CS 106X
Classes and Objects

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reading:

Programming Abstractions in C++, Chapter 6

Class examples

- A calendar program might want to store information about dates, but C++ does not have a **`Date`** type.

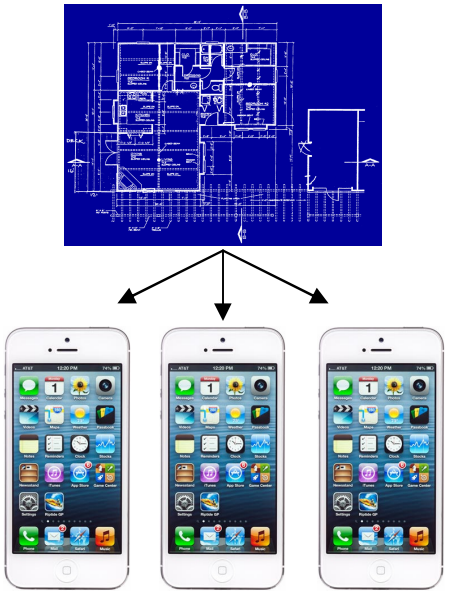
- A student registration system needs to store info about students, but C++ has no **`Student`** type.

- A bank app might want to store information about users' accounts, but C++ has no **`BankAccount`** type.

- However, C++ does provide a feature for us to add new data types to the language: **classes**.
  - Writing a class defines a new data type.

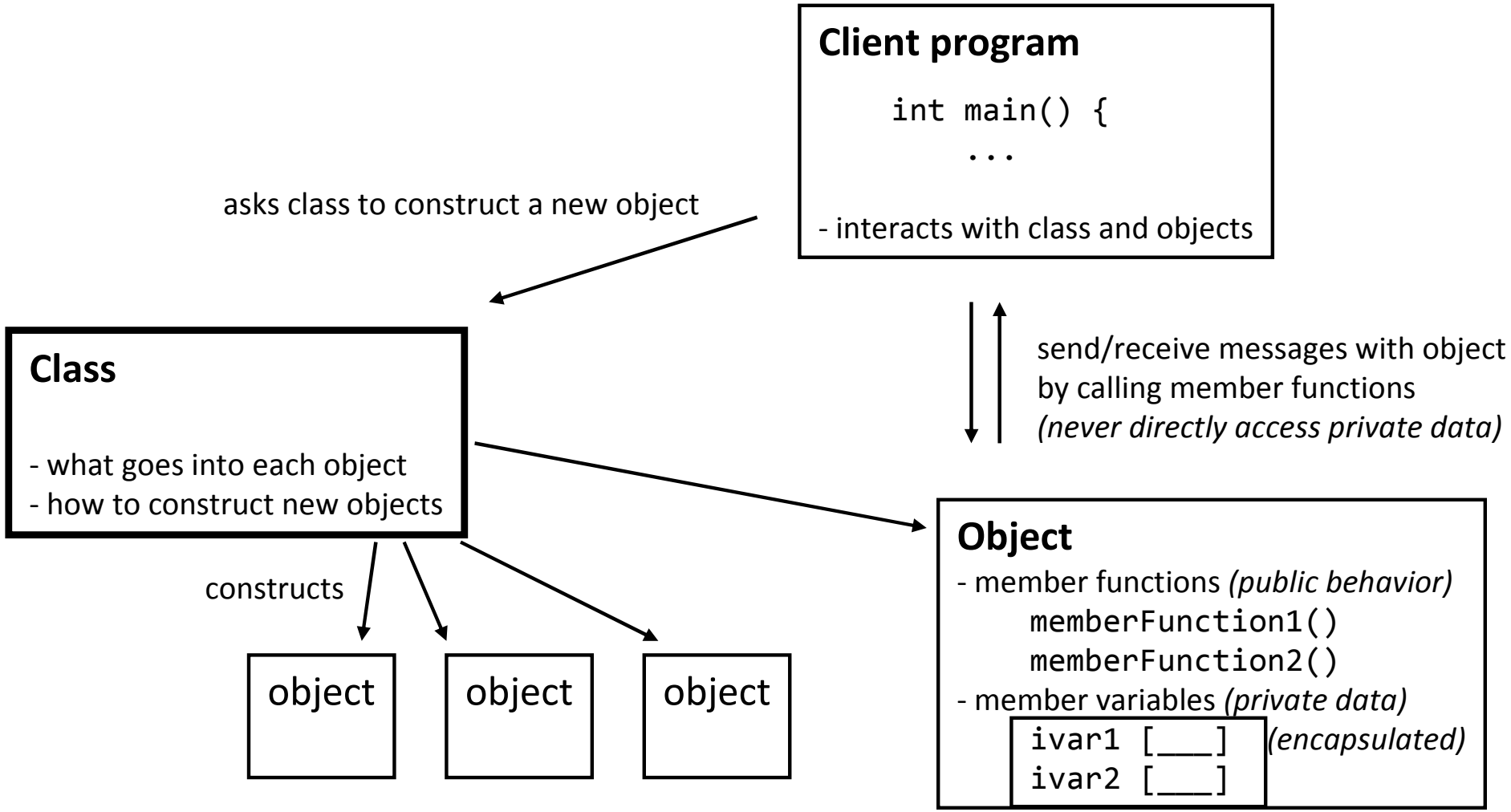
Classes and objects (6.1)

