

ECE 220

Lecture x0015 - 04/09

C++ - Inheritance, polymorphism

Recap

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 - C vs. C++ obvious differences

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 - Default arguments

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 - Default arguments
 - Dynamic allocation
 - Function & operator overloading
 - Structs vs. classes

Default arguments

```
float bmi_si(float hcm, float kg){  
    return kg / (hcm/100 * hcm/100);  
}
```

```
float bmi_usa(float hin, float lbs){  
    return lbs / (hin * hin) * 703;  
}
```

```
float bmi(float ht, float wt, bool si=false){  
    float val = wt/(ht*ht);  
    if (si)  
        return val*10000;  
    else  
        return val*703;  
}
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C: Write two functions and use appropriate one depending on units at hand.

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    float val = wt/(ht*ht);  
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        return val*10000;  
    else  
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}
```



Default value is false

Dynamic allocation in C & C++

```
# include <iostream>

int main(){
    int *p;

    // Allocating an integer's worth of space
    p = new int;

    .
    .
    .
    // Deallocating
    delete p;
}
```

Dynamic allocation in C & C++

C

C++

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# include <iostream>
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int main(){
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```
    int *p;
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    p = new int;
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```
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```
    delete p;
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Dynamic allocation in C & C++

C	C++
Dynamic allocation is accomplished by <code>malloc</code>	Dynamic allocation is accomplished by <code>new</code>

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int main(){  
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```
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delete p;
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Dynamic allocation in C & C++

C	C++
Dynamic allocation is accomplished by <code>malloc</code>	Dynamic allocation is accomplished by <code>new</code>
Deallocation accomplished by <code>free</code>	Deallocation accomplished by <code>delete</code>
Both <code>malloc</code> and <code>free</code> are library functions	Both <code>new</code> and <code>delete</code> are keyword/operators

```
# include <iostream>

int main(){
    int *p;

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Function overloading

- C++ allows multiple functions with the same name but **different** parameters.

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```
double volume(float r){  
    return 22.0/7*r*r*r*4/3;  
}
```

```
double volume(float r, float l){  
    return 22.0/7*r*r*l;  
}
```

```
double volume(float w, float h, float l){  
    return width * height * length;  
}
```

Function overloading

- C++ allows multiple functions with the same name but **different** parameters.
- **Note:** The return value cannot be different

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    return 22.0/7*r*r*r*4/3;  
}
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```
double volume(float r, float l){  
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```
struct student{  
    char name[74];  
    unsigned long UIN;  
    unsigned int year;  
    float GPA;  
};
```

Structs vs. classes

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struct student{
    char name[74];
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```
public:
    Student(char const *name, unsigned int UIN,
            unsigned int year, float GPA);
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struct student{
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```
Student::Student(char const *name,
                 unsigned int UIN,
                 unsigned int year,
                 float GPA){
    strcpy(this->name, name);
    this->UIN = UIN;
    this->year = year;
    this->GPA = GPA;
}
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    float get_GPA();
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    char const * get_name();
    void set_GPA(float gpa);
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Operator overloading

```
int main(){  
    Complex c1 = Complex(2, 4);  
    Complex c2 = Complex(3, -5);  
    Complex c3 = c1 + c2;  
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Operator overloading

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

class Complex{
    double real;
    double imag;

public:
    Complex(double real, double imag){
        this->real = real;
        this->imag = imag;
    }

