

# CS 6015: Software Practice

Spring 2024

Lecture 2: Classes and interface-like classes

# Forward declaration

- Tells the compiler that there is a declaration of an entity before defining that entity. Used with:
  - Functions
  - User-defined types

```
#include <iostream>
```

```
int main() {  
    int array[2] = {1, 2};  
    int val = sum(2); --> Does this code work?  
    std::cout << "Result: " << val <<  
    "\n";  
}
```

```
int sum(int n) {  
    int i, s = 0;  
    for (i = 0; i < n; i++)  
        s += array[i];  
    return s;  
}
```

# Forward declaration

- Tells the compiler that there is a declaration of an entity before defining that entity. Used with:
  - Functions
  - User-defined types

```
#include <iostream>
```

```
int sum(int); //forward declaration
int main() {
    int array[2] = {1, 2};
    int val = sum(2);
    std::cout << "Result: " << val << "\n";
}
```

-> declared here if no header files are used

```
int sum(int n) {
    int i, s = 0;
    for (i = 0; i < n; i++)
        s += array[i];
    return s;
}
```

# C++ vs Java

# C++ vs Java

- Object oriented programming languages
- Syntax
- Pointers
- Overloading
- Garbage collector

# Classes in C++ vs classes in Java

- Create objects using pointers:  
`Posn *Obj1 = new Posn(2,3);`  
Use `->` not `.` to access member variables and methods
- Use **virtual** keyword before member functions that need to be overridden in sub classes
- No interfaces in c++, we will use abstract classes
- C++ supports multiple inheritance
- Java uses "garbage collection" to free unreachable objects

# Simple Class

```
class Posn {  
public:  
    int x;  
    int y;  
  
    Posn(int x, int y) {  
        this->x = x;  
        this->y = y;  
    }  
  
    bool close_to_origin(int d) {  
        return (abs(x) < d) && (abs(y) < d);  
    }  
};
```

# Separating Declaration and Implementation

```
class Posn {  
public:  
    int x;  
    int y;  
  
    Posn(int x, int y);  
    virtual bool close_to_origin(int d);  
};  
  
Posn::Posn(int x, int y) {  
    this->x = x;  
    this->y = y;  
}  
  
bool Posn::close_to_origin(int d) {  
    return (abs(x) < d) && (abs(y) < d);  
}
```



# Separating Declaration and Implementation

```
class Posn {  
public:  
    int x;  
    int y;  
  
    Posn(int x, int y);  
    virtual bool close_to_origin(int d);  
};
```

connects to the **Posn** declaration

```
Posn::Posn(int x, int y) {  
    this->x = x;  
    this->y = y;  
}  
  
bool Posn::close_to_origin(int d) {  
    return (abs(x) < d) && (abs(y) < d);  
}
```

# Separating Declaration and Implementation

posn.h

```
class Posn {  
public:  
    int x;  
    int y;  
  
    Posn(int x, int y);  
    bool close_to_origin(int d);  
};
```

posn.cpp

```
#include "posn.h"  
Posn::Posn(int x, int y) {  
    this->x = x;  
    this->y = y;  
}  
  
bool Posn::close_to_origin(int d) {  
    return (abs(x) < d) && (abs(y) < d);  
}
```

Avoid `#include "...h"`  
in `.h` / `.hpp` files

# Recall Person / Employee example

# Inheritance – Virtual method

main.cpp

```
#include "shape.hpp"

int main (int argc, char * argv[]) {

    Rectangle r1 (2,4);
    Circle c1 (5);

    printArea(r1);
    printArea(c1);
}
```

shape.hpp

```
class Shape {
public:
    virtual float getarea()=0;
};

class Circle: public Shape {
public:
    float radius;
    Circle(float radius);
    float getarea();
};

class Rectangle: public Shape {
public:
    float width;
    float height;
    Rectangle(float width, float height);
    float getarea() ;
};

void printArea(Shape& shape);
```

shape.cpp

```
#include "shape.hpp"
#include <iostream>
using namespace std;

Rectangle::Rectangle(float width, float height):width(width),height(height) {}

Circle::Circle(float radius){
    this->radius=radius;
}

float Rectangle::getarea() {
    return width * height ;
}

float Circle::getarea() {
    return 3.14 * radius * radius ;
}

void printArea(Shape& shape) {
    cout<< "Area: " << shape.getarea() <<endl;
}
```

