CMPT 373
Software Development Methods

Object Oriented Programming & Inheritance

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- Applied well and thoughtfully, it helps solve real problems
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- OOP will not *solve* your design for you, but it can be an effective tool

Our Goal

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Treat these as guides rather than laws.
Dogma has no value. Understand the cost/benefit.

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Consider out maze prototyping example.
Have we already seen *one* way this can be useful?

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  - OOP is about decoupling implementation from use

Review of classes (the same exist in Java, .NET, ...)

- Classes describe the services of objects
  - Objects are instances of classes

```
class Student : public Person {
public:
   enum class Degree {
     UNDERGRAD, MASTERS, PHD,
   };

   Student(Degree degree);

   void studyOneHour();

   void sleep() override;

private:
   int hoursStudied;
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class Person {
public:
  Person();
  virtual ~Person() = default;

  virtual void sleep() = 0;
};
```

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class Student : public Person {
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```
void processPerson(Person& p);
...
Student s{Student::Degree::PHD};
processPerson(s);
```

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All of these relate to Ousterhout's complexity criteria, but *blind* application can be worse.

General guidelines for classes (common)

- Be careful about compiler provided methods

```
class Thing {
   // Thing()
}
```

```
class Thing {
   // Thing()
   // Thing(const Thing&);
   // Thing(Thing&&);
   // [virtual] ~Thing();
   // Thing& operator=(const Thing&);
   // Thing& operator=(Thing&&);
};
```

General guidelines for classes (common)

- Be careful about compiler provided methods
- Minimize mutability

```
class RGBColor {
public:
  RGBColor(const Intensity r,
           const Intensity g,
           const Intensity b);

  Hue convertToHue() const;

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  const Intensity red;
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const RGBColor color = ...;
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template<typename T>
class Set {
public:
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struct Point {
  int x;
  int y;
};
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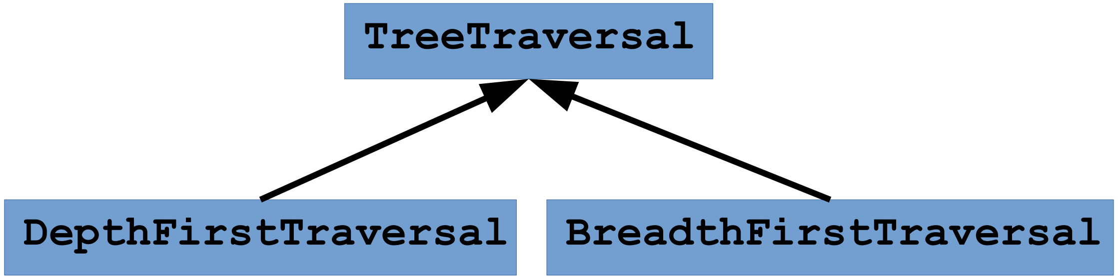

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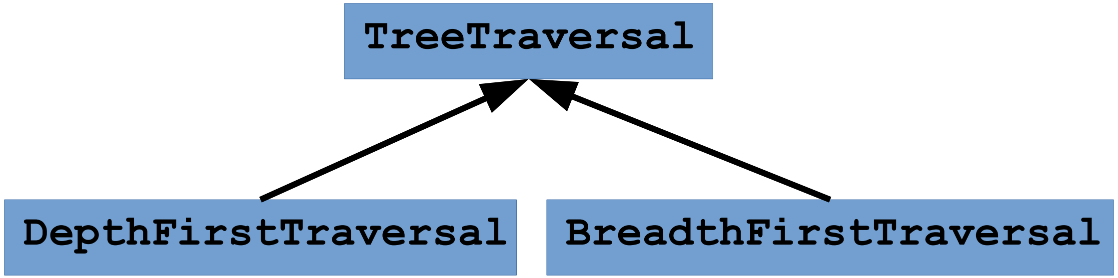


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void
printTree(const Tree& tree,
          const TreeTraversal& t) {
  t.traverse(tree, printNode);
}
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```
class IntBuffer {
public:
   ...
   std::vector& getContents();
   ...
private:
   std::vector<int> integers;
};
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General guidelines for classes

- Prefer dependency injection to hardwiring resources [Block 2001,2018]
  - Objects that allocate their own state are hard to:
    prove correct, extend, configure, test, …

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Separating the *creation* of objects
from the *wiring* of objects
creates a more flexible system

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Thing.cpp

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Thing::Thing()
  : impl{std::make_unique<ThingImpl>()}
    { }

void
Thing::doStuff() const {
  impl->doStuff();
}
```

Thinking in terms of services

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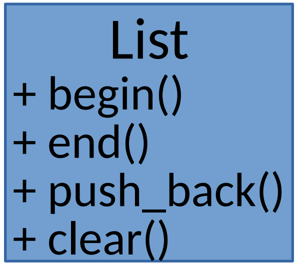

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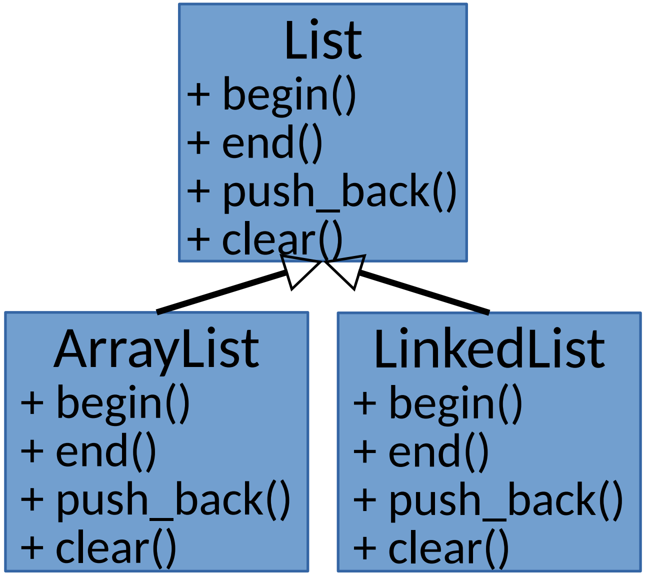

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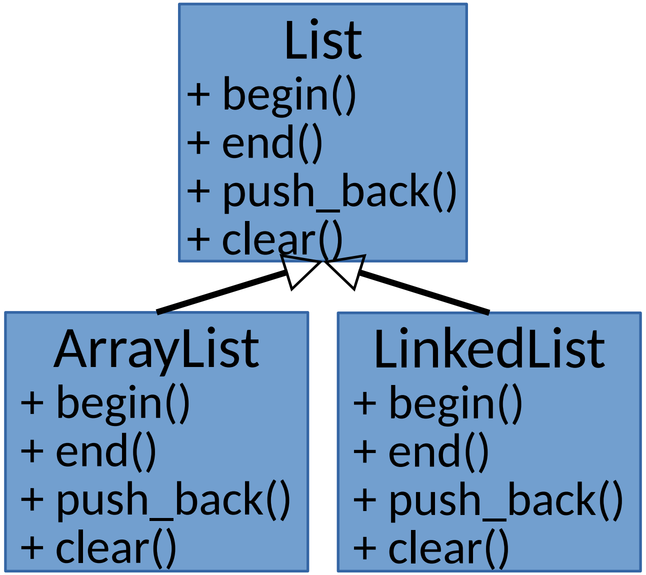

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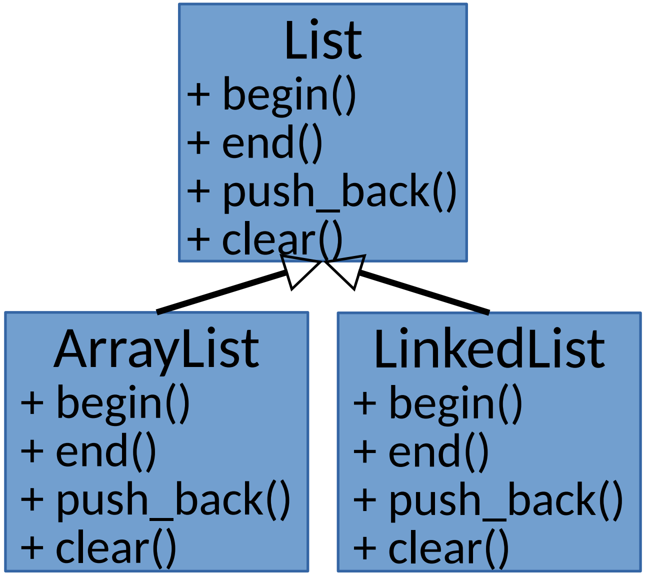
transferStudents(List<Student>& from, List<Student>& to) {
    ranges::copy(from, std::back_inserter(to));
    from.clear();
}
```



