Inheritance

OOP Principles, Inheritance

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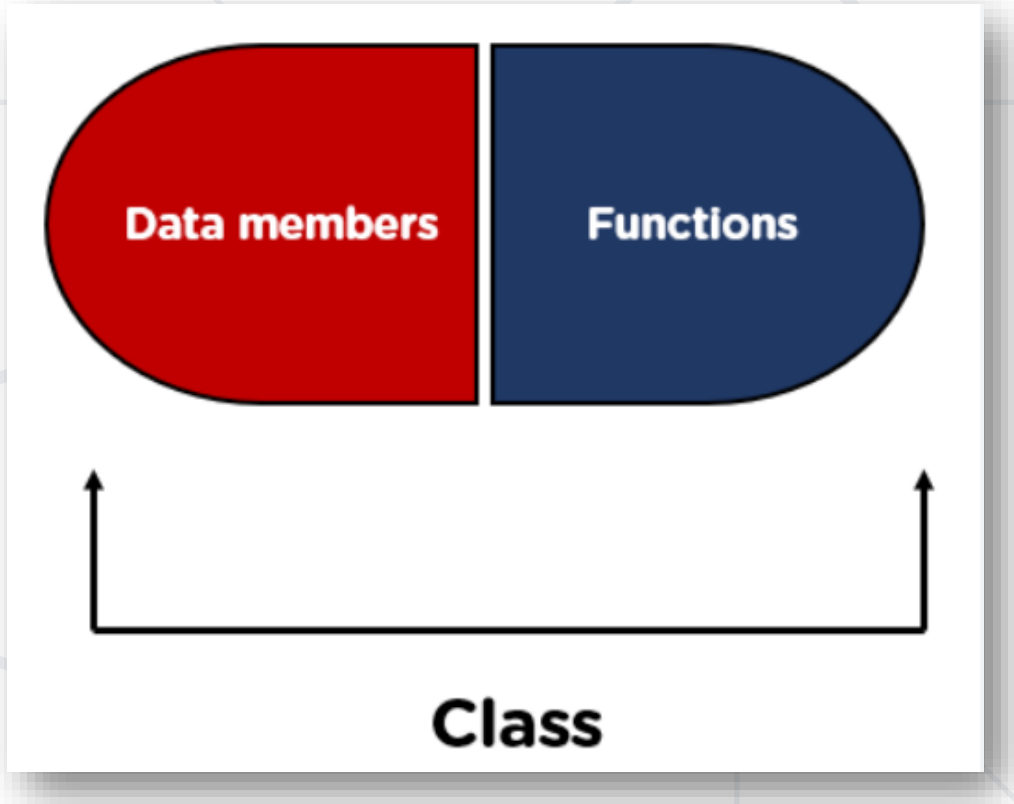
OOP Principles

Encapsulation, Inheritance, Polymorphism, Abstraction

Encapsulation

- In general, encapsulation is a **process of wrapping similar code in one place**
- In OOP, encapsulation is **combining member functions** and **data members** in a single unit called a class



Abstraction

- Classes have internal state (`vector`'s capacity)
  - `private` / `protected` – state inaccessible to outside code
  - `public` – outside code interacts with object state through public members

```
class IntArray
{
private:
  int* data; int size;
public:
  IntArray(int size) : data(new int[size]), size(size) {}
  ~IntArray() { delete[] this->data; }
  ...
};
```

Can't be modified from the outside, so the class can:
- assume last index in `data` is `size-1`
- rename `size` to `length` without checking for outside usages

Abstraction

- Abstraction – using base virtual members
  - So allowing any class with **override**s for them
- **ostream& operator<<(ostream& out, const Person& p)**
  - Allows any **ostream** – **ostringstream**, **ofstream**, **cout**

```
void stopIfOverLimit(Vehicle* v, double limit)
{
  if (v->getSpeed() > limit)
  {
    v->stop();
  }
}
```

Inheritance

- **Derived** classes **inherit** a **base** class to reuse its members

```
class Vehicle { private: double speed;
public: Vehicle(double speed) : speed(speed) {}
        void setSpeed(double speed) { this->speed = speed; }
};
```

```
class Car : public Vehicle {
private: bool parkingBrakeOn;
public:
Car(double spd, bool park) : Vehicle(spd), parkingBrakeOn(park) {}
};
```

```
class Airplane : public Vehicle {
private: double altitude;
public:
Airplane(double spd, double alt) : Vehicle(spd), altitude(alt) {}
};
```

Inheritance

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```
class Vehicle {
    private:
      double speed;
    public:
      Vehicle(double speed) : speed(speed) {}
      void setSpeed(double speed) { this->speed = speed; }
};
```

Base class

```
class Car : public Vehicle
{
   private:
      bool parkingBrakeOn;
   public:
      Car(double spd, bool park)
:       Vehicle(spd),
parkingBrakeOn(park) {}
};Der
```

Derived class

```
class Airplane : public Vehicle
{
    private:
      double altitude;
    public:
      Airplane(double spd, double alt) :
Vehicle(spd), altitude(alt) {}
};
```

Derived class

Polymorphism – virtual Members

- Base class can have **virtual** members
  - Derived classes **override** them to have different behavior

```
class Vehicle { ...
  virtual void stop() { this->speed = 0; }
};
```

```
class Car : public Vehicle override {
  ...
  virtual void stop() override {
    Vehicle::stop();
    this->parkingBrakeOn = true;
  }
};
```

