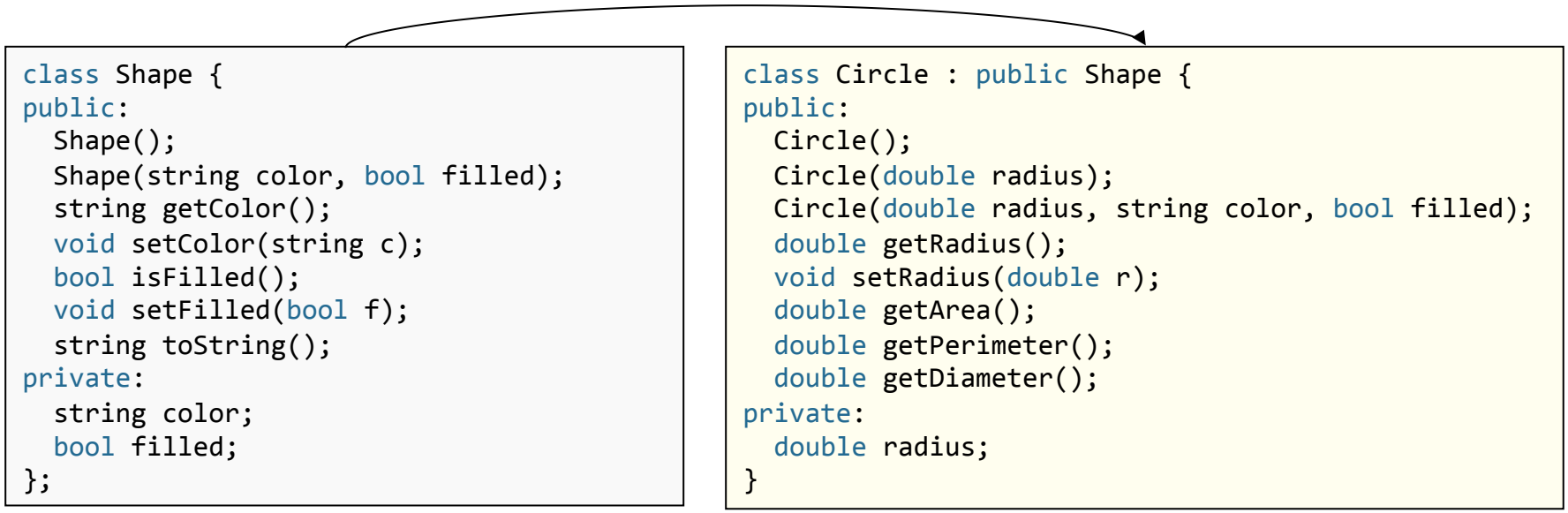
CMPS 148

INHERITANCE - REVIEW

Derived Classes



```
class Shape {
public:
  Shape();
  Shape(string color, bool filled);
  string getColor();
  void setColor(string c);
  bool isFilled();
  void setFilled(bool f);
  string toString();
private:
  string color;
  bool filled;
};
```

```
class Circle : public Shape {
public:
  Circle();
  Circle(double radius);
  Circle(double radius, string color, bool filled);
  double getRadius();
  void setRadius(double r);
  double getArea();
  double getPerimeter();
  double getDiameter();
private:
  double radius;
}
```

```
int main() {
  Circle c(5, "white", true);
  cout << c.getColor() << endl;
}
```

Generic functions

- Functions can declare parameters of the base type, but you can actually pass any instance **derived** from the base!

```
void doSomething(Shape s);
Shape s;
Circle c;
doSomething(s);  // fine..
doSomething(c);  // also ok!
```

Refinement

- Derived classes may implement methods already defined in the base class.
- The derived class's version is called whenever the compiler knows the instance is of the derived type.
- `Shape s;`
- `Circle c;`
- `c.toString()` will map to Circle's version
- `s.toString()` will still map to Shape's