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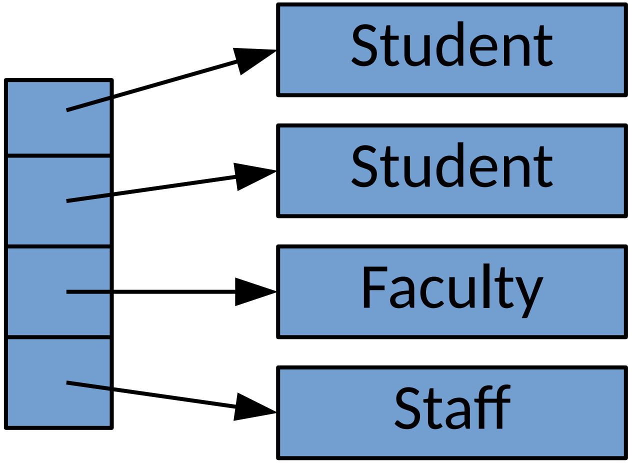
- This also enables heterogeneous aggregates

```
void
letThePeopleSleep(List<Person*>& people) {
  for (Person* person : people) {
    person->sleep();
  }
}
```



So let's try it out…

Note: We will go from absurd to practical

So let’s try it out…

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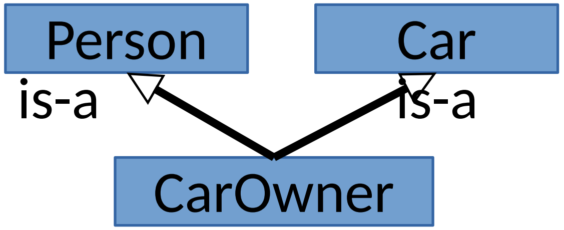

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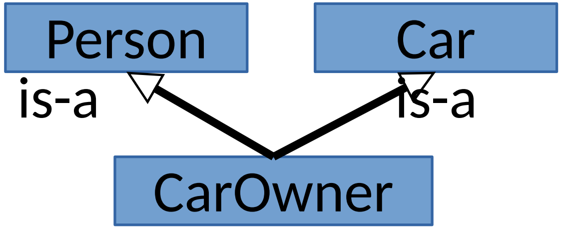


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class CarOwner : public Person, Car
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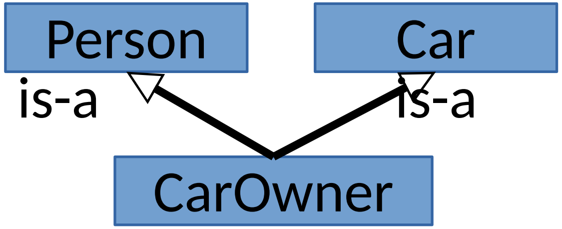


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Is this good or bad?
Why?

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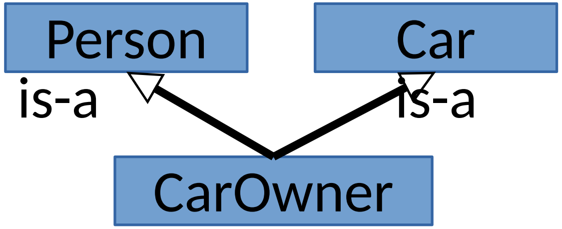


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How could you make it better?

So let's try it out…

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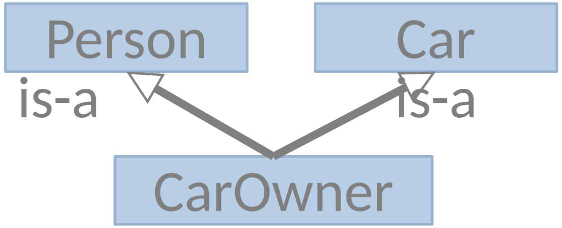

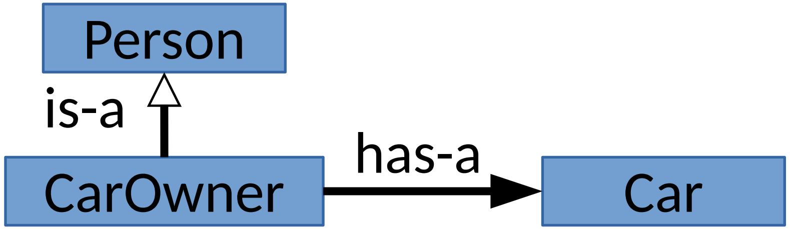

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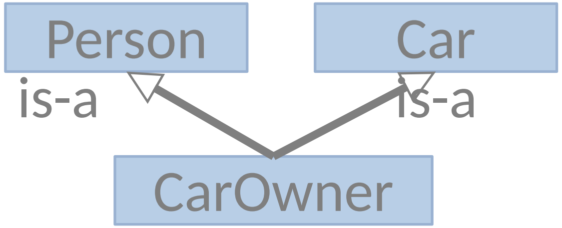

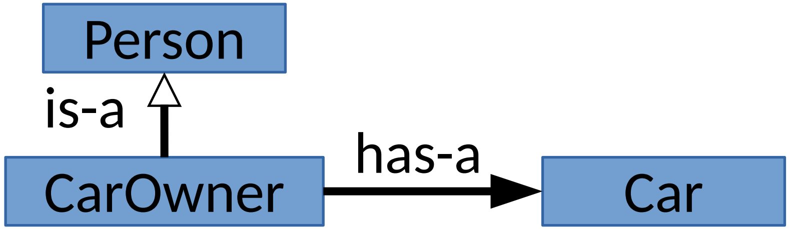

Even simpler?

So let’s try it out…

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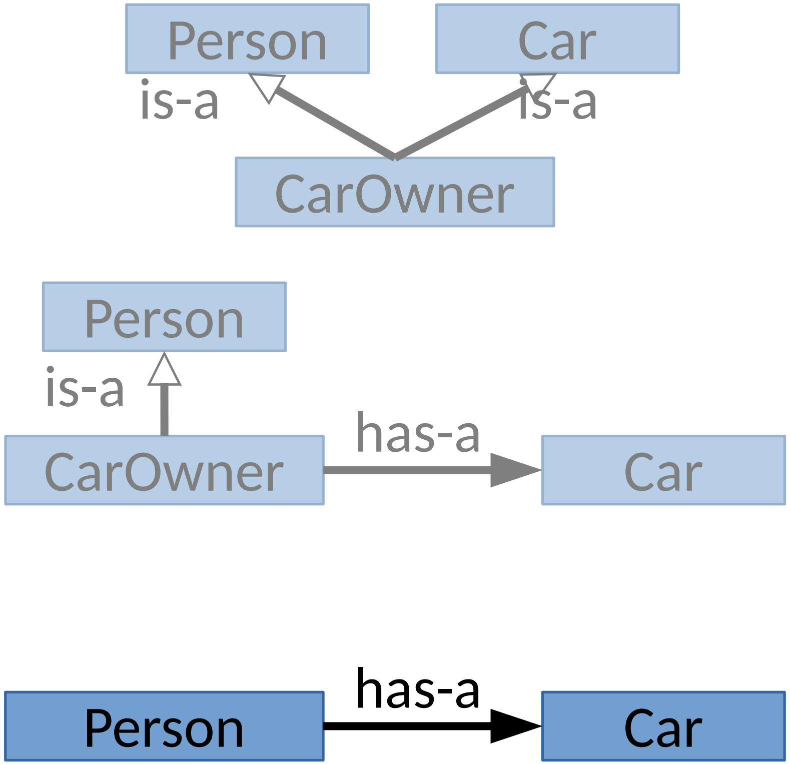

