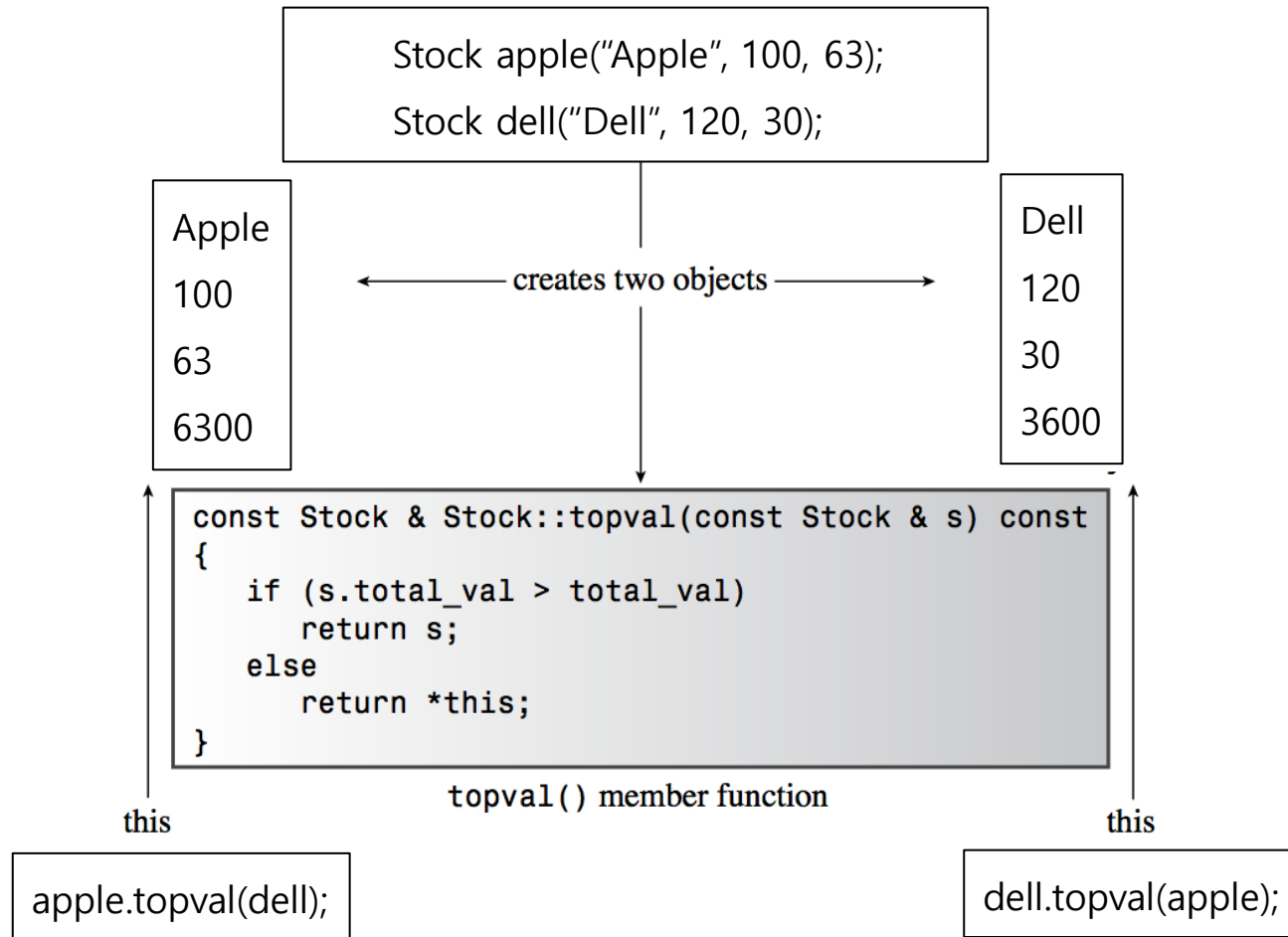
- Every object in C++ has access to its own address through a pointer called *this* pointer.
- "*this* pointer" points to "this object", used to invoke a member function or access to a member variable (passed as a hidden argument to the function)

```
class Rectangle {
private:
    int width, height;
public:
    void setValues(int x, int y) {
        width = x;
        height = y;
    }
};
```

=

```
class Rectangle {
private:
    int width, height;
public:
    void setValues(int x, int y) {
        this->width = x;
        this->height = y;
    }
};
```

this pointer – returning self reference



Invokes topval() with apple,
so *this* points to apple:
s is dell, **this* is apple

Invokes topval() with dell,
so *this* points to dell:
s is apple, **this* is dell

Member Var. and Parameter Names

- Question: Can member variables and function parameters have the same name? -> Yes, but it's not recommended.

```
class Rect
{
public:
    int width, height;
    Rect():width(1), height(2) {}
    void setValues(int width, int y)
    {
        this->width = width;
        height = y;
    }
};
int main()
{
    Rect rt;
    rt.setValues(10, 20);
    cout << rt.width << endl; // 10
    return 0;
}
```

if you always use the “this” pointer, that would be okay.

```
class Rect
{
public:
    int width, height;
    Rect():width(1), height(2) {}
    void setValues(int width, int y)
    {
        width = width;
        height = y;
    }
};
int main()
{
    Rect rt;
    rt.setValues(10, 20);
    cout << rt.width << endl; // 1 ?
    return 0;
}
```

But if you don't, it compiles and runs fine, but the result will not be what you think.