# Inheritance – Virtual method

shape.hpp

```
//Shape: abstract class
class Shape {
public:
    //No implementation: pure virtual function
    virtual float getarea()=0;
};

// : equivalent to extends in java
class Circle: public Shape {
public:
    float radius;
    Circle(float radius);
    float getarea();
};

class Rectangle: public Shape {
public:
    float width;
    float height;
    Rectangle(float width, float height);
    float getarea();
};

void printArea(Shape* shape);
```

main.cpp

```
#include <iostream>
#include "shape.hpp"

bool coinFlip();

int main (int argc, char * argv[]) {

    //importance of inheritance if we do not
    know the type until runtime
    Shape *s;

    if(coinFlip()){
        s = new Rectangle(3,6);
    }
    else {
        s = new Circle(10);
    }

    std::cout<<"The aread with coinFlip is:
"<<s->getarea()<<std::endl;
}

bool coinFlip(){
    int x;
    std::cin>>x;
    if (x==0) {
        return true;
    } else {
        return false;
    }
}
```

Project: Related

# Implementing Equality

```
class Animal {  
};
```

```
class Tiger : public Animal {  
    std::string color;  
    int stripe_count;  
  
}  
};
```

```
class Snake : public Animal {  
    std::string color;  
    int weight;  
    std::string food;  
  
}  
};
```

How to compare 2 tigers, 2 snakes?

# Implementing Equality

```
class Animal {  
    virtual bool equals(Animal *o) = 0;  
};
```

```
class Tiger : public Animal {  
    std::string color;  
    int stripe_count;  
  
};
```

```
class Snake : public Animal {  
    std::string color;  
    int weight;  
    std::string food;  
  
};
```

Add the method in the super class



# Implementing Equality

```
class Animal {  
    virtual bool equals(Animal *o) = 0;  
};
```

```
class Tiger : public Animal {  
    std::string color;  
    int stripe_count;  
  
    bool equals(Animal *a) {  
        return ...;  
    }  
};
```

```
class Snake : public Animal {  
    std::string color;  
    int weight;  
    std::string food;  
  
    bool equals(Animal *a) {  
        return ...;  
    }  
};
```

Implement in the derived classes

# Implementing Equality

```
class Animal {  
    virtual bool equals(Animal *o) = 0;  
};
```

```
class Tiger : public Animal {  
    std::string color;  
    int stripe_count;  
  
    bool equals(Animal *a) {  
        Tiger *t = dynamic_cast<Tiger*>(a);  
        if (t == NULL)  
            return false;  
        else  
            return (this->color == t->color  
                    && this->stripe_count == t->stripe_count);  
    }  
};
```

```
class Snake : public Animal {  
    std::string color;  
    int weight;  
    std::string food;  
  
    bool equals(Animal *a) {  
        return ...;  
    }  
};
```

Implement in the derived classes

# Implementing Equality

```
class Animal {  
    virtual bool equals(Animal *o) = 0;  
};
```

```
class Tiger : public Animal {  
    std::string color;  
    int stripe_count;  
  
    bool equals(Animal *a) {  
        return ...;  
    }  
};
```

```
class Snake : public Animal {  
    std::string color;  
    int weight;  
    std::string food;  
  
    bool equals(Animal *a) {  
        Snake *s = dynamic_cast<Snake*>(a);  
        if (s == NULL)  
            return false;  
        else  
            return (this->color == s->color  
                    && this->weight == s->weight  
                    && this->food == s->food);  
    }  
};
```

# Project: Introduction

# Simple Arithmetic Expressions

1

2 + 3

4 \* 5

6\*(7+8)

(1+2) \* (3+4\*6)

Each of those is an *expression*

An *expression* can be nested in another *expression*

To calculate the result, we can ignore details like whitespace and parentheses

# Simple Arithmetic Expressions

1

2 + 3

4 \* 5

6 \* (7+8)

(1+2) \* (3+4\*6)

Three kinds of *expressions*:

- number
- addition of two expressions
- multiplication of two expressions

# Simple Arithmetic Expressions

1

2 + 3

4 \* 5

6 \* (7+8)

(1+2) \* (3+4\*6)