```
class Airplane : public Vehicle override {
  ...
  virtual void stop() override {
    Vehicle::stop();
    this->altitude = 0;
  }
};
```

Polymorphism – Base Class Pointers

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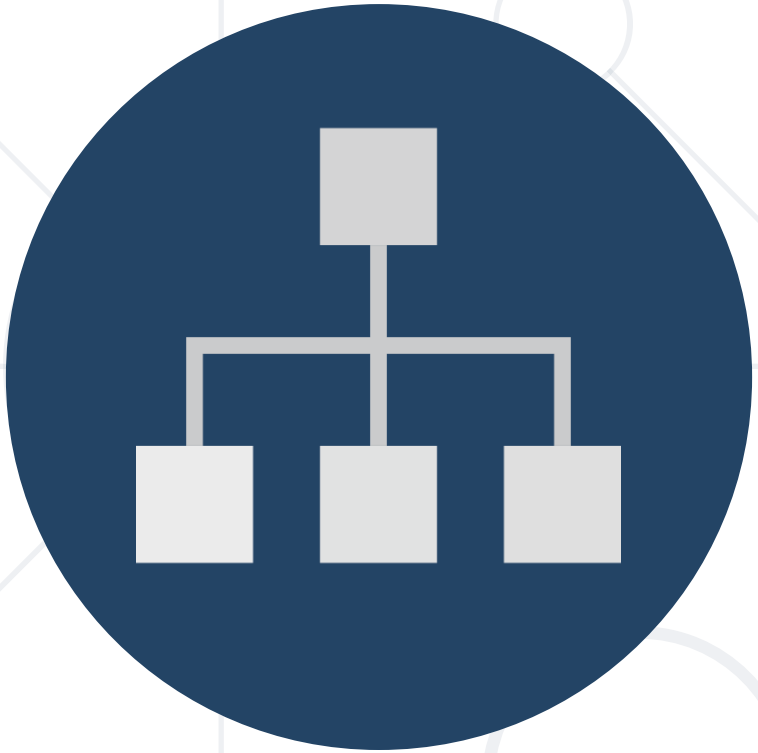
- Base class pointers / references can point to any derived class object
  - Normal members call **base** class member
  - **virtual** members call **override** member in **derived**

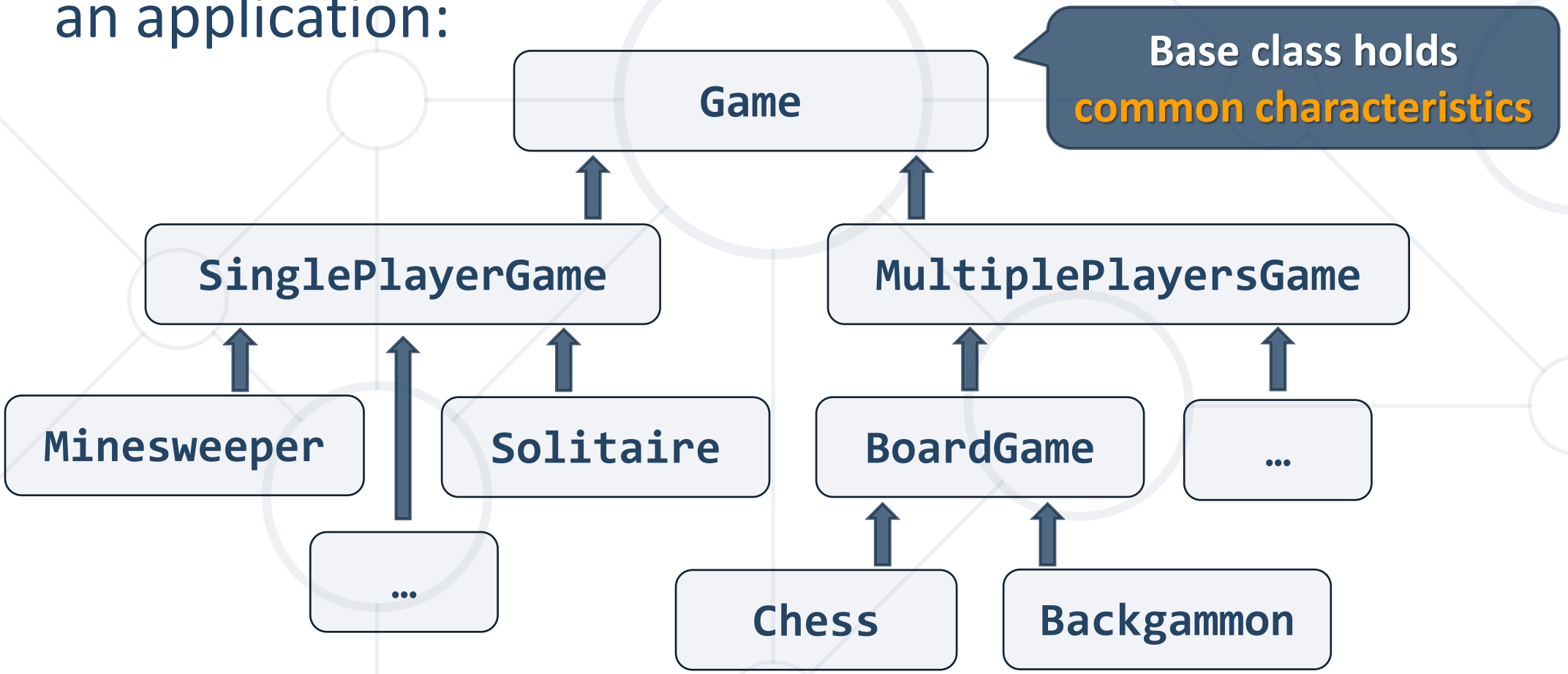
```
std::vector<Vehicle*> vehicles