    void print(){
        cout<<"(" <<this->real<<" + "<<this->imag<<"");
    }

    Complex operator+(Complex c){
        return Complex(this->real + c.real, this->imag + c.imag);
    }
};
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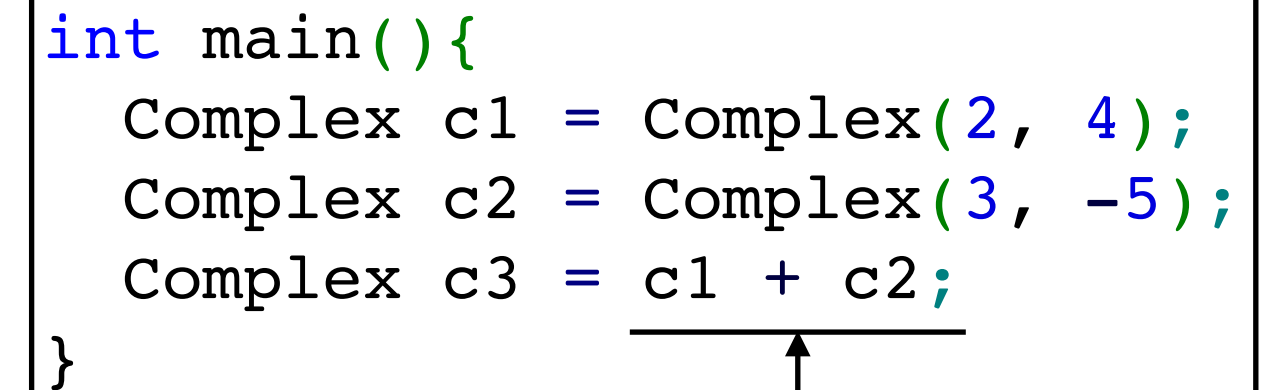
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- Reference is yet another addition to the C/C++ zoo.
- **Key difference**: A pointer is *still a variable* that takes up memory whereas a reference does/is not.
 - Think of it as an *alias* for a variable.
- If you remember the key difference then rest of the behavior is logical.

Pointers vs. references

Pointer

Reference

https://www3.ntu.edu.sg/home/ehchua/programming/cpp/cp4_PointerReference.html

Pointers vs. references

	Pointer	Reference
Memory address	Has memory allocated for it	No memory allocated for it

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Dereferencing	Must use the * operator	Automatically dereferenced
Arrays	Can have array of pointers	Cannot create array of references

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Examples

Examples

What will be the output?

Examples

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

int main(){
    int val = 10;
    int *ptr = &val; // & to get address
    int &ref = val; // & to declare reference

    cout<<"val = "<<val<<endl;
    cout<<"*ptr = "<<*ptr<<endl;
    cout<<"ref = "<<ref<<endl;

    ref = 20;
    cout<<endl<<"val = "<<val<<endl;

    val = 30;
    cout<<"ref = "<<ref<<endl;

    cout<<"ptr = "<<ptr<<endl;
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What will be the output?

← Which variable(s) changed here?

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What will be the output?

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← What about here?

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```
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What will be the output?

← Which variable(s) changed here?

← What about here?

Are these addresses same or different?

Why references when have pointers?

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Why references when have pointers?

- Mostly safety:
 - No such thing as reference arithmetic & cannot reassign references (can do both to pointers).
 - *Paradigm*: Use references for most use cases and use pointers only when you *must*.
- Passing around large objects to/via functions is simplified (for the programmer) with references:
 - Example *later*: copy constructors

Examples

Examples

```
void swap(int *a, int *b){  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap(int &a, int &b){  
    int temp = a;  
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}
```

```
int main(){  
    int val1, val2;  
    val1 = 10, val2 = 20;  
  
    cout<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;  
  
    swap(&val1, &val2);  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;  
  
    swap(val1, val2);  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;  
}
```

Examples

```
void swap(int *a, int *b){
    int temp = *a;
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    cout<<"val1 = "<<val1<<endl;
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```

```
    swap(&val1, &val2);      Which function is called?
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    swap(val1, val2);
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```

Examples

Can fail for uninitialized, dangling, or ill-formed pointers!

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void swap(int *a, int *b){
    int temp = *a;
    *a = *b;
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    swap(val1, val2);           Which function is called?
    cout<<endl<<"val1 = "<<val1<<endl;
    cout<<"val2 = "<<val2<<endl;
}
```

Examples

Can fail for uninitialized, dangling, or ill-formed pointers!

```
void swap(int *a, int *b){
    int temp = *a;
    *a = *b;
    *b = temp;
}
```

```
void swap(int &a, int &b){
    int temp = a;
    a = b;
    b = temp;
}
```

Less can go wrong with this version.