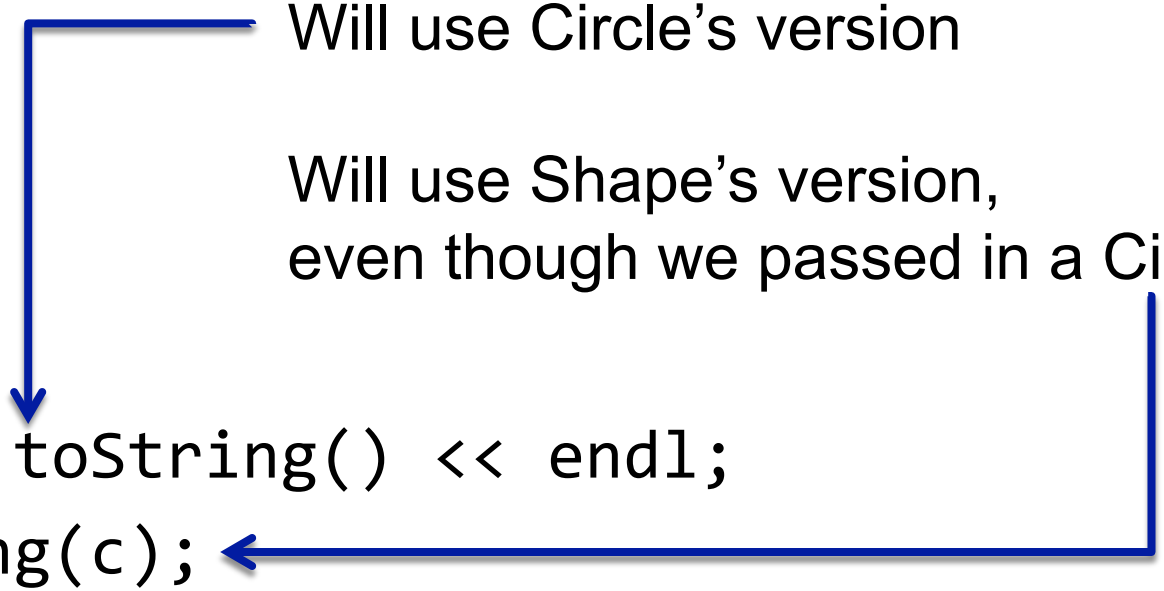
Refinement and Functions

```
void doSomething(Shape s) {
  cout << s.toString() << endl;
}
```

Will use Circle's version

Will use Shape's version,
even though we passed in a Circle

```
Circle c;
cout << c.toString() << endl;
doSomething(c);
```



Polymorphism

- The concept of polymorphism takes "refinement" to a more powerful level.
- Polymorphism will allow a **reference**/**pointer** to a base class to work intelligently when pointing to **derived** types.
- We will need some additional syntax however…

Keyword: virtual

- For a method to participate in polymorphism, it must be marked as *virtual* in the **base** class's definition

```
class Shape {
public:
...
  virtual string toString() {
    stringstream ss;
    ss << "A " << getColor();
    if ( isFilled() ) ss << " solid ";
    else ss << " outlined ";
    ss << "shape.";
    return ss.ToString();
  }
```

```
class Cicle {
public:
 ...
  string toString() {
   stringstream ss;
   ss << "A " << getColor();
   if ( isFilled() ) ss << " solid ";
   else ss << " outlined ";
   ss << "circle with radius = " << getRadius();
   return ss.ToString();
}
```

Polymorphism with References

- Polymorphism works when using pass-by-reference or pointers.
- When a function takes a reference to a base type as a parameter, calls on the passed object will map to the **derived** type

```
void printShape(Shape & s) {
  cout << s.toString() << endl;
}

int main() {
  Shape s;
  Circle c(1, "black", false);
  Rectangle(r(3, 4, "red", true);
  printShape(s);
  printShape(c);
  printShape(r);
}
```

- At runtime, **printShape** call the toString function on Shape for s, Circle for c, and Rectangle for r.

Pointers and Objects

```
void printShape(Shape & s) {
  cout << s.toString() << endl;
}

int main() {
  Shape s;
  Circle c(1, "black", false);
  Rectangle(r(3, 4, "red", true);
  printShape(s);
  printShape(c);
  printShape(r);
}
```

```
void printShape(Shape * s) {
  cout << s->toString() << endl;
}

int main() {
  Shape s;
  Circle c(1, "black", false);
  Rectangle(r(3, 4, "red", true);
  printShape(&s);
  printShape(&c);
  printShape(&r);
}
```