{
  new Car(90, false),
  new Airplane(700, 10000, 242),
  new Car(0, true)
};
vehicles[0]->stop(); // calls Car::stop()
vehicles[1]->stop(); // calls Airplane::stop()
vehicles[2]->stop(); // calls Car::stop()
```



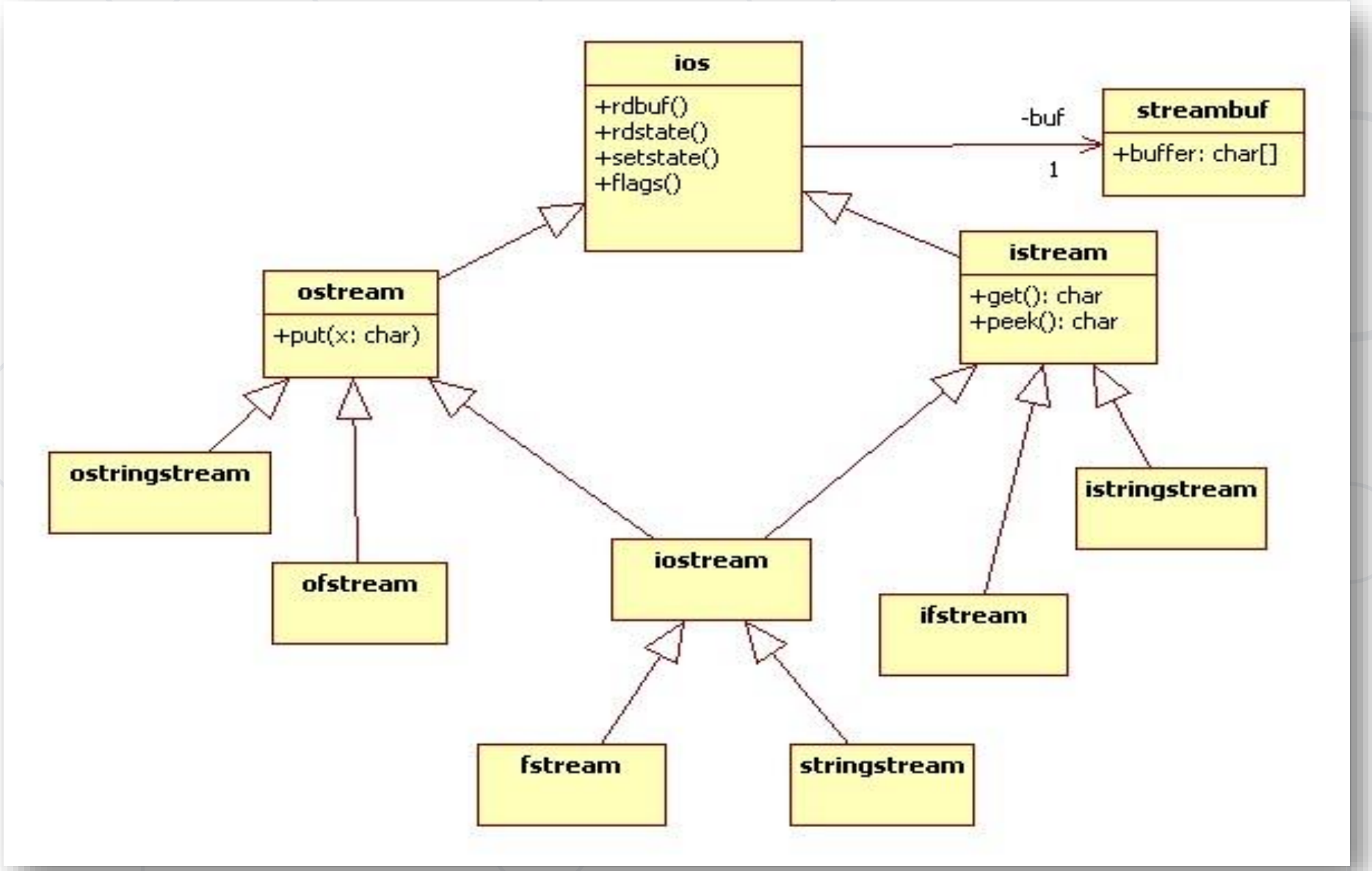
Class Hierarchies

Class Hierarchies

- **Inheritance** leads to **hierarchies** of classes and/or interfaces in an application:



Class Hierarchies

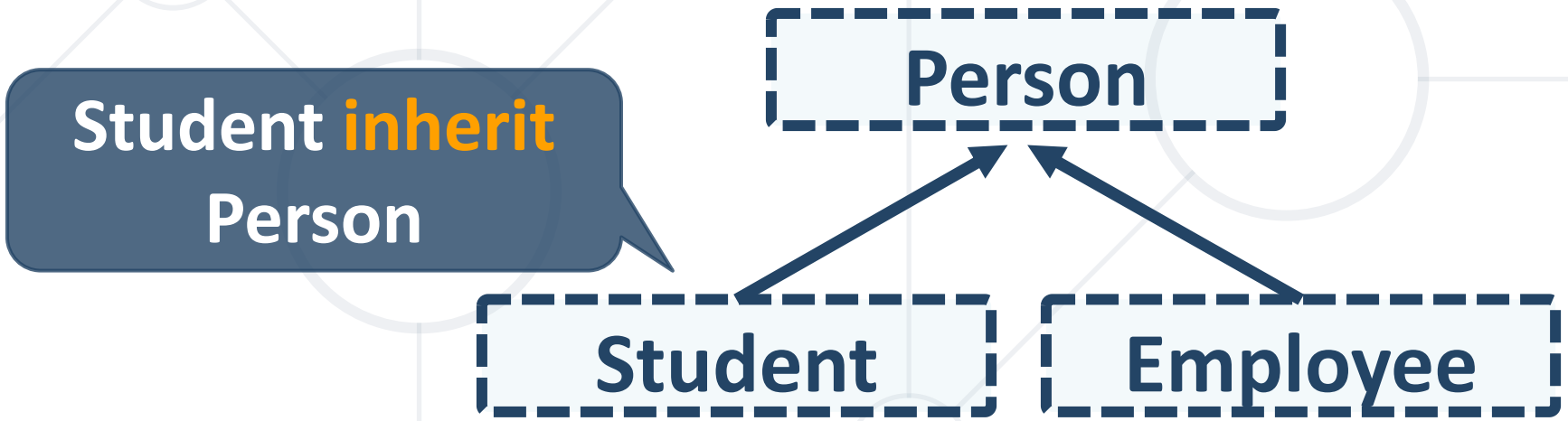


Inheritance

- C++ supports inheritance through **access modifier**