- **class**: A program entity that represents a template for a new type of objects.
  - e.g. class `Vector` defines a new data type named Vector and allows you to declare objects of that type.



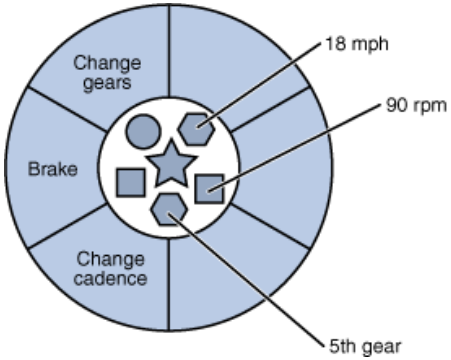
- **object**: Entity that combines **state** and **behavior**.
  - **object-oriented programming (OOP)**: Programs that perform their behavior as interactions between objects.
  - **abstraction**: Separation between concepts and details.
    Objects provide abstraction in programming.

Client, class, object



Elements of a class

- **member variables**: State inside each object.
  - Also called "instance variables" or "fields"
  - Declared as `private`
  - Each object created has a copy of each field.



- **member functions**: Behavior that executes inside each object.
  - Also called "methods"
  - Each object created has a copy of each method.
  - The method can interact with the data inside that object.

- **constructor**: Initializes new objects as they are created.
  - Sets the initial state of each `new` object.
  - Often accepts parameters for the initial state of the fields.

Interface vs. code

- In C++, when writing classes you must understand separation of:
  - **interface**: Declarations of functions, classes, members, etc.
  - **implementation**: Definitions of how the above are implemented.

- C++ implements this separation using two kinds of code files:
  - `.h`: A "header" file containing only interface (declarations).
  - `.cpp`: A "source" file containing definitions.
    - When you define a new class Foo, you write `Foo.h` and `Foo.cpp`.

- The content of .h files is "#included" inside .cpp files.
  - Makes them aware of declarations of code implemented elsewhere.
  - At compilation, all definitions are *linked* together into an executable.

Structure of a .h file

```
// classname.h
#ifndef _classname_h
#define _classname_h

class declaration;

#endif
```

This is protection in case multiple .cpp files include this .h, so that its contents won't get declared twice

A class declaration

```
class ClassName {                          // in ClassName.h
public:
    ClassName(parameters);                 // constructor

    returnType name(parameters); // member functions
    returnType name(parameters); // (behavior inside
    returnType name(parameters); //  each object)

private:
    type name;       // member variables
    type name;       // (data inside each object)
};
```

IMPORTANT: *must* put a semicolon at end of class declaration (argh)

Class example (v1)

```
// Initial version of BankAccount.h.
// Uses public member variables and no functions.
// Not good style, but we will improve it.

#ifndef _bankaccount_h
#define _bankaccount_h

class BankAccount {
public:
    string name;       // each BankAccount object
    double balance;    // has a name and balance
};

#endif
```

Using objects

```
// v1 with public fields (bad)
BankAccount ba1;
ba1.name = "Marty";
ba1.balance = 1.25;

BankAccount ba2;
ba2.name = "Mehran";
ba2.balance = 9999.00;
```

ba1

```
name    = "Marty"
balance = 1.25
```

ba2

```
name    = "Mehran"
balance = 9999.00
```

- Think of an object as a way of grouping multiple variables.
  - Each object contains a name and balance field inside it.
  - We can get/set them individually.
  - Code that uses your objects is called *client* code.