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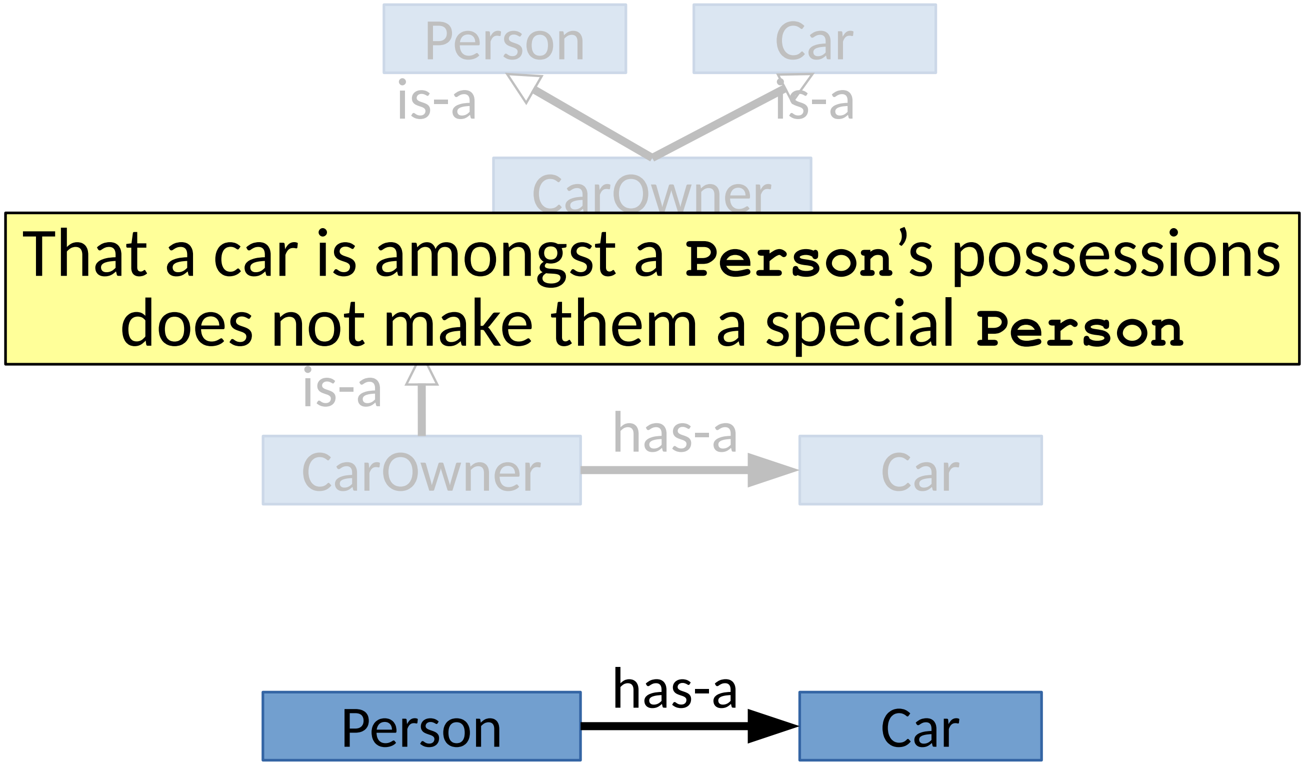

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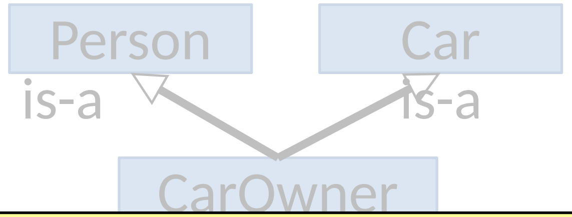

That a car is amongst a **`Person`**'s possessions does not make them a special **`Person`**

This absurd example captures common, subtle mistakes

So why is inheritance hard?

- Do the *LSP* and *has-a* relationships *unambiguously* tell us how to apply inheritance?

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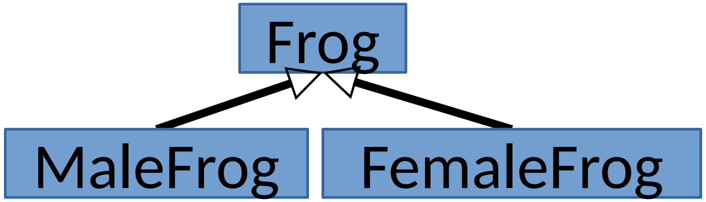

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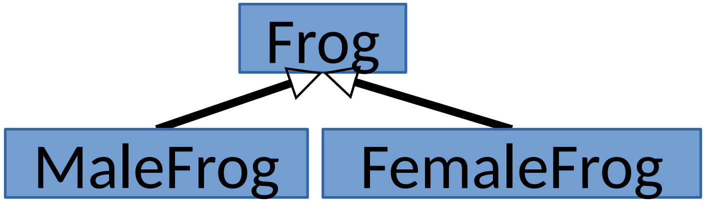

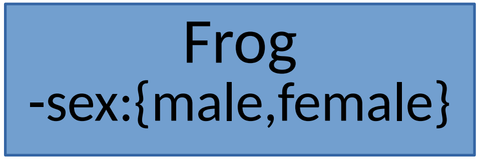

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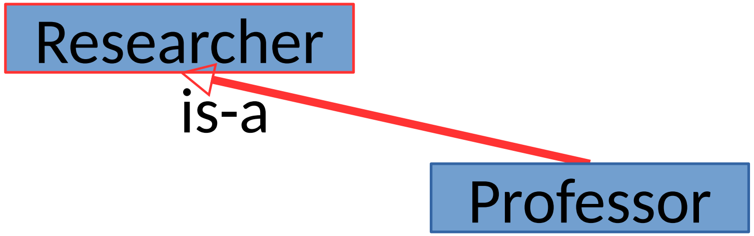

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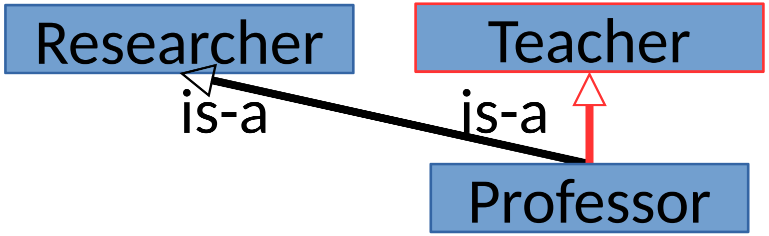

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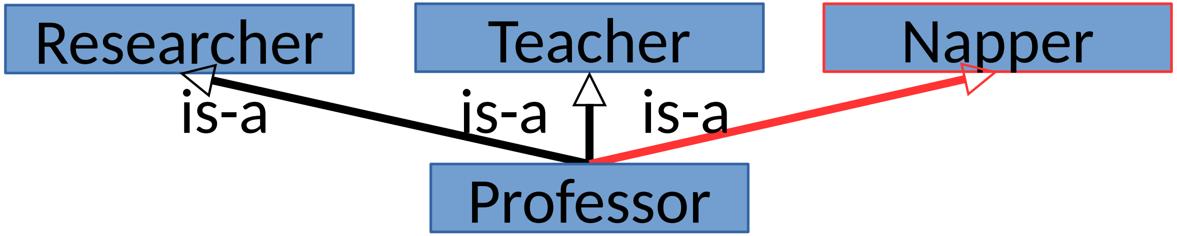

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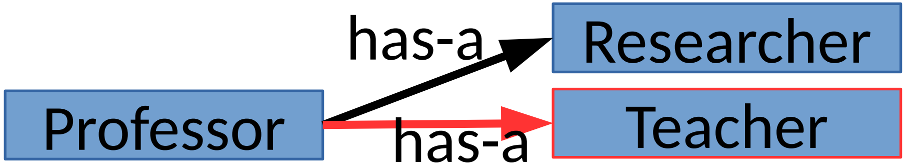

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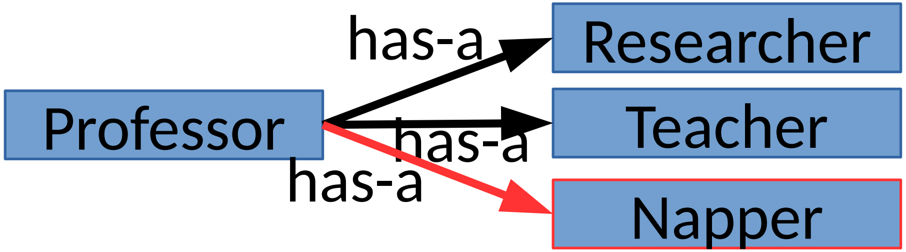

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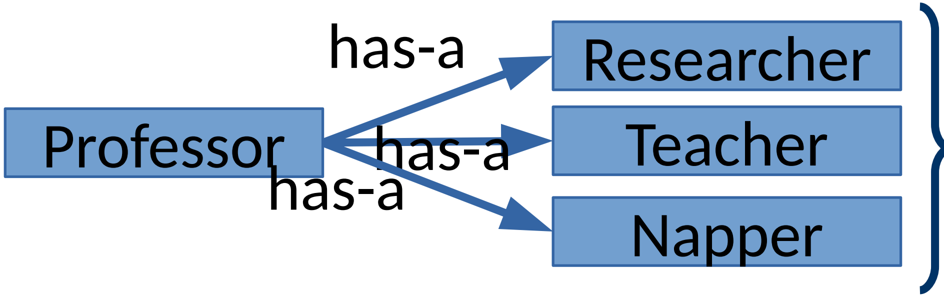

Note, these are now *roles*, not *people*.