```
class Person { … }

class Student  : public Person { … }
class Employee : public Person { … }
```



Inheritance

Syntax, Protected Members, Accessing Base

Class Code Reuse

- Code **reuse patterns**:
  - Repeated code -> extract **function**
  - Functions using similar parameters / globals -> extract **class**
  - Repeated members in multiple classes -> extract **base class**
- Inheritance – sharing member definitions
  - A class **declares** / **defines** members
  - Other classes inherit it – get all members of inherited class

Inheritance

- `class Derived : access-modifier Base { ... }`
  - **access-modifier** – one of `public`/`protected`/`private`
- Members of **`Base`** class added to **`Derived`** class
  - Access limited to inheritance access-modifier
  - `public`: doesn't change **`Base`** modifiers
  - `protected`: `public` from **`Base`** -> `protected` in **`Derived`**
  - `private`: any from `Base` -> `private` in **Derived**

Inheritance – Extracting Base Class

- Extract common members into a **base class**

```
class Vehicle
{
public: double speed;
};
```

Can't use initializer-list for base class field

```
class Car : public Vehicle
{
  bool parkingBrakeOn;

public:
  Car(double speed, bool parked)
    : parkingBrakeOn(parked)
  {
    this->speed = speed;
  }
};
```

```
class Airplane : public Vehicle
{
  double altitude;
  double heading;
public:
  Airplane(double spd, double alt, double hdg)
    : altitude(alt), heading(hdg)
 {
    this->speed = spd;
 }
};
```

Share Access with Derived – protected

- `public speed` – breaking encapsulation
  - Can't use `private`, because we lose access to `speed`
- `protected` members – accessible to inheriting class

```
class Vehicle
{
protected:
  double speed;
};
```

```
class Car : public Vehicle
{ ...
public:
  Car(...) { this->speed = speed; }
};
```

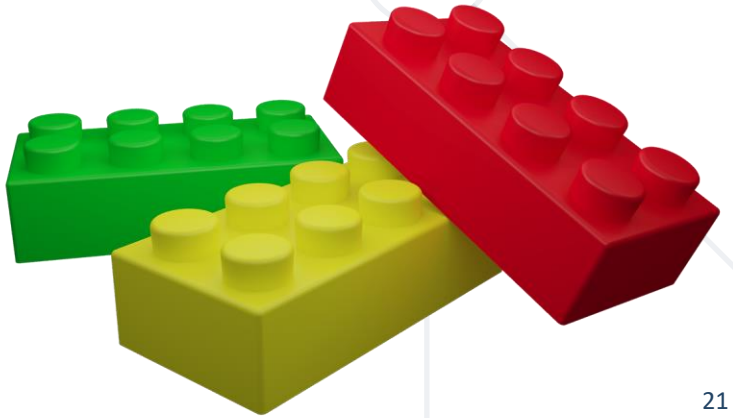
```
Car car(90, false);
cout << car.speed << std::endl;
 // compilation error
```

Can't be used outside of the class hierarchy

Using Base Constructors

- Inheriting class can call **base** constructor
  - In initializer list, like field, BUT with base class name
  - **Syntax:**

```
Derived(...) : Base(...), ... { ... }
```



Using Base Constructors - Example

```
class Vehicle { protected:
double speed;
Vehicle(double speed) : speed(speed) {}
```

```
class Car : public Vehicle {
...
Car(double speed, bool park)
  : Vehicle(speed), parkingBrakeOn(park) {}
```

```
class Airplane : public Vehicle {
...
Airplane(double s, double a, double h)
  : Vehicle(s), altitude(a), heading(h) {}
```

Hiding Methods

- Methods are inherited just like any member
- Hiding – using same signature in **derived** as in **base**
  - E.g. **base** has `void f()`, **derived** hides with `int f()`
    – calling `f()` in **derived** calls **derived** version (same for objects)
- Explicit access to base member (field/method/...)
  - Prefix member with **base** class name and `operator::`
  - E.g. `Base::f()` calls `f()` of inherited class `Base`

Example: Hiding & Calling Base Methods

- Example: Let's make a `toString()` for `Vehicle`
  - Reuse it in `Car`'s `toString()`

```
class Vehicle {

...
  string toString() const {
    ostringstream stream;
    stream << "speed: "
      << this->speed;
    return stream.str();
  }
}
```