```
int main(){
    int val1, val2;
    val1 = 10, val2 = 20;
```

```
    cout<<"val1 = "<<val1<<endl;
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(&val1, &val2);           Which function is called?
    cout<<endl<<"val1 = "<<val1<<endl;
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(val1, val2);           Which function is called?
    cout<<endl<<"val1 = "<<val1<<endl;
    cout<<"val2 = "<<val2<<endl;
}
```

Examples

```
void swap(int *a, int *b){
    int temp = *a;
    *a = *b;
    *b = temp;
}
```

```
void swap(int &a, int &b){
    int temp = a;
    a = b;
    b = temp;
}
```

```
void swap(int a, int b){
    int temp = a;
    a = b;
    b = temp;
}
```

```
int main(){
    int val1, val2;
    val1 = 10, val2 = 20;
```

```
    cout<<"val1 = "<<val1<<endl;
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(&val1, &val2);           Which function is called?
    cout<<endl<<"val1 = "<<val1<<endl;
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(val1, val2);           Which function is called?
    cout<<endl<<"val1 = "<<val1<<endl;
    cout<<"val2 = "<<val2<<endl;
}
```

Examples

```
void swap(int *a, int *b){  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap(int &a, int &b){  
    int temp = a;  
    a = b;  
    b = temp;  
}
```

```
void swap(int a, int b){  
    int temp = a;  
    a = b;  
    b = temp;  
}
```

```
int main(){  
    int val1, val2;  
    val1 = 10, val2 = 20;
```

```
    cout<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(&val1, &val2);           Which function is called?  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(val1, val2);           Which function is called?  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;  
}
```

What happens now?

Examples

```
void swap(int *a, int *b){  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap(int &a, int &b){  
    int temp = a;  
    a = b;  
    b = temp;  
}
```

```
void swap(int a, int b){  
    int temp = a;  
    a = b;  
    b = temp;  
}
```

```
int main(){  
    int val1, val2;  
    val1 = 10, val2 = 20;
```

```
    cout<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(&val1, &val2);           Which function is called?  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(val1, val2);           Which function is called?  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;  
}
```

Overload resolution fails!

What happens now?

Examples

```
void swap(int *a, int *b){  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap(int &a, int &b){  
    int temp = a;  
    a = b;  
    b = temp;  
}
```

```
void swap(int a, int b){  
    int temp = a;  
    a = b;  
    b = temp;  
}
```

```
int main(){  
    int val1, val2;  
    val1 = 10, val2 = 20;
```

```
    cout<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(&val1, &val2);           Which function is called?  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;
```

```
    swap(val1, val2);           Which function is called?  
    cout<<endl<<"val1 = "<<val1<<endl;  
    cout<<"val2 = "<<val2<<endl;  
}
```

Overload resolution fails!

Solution: Explicit casts

What happens now?

Examples

```
void swap(int *a, int *b){
    int temp = *a;
    *a = *b;
    *b = temp;
}
```

```
void swap(int &a, int &b){
    int temp = a;
    a = b;
    b = temp;
}
```

```
void swap(int a, int b){
    int temp = a;
    a = b;
    b = temp;
}
```

```
int main(){
    int val1, val2;
    val1 = 10, val2 = 20;
```

```
cout<<"val1 = "<<val1<<endl;
cout<<"val2 = "<<val2<<endl;
```

```
swap(&val1, &val2);           Which function is called?
cout<<endl<<"val1 = "<<val1<<endl;
cout<<"val2 = "<<val2<<endl;
```

```
swap(val1, val2);           Which function is called?
cout<<endl<<"val1 = "<<val1<<endl;
cout<<"val2 = "<<val2<<endl;
}
```

Overload resolution fails!

Solution: Explicit casts

What happens now?

Exercise using classes

- Implement our old linked list using:

```
class Person{
    const char *name;
    unsigned int byear;

public:

    Person *next;
    Person(const char *name, unsigned int byear){
        this->name = name;
        this->byear = byear;
        this->next = NULL;
    }
};
```

Exercise using classes

- Implement our old linked list using:

```
class Person{  
    const char *name;  
    unsigned int byear;
```



These are private, if we want to be able to print our linked list will need to implement a print function.

