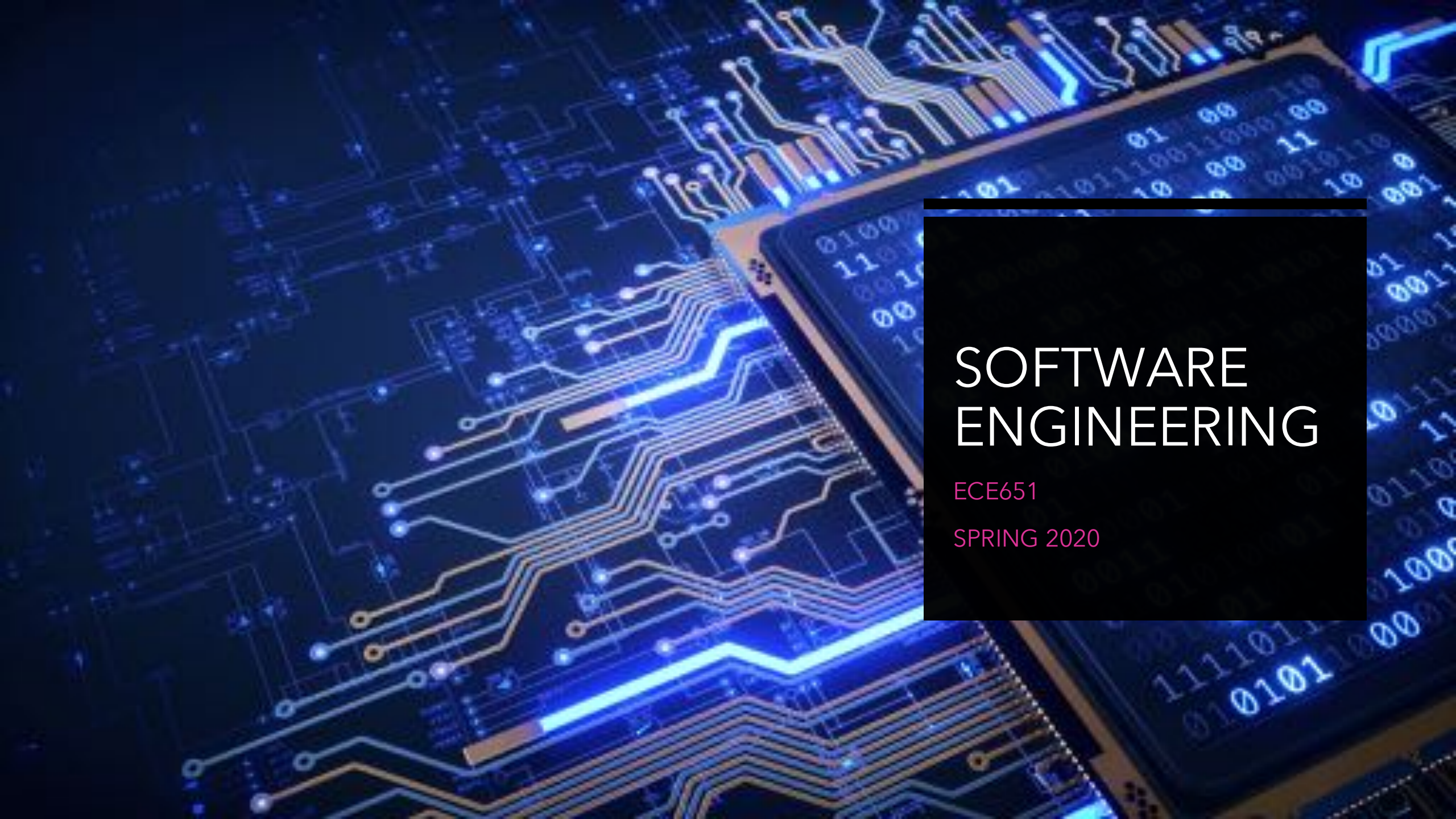


SOFTWARE ENGINEERING

ECE651

SPRING 2020

GOALS & DESIGN PRINCIPLES

THINK, PAIR, SHARE

- What characteristics of software would customers desire?
- Of these, which work well together, which are in opposition?

GOALS

- **Correct**: does what it is supposed to (no bugs)
- **Robust**: secure, dependable, resilient
- **Useable**: UI, compatibility,…
- **Many features**: does lots of "good" stuff
- **Good performance**: fast, low energy usage,…
  - **Scalable**
- **Maintainable/extensible**: Can add and change features
- **Quick delivery**: low development time
- **Low cost**: less spending is preferred