```
class Car {
...
  string toString() const {
    ostringstream stream;
    stream << Vehicle::toString()
      << " parking brake: "
      << this->parkingBrakeOn;
    return stream.str();
  }
}
```

Object Slicing

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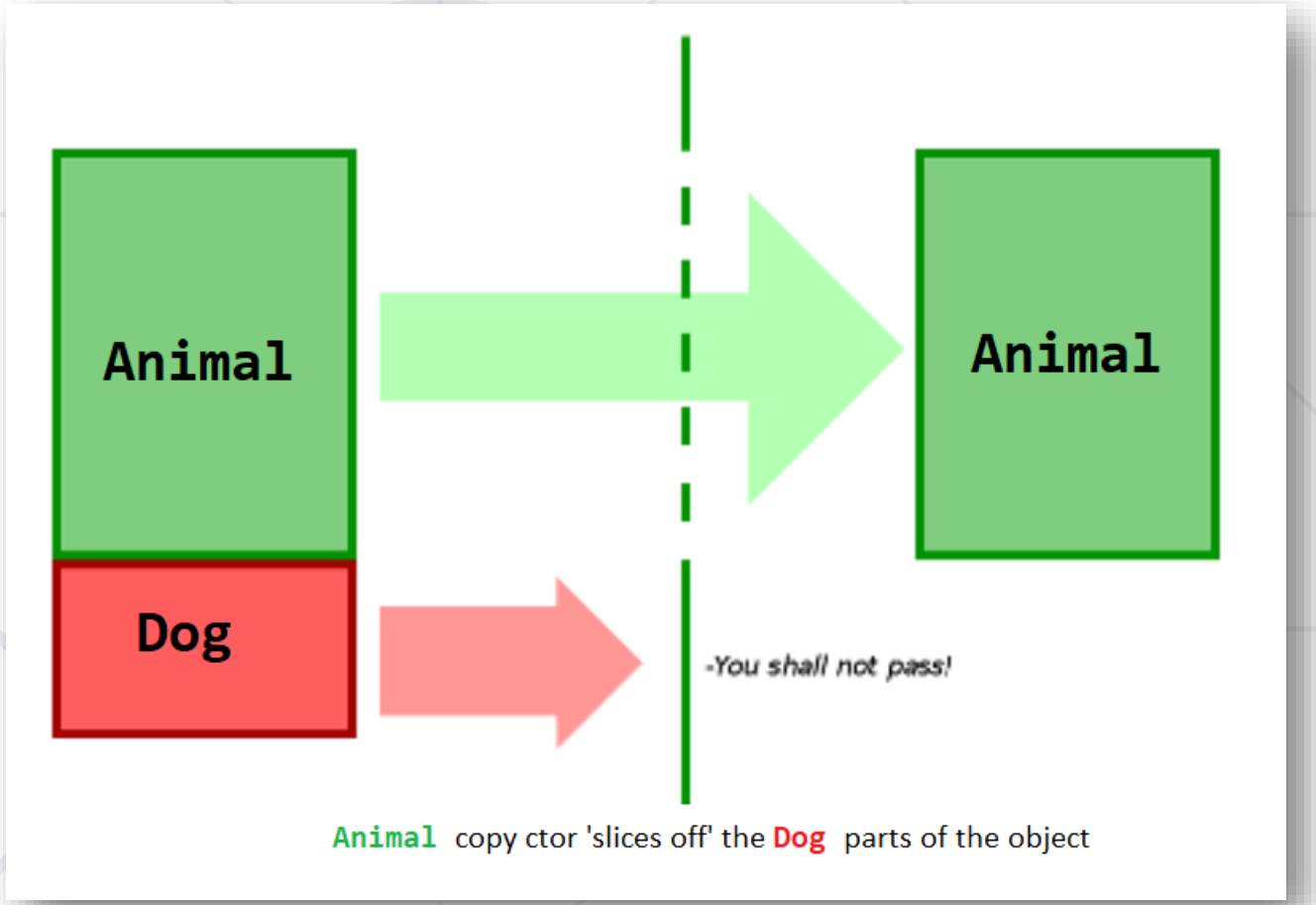
- Happens when we assign an **object of a derived class** to an **object of a base class**
  - Implicit cast, called **upcasting**
  - Fields from derived object are "sliced off"
  - Should generally be avoided
- `Base x = Derived();`
  - **Base** class copy constructor is called
  - **Derived** part of the object is lost
  - `x` contains only `Base` fields

C++ Object Slicing



Constructors and Assignments

- If a **base** has no default constructor
  - **Derived** must define constructor calling the **base** constructor
- Assignment operator is always hidden in a **derived** class
  - Signature not the same, but implicitly the same as base (**upcast**)
- Constructors aren't inherited – can't be used externally
  - Only used internally in initializer list
  - This also applies to copy/move constructors

Base Pointers to Derived Objects

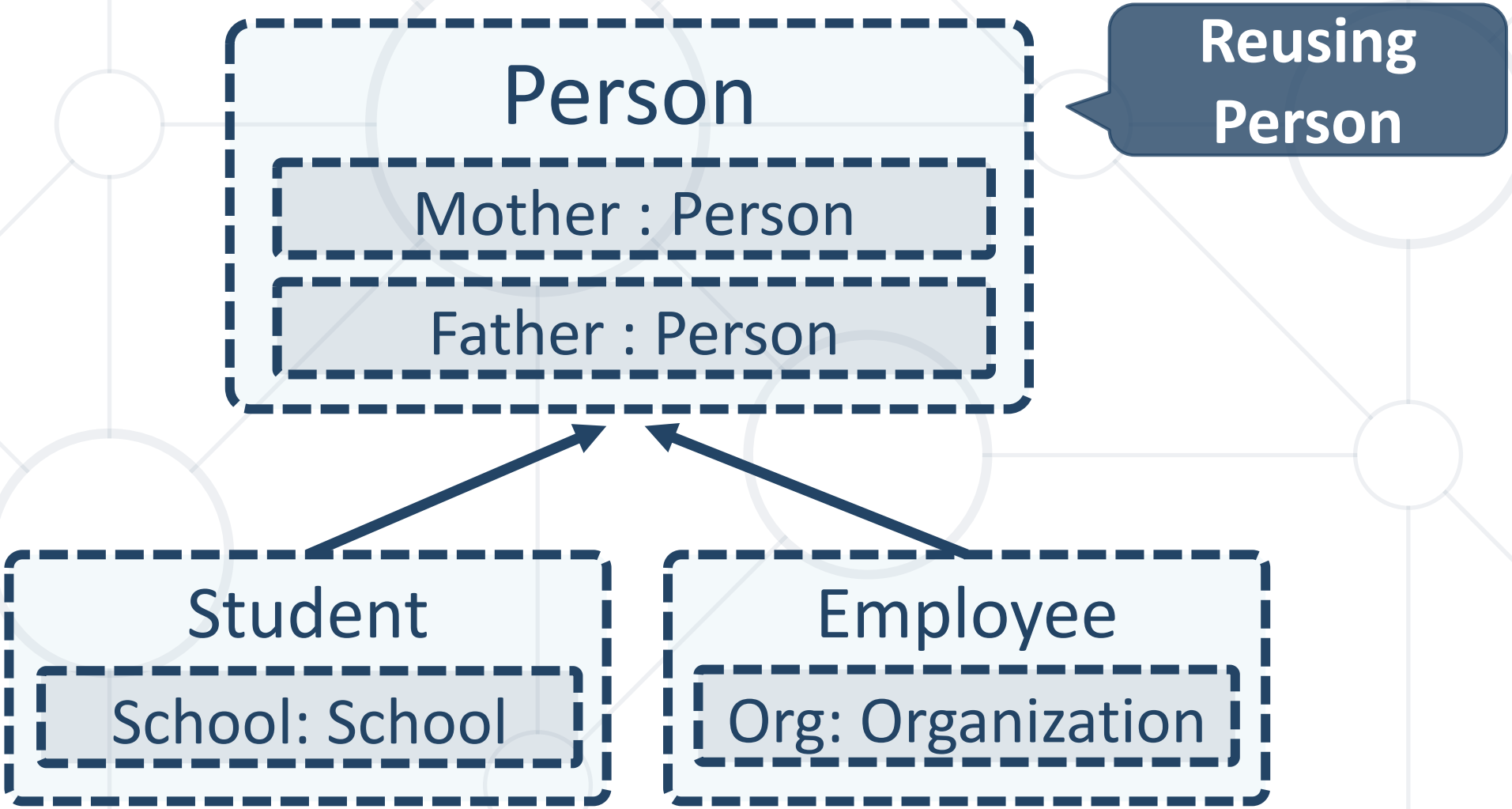
- **Base** pointers / references can point to **derived** objects
  - **upcast**, NO slicing – not fitting larger into smaller object
  - `Derived d; Base* p = &d;`
  - `Base* p = new Derived(); ...`
- Accesses base members, regardless of hiding