```
public:
```

```
    Person *next;  
    Person(const char *name, unsigned int byear){  
        this->name = name;  
        this->byear = byear;  
        this->next = NULL;  
    }  
};
```

Exercise using classes

- Implement our old linked list using:

```
class Person{
    const char *name;
    unsigned int byear;

public:

    Person *next;
    Person(const char *name, unsigned int byear){
        this->name = name;
        this->byear = byear;
        this->next = NULL;
    }

    void print(){
        cout<< "(" << this->name << ", " << this->byear << ")" <<endl;
    }
};
```

Exercise using classes

- How to maintain head pointer, and add/remove functions?

Exercise using classes

- How to maintain head pointer, and add/remove functions?
 - Adopt the OOP way

Exercise using classes

- How to maintain head pointer, and add/remove functions?
- Adopt the OOP way

```
class LinkedList{
    Person *head;

public:
    LinkedList(){
        this->head = NULL;
    }

};
```


Exercise using classes

- How to maintain head pointer, and add/remove functions?
 - Adopt the OOP way
 - Basic functions to implement for a linked list?

```
class LinkedList{
    Person *head;

public:
    LinkedList(){
        this->head = NULL;
    }

};
```

Exercise using classes

- How to maintain head pointer, and add/remove functions?
 - Adopt the OOP way
 - Basic functions to implement for a linked list?
 - Function to print list

```
class LinkedList{
    Person *head;

public:
    LinkedList(){
        this->head = NULL;
    }
    void print_list();

};
```

Exercise using classes

- How to maintain head pointer, and add/remove functions?
 - Adopt the OOP way
 - Basic functions to implement for a linked list?

```
class LinkedList{
    Person *head;

public:
    LinkedList(){
        this->head = NULL;
    }
    void print_list();
    void add_at_head(Person &p);

};
```

- Function to print list
- Function to add at head

Exercise using classes

- How to maintain head pointer, and add/remove functions?
 - Adopt the OOP way
 - Basic functions to implement for a linked list?

```
class LinkedList{
    Person *head;

public:
    LinkedList(){
        this->head = NULL;
    }
    void print_list();
    void add_at_head(Person &p);
    void del_at_head();

};
```

- Function to print list
- Function to add at head
- Function to remove from head

Friend functions

Friend functions

- What if we would like a ***select*** few functions to have access to the objects members?

Friend functions

- What if we would like a ***select*** few functions to have access to the objects members?
 - C++ lets you define ***friend*** functions in a class declaration.

Friend functions

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 - These classes have access to all class members but are **not** class members themselves

Friend functions

- What if we would like a ***select*** few functions to have access to the objects members?
 - C++ lets you define ***friend*** functions in a class declaration.
 - These classes have access to all class members but are **not** class members themselves

```
class Box {
    double width;

    public:
        friend void printWidth( Box box );
        void setWidth( double wid);
};

// Member function definition
void Box::setWidth( double wid) {
    width = wid;
}

/* Note: printWidth() is not a member
function of any class */
void printWidth( Box box ) {
    /* Because printWidth() is a friend of Box,
    it can directly access any member of this
    class */
    cout << "Width of box : " << box.width <<endl;
}
```

Inheritance

Inheritance

```
class Dog{
    const char *name;
    int breed;
    int age;
    bool nail_clip;

public:
    Dog(const char *n, int b, int a){
        name = n, breed = b; age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
        cout<<name<<" : Woof!"<<endl;
    }
};
```

```
class Cat{
    const char *name;
    int breed;
    int age;

public:
    Cat(const char *n, int b, int a){
        name = n, breed = b, age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
        cout<<name<<" : Meow!"<<endl;
    }
};
```

Inheritance

```
class Dog{
    const char *name;
    int breed;
    int age;
    bool nail_clip;

public:
    Dog(const char *n, int b, int a){
        name = n, breed = b; age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
        cout<<name<<" : Woof!"<<endl;
    }
};
```

```
class Cat{
    const char *name;
    int breed;
    int age;

public:
    Cat(const char *n, int b, int a){
        name = n, breed = b, age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
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```