Member func. bodies

- In ***ClassName***`.cpp`, we write bodies (definitions) for the member functions that were declared in the ***`.h`*** file:

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

// member function
returnType ClassName::methodName(parameters) {
    statements;
}
```

  - Member functions/constructors can refer to the object's fields.

- *Exercise:* Write a `withdraw` member function to deduct money from a bank account's balance.

The implicit parameter

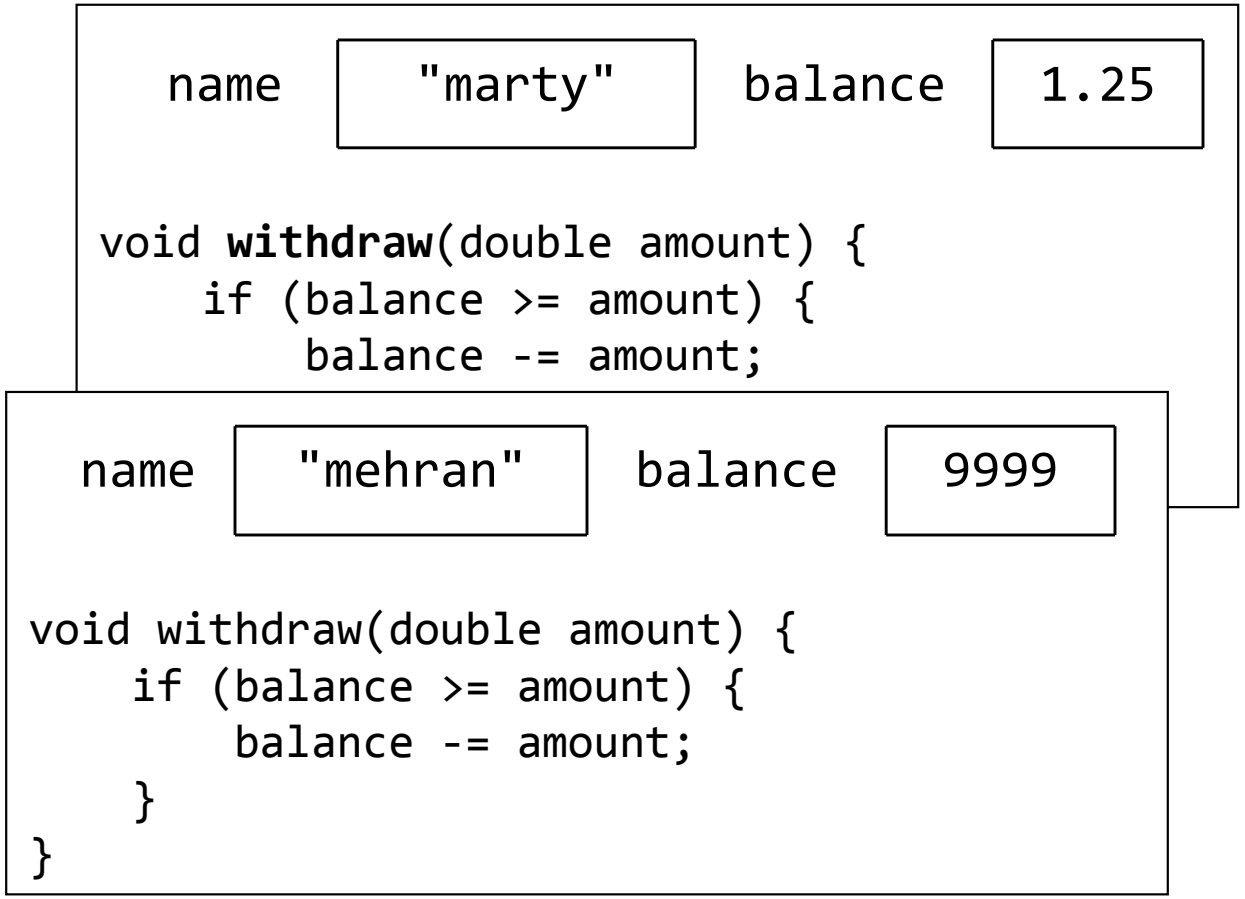
- **implicit parameter**:
  The object on which a member function is called.
  - During the call `marty.withdraw(...)`,
    the object named `marty` is the implicit parameter.
  - During the call `mehran.withdraw(...)`,
    the object named `mehran` is the implicit parameter.
  - The member function can refer to that object's member variables.
    - We say that it executes in the *context* of a particular object.
    - The function can refer to the data of the object it was called on.
    - It behaves as if each object has its own *copy* of the member functions.

Member func diagram