Array of Objects

```
int main()
{
// create an array of initialized objects
    Stock stocks[STKS] = {
        Stock("NanoSmart", 12, 20.0),
        Stock("Boffo Objects", 200, 2.0),
        Stock("Monolithic Obelisks", 130, 3.25),
        Stock("Fleep Enterprises", 60, 6.5)
    };

    std::cout << "Stock holdings:\n";
    int st;
    for (st = 0; st < STKS; st++)
        stocks[st].show();
// set pointer to first element
    const Stock * top = &stocks[0];
    for (st = 1; st < STKS; st++)
        top = &top->topval(stocks[st]);
// now top points to the most valuable holding
    std::cout << "\nMost valuable holding:\n";
    top->show();
    return 0;
}
```

```
Stock holdings:
Company: NanoSmart  Shares: 12
    Share Price: $20.000  Total Worth: $240.00
Company: Boffo Objects  Shares: 200
    Share Price: $2.000  Total Worth: $400.00
Company: Monolithic Obelisks  Shares: 130
    Share Price: $3.250  Total Worth: $422.50
Company: Fleep Enterprises  Shares: 60
    Share Price: $6.500  Total Worth: $390.00

Most valuable holding:
Company: Monolithic Obelisks  Shares: 130
    Share Price: $3.250  Total Worth: $422.50
```

Struct in C vs. Struct in C++

- In C, struct has only member variables, and is usually used with `typedef`
 - to avoid using `struct` keyword when declaring a variable (`struct _Point p1;`).
- In C++, struct has member variables and **member functions**, and **do es not need typedef.**

```
typedef struct _Point {
    int x;
    int y;
}Point;

int main(void){

    Point P1;
    P1.x = 3;
    P1.y = 4;
    return 0;
}
```

C

```
struct Point {
    int x;
    int y;
    void setXY(int a, int b) {x=a; y=b;}
};

int main(void){

    Point P1;
    P1.x = 3;
    P1.y = 4;
    P1.setXY(1, 2);
    return 0;
}
```

C++

Struct in C vs. Struct in C++

- In C, all struct member variables are *public* (can be accessed from anywhere).
- In C++, struct members can be one of *public*, *private*, or *protected* (the default is *public*).

```
typedef struct _Point {
    int x;
    int y;
}Point;

int main(void){

    Point P1;
    P1.x = 3;
    P1.y = 4;
    return 0;
}
```

C

=

```
struct Point {
    int x;
    int y;
};

int main(void){

    Point P1;
    P1.x = 3;
    P1.y = 4;
    return 0;
}
```

C++

=

```
struct Point {
public:
    int x;
    int y;
};

int main(void){

    Point P1;
    P1.x = 3;
    P1.y = 4;
    return 0;
}
```

C++

Struct in C vs. Struct in C++

- In C++, `struct` members can be one of *public*, *private*, or *protected* (the default is *public*).
- If members are *private*, they are not accessible outside of the class. They need *public access functions*.

```
struct Point {  
    private:  
    int x;  
    int y;  
};  
  
int main(void){  
  
    Point P1;  
    P1.x = 3; // compile error!  
    P1.y = 4; // compile error!  
    return 0;  
}
```

```
struct Point {  
    private:  
    int x;  
    int y;  
    public:  
    void setXY(int a, int b)  
    {x=a; y=b;}  
};  
  
int main(void){  
  
    Point P1;  
    P1.setXY(3, 4);  
    return 0;  
}
```

Struct vs. Class in C++

- In C++, `struct` and `class` are almost the same.
- The only difference is default accessibility of members:
 - In `struct`, *public* is default
 - In `class`, *private* is default

```
struct Point {  
private:  
    int x;  
    int y;  
public:  
    void setXY(int a, int b) {x=a; y=b;}  
};  
  
int main(void){  
  
    Point P1;  
    P1.setXY(3, 4);  
    return 0;  
}
```

=

```
class Point {  
    int x;  
    int y;  
public:  
    void setXY(int a, int b) {x=a; y=b;}  
};  
  
int main(void){  
  
    Point P1;  
    P1.setXY(3, 4);  
    return 0;  
}
```

Next Time

- Labs in this week:
 - Lab1: Assignment 6-1
 - Lab2: Second practice time for online exams. You **MUST** take the mock exam !

- Next lecture:
 - 7 - Standard Template Library