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class Dog{
    const char *name;
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    int age;
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public:
    Dog(const char *n, int b, int a){
        name = n, breed = b; age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
        cout<<name<<" : Woof!"<<endl;
    }
};
```

```
class Cat{
    const char *name;
    int breed;
    int age;

public:
    Cat(const char *n, int b, int a){
        name = n, breed = b, age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
        cout<<name<<" : Meow!"<<endl;
    }
};
```

What about a class
Hamster which
squeaks?

Inheritance

```
class Dog{
    const char *name;
    int breed;
    int age;
    bool nail_clip;

public:
    Dog(const char *n, int b, int a){
        name = n, breed = b; age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
        cout<<name<<" : Woof!"<<endl;
    }
};
```

```
class Cat{
    const char *name;
    int breed;
    int age;

public:
    Cat(const char *n, int b, int a){
        name = n, breed = b, age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    void speak(){
        cout<<name<<" : Meow!"<<endl;
    }
};
```

Inheritance

Inheritance

C++ allows us to define a class based on an existing class, and the new class will inherit members of the existing class.

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- The **existing** class - **Base class**

Inheritance

C++ allows us to define a class based on an existing class, and the new class will inherit members of the existing class.

- The **existing** class - **Base class**
- The **new** class - **Derived class**

Inheritance

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Exceptions in inheritance (things not inherited):

Inheritance

C++ allows us to define a class based on an existing class, and the new class will inherit members of the existing class.

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Exceptions in inheritance (things not inherited):

- Constructors, destructors of the base class

Inheritance

C++ allows us to define a class based on an existing class, and the new class will inherit members of the existing class.

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Exceptions in inheritance (things not inherited):

- Constructors, destructors of the base class
- Overloaded operators of the base class

Inheritance

C++ allows us to define a class based on an existing class, and the new class will inherit members of the existing class.

- The **existing** class - **Base class**
- The **new** class - **Derived class**

Exceptions in inheritance (things not inherited):

- Constructors, destructors of the base class
- Overloaded operators of the base class
- Friend functions of the base class

Inheritance

Inheritance

```
class Animal{
    const char *name;
    int breed;
    int age;

public:
    Animal(const char *n, int b, int a){
        name = n;
        breed = b;
        age = a;
    }

    void greet(const char *p){
        cout<<name<<": Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<": Zzzzzz"<<endl;
    }

    const char* get_name(){
        return name;
    }
};
```


Inheritance

Base class

```
class Animal{
    const char *name;
    int breed;
    int age;

public:
    Animal(const char *n, int b, int a){
        name = n;
        breed = b;
        age = a;
    }

    void greet(const char *p){
        cout<<name<<": Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<": Zzzzzz"<<endl;
    }

    const char* get_name(){
        return name;
    }
};
```

Inheritance

Base class

```
class Animal{
    const char *name;
    int breed;
    int age;

public:
    Animal(const char *n, int b, int a){
        name = n;
        breed = b;
        age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    const char* get_name(){
        return name;
    }
};
```

```
class Dog: public Animal{
    bool nail_clip;

public:
    void speak(){
        cout<<get_name()<<" : Woof!"<<endl;
    }
};
```

Derived class

```
class Cat: public Animal{
public:

    void speak(){
        cout<<get_name()<<" : Meow!"<<endl;
    }
};
```

Derived class

Inheritance

Base class

```
class Animal{
    const char *name;
    int breed;
    int age;

public:
    Animal(const char *n, int b, int a){
        name = n;
        breed = b;
        age = a;
    }

    void greet(const char *p){
        cout<<name<<": Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<": Zzzzzz"<<endl;
    }

    const char* get_name(){
        return name;
    }
};
```

```
class Dog: public Animal{
    bool nail_clip;

public:
    void speak(){
        cout<<get_name()<<": Woof!"<<endl;
    }
};
```

Derived class