```
// BankAccount.cpp
void BankAccount::withdraw(double amount) {
    if (balance >= amount) {
        balance -= amount;
    }
}
```

```
// client program
BankAccount marty;
BankAccount mehran;
...
marty.withdraw(5.00);

mehran.withdraw(99.00);
```



Initializing objects

- It's bad to take 3 lines to create a BankAccount and initialize it:

```
BankAccount ba;
ba.name = "Marty";
ba.balance = 1.25;                    // tedious
```

- We'd rather specify the fields' initial values at the start:

```
BankAccount ba("Marty", 1.25);    // better
```

  - We are able to this with most types of objects in C++ and Java.
  - You can achieve this functionality using a **constructor**.

Constructors

```
ClassName::ClassName(parameters) {
    statements to initialize the object;
}
```

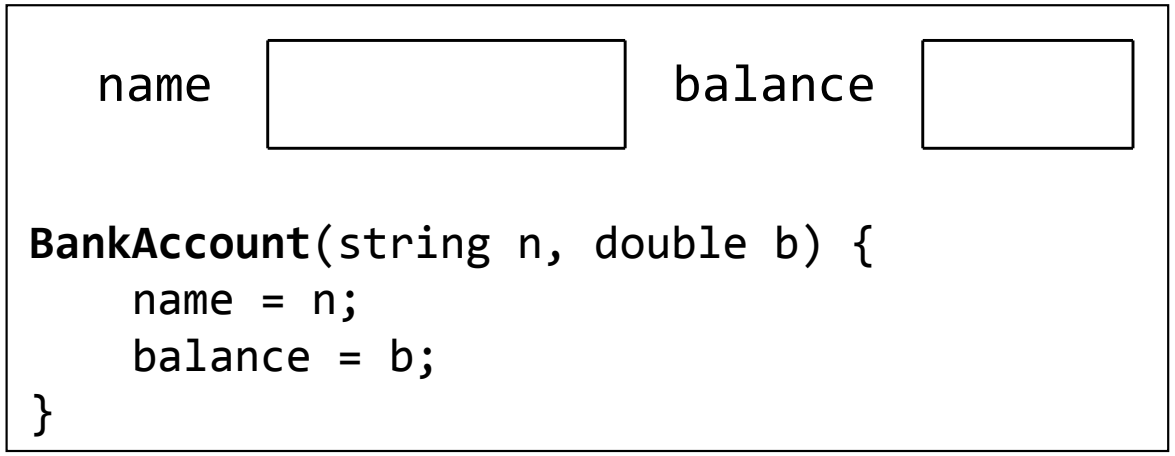
- **constructor**: Initializes state of new objects as they are created.
  - runs when the client declares a new object
  - no return type is specified;
    it implicitly "returns" the new object being created
  - If a class has no constructor, C++ gives it a *default constructor* with no parameters that does nothing.

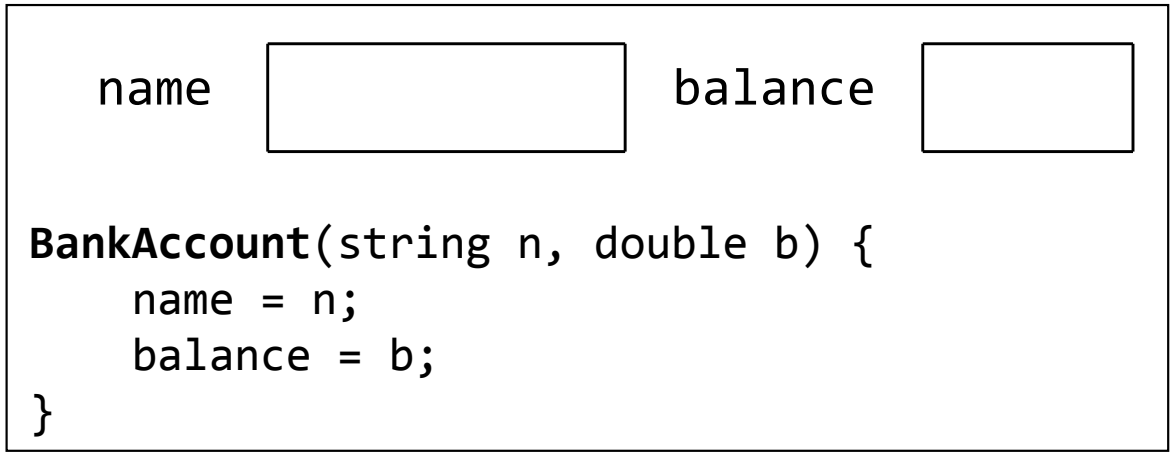
Constructor diagram