GOALS

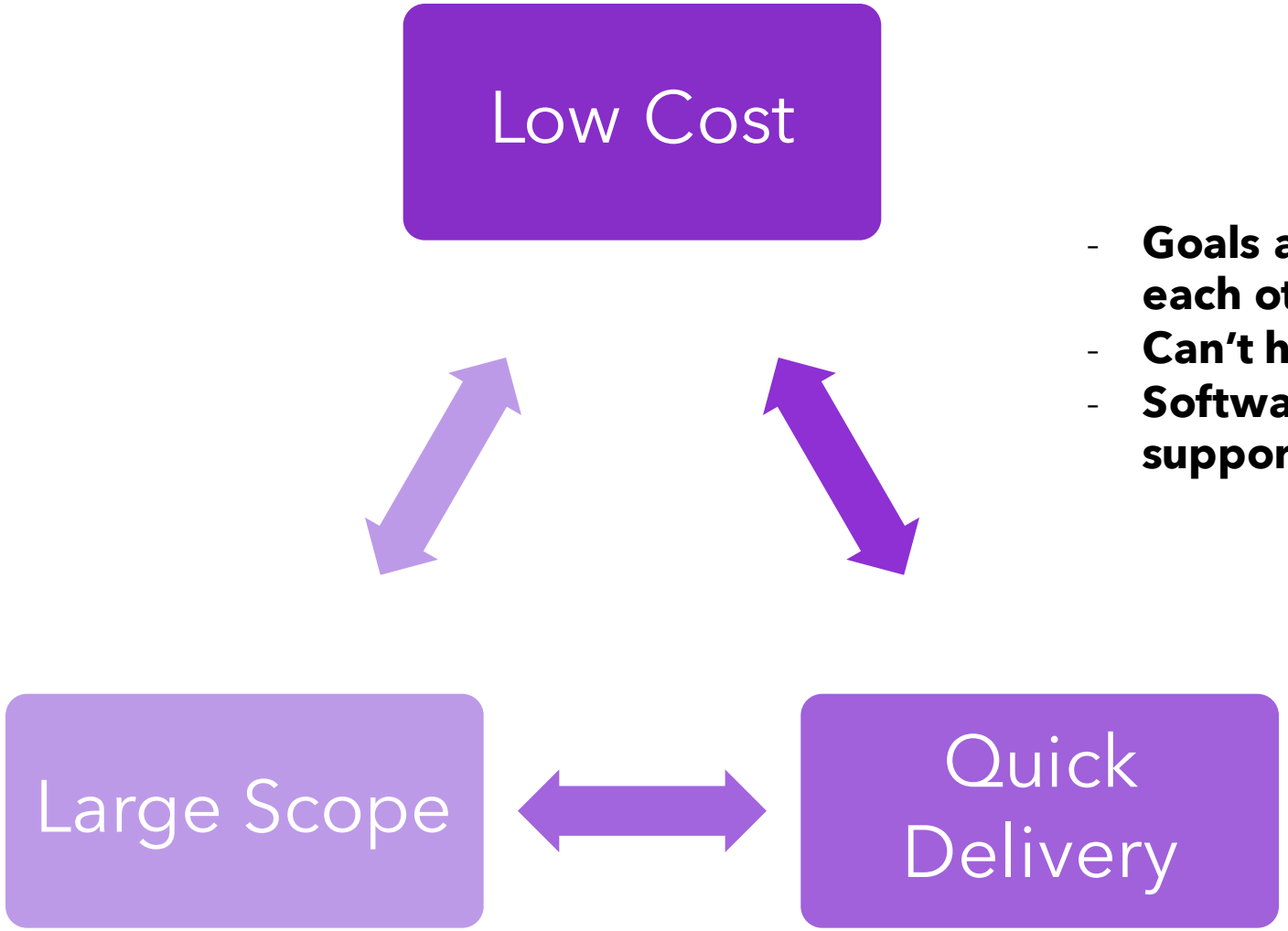
- **Correct**: does what it is supposed to (no bugs)

Must have

- **Robust**: secure, dependable, resilient
- **Useable**: UI, compatibility,…
- **Many features**: does lots of "good" stuff
- **Good performance**: fast, low energy usage
  - **Scalable**
- **Maintainable/extensible**: Can add and change features

Scope: What we must build

- **Quick delivery**: low development time
- **Low cost**: less spending is preferred



- **Goals are in opposition with each other**
- **Can't have all 3**
- **Software engineering may support more of each**

- We have **10** developers to build our software product
  - Estimated time **1 year**
  - Developer salary: $125,000/year
  - Total cost: $1,250,000
- Can we just hire **20** developers and do it in **6 months**?
  - Each person does half as much work
  - Total cost still $1,250,000
  - Seems better, right?
- Could we take this further?
  - 40 developers in 3 months?
  - 3,650 developers in 1 day?
  - 87,600 developers in 1 hour?
  - 5,256,000 developers in 1 minute?

EMBARRASSINGLY PARALLEL PROBLEM

LITTLE OR NO EFFORT IS REQUIRED TO SEPARATE THE PROBLEM INTO A NUMBER OF

PARALLEL TASKS

SOFTWARE DEVELOPMENT IS **NOT** EMBARRASSINGLY PARALLEL

- Significant communication & synchronization overheads
- 20 developers accomplish in 9 months
- 40 developers accomplish in 8 months
- Adding person power to a project often makes it later

“HOW DOES A SOFTWARE SYSTEM GET TO BE ONE YEAR LATE? ONE DAY AT A TIME”

– FREDERICK P. BROOKS, PHD

COROLLARY

- **Effective parallelism** between developers requires independent tasks
- Independent tasks are achieved by clearly **specified interfaces** that one developer can use while another implements

OBJECT-ORIENTED DESIGN FOUNDATIONS

- Inheritance
- Polymorphism
- Abstraction
- Encapsulation

DESIGN PRINCIPLES

- Least Surprise/Astonishment
- Don't Repeat Yourself (DRY)
- Low Coupling/High Cohesion
- Single Responsibility
- Open/Closed
- Liskov Substitution
- Interface Separation
- Dependency Injection
- Design for testability

S.O.L.I.D.

We will keep coming back to these throughout the semester

LEAST SURPRISE/ ASTONISHMENT

- Reduce how much another developer is surprised by what happens
  - **No unexpected side-effects**
    - getSomething() should not change state
  - **No reliance on hidden knowledge to make it work**
    - "You have to call methodA right before methodB or it crashes"
    - "It got stuck in an infinite loop? Yeah, that happens if you pass a negative number to methodC…"
  - **Names make sense.**

DON'T REPEAT YOURSELF (DRY)

- Same code should only appear once
- If code needed more than once, use a function
- If constant needed more than once, give it a name
- **Gut Check**: If you change in place 1 and that requires you to make the same change in place 2, then you've violated DRY

LOW COUPLING/ HIGH COHESION

- **Coupling**: interdependence and coordination between entities (i.e., classes, functions, modules)
- **Cohesion**: how related are things inside one entity

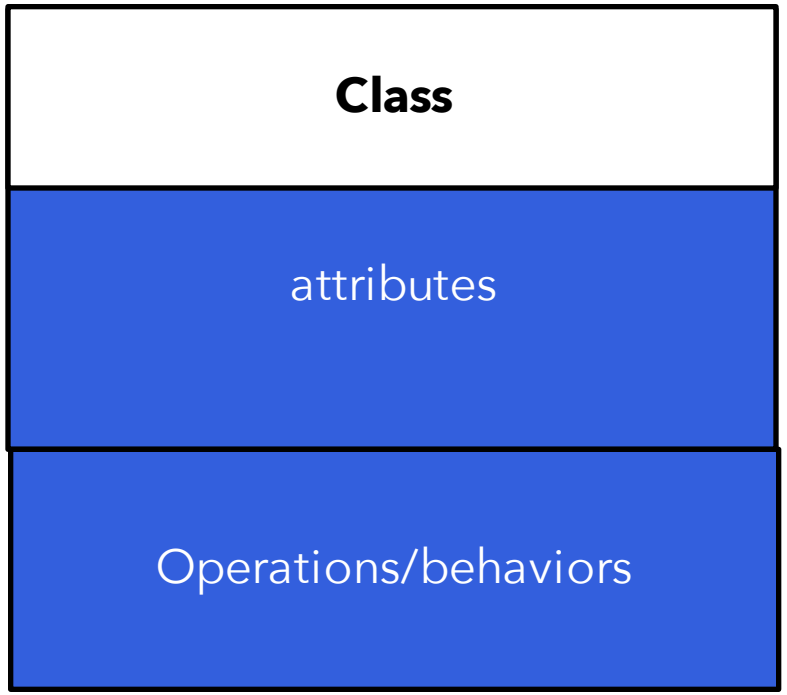
SINGLE RESPONSIBILITY PRINCIPLE

- Software should do "one thing”

"UNCLE BOB"

- "Gather together the things that change for the same reasons. Separate those things that change for different reasons."