$\langle \text{expr} \rangle = \langle \text{number} \rangle$

|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$

|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

# Simple Arithmetic Expressions

1

2 + 3

4 \* 5

6 \* (7 + 8)

(1 + 2) \* (3 + 4 \* 6)

Abstract syntax *grammar*

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$



# Simple Arithmetic Expressions

1

2 + 3

4 \* 5

6 \* (7 + 8)

(1 + 2) \* (3 + 4 \* 6)

Abstract syntax *grammar*

$\langle \text{expr} \rangle = \langle \text{number} \rangle$

“or” |  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$

|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

# Simple Arithmetic Expressions

1

2 + 3

4 \* 5

6 \* (7 + 8)

(1 + 2) \* (3 + 4 \* 6)

Abstract syntax *grammar*

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

Gray box corresponds to literal text

# Simple Arithmetic Expressions

1

2 + 3

4 \* 5

6 \* (7 + 8)

(1 + 2) \* (3 + 4 \* 6)

Abstract syntax *grammar*

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

$\langle \text{expr} \rangle$  corresponds to an interface, and  
three classes should implement it

# Arithmetic Representation Classes

```
⟨expr⟩ = ⟨number⟩  
      | ⟨expr⟩ + ⟨expr⟩  
      | ⟨expr⟩ * ⟨expr⟩
```

# Arithmetic Representation Classes

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

```
class Expr { };
```

```
class Num : public Expr {  
};
```

```
class Add : public Expr {  
};
```

```
class Mult : public Expr {  
};
```

# Arithmetic Representation Classes

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

```
class Expr { };
```

```
class Num : public Expr {  
public:  
    int val;  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
};
```

# Arithmetic Representation Classes

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

```
class Expr { };
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

# Arithmetic Representation Classes

42  
⇒  
new Num(42)

⟨expr⟩ = ⟨number⟩  
| ⟨expr⟩ + ⟨expr⟩  
| ⟨expr⟩ \* ⟨expr⟩

```
class Expr { };
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```



# Arithmetic Representation Classes

42+2

⇒

```
new Add(new Num(42),  
        new Num(2));
```

⟨expr⟩ = ⟨number⟩  
| ⟨expr⟩ + ⟨expr⟩  
| ⟨expr⟩ \* ⟨expr⟩

```
class Expr { };
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

# Arithmetic Representation Classes

`((42)+2)`

$\Rightarrow$

```
new Add(new Num(42),  
        new Num(2));
```

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

```
class Expr { };
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

# Arithmetic Representation Classes

`((42)+2)`

⇒

```
new Add(new Num(42),  
        new Num(2));
```

$\langle \text{expr} \rangle = \langle \text{number} \rangle$

|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$

For tests, we'll need a way to compare expressions

```
class Expr { };
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

# Arithmetic Representation Classes

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

```
class Expr {  
public:  
    virtual bool equals(Expr *e) = 0;  
};
```

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

# Arithmetic Representation Classes

$\langle \text{expr} \rangle = \langle \text{number} \rangle$   
|  $\langle \text{expr} \rangle + \langle \text{expr} \rangle$   
|  $\langle \text{expr} \rangle * \langle \text{expr} \rangle$

```
class Expr {  
public:  
    virtual bool equals(Expr *e) = 0;  
};
```

= 0 means each subclass *must* override

```
class Num : public Expr {  
public:  
    int val;  
  
    Num(int val) {  
        this->val = val;  
    }  
};
```

```
class Add : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Add(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

```
class Mult : public Expr {  
public:  
    Expr *lhs;  
    Expr *rhs;  
  
    Mult(Expr *lhs, Expr *rhs) {  
        this->lhs = lhs;  
        this->rhs = rhs;  
    }  
};
```

Backup slides: More examples

# Simple class

posn.h

```
class Posn {  
public:  
    int x;  
    int y;  
  
    Posn(int x, int y);  
    virtual bool close_to_origin(int d);  
};
```

posn.cpp

```
#include "posn.h"  
Posn::Posn(int x, int y) {  
    this->x = x;  
    this->y = y;  
}  
  
bool Posn::close_to_origin(int d) {  
    return (abs(x) < d) && (abs(y) < d);  
}
```