```
// BankAccount.cpp
BankAccount::BankAccount(string n, double b) {
    name = n;
    balance = b;
}
```

```
// client program
BankAccount b1(
    "Marty", 1.25);

BankAccount b2(
    "Mehran", 9999);
```





The keyword this

- As in Java, C++ has a `this` keyword to refer to the current object.
  - Syntax: `this->`***`member`***
  - *Common usage:* In constructor, so parameter names can match the names of the object's member variables:

```
BankAccount::BankAccount(string name,
                         double balance) {
    this->name = name;
    this->balance = balance;
}
```

`this` uses `->` not `.` because it is a "pointer"; we'll discuss that later

Preconditions

- **precondition**: Something your code *assumes is true* at the start of its execution.
  - Often documented as a comment on the function's header:

```
// Initializes a BankAccount with the given state.
// Precondition: balance is non-negative
BankAccount::BankAccount(string name, double balance) {
    this->name = name;
    this->balance = balance;
}
```

  - Stating a precondition doesn't really "solve" the problem, but it at least documents our decision and warns the client what not to do.

  - What if we want to actually enforce the precondition?

Throwing exceptions

```
throw expression;
```

- Generates an exception that will crash the program, unless it has code to handle ("catch") the exception.

```
// Initializes a BankAccount with the given state.
// Precondition: balance is non-negative
BankAccount::BankAccount(string name, double balance) {
    if (balance < 0) {
        throw "Illegal negative balance";
    }
    this->name = name;
    this->balance = balance;
}
```

- Why would anyone ever *want* a program to crash?

Private data

```
private:
    type name;
```

- **encapsulation**: Hiding implementation details of an object from its clients.
  - Encapsulation provides *abstraction*.
    - separates external view (behavior) from internal view (state)
  - Encapsulation protects the integrity of an object's data.

- A class's data members should be declared *private*.
  - No code outside the class can access or change it.

Accessor functions

- We can provide methods to get and/or set a data field's value:

```
// "read-only" access to the balance ("accessor")
double BankAccount::getBalance() {
    return balance;
}

// Allows clients to change the field ("mutator")
void BankAccount::setName(string newName) {
    name = newName;
}
```

  - Client code will look like this:

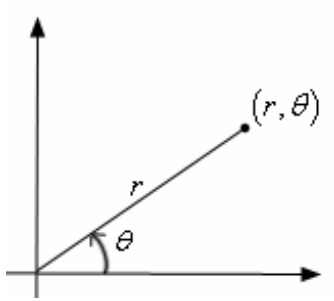
```
cout << ba.getName() << ":$" << ba.getBalance() << endl;
ba.setName("Cynthia");
```

Encapsulation benefits

- Provides abstraction between an object and its clients.

- Protects an object from unwanted access by clients.

- Allows you to change the class implementation.
  - `Point` could be rewritten to use polar coordinates (radius *r*, angle ϑ), but with the same methods.



- Allows you to constrain objects' state (**invariants**).
  - Example: Don't allow a `BankAccount` with a negative balance.

Operator overloading (6.2)

- C++ allows you to *overload*, or redefine, the behavior of many common operators in the language:
  - unary: `+ - ++ -- * & ! ~ new delete`
  - binary: `+ - * / % += -= *= /= %= & | && || ^`
    `== != < > <= >= = [] -> () ,`

- Overuse of operator overloading can lead to confusing code.
  - *Rule of Thumb:* Don't abuse this feature. Don't define an overloaded operator unless its meaning and behavior are completely obvious.

Op overload syntax

- Declare your operator in a .h file, implement it in a .cpp file.