```
class Cat: public Animal{
public:

    void speak(){
        cout<<get_name()<<": Meow!"<<endl;
    }
};
```

Derived class

Inheritance

Base class

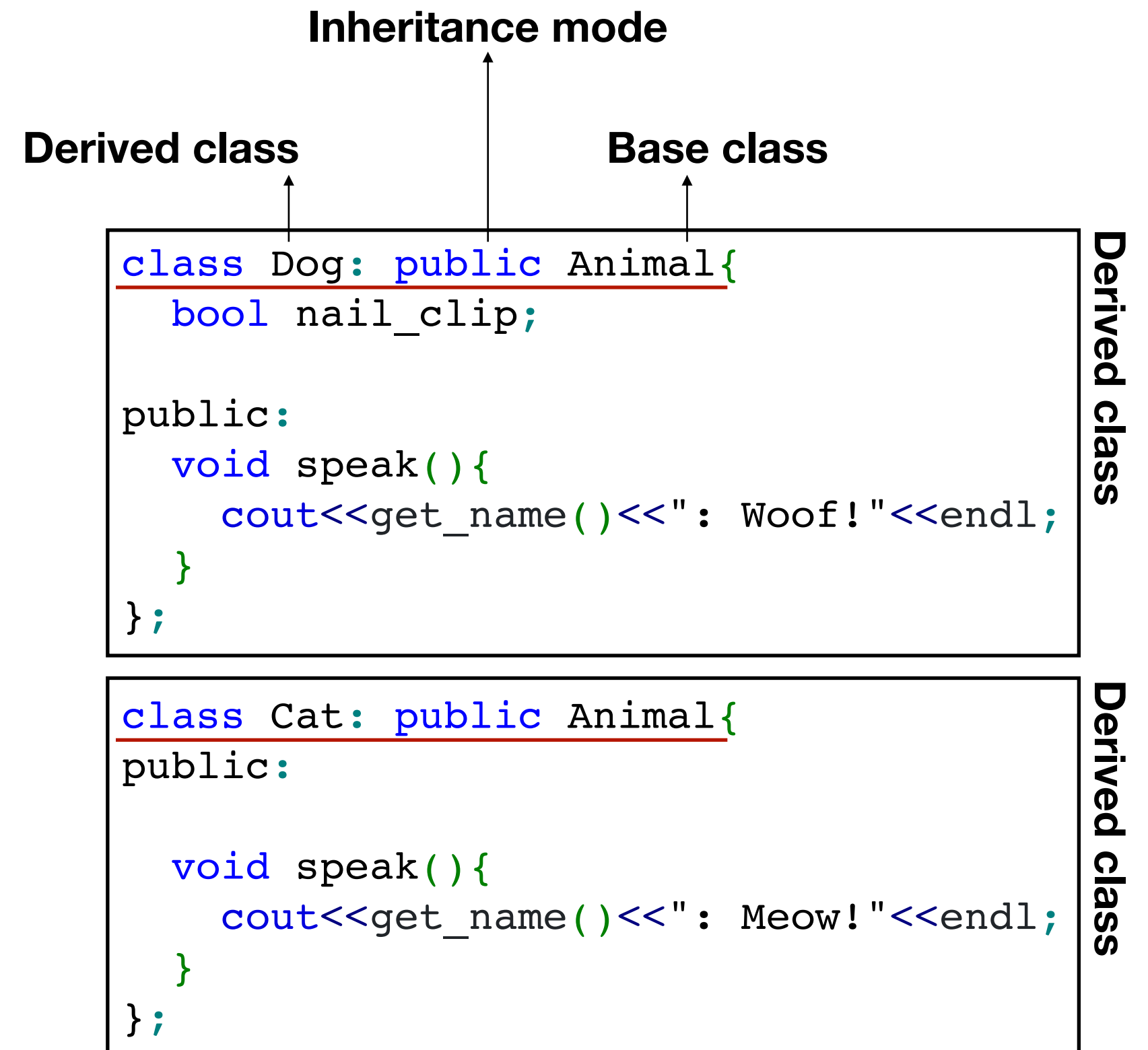
```
class Animal{
    const char *name;
    int breed;
    int age;

public:
    Animal(const char *n, int b, int a){
        name = n;
        breed = b;
        age = a;
    }