Abstract Classes

- An abstract class represents a "generic" thing, that cannot be used directly:
  - It defines "pure" virtual functions, with no implementation
  - All classes that derive from the abstract class **must** provide a full implementation of all pure virtual functions
  - Your abstract class defines an **interface** for using a bunch of different types of objects…
- Example: A shape must have an area and perimeter, but its up to Circle and Rectangle to figure it out…

Abstract Classes

```
class Shape {
public:
   ...
   virtual double getPerimeter() = 0;
   virtual double getArea() = 0;
   ...
```

```
class Circle : public Shape {
public:
   double getPerimeter() {
     return 2 * PI * radius;
   }
   double getArea() {
     return PI * radius * radius;
   }
};
```

```
class Rectangle : public Shape {
public:
   double getPerimeter() {
     return 2 * height * width;
   }
   double getArea() {
     return height * width;
   }
};
```

Lab 8

- Create a Triangle class which extends Shape
- Use the same functions as in main
  - make sure you can create instances
  - call the print shape method

- *Triangle can be assumed to be a* ***right triangle, which means the area = ½ base * height.***

Inheritance, Polymorphism, Abstract?

- Inheritance means a derived class **borrows** implementation and member variables from **base**
  - A derived class will often add members
  - Sometimes, a derived class ***refines*** some of the base's methods

- **Sometimes**, a base class can mark one (or more) of its functions as **virtual** – meaning the method can be ***overridden*** and participate in **polymorphism.**
  - If the base doesn't override the function, no polymorphism!
  - Polymorphism only works with references/pointers

- **Sometimes** the base class shouldn't even be instantiated.
  - **You know all Shapes** should have getArea()
  - **Abstract class!**

CHAPTER 13
OPERATOR OVERLOADING

CMPS 148

Operator Overloading

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

int main() {
  string s1(”hello");
  string s2(”world");
  string s3 = s1 + ” " + s2;
  cout << s3 << endl;
  cout << s3[1] << endl;
}
```

```
> hello world
> e
```

- The string class also works with many standard C++ operators:
  - +
  - […]
  - << and >>
- Can our own classes do this?

Operator Overloading

- Overloading refers to the ability to add extra functionality to standard C++ operators
- All of the following operators *can* be "overloaded" to work with your own types

```
+       -       *       /       %
+=      -=      *=      /=      %=
++      --
^       &       |       ~       !
=       ^=      &=      |=
<       >       <=      >=       ==     !=
<<      >>      &&      ||
->*     ,       ->      []      ()      new    delete
```

Example: Rational

- A rational number is anything with a numerator and denominator (both integers)

```
class Rational {
    public:
        Rational();
        …
    private:
        int num;
        int den;
};
```

Rational numbers can be added/ subtracted…

They can be compared…

They can be printed… etc.

The full class description is in the text and on appiversity

Example Program

```
int main() {
   Rational r1 (5, 6);
   Rational r2 (10, 12);
   if ( r1.equals(r2) )
        cout << "Equal!";
   Rational r3;
   r3 = r2.add(r1);
   r3.print();
}
```

```
int main() {
   Rational r1 (5, 6);
   Rational r2 (10, 12);
   if ( r1 == r2 )
        cout << "Equal!";
   Rational r3;
   r3 = r1 + r2;
   cout << r3 << endl;
}
```

Overloading Operators

- Overloading operators is great for the *user* of your class…
  - However… the syntax to define the overloading is tricky…
- You need to think of an operator ***as a function*** involving your class

Implementation

- There are several classifications of operators:
  - Relational (<, >, ==, etc.)
    - Normal functions with 2 Rational parameters (left and right hand side). *Returns true or false*
  - Mathematical (+, -, *, /)
    - Normal functions with 2 rational parameters (left and right hand side). *Returns new instance of Rational*
  - Combined Assignment (+=, -=, *=, /=)
    - *Member functions with single parameter. Returns same instance of Rational*
  - I/O Operators << and >>
    - ***friend*** functions with stream and rational parameters. Returns stream

return value	*function name*	*parameters*

Relational Operators

```
class Rational {
public:
  Rational();
  int compareTo(Rational & other) {
    …
  }
    …
};
```

```
bool operator < (const Rational & r1, const Rational & r2)
{
    return r1.compareTo(r2) < 0 ) ;
}
```

const ?????

- We've all seen const used in variable declarations – what about parameters?
  - It tells the compiler that you will NOT change the parameter's value within the function
  - Why do we do this?
    - *Notice that they are passed by reference…*

Mathematical Operators