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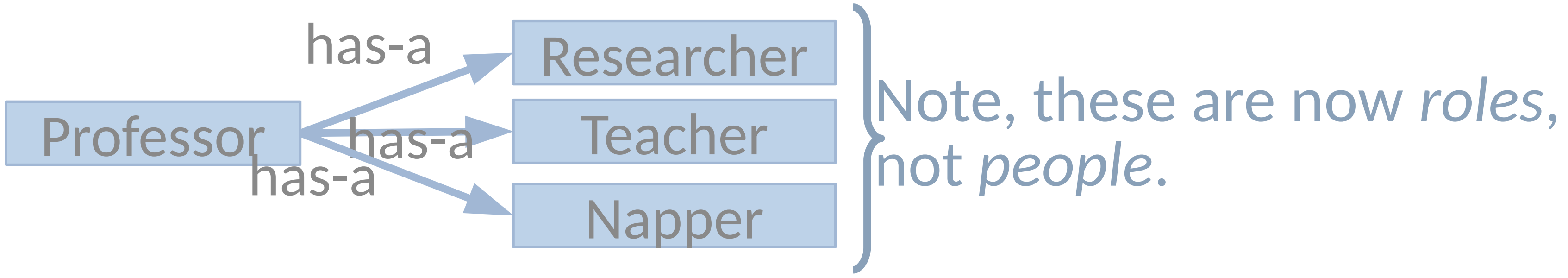

- **Whenever *is-a* applies, you must still make a decision**

Choosing is-a or has-a

- Guide 1: Might the behavior need to change?
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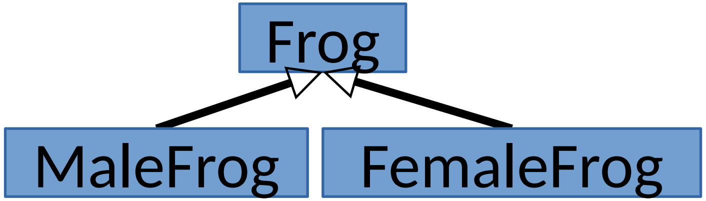

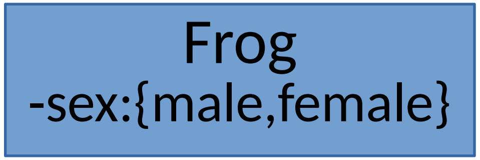

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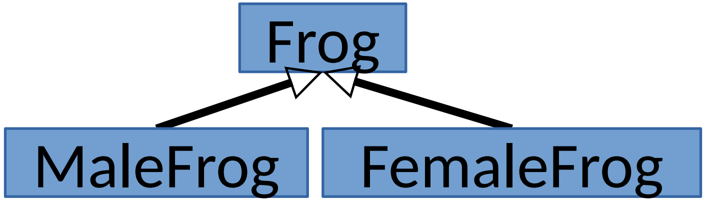

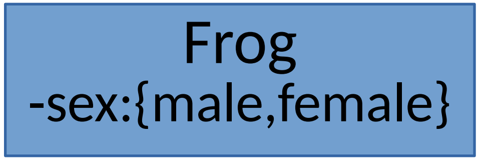

`Frog`s and other animals
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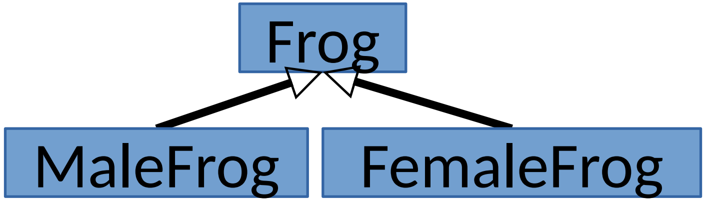

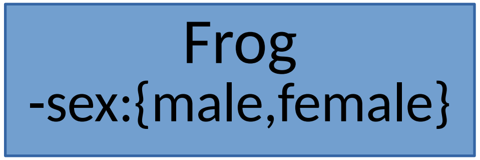

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Knowing in advance is hard.
Composition is flexible & adapts to requirements.

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std::vector<People*> folks;
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2) Lecturer
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We will revisit this in the context of ***algebraic data types***.

So let's try it out…

- I need
  - Many different types of animals.

This should sound familiar…

So let's try it out…

- I need
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  - Each should be able to **`move()`** and **`speak()`**.

So let's try it out…

- I need
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What does my design look like based on the rules?

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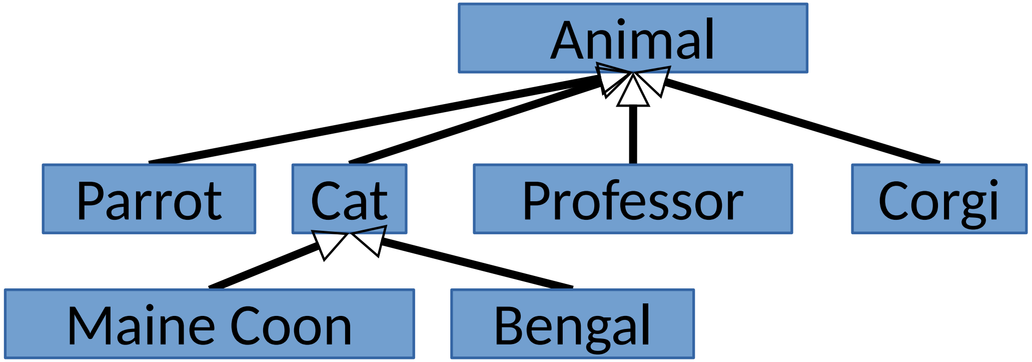

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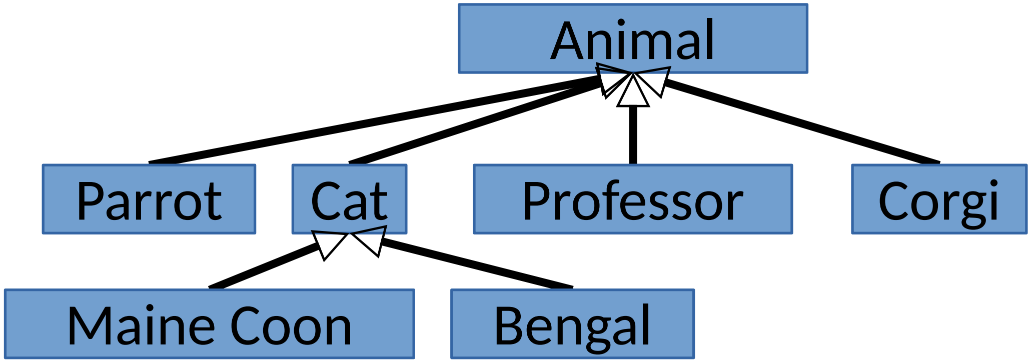

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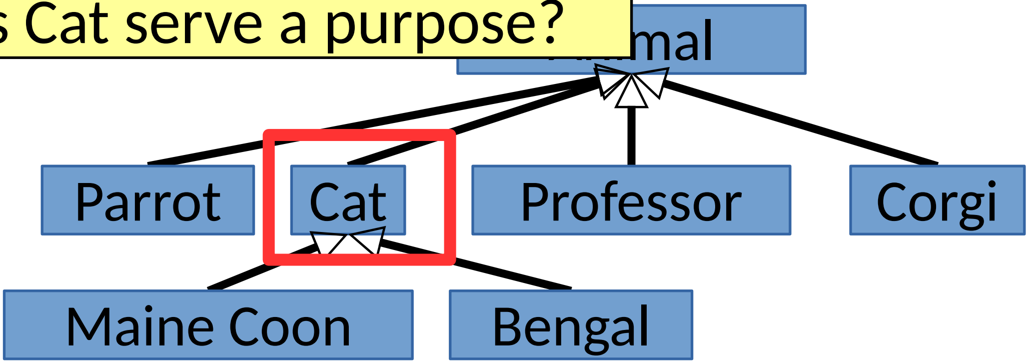
Does Cat serve a purpose?