QUICK PREVIEW: UML CLASS DIAGRAMS

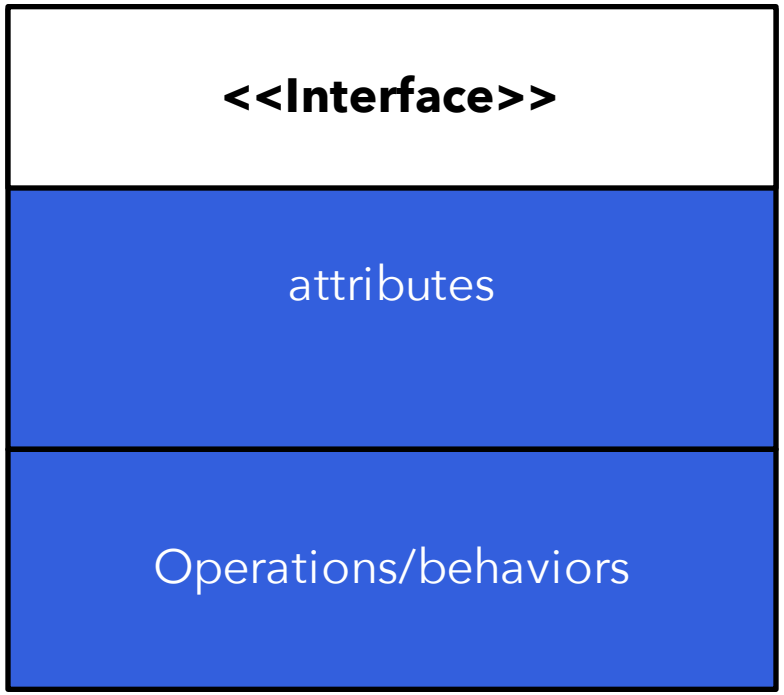


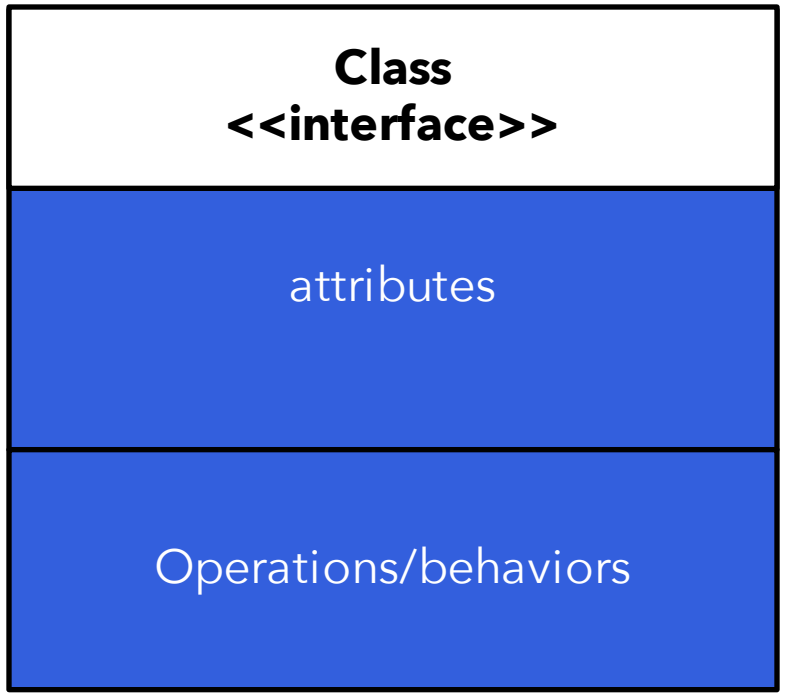
- We will discuss more in a forthcoming lecture
- Simplified class diagram to visually describe a system's organization
- Inheritance

Generalization (class extends another class)

Realization (class implements an interface)

QUICK PREVIEW: UML CLASS DIAGRAMS (2)