```
Airplane plane(510, 2400, 90);
Vehicle* v = &plane;
cout << v->toString() << endl; // calls Vehicle::toString()
```

  - Unless members are **`virtual override`**s
    (will be covered in the next lecture - Polymorphism)

Inheritance – Derived Class

- Class **taking all members** from another class



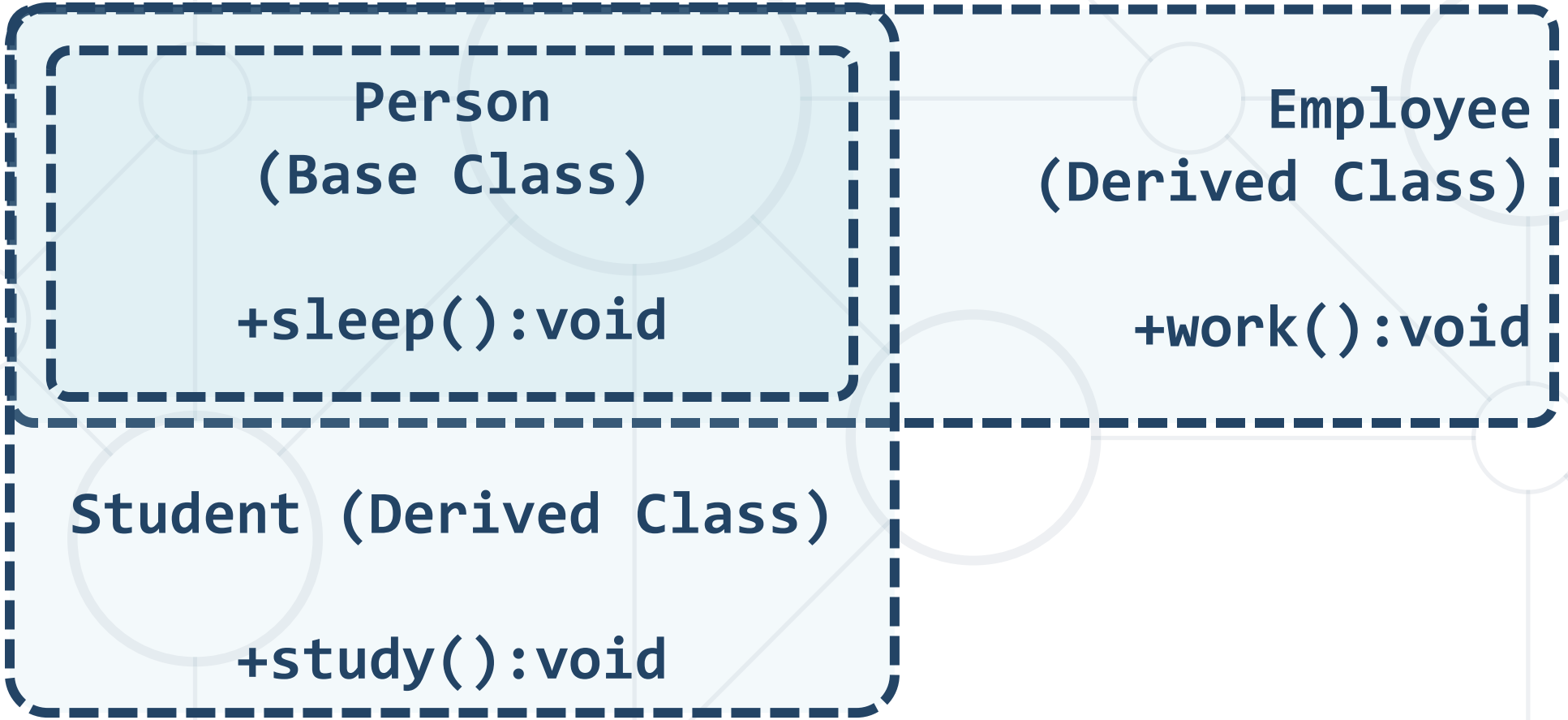
Using Inherited Members

```
class Person { public void sleep() { … } }
class Student  :public  Person { … }
class Employee :public  Person { … }
```