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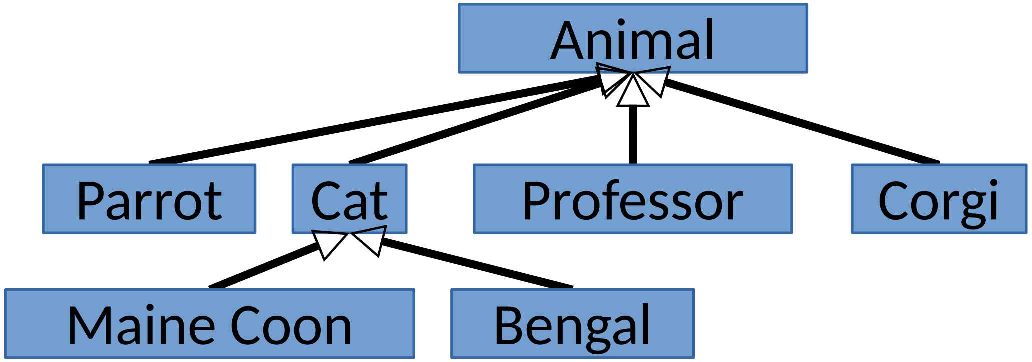

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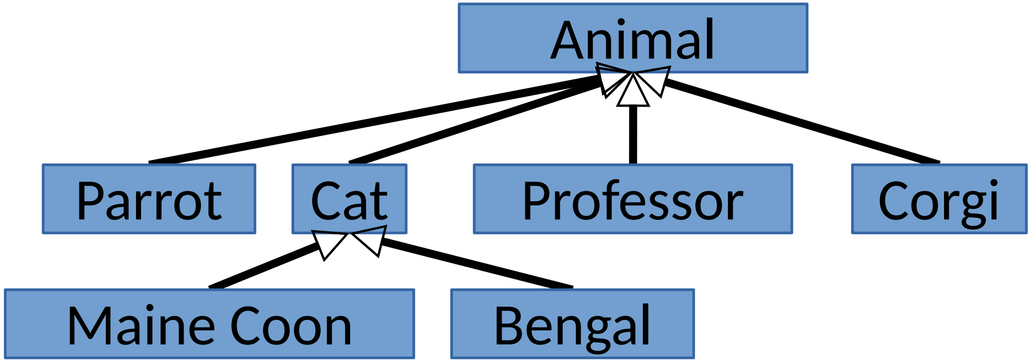

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What if I want a new Animal at run time?

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If someone on my team did this multiple times,
I would fire them.

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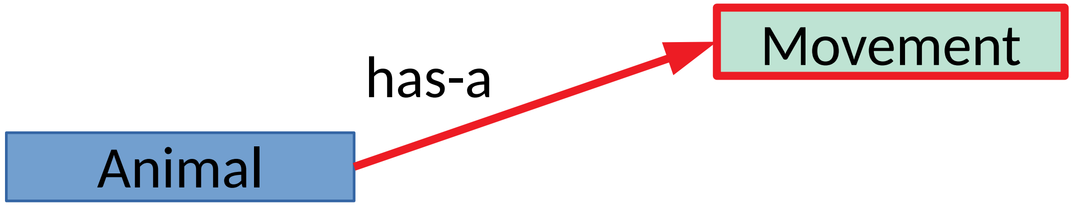

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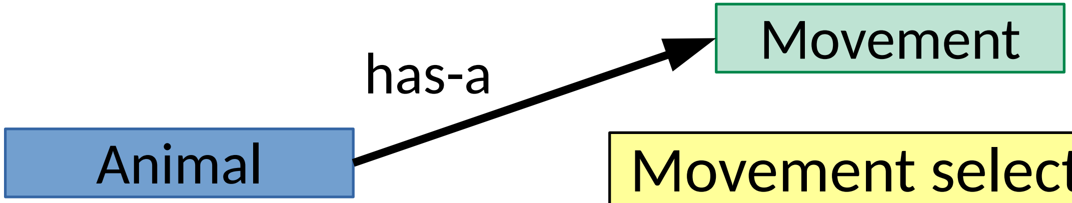

Movement selects from the ways any Animal can move.

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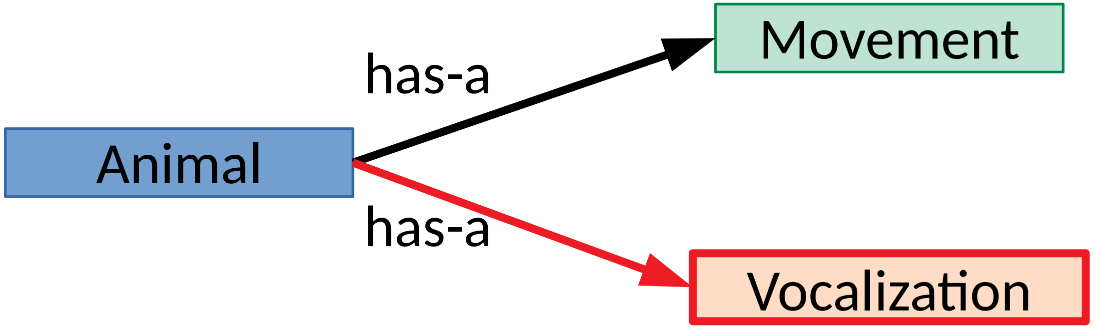

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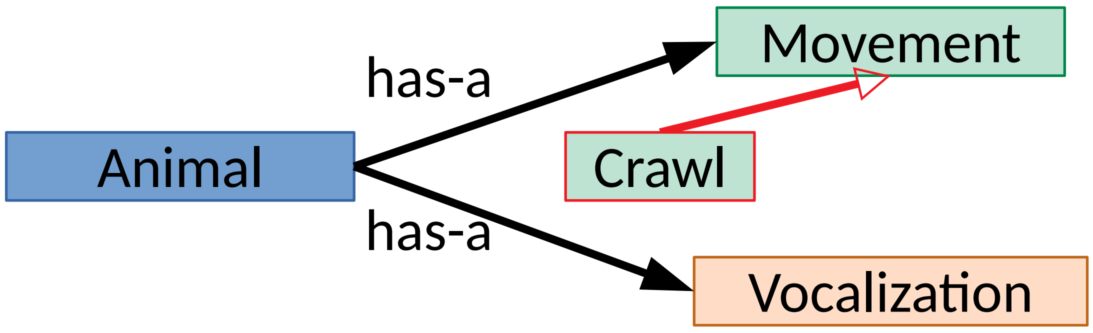

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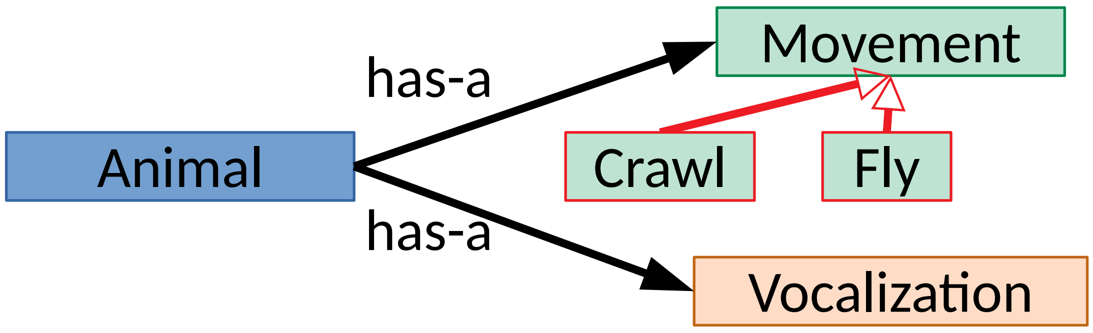

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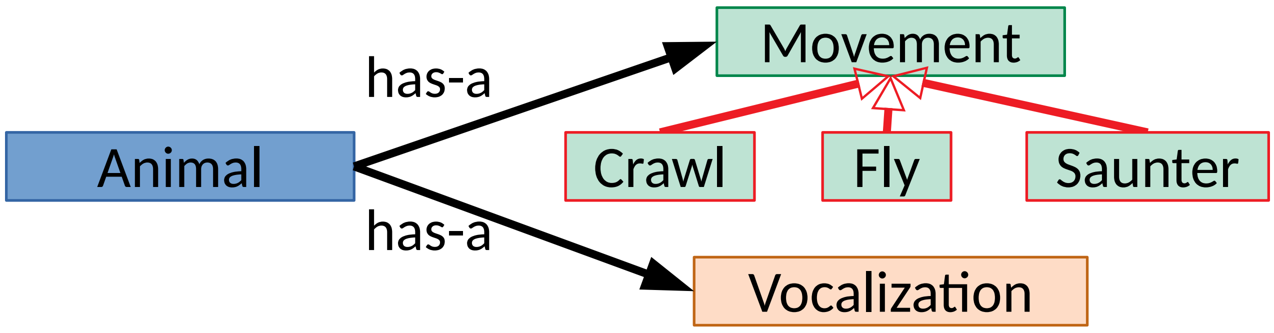