    void greet(const char *p){
        cout<<name<<" : Hi, "<<p<<endl;
    }

    void sleep(){
        cout<<name<<" : Zzzzzz"<<endl;
    }

    const char* get_name(){
        return name;
    }
};
```



Inheritance rules

Inheritance	Derived class has access to		
	private members	public members	protected members
Private inheritance	No	No (inherited as private variables)	Yes (inherited as private variables)
Public inheritance	No	Yes (inherited as public variables)	Yes
Protected inheritance	No	Yes (inherited as protected variables)	Yes

Inheritance rules

Inheritance	Derived class has access to		
	private members	public members	protected members
Private inheritance	No	No (inherited as private variables)	Yes (inherited as private variables)
Public inheritance	No	Yes (inherited as public variables)	Yes
Protected inheritance	No	Yes (inherited as protected variables)	Yes

Derived class constructor?

Derived class constructor?

```
class Dog: public Animal{
    bool nail_clip;

public:
    Dog(const char *n, int b, int a, bool c){
        nail_clip = c;
    }
    void speak(){
        cout<<get_name()<<" : Woof!"<<endl;
    }
};
```

```
class Cat: public Animal{
public:


    Cat(const char*n, int b, int a){
    };

    void speak(){
        cout<<get_name()<<" : Meow!"<<endl;
    }
};
```


Derived class constructor?


```
class Dog: public Animal{
    bool nail_clip;

public:
    Dog(const char *n, int b, int a, bool c){
        nail_clip = c;
    }
    void speak(){
        cout<<get_name()<<" : Woof!"<<endl;
    }
};
```



```
class Cat: public Animal{
public:
    Cat(const char*n, int b, int a){
    };

    void speak(){
        cout<<get_name()<<" : Meow!"<<endl;
    }
};
```



How will Dog and Cat set their breed, name and age which are part of the `Animal` class and its private members?

Derived class constructor?

```
class Dog: public Animal{
    bool nail_clip;

public:
    Dog(const char *n, int b, int a, bool c) : Animal(n, b, a){
        nail_clip = c;
    }
    void speak(){
        cout<<get_name()<<" : Woof!"<<endl;
    }
};
```

```
class Cat: public Animal{
public:

    Cat(const char*n, int b, int a) : Animal(n, b, a){
    };

    void speak(){
        cout<<get_name()<<" : Meow!"<<endl;
    }
};
```

Derived class constructor?

```
class Dog: public Animal{  
    bool nail_clip;
```

```
public:
```

```
    Dog(const char *n, int b, int a, bool c) : Animal(n, b, a){  
        nail_clip = c;  
    }
```

```
    void speak(){  
        cout<<get_name()<<" : Woof!"<<endl;  
    }
```

```
};
```

```
class Cat: public Animal{
```

```
public:
```

```
    Cat(const char*n, int b, int a) : Animal(n, b, a){  
    };
```

```
    void speak(){  
        cout<<get_name()<<" : Meow!"<<endl;  
    }
```

```
};
```

Will make sure to call the base class constructor first.

Derived class constructor?

```
class Dog: public Animal{  
    bool nail_clip;
```

```
public:
```

```
    Dog(const char *n, int b, int a, bool c) : Animal(n, b, a){  
        nail_clip = c;  
    }
```

```
    void speak(){  
        cout<<get_name()<<" : Woof!"<<endl;  
    }
```

```
};
```

```
class Cat: public Animal{
```

```
public:
```

```
    Cat(const char*n, int b, int a) : Animal(n, b, a){  
};
```

```
    void speak(){  
        cout<<get_name()<<" : Meow!"<<endl;  
    }
```

```
};
```

Will make sure to call the base class constructor first.

It is called *member initializer list* syntax!

Virtual functions

Virtual functions

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

class Animal{
public:
    void eat(){
        cout << "I'm eating generic food." << endl;
    }
};

class Cat : public Animal{
public:
    void eat(){
        cout << "I'm eating a mouse." << endl;
    }
};

void eat_lunch(Animal *a){
    a->eat();
}
```