# Referring to Classes

```
class Circle {  
public:  
    Posn* center;  
    int radius;  
  
    Circle(Posn* center, int radius) {  
        this->center = center;  
        this->radius = radius;  
    }  
  
    int area() {  
        return radius * radius * 3.14;  
    }  
};
```



# Referring to Classes

Use `Posn*`  
to refer to a  
`Posn` object

```
class Circle {  
public:  
    Posn* center;  
    int radius;  
  
    Circle(Posn* center, int radius) {  
        this->center = center;  
        this->radius = radius;  
    }  
  
    int area() {  
        return radius * radius * 3.14;  
    }  
};
```

# Referring to Classes

```
class Circle {  
public:  
    Posn* center;  
    int radius  
    new Circle(new Posn(1, -3), 10)  
  
    Circle(Posn* center, int radius) {  
        this->center = center;  
        this->radius = radius;  
    }  
  
    int area() {  
        return radius * radius * 3.14;  
    }  
};
```

# Referring to Classes

```
class Circle {  
public:  
    Posn* center;  
    int radius;  
  
    Circle(Posn* center, int radius) {  
        this->center = center;  
        this->radius = radius;  
    }  
  
    int area() {  
        return radius * radius * 3.14;  
    }  
};
```

So far, could declare with  
`class Posn;`  
before `class Circle...`

# Referring to Classes

```
class Circle {
public:
    Posn* center;
    int radius;

    Circle(Posn* center, int radius) {
        this->center = center;
        this->radius = radius;
    }

    int area() {
        return radius * radius * 3.14;
    }

    bool covers_origin() {
        return center->close_to_origin(radius);
    }
};
```

# Referring to Classes

```
class Circle {  
public:  
    Posn* center;  
    int radius;  
  
    Circle(Posn* center, int radius) {  
        this->center = center;  
        this->radius = radius;  
    }  
  
    int area() {  
        return radius * radius * 3.14;  
    }  
  
    bool covers_origin() {  
        return center->close_to_origin(radius);  
    }  
};
```

Needs `#include "posn.h"`

# Separating Declaration and Implementation

circle.h

Posn.h must be before circle.h, otherwise, Posn\* center will be unknown to the compiler and in this case you need to declare as `class Posn` here;

```
class Circle {  
    public:  
        Posn* center;  
        int radius;  
  
        Circle(Posn* center, int radius);  
        int area();  
        bool covers_origin();  
};
```

circle.cpp

```
#include "posn.h"  
#include "circle.h"  
  
Circle::Circle(Posn* center, int radius) {  
    this->center = center;  
    this->radius = radius;  
}  
  
int Circle::area() {  
    return radius * radius * 3.14;  
}  
  
bool Circle::covers_origin() {  
    return center->close_to_origin(radius);  
}
```

Avoid `#include "...h"`  
in `.h` files

# Subclasses

posn3d.h

```
#include "posn.h"

class Posn3D : public Posn {
    int z;

    Posn3D(int x, int y, int z);

    virtual bool close_to_origin(int d);
};
```

posn3d.cpp

```
#include "posn3d.h"

Posn3D::Posn3D(int x, int y, int z)
: Posn(x, y)
{
    this->z = z;
}

bool Posn3D::close_to_origin(int d) {
    return (Posn::close_to_origin(d)
        && (abs(z) < d));
}
```

# Subclasses

Means **extends**

posn3d.h

```
#include "posn.h"

class Posn3D : public Posn {
    int z;

    Posn3D(int x, int y, int z);

    virtual bool close_to_origin(int d);
};
```

posn3d.cpp

```
#include "posn3d.h"

Posn3D::Posn3D(int x, int y, int z)
: Posn(x, y)
{
    this->z = z;
}

bool Posn3D::close_to_origin(int d) {
    return (Posn::close_to_origin(d)
        && (abs(z) < d));
}
```



# Subclasses

Needed for subclassing

posn3d.h

```
#include "posn.h"

class Posn3D : public Posn {
    int z;

    Posn3D(int x, int y, int z);

    virtual bool close_to_origin(int d);
};
```

posn3d.cpp

```
#include "posn3d.h"

Posn3D::Posn3D(int x, int y, int z)
: Posn(x, y)
{
    this->z = z;
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bool Posn3D::close_to_origin(int d) {
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# Subclasses

posn3d.h

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posn3d.cpp

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    this->z = z;
}

bool Posn3D::close_to_origin(int d) {
    return (Posn::close_to_origin(d)
        && (abs(z) < d));
}
```