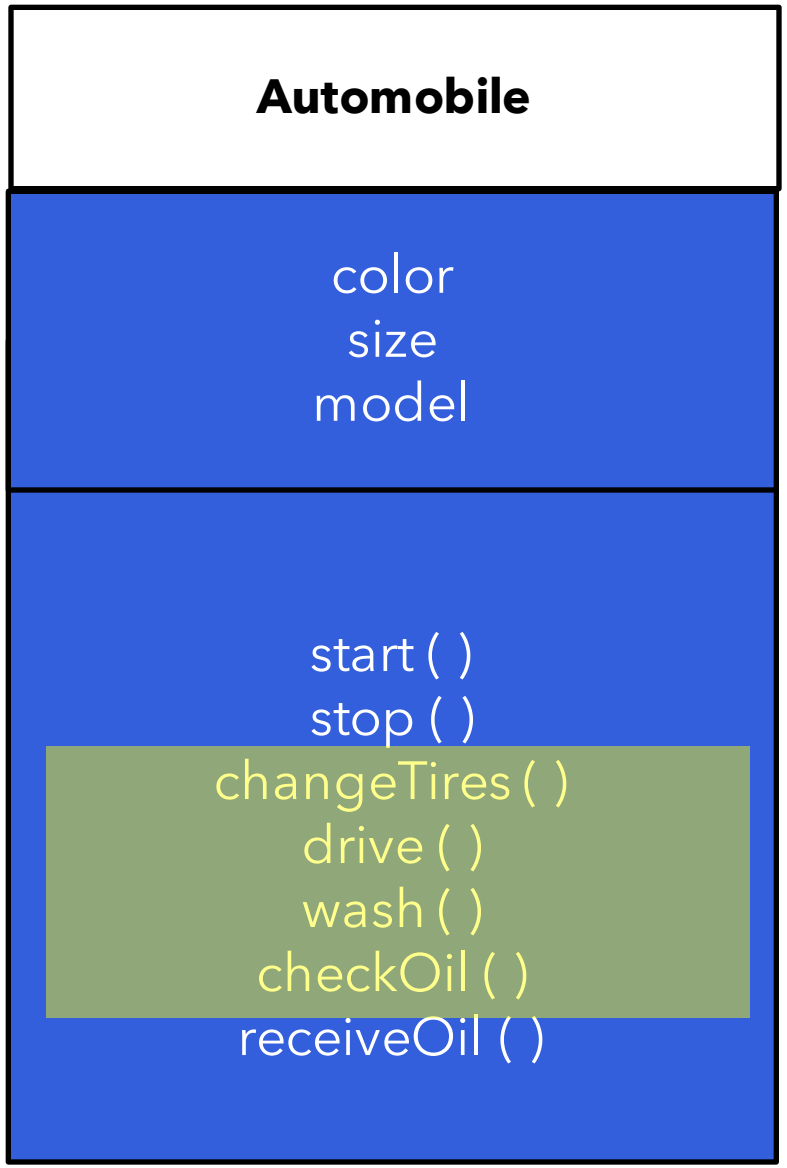
- Interface representations

THINK, PAIR, SHARE

- Does the following class adhere to the Single Responsibility Principle?

SINGLE RESPONSIBILITY PRINCIPLE

- For each method X, ask, "Does the Automobile have primary responsibility for X-ing?"
- If the answer is no, the method doesn't belong.



**For space, focusing on behaviors

AUTOMOBILE: REFACTORED

Automobile

start ( )
stop ( )
receiveOil ( )

Mechanic

changeTires ( )
checkOil ( )

CarWash

wash (Automobile)

Driver

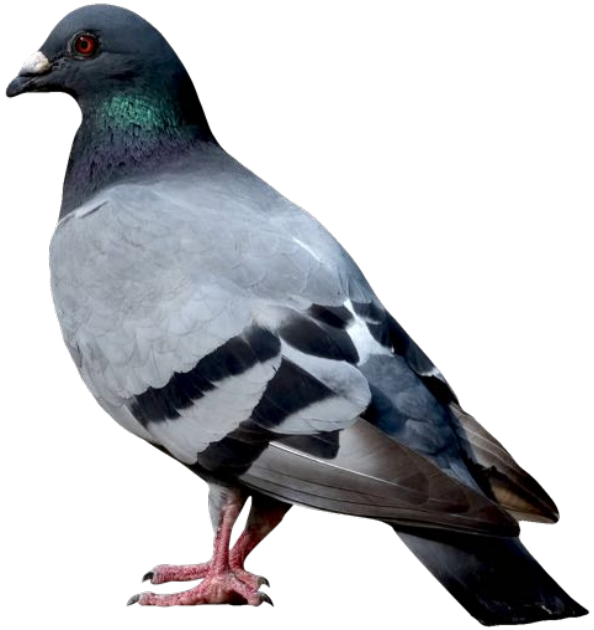
drive (Automobile)

GUT CHECK

IF YOUR DESCRIPTION OF A CLASS HAS MULTIPLE "ANDS" THEN IT PROBABLY NEEDS TO BE REFACTORED.

OPEN/CLOSED PRINCIPLE

- **Software entities should be open to extension but closed to modification**
- We should be able to use software entities in new ways, without changing the code
  - Can "lock code in a vault"
  - But use for things we did not think of when we wrote it



FLYING BIRDS PROGRAM

Use to Control bird motion

Source: Tom Dalling

```
9  class Bird {
10 public:
11     virtual void setLocation(double longitude, double latitude) = 0;
12     virtual void setAltitude(double altitude) = 0;
13     virtual void draw() = 0;
14 };
```

VERSION 1: IS A SUCCESS!

BUT WHAT IF WE USED IF/ELSE FOR BIRDS?

- What if we want to check the bird type in 100 places?
- What if we want to add Hawk with this structure?

```
8  void someMethod(Bird b) {
9      if (b.getType() == Bird.PIGEON) {
10         //pigeon code
11     }
12     else if (b.getType() == Bird.PARROT) {
13         //parrot code
14     }
15     else if (b.getType() == Bird.EAGLE) {
16         //eagle code
17     }
18     //…
19 }
```

If/Else or switch are the enemies of Open/Closed

```
8  void someMethod(Bird b) {
9      if (b.getType() == Bird.PIGEON) {
10         //pigeon code
11     }
12     else if (b.getType() == Bird.PARROT) {
13         //parrot code
14     }
15     else if (b.getType() == Bird.EAGLE) {
16             //eagle code
17     }
18     //…
19 }
```

```
21 class Pigeon : public Bird {
22   void someMethod() {
23     //pigeon code
24   }
25 };
26
27 class Parrot : public Bird {
28   void someMethod() {
29     //parrot code
30   }
31 };
32
33
34 class Eagle : public Bird {
35   void someMethod() {
36     //eagle code
37   }
38 };
```

WHAT SHOULD WE DO INSTEAD?

- Dynamic dispatch and polymorphism

```
16 void Hawk::setAltitude(double altitude)
17 {
18     //code here
19 }
```

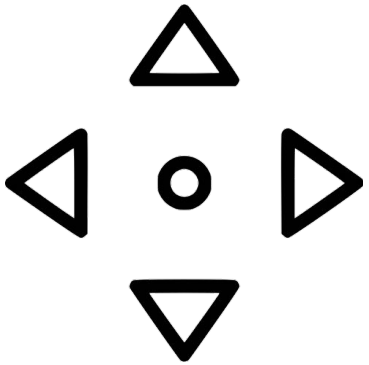
VERSION 2: ADDS A HAWK AND 10 OTHER BIRDS WITH NO ISSUE

Open/Closed Principle Satisfied

VERSION 3: ADDS A PENGUIN

DO YOU EXPECT ANY ISSUE?

Bird behavior when you run the program



Pigeon

Parrot

Penguin

WHY ARE PENGUINS FLOPPING?

Penguins don't fly!
All the penguin objects ignore the attempts of the user to make them to fly

```
class Bird {
public:
    virtual void setLocation(double longitude, double latitude) = 0;
    virtual void setAltitude(double altitude) = 0;
    virtual void draw() = 0;
};
```

- Because the Penguin subclass violates the flying assumption, it does not satisfy the **Liskov Substitution Principle** for the Bird superclass.