Virtual functions

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

class Animal{
public:
    void eat(){
        cout << "I'm eating generic food." << endl;
    }
};

class Cat : public Animal{
public:
    void eat(){
        cout << "I'm eating a mouse." << endl;
    }
};

void eat_lunch(Animal *a){
    a->eat();
}

int main(){
    Animal *anim = new Animal();
    Cat *bruno = new Cat();
    anim->eat();
    bruno->eat();

    eat_lunch(anim);
    eat_lunch(bruno);
}
```

Virtual functions

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

class Animal{
public:
    void eat(){
        cout << "I'm eating generic food." << endl;
    }
};

class Cat : public Animal{
public:
    void eat(){
        cout << "I'm eating a mouse." << endl;
    }
};

void eat_lunch(Animal *a){
    a->eat();
}
```

```
int main(){
    Animal *anim = new Animal();
    Cat *bruno = new Cat();
    anim->eat();
    bruno->eat();

    eat_lunch(anim);
    eat_lunch(bruno);
}
```

Why didn't Bruno eat a mouse for lunch ?

Virtual functions

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

class Animal{
public:
    void eat(){
        cout << "I'm eating generic food." << endl;
    }
};

class Cat : public Animal{
public:
    void eat(){
        cout << "I'm eating a mouse." << endl;
    }
};

void eat_lunch(Animal *a){
    a->eat();
}
```

```
int main(){
    Animal *anim = new Animal();
    Cat *bruno = new Cat();
    anim->eat();
    bruno->eat();

    eat_lunch(anim);
    eat_lunch(bruno);
}
```

Why didn't Bruno eat a mouse for lunch ?

Need a way for the derived class to **override** the base class function,

... or

We will have to *overload* **eat_lunch** for each new species!

Virtual functions

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

class Animal{
public:
    virtual void eat(){
        cout << "I'm eating generic food." << endl;
    }
};

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- A virtual function is a member function in the base class that we expect to redefine in derived classes
- What if your colleagues forget to override a virtual function? How to **ensure** it?

Pure virtual functions

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```
class Animal{
public:
    virtual void eat()=0;
};

class Cat : public Animal{
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    void eat(){
        cout << "I'm eating a mouse." << endl;
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```

Pure virtual functions

Pure virtual functions are used

- if a function doesn't have any use in the base class
- but the function must be implemented by all its derived classes

A pure virtual function doesn't have a function body and it ends with “=0”

```
class Animal{
public:
    virtual void eat()=0;
};

class Cat : public Animal{
public:
    void eat(){
        cout << "I'm eating a mouse." << endl;
    }
};
```

Adding a pure virtual function turns a normal class to an ***abstract*** class!

Abstract class

- **Abstract class** is a class that contains one or more *pure virtual functions*.

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 - No objects of that abstract class can be created
 - A pure virtual function that is not implemented in a derived class remains a pure virtual function, so the derived class is also an abstract class
 - An abstract class is intended as an interface to objects accessed through pointers and references (e.g. `eat_lunch` function)

Copy constructor

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Copy constructor

- Recall that we could implement a Stack ADT with a linked list
 - Push: add at head of linked list
 - Pop: remove from head + *give popped value to caller*
 - How can we do the second part?

Copy constructor

Copy constructor

```
class Person{
    const char *name;
    unsigned int byear;

public:
    Person *next;
    Person(const char *name, unsigned int byear);
    Person(const Person &p);
};

Person::Person(const Person &p){
    this->name = p.name;
    this->byear = p.byear;
    this->next = NULL;
}
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Second constructor
useful to copy an
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**Second constructor
useful to copy an
instance of Person.**



```
Person::Person(const Person &p){
    this->name = p.name;
    this->byear = p.byear;
    this->next = NULL;
}
```

**Called pass by
constant reference.**



Copy constructor

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class Person{
    const char *name;
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    Person *next;
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- **Exercise:** Can we appropriately modify the `LinkedList` class definition and create a derived `Stack` class from it?

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- **Exercise:** Can we appropriately modify the `LinkedList` class definition and create a derived `Stack` class from it?
- Stack should **only** expose the push and pop functions.

Exercise

- How to modify the `LinkedList` class?
 - Does `add_at_head` and `del_at_head` need to be public?
 - Can they be private?
 - When popping, we need access to head pointer to call copy constructor - can it still be private?