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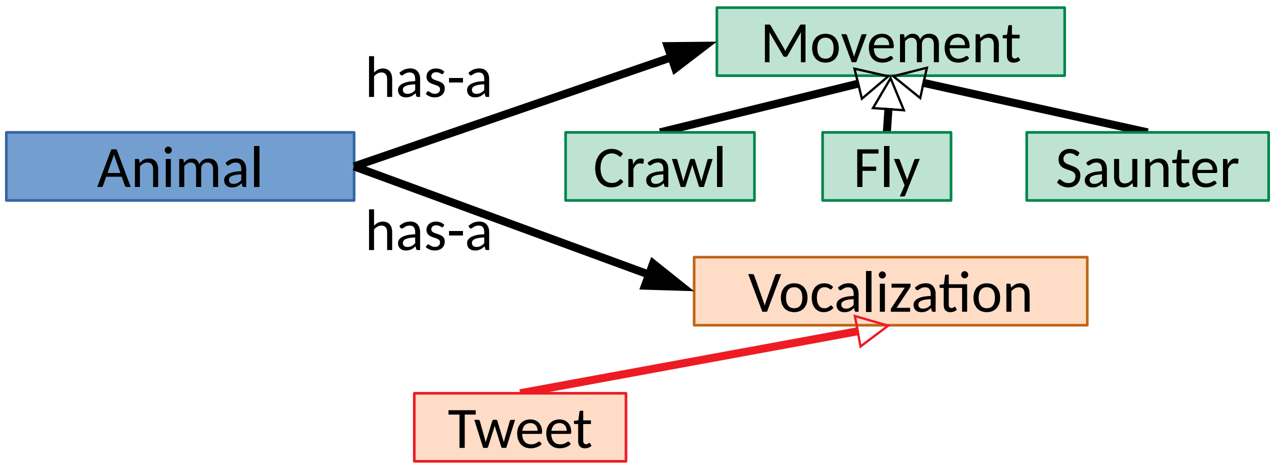

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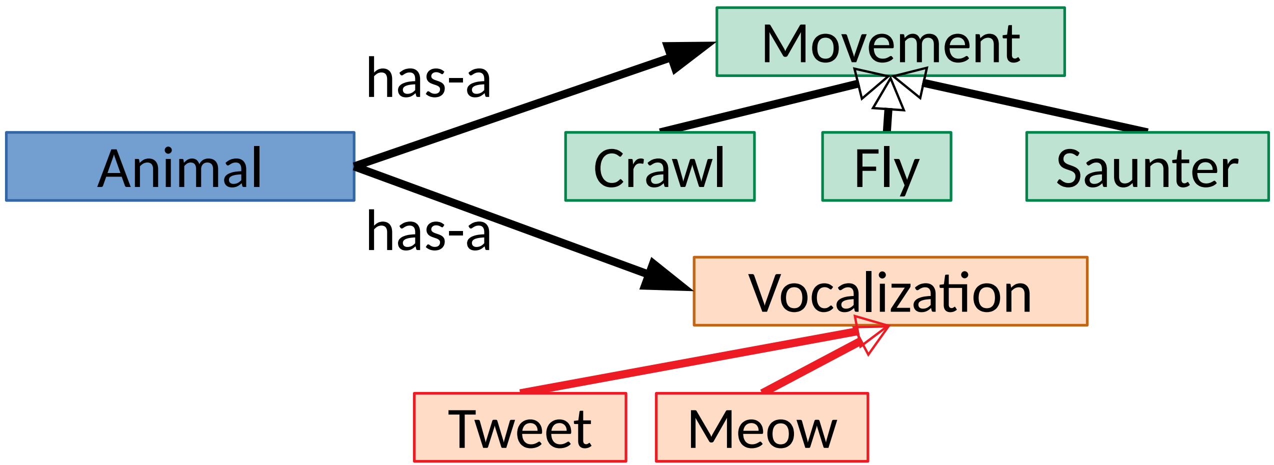

So let's try it out...

- I need
  - Many different types of animals.
  - Each should be able to **`move()`** and **`speak()`**.
  - An **`Animal&`** should be able to refer to any of them.

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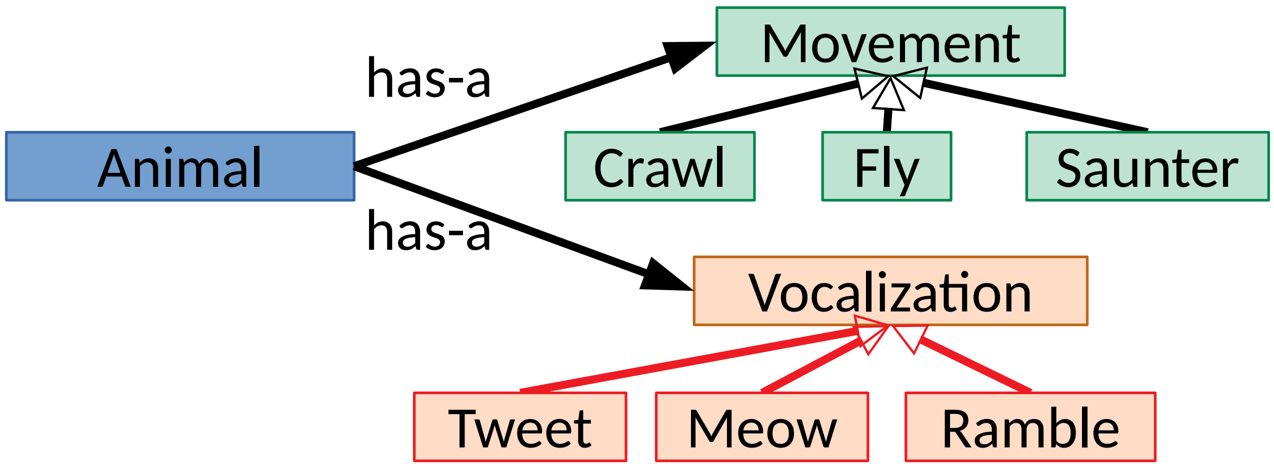

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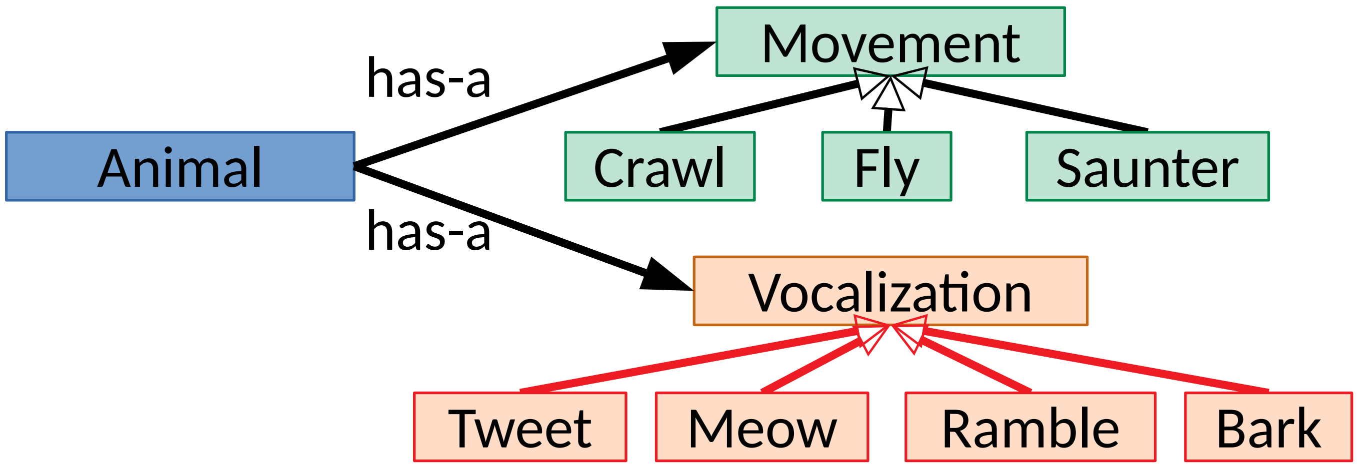

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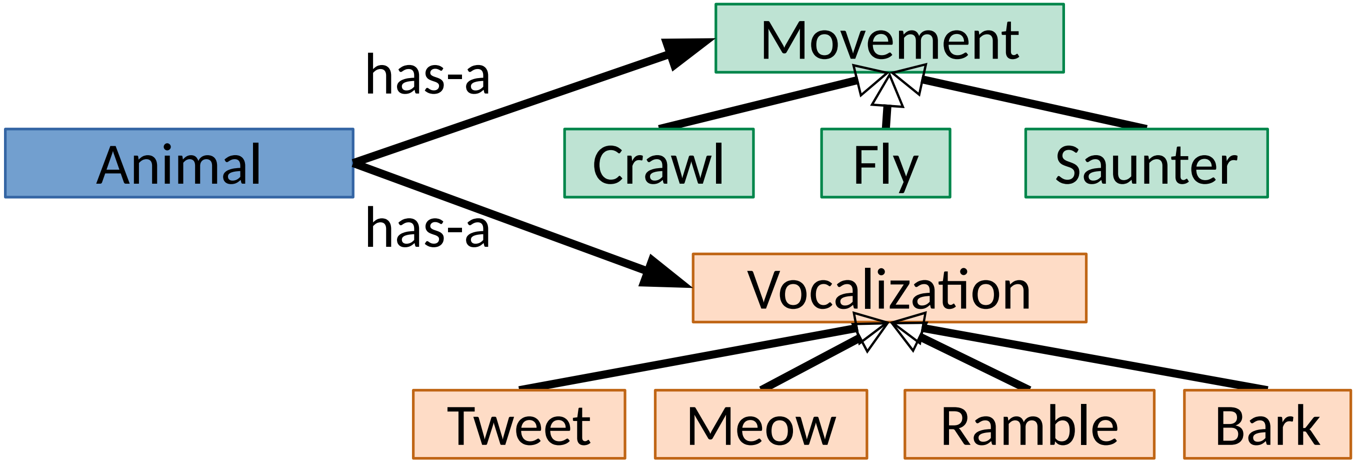