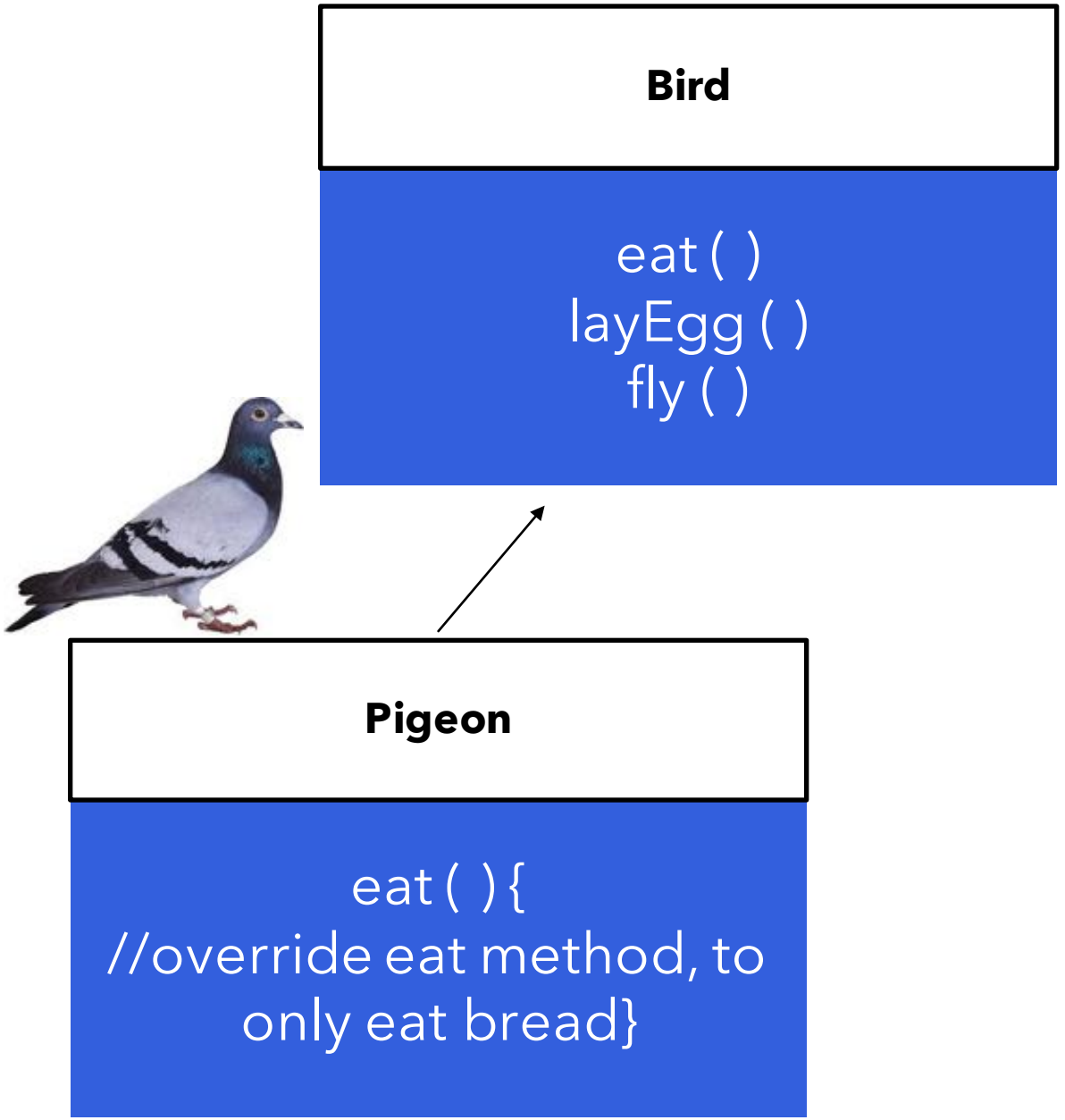
LISKOV SUBSTITUTION PRINCIPLE

LISKOV SUBSTITUTION

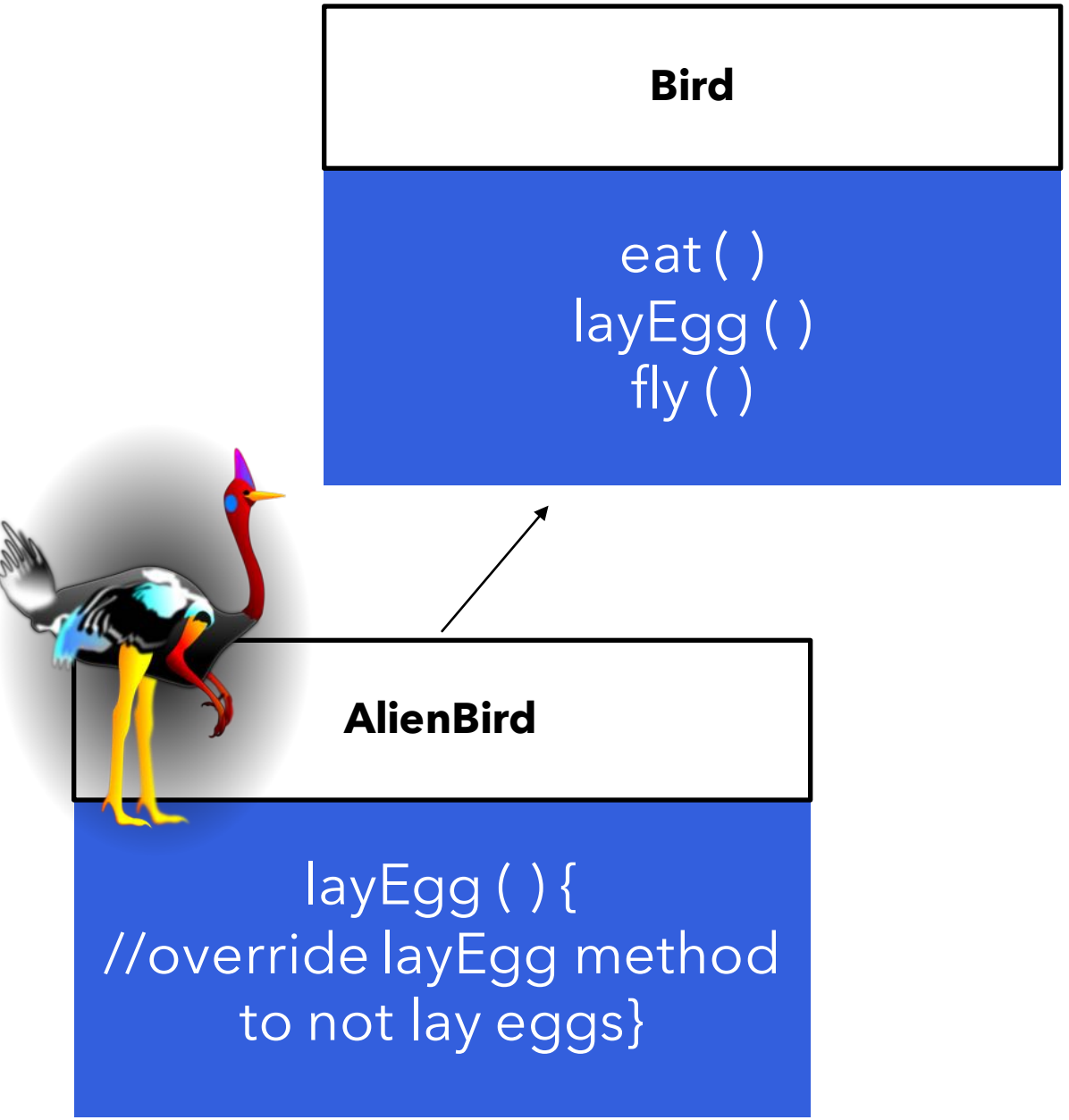
- Ability to replace any instance of a superclass with an instance of one of its subclasses without negative side effects
- Not the same as subtype polymorphism because "not breaking the program" is a requirement