```
class Rational {
public:
  Rational();
  Rational add(Rational & other) {
     // returns new Rational instance which is this + other
  }
    …
};
```

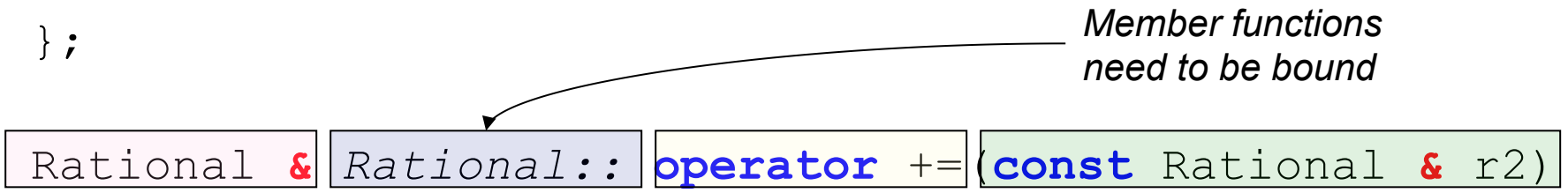
```
Rational operator + (const Rational & r1, const Rational & r2)
{
    return r1.add(r2);
}
```

More const "problems"

- When defining the + operator, compiler errors are generated when calling the add function
  - This is because we haven't "promised" the compiler add won't change
    - 1) its parameter (r2)
    - 2) the instance itself (r1)
  - return type functionName(*params*) **const**

Combined Assignment

```
class Rational {
public:
   Rational();
   Rational &operator += (const Rational & r2);
            …
};
```




```
{
    *this = this->add(r2);
    return *this;
}
```

IO Operators

```
class Rational {
public:
  Rational();
  friend ostream &operator << (ostream &, const Rational &);
};

ostream & operator << (ostream & out, const Rational & r)
{
    out << r.numerator << " / " << r.denominator" << endl;
    return out;
}
```

Why friend?

- The << and >> operators are defined in ostream and istream, so the Rational class can't overload them from *within* the Rational class
- The only reason we make it a friend, and not just a normal external functions (like mathematical operators) is so we can access private data
- If you don't need to access private data, then you don't need to use friend.

Exam 2

- Next week – 11/24
- Open Book/Notes/Computer etc.

- Focused entirely on Object Oriented Programming

Classes

- You must know the various vocabulary associated with object oriented programming:
  - Class, Instance, Object
  - Member variables, properties, functions, methods.
  - Composition, “Has a” relationships
  - Encapsulation with public/private/protected
  - Inheritance -> parent/child, base/derived, specialization, polymorphism

Syntax

- Know how to construct classes and to split them between header files and implementation files
- Know how to create constructors and **destructors.**
- Know how to derive from a base class.
- Know how to work with **pointers to objects.**
- Know what the **const** keyword means in **all of the locations we've seen!**

Using classes

- You must be comfortable working with the following built-in types:
  - string
  - stringstream

Polymorphism

- You must understand all the degrees of inheritance:
  - Simple overrides
  - Virtual functions and polymorphism
  - Abstract classes and pure virtual functions

Overloading Operators

- Know the 4 categories of overloading syntax
- Be able to create overloaded functions
- Be able to tell which operators need to be overloaded given code that uses a class.

Practice Problem: Time Class

- Holds the time of day
  - Single member variable – seconds since midnight..
- Prints as hours, minutes, seconds
- Can be set to print in 12 am/pm or 24 hour mode
  - Based on a variable
- Can be printed with <<
- Supports + and -, += and -= based on seconds
  - We'll skip ++ and --, they aren't pretty…
- We'll write some unit tests before creating the full class to help us work towards a correct solution.

Study Problem

- Write a function that accepts a string
  - The string will be a binary number (“10011”).
  - The function should return the integer the binary string represents.
- Write a main program that allows the user to enter a string (no more than 32 characters) and prints out the corresponding integer.

Study Problem

- Read the input as a normal string.
- Start at the right-most character.
- Set **value** = 0
- Set **addend** = 1
- Working right to left, for **each** character:
  - Check that the character is '1' or '0'.
  - If its '1', then add **addend** to **value**
  - Multiply **addend** by 2
  - If its not '1' or '0', throw an exception