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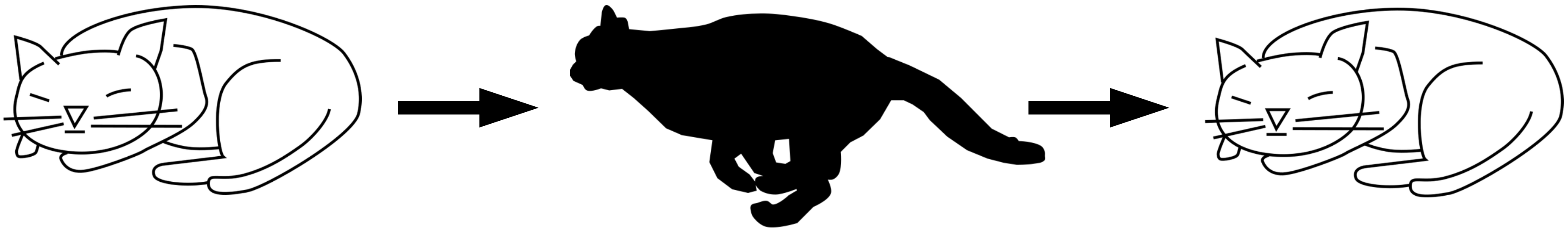

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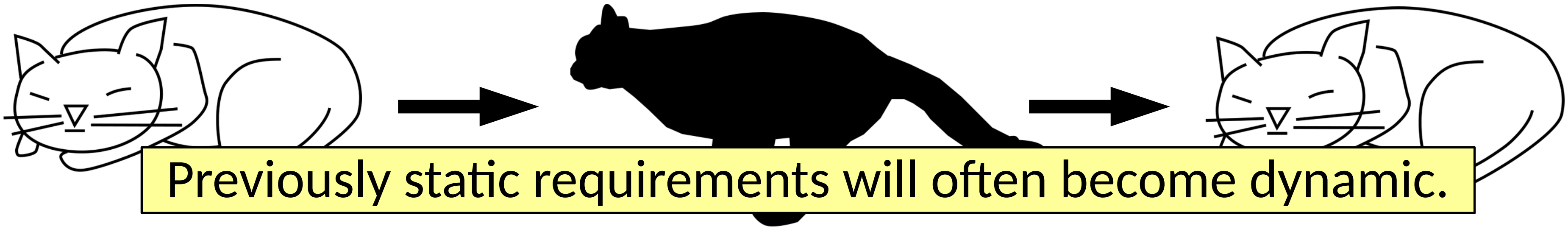

Previously static requirements will often become dynamic.

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- Directly identifies & addresses risks of change in class design
- We will see shortly how this interacts with other forms of polymorphism

Guidelines for inheritance

- Favor composition over inheritance
- Do not inherit to reuse. Inherit to be reused.

For some reason, textbooks & teachers often get these wrong

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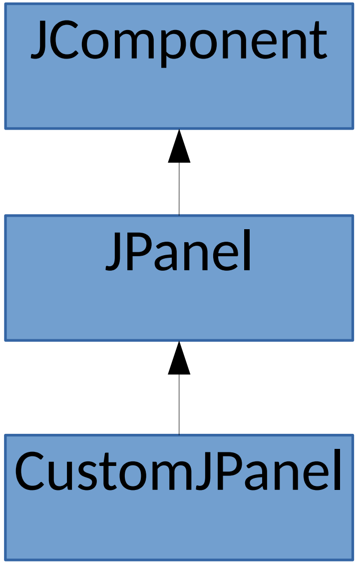

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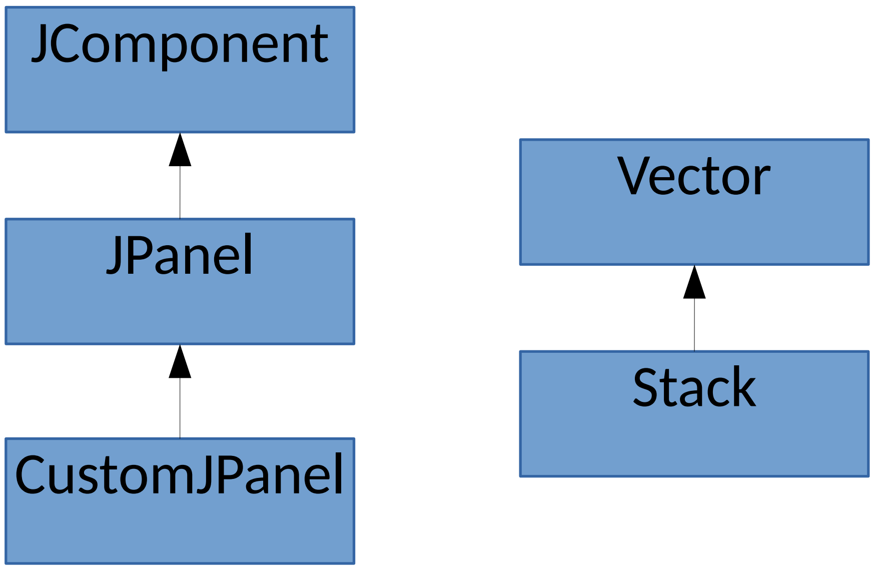

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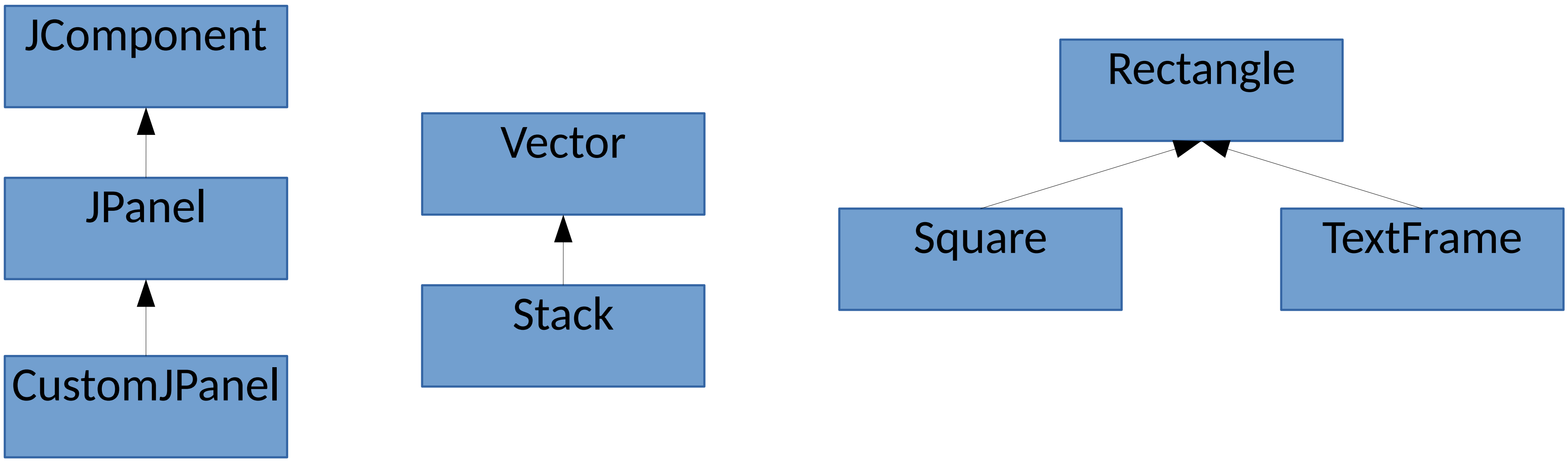