```
Student student;
student.sleep();
Employee* employee = new Employee();
employee->sleep();
```

Thinking about Inheritance – : access-specifier

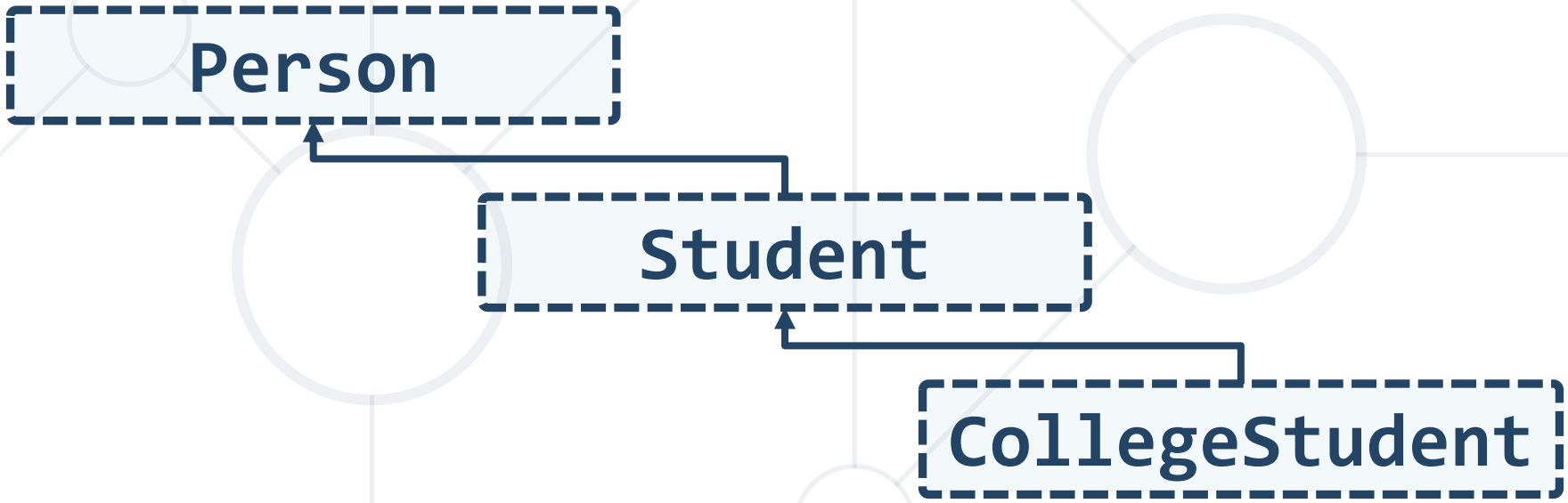
- A derived class instance **contains** an instance of its base class



Inheritance

- Inheritance has a **transitive relation**

```
class Person { … }
class Student         :public Person { … }
class CollegeStudent  :public Student { … }
```



Final Classes

- Inheriting from a final classes is forbidden

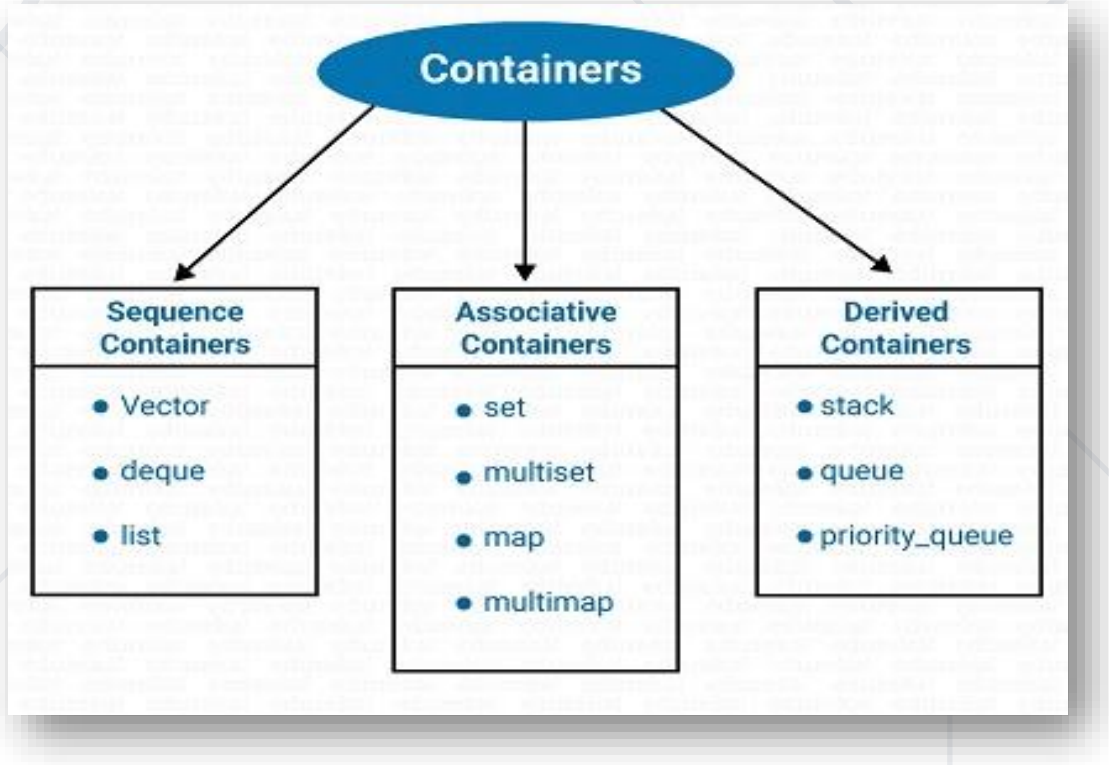
```
class Animal final {
   …
}
```