```
returnType operator op(parameters);        // .h

returnType operator op(parameters) {       // .cpp
    statements;
};
```

  - where ***op*** is some operator like +, ==, <<, etc.
  - the ***parameters*** are the operands next to the operator;
    for example, `a + b` becomes `operator +(Foo a, Foo b)`

Overloaded operators can also be declared inside a class (not shown here)

Op overload example

```
// BankAccount.h
class BankAccount {
    ...
};

bool operator ==(BankAccount& ba1, BankAccount& ba2);
bool operator !=(BankAccount& ba1, BankAccount& ba2);
```

```
// BankAccount.cpp
bool operator ==(BankAccount& ba1, BankAccount& ba2) {
    return ba1.getName() == ba2.getName()
        && ba1.getBalance() == ba2.getBalance();
}

bool operator !=(BankAccount& ba1, BankAccount& ba2) {
    return !(ba1 == ba2);   // calls operator ==
}
```

Make objects printable

- To make it easy to print your object to `cout`, overload the `<<` operator between an `ostream` and your type:

```
ostream& operator <<(ostream& out, Type& name) {
    statements;
    return out;
}
```

  - The operator returns a reference to the stream so it can be chained.
    - `cout << a << b << c` is really `((cout << a) << b) << c`
    - Technically `cout` is being returned by each `<<` operation.

<< overload example

```
// BankAccount.h
class BankAccount {
    ...
};

ostream& operator <<(ostream& out, BankAccount& ba);
```

```
// BankAccount.cpp
ostream& operator <<(ostream& out, BankAccount& ba) {
    out << ba.getName() << ": $"
        << setprecision(2) << ba.getBalance();
    return out;
}
```

The keyword const

- C++ `const` keyword indicates that a value cannot change.

```
const int x = 4;                    // x will always be 4
```

- a **`const` reference parameter** can't be modified by the function:

```
void foo(const BankAccount& ba) {   // won't change ba
```

  - Any attempts to modify d inside `foo`'s code won't compile.

- a **`const` member function** can't change the object's state:

```
class BankAccount { ...
    double getBalance() const;  // won't change account
```

  - On a `const` reference, you can only call `const` member functions.

Overflow (extra) slides

Class constants

- To make a **class constant**, declare a static variable in the .h file.
  - Assign its value in the .cpp, outside of any method.
  - Don't write static or const when assigning the value in the .cpp.

```
// BankAccount.h
class BankAccount {
    static const double INTEREST_RATE;
};

// BankAccount.cpp
double BankAccount::INTEREST_RATE = 0.0325;   // 3.25%
```

Structs

- C++ also has an entity called a *structure* (`struct`).
  - Very similar to a class; a collection of data and (maybe) behavior.
  - But has (by default) public fields and no methods.

```
struct Point {
    int x;
    int y;
};
...
Point p;
p.x = 15;
...
```

  - A holdover from C, which did not have classes or objects.
  - Not used as often as classes, but you may see them from time to time.

C++ preprocessor

- **preprocessor** : Part of the C++ compilation process; recognizes special # statements, modifies source code before it is compiled

function	description
`#include <`***filename***`>`	insert a library file's contents into this file
`#include "`***filename***`"`	insert a user file's contents into this file
`#define` ***name [value]***	create a preprocessor symbol ("variable")
`#if` ***test***	`if` statement
`#else`	`else` statement
`#elif` ***test***	`else if` statement
`#endif`	terminates an `if` or `if/else` statement
`#ifdef` ***name***	`if` statement; `true` if ***name*** is defined
`#ifndef` ***name***	`if` statement; `true` if ***name*** is *not* defined
`#undef` ***name***	deletes the given symbol name