Superclass constructor

Superclass constructor: similar to super in java

# Subclasses

posn3d.h

```
#include "posn.h"

class Posn3D : public Posn {
    int z;

    Posn3D(int x, int y, int z);

    virtual bool close_to_origin(int d);
};
```

posn3d.cpp

```
#include "posn3d.h"

Posn3D::Posn3D(int x, int y, int z)
: Posn(x, y)
{
    this->z = z;
}

bool Posn3D::close_to_origin(int d) {
    return (Posn::close_to_origin(d)
        && (abs(z) < d));
}
```

Super method call

# Subclasses

posn3d.h

```
#include "posn.h"

class Posn3D : public Posn {
    int z;

    Posn3D(int x, int y, int z);

    virtual bool close_to_origin(int d);
};
```

Can't avoid `#include "posn.h"`  
in `posn3d.h`

posn3d.cpp

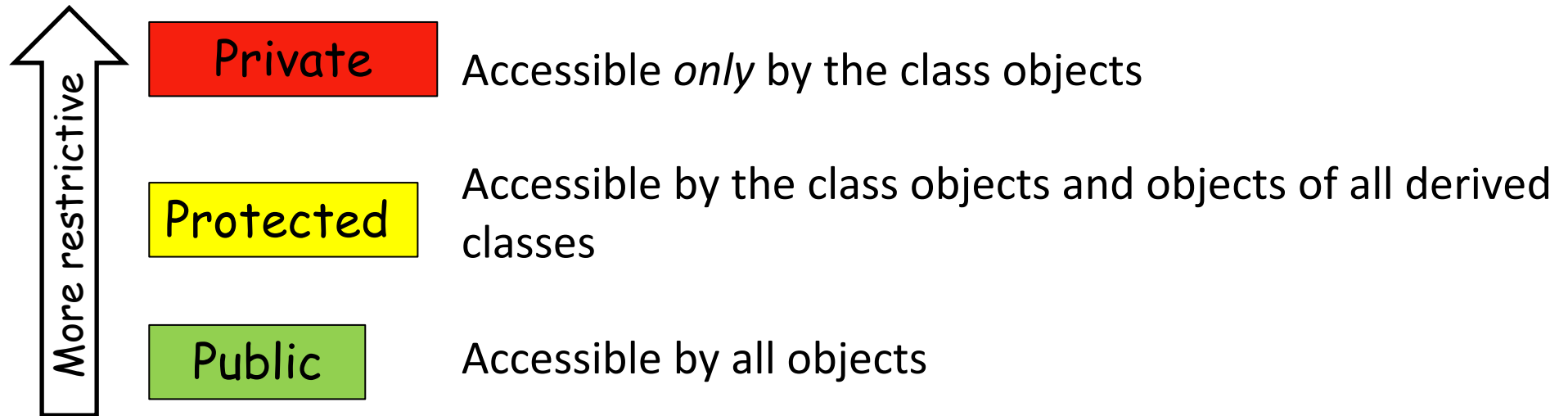
```
#include "posn3d.h"

Posn3D::Posn3D(int x, int y, int z)
: Posn(x, y)
{
    this->z = z;
}

bool Posn3D::close_to_origin(int d) {
    return (Posn::close_to_origin(d)
        && (abs(z) < d));
}
```

# Access Modifiers

# Inheritance: Access Modifiers



Access Specifiers in the base class			
	private	protected	public
Private inheritance →	The member is inaccessible.	The member is private.	The member is private.
Protected inheritance	The member is inaccessible.	The member is protected.	The member is protected.
Public inheritance	The member is inaccessible.	The member is protected.	The member is public.

# Access Modifiers: Example

```
class A
{
public:
    int x;
protected:
    int y;
private:
    int z;
};

class B : public A
{
    // x is public
    // y is protected
    // z is not accessible from B
};

class C : protected A
{
    // x is protected
    // y is protected
    // z is not accessible from C
};

class D : private A    // 'private' is default for classes
{
    // x is private
    // y is private
    // z is not accessible from D
};
```