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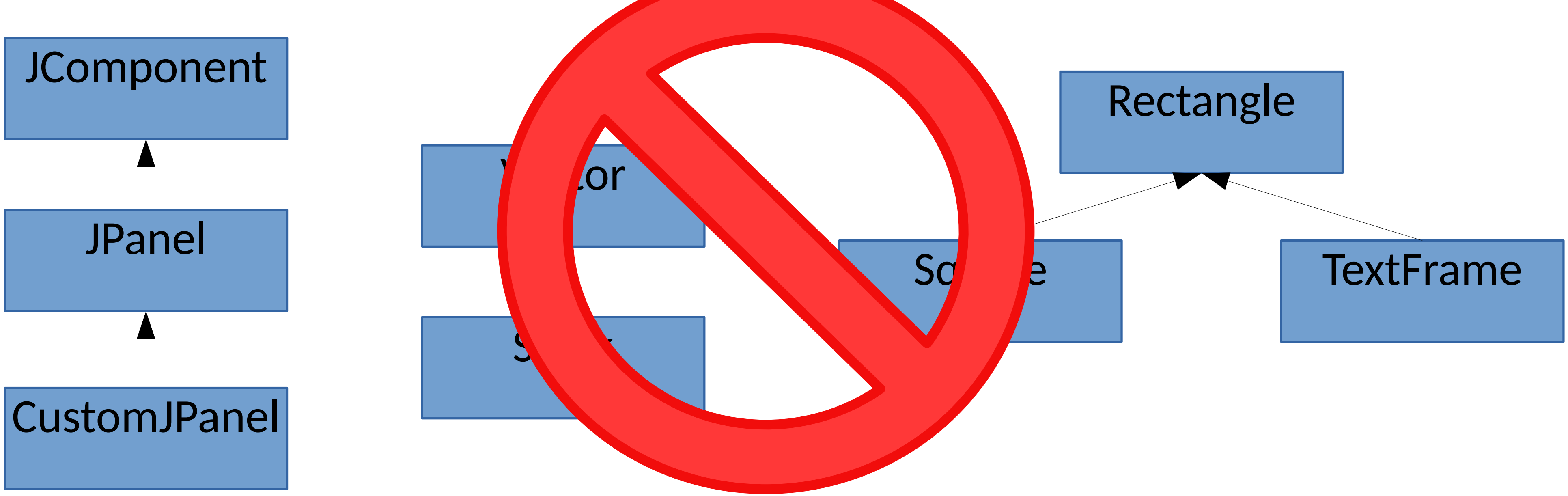

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Derived is ***substitutable*** for Base

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A foo(B b)

Derived
C foo(D d)

Guidelines for inheritance

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    - If φ is true for the base, then φ is true the derived
    - Arguments in the subtype may be more general

B <: D

Base
A foo(**B b**)

Derived
C foo(**D d**)

Arguments are ***contravariant***

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    - If φ is true for the base, then φ is true the derived
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    - Return values in the subtype may be more constrained

C <: A

Base
A foo(B b)

Derived
C foo(D d)

Return types are ***covariant***

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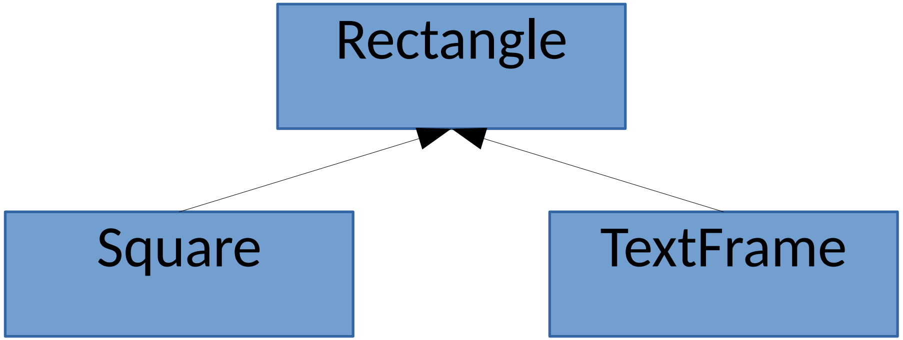
  - *Semantic* substitutability is robust to drift



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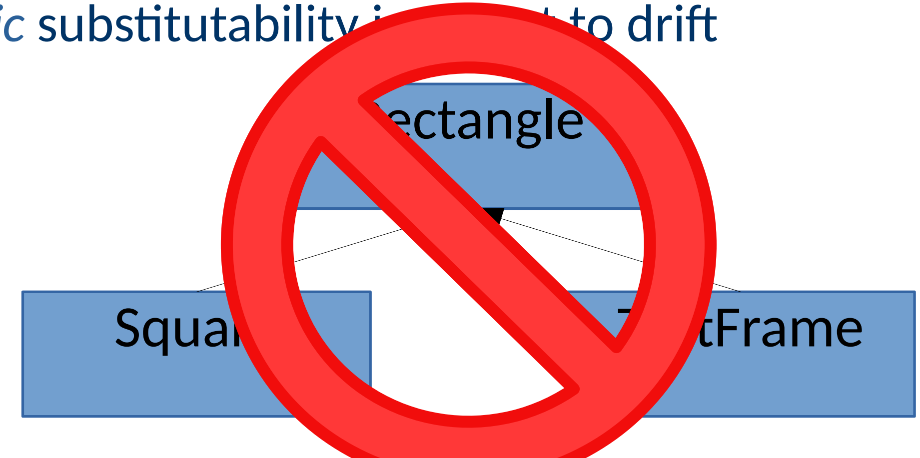
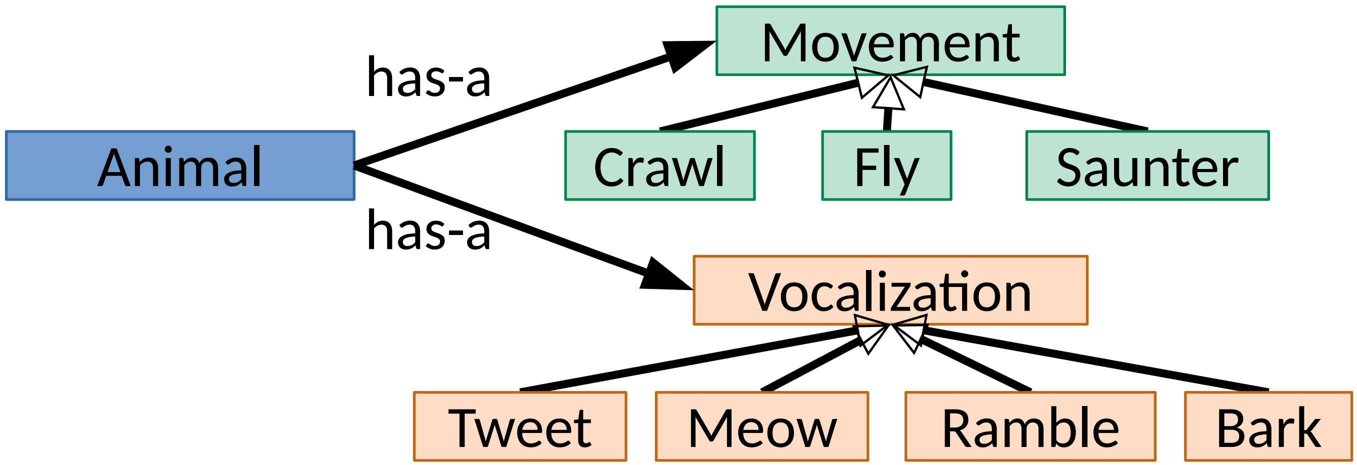


Guidelines for inheritance

- Inherit interfaces. Push implementation into the leaves.

```
class Animal {
  Movement& m;
  void move() {
    m.move();
  }
};
```



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- Inherit interfaces. Push implementation into the leaves.
  - Hierarchies delocalize code, yielding a yo-yo effect
  - Ambiguous overrides break encapsulation

[Bloch, “Effective Java”]

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Alternatively: Only leaves should be instantiable.

[Bloch, “Effective Java”]

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```
class Parent {
  virtual void foo() { bar(); }
  virtual void bar() {}
};
```

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class Parent {
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};
```

```
class Child : public Parent {
public:
  virtual void bar() { foo(); }
};
```

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```
class Child : public Parent {
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};
```

[Bloch, “Effective Java”]

```
class Parent {
public:
  void foo() { barImpl(); }
  void bar() { barImpl(); }
private:
  virtual void barImpl() = 0;
};
```

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```
class Parent {
```

Non Virtual Interfaces (NVI) help clarify & are common in C++.

```
};class Child : public Parent {
public:
                                    }
};
```

Other patterns help even more…

[Bloch, "Effective Java"]

```
class Parent {
public:
  void foo() { barImpl(); }
  void bar() { barImpl(); }
private:
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```

Guidelines for inheritance

- Design for inheritance.
  Choose *customization points* for runtime polymorphism.
  Prevent inheritance elsewhere.

```
class Student final : public Person {
public:
  enum class Degree {
    UNDERGRAD, MASTERS, PHD,
  };

  Student(Degree degree);

  void studyOneHour();

  void sleep() override;

private:
  int hoursStudied;
  Degree degree;
};
```

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- It can be challenging to use well and should be deliberate
- Inheritance, specifically, is powerful but often abused
- Object orientation does not solve problems in modeling;
  that requires more effort, as we will see.