```
public class Dog :public Animal { }      // Error…
```

Reusing Classes

Extension

- **Duplicate code** is error prone
- **Reuse classes** through an **extension**
- Sometimes the only way



Composition

- Using classes to **define classes**

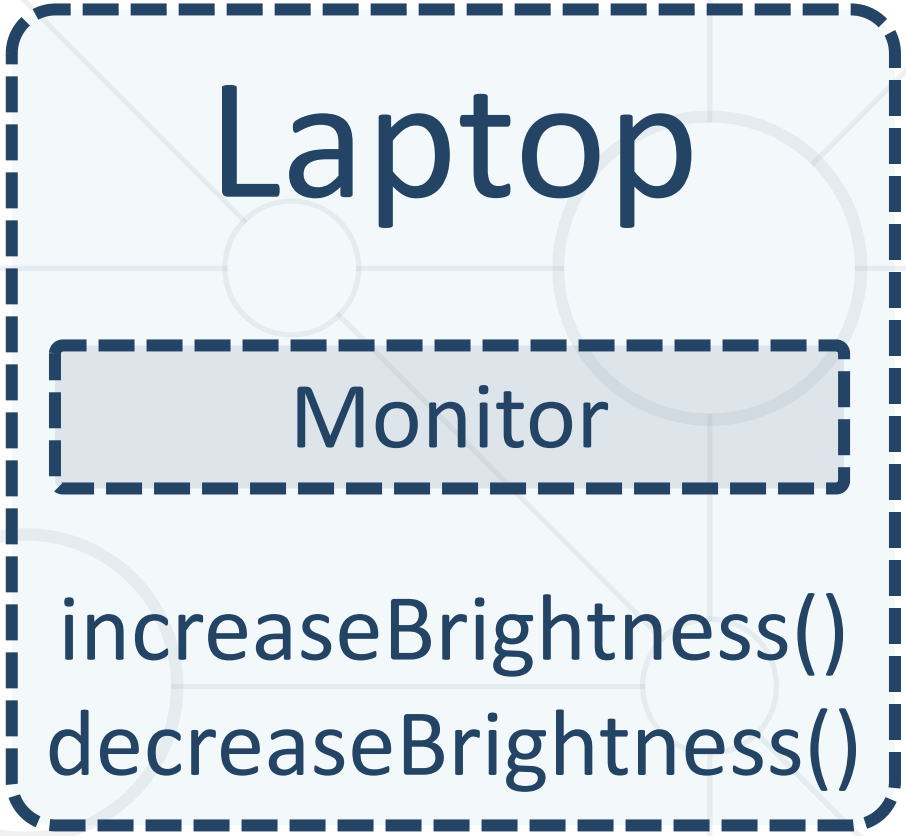
```
class Laptop {
  Monitor monitor;
  Touchpad touchpad;
  Keyboard keyboard;
  …
}
```

Reusing classes

Delegation

```
class Laptop {
  Monitor monitor;
  void incrBrightness() {
    monitor.brighten();
  }

  void decrBrightness() {
    monitor.dim();
  }
}
```



When to Use Inheritance

- Classes share **IS-A** relationship

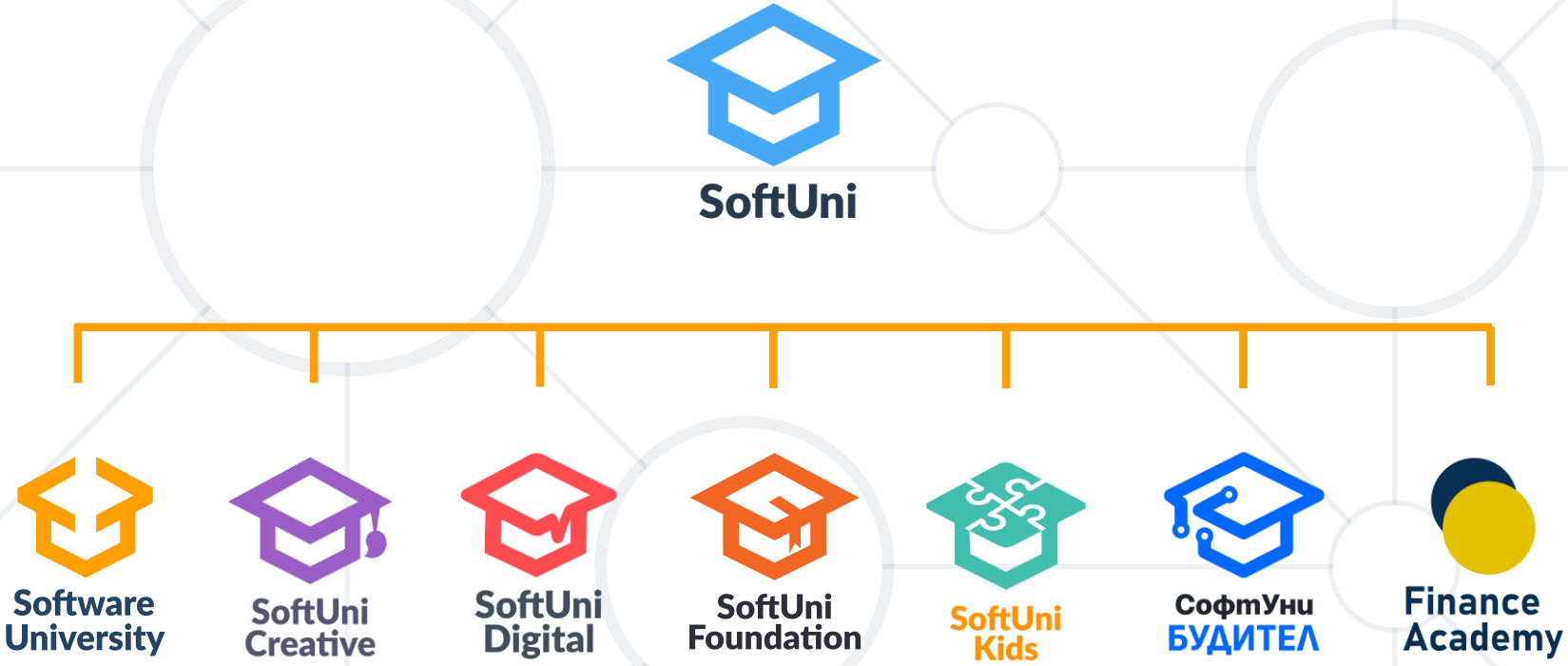
  Too simplistic

  - A car "is a" vehicle, a person "is a" mammal
- Derived class **IS-A-SUBSTITUTE** for the base class
- Share the **same role**
- Derived class is the **same as the base class** but adds a **little bit more functionality**
- Composition **HAS-A** relationship
  - A car "has an" engine, a person "has a" name

Summary

- Inheritance is a powerful tool for code reuse
- Subclass inherits members from Superclass
- Subclass can override methods
- Look for classes with the same role
- Look for IS-A and IS-A-SUBSTITUTE for relationship
- Consider Composition and Delegation instead
- Extract multiple-usage code into a base class

Questions?



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