PRECONDITIONS & POST-CONDITIONS

Preconditions: things that are supposed to be true before the method is called	• Must not be strengthened in a subclass
Post-conditions: things that are true after the method (assuming preconditions were satisfied)	• Must not be weakened in a subclass
Invariants: must be valid before and after a method call	• Invariants of the superclass must be preserved in the subclass
History: observable states of the object	• Any history must be valid for the superclass



- Subclass should not strengthen preconditions
- Stated Differently: **Requirements on inputs to a subclass cannot be stricter than its base class**
- If attempt bird.eat(worm), then raises an error
- Violates LSP because Pigeon expectations for input (only bread) stricter than Bird



- Postconditions must not be weakened in a subtype
- Stated Differently: **Possible outputs from a subclass must be more than or equally as restrictive as from the base class**
- If attempt bird.hatch( ) exception raised because no return in alien subclass
- Violates LSP because there are less possible outputs. So post conditions are weakened

INVARIANTS MUST ALWAYS BE TRUE

Example Bird Invariant:

If *isFlying()* is true, then

get Altitude() > 0

All subclasses must ensure this relationship too!

substitutable

NOT substitutable

Source: Baniassad, 2018

Egg

Hatching

Baby

Adult

A sub-class that can go from Adult->Baby
Violates LSP

Parenting

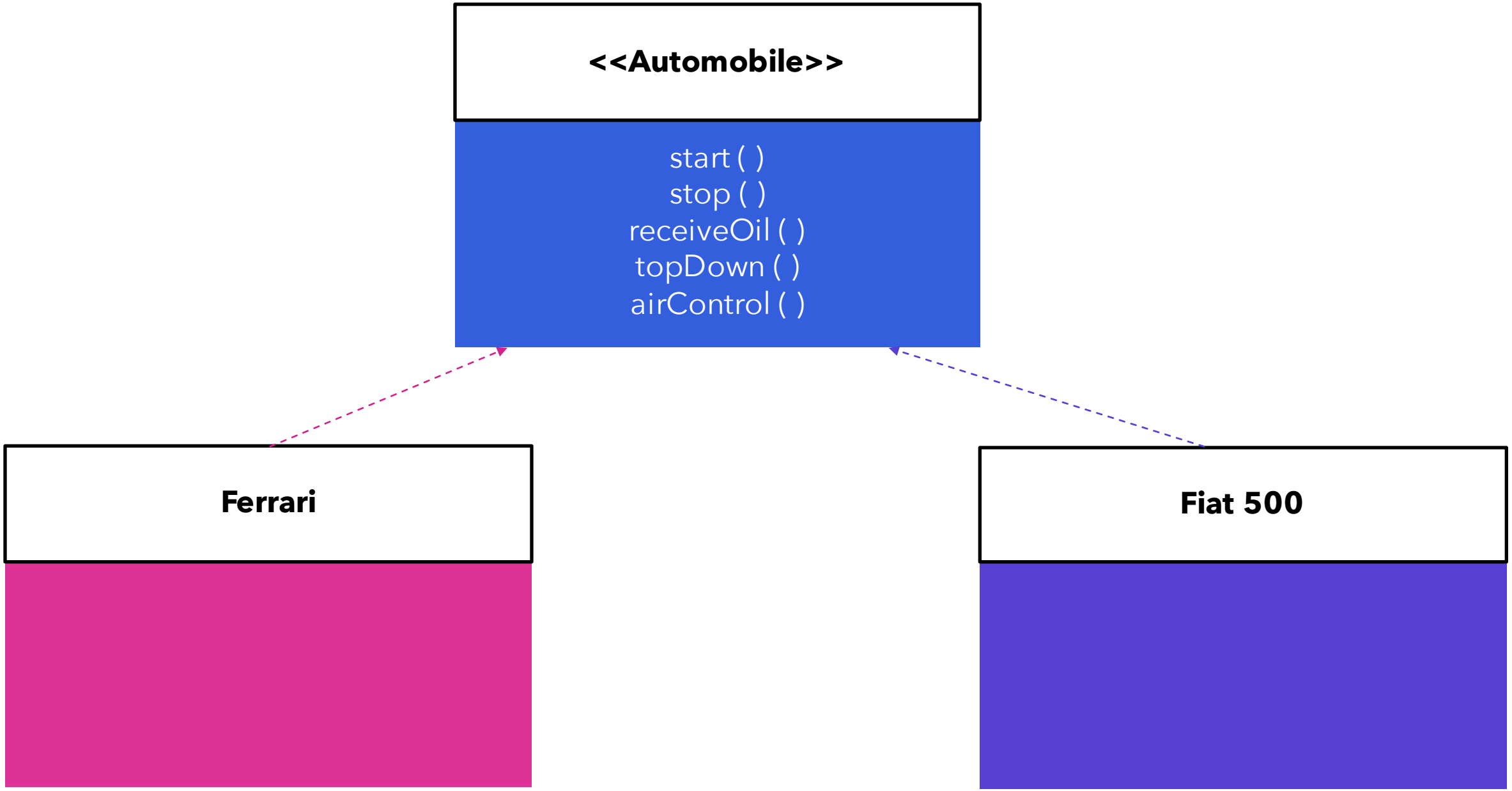
Incubating

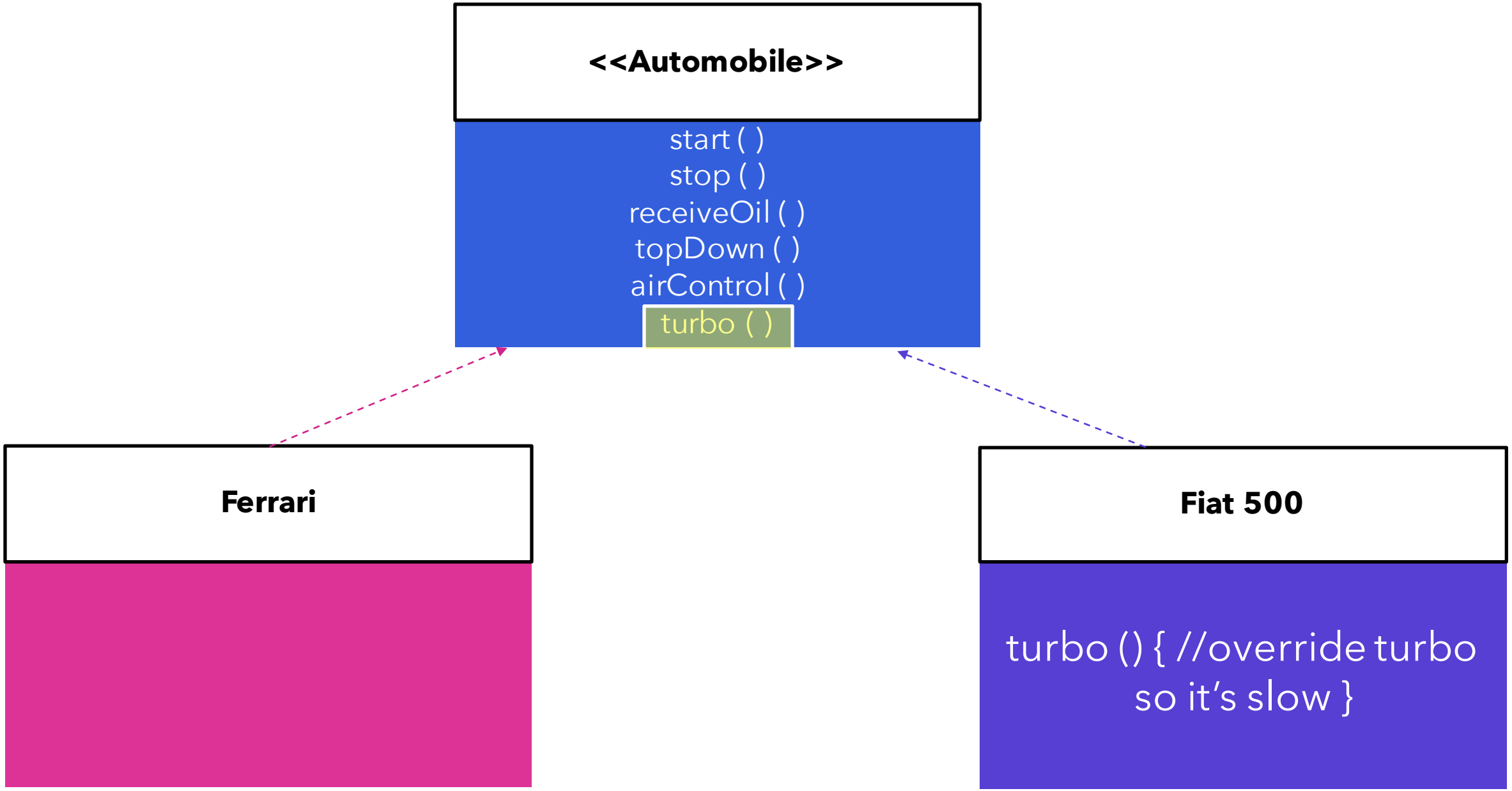
BARBARA LISKOV

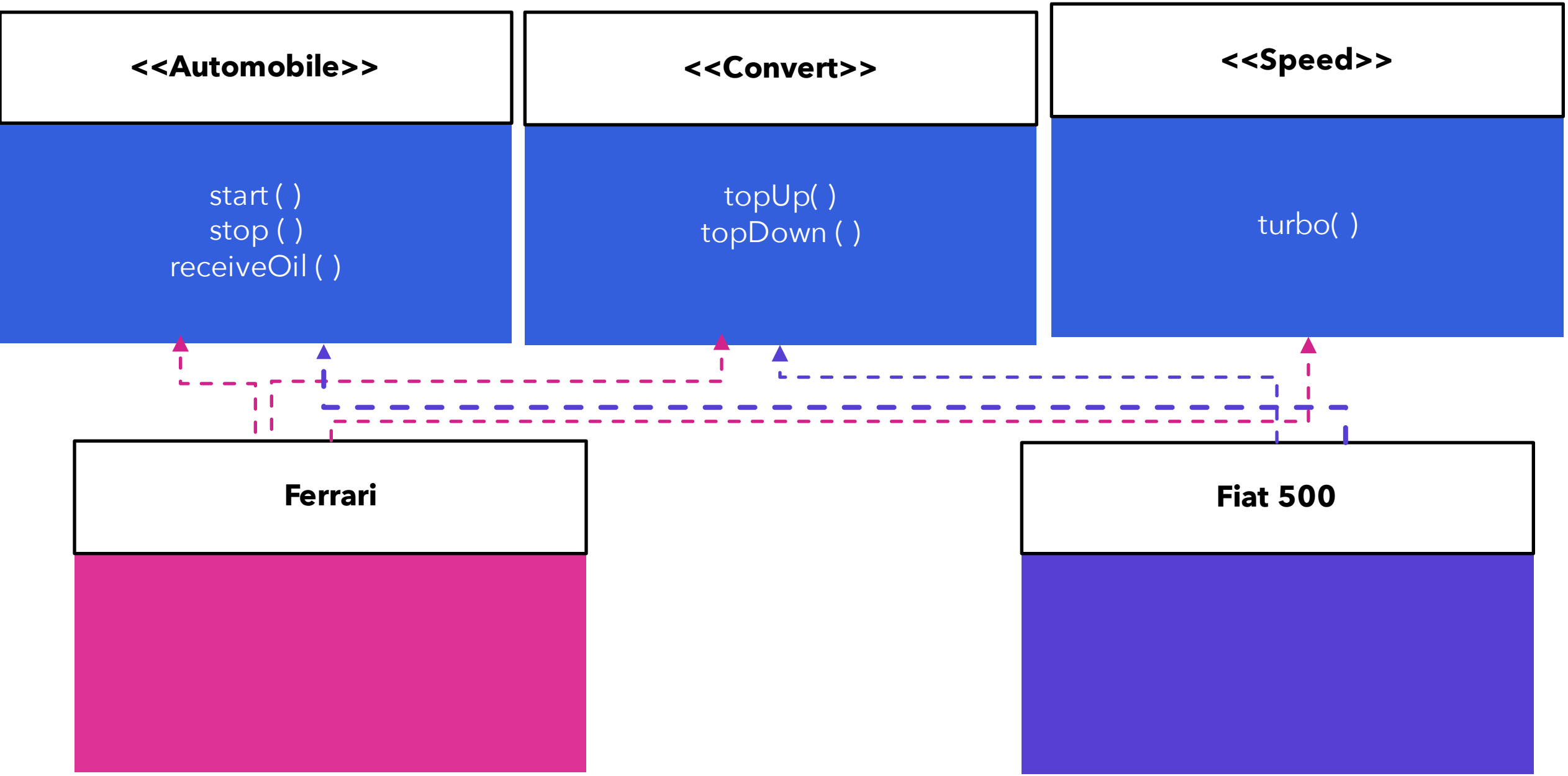
MIT INSTITUTE PROFESSOR AND HEAD OF THE PROGRAMMING METHODOLOGY GROUP

INTERFACE SEGREGATION PRINCIPLE

- A client shouldn't be forced to depend on interfaces they don't use
- Better to have many small interfaces than a few very large interfaces
- "Too many is better than too few"

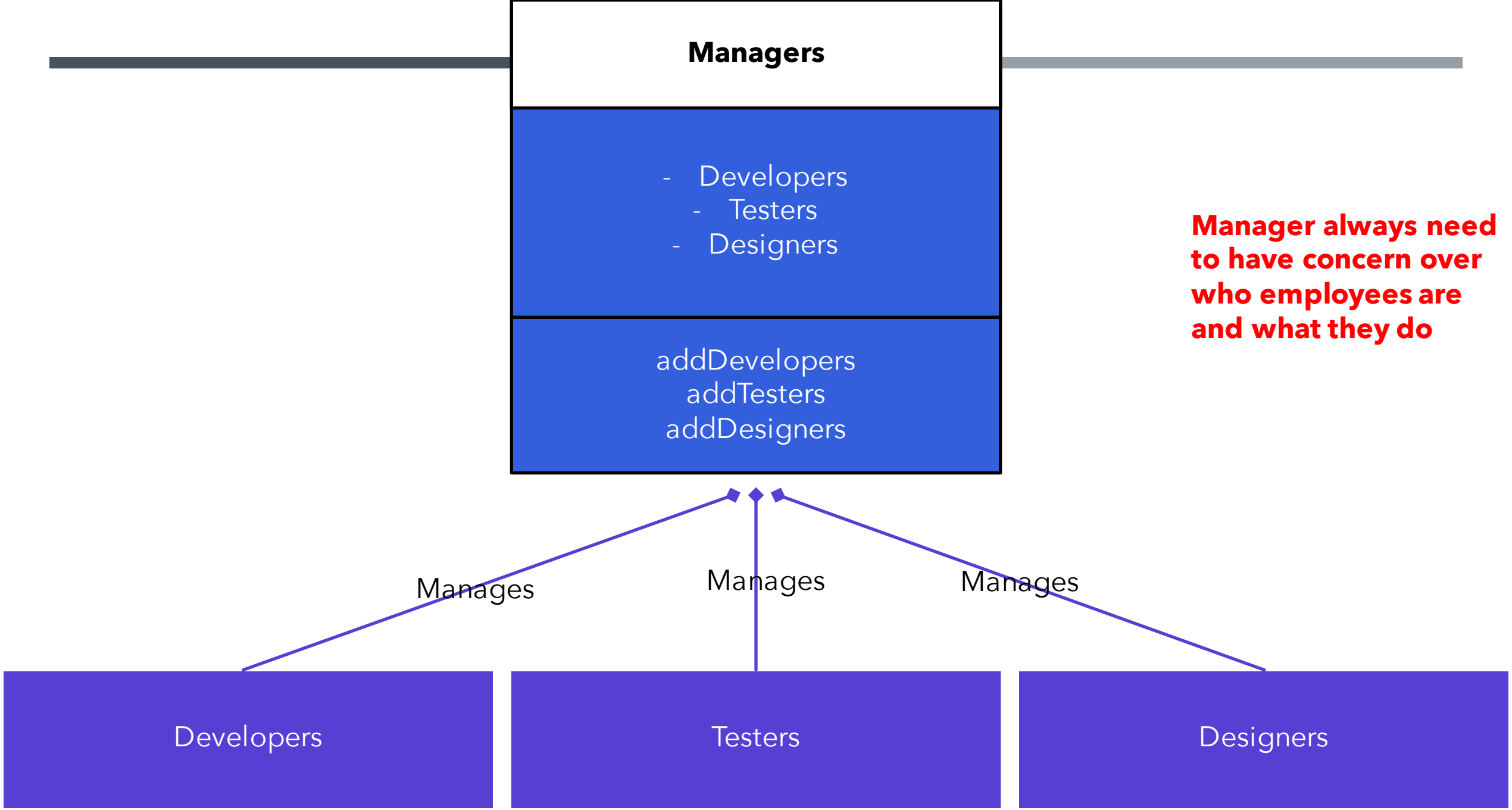

<<Automobile>>
start ( )
stop ( )
receiveOil ( )
topDown ( )
airControl ( )
Ferrari
Fiat 500


<<Automobile>>
start ( )
stop ( )
receiveOil ( )
topDown ( )
airControl ( )
turbo ( )
Ferrari
Fiat 500
turbo () { //override turbo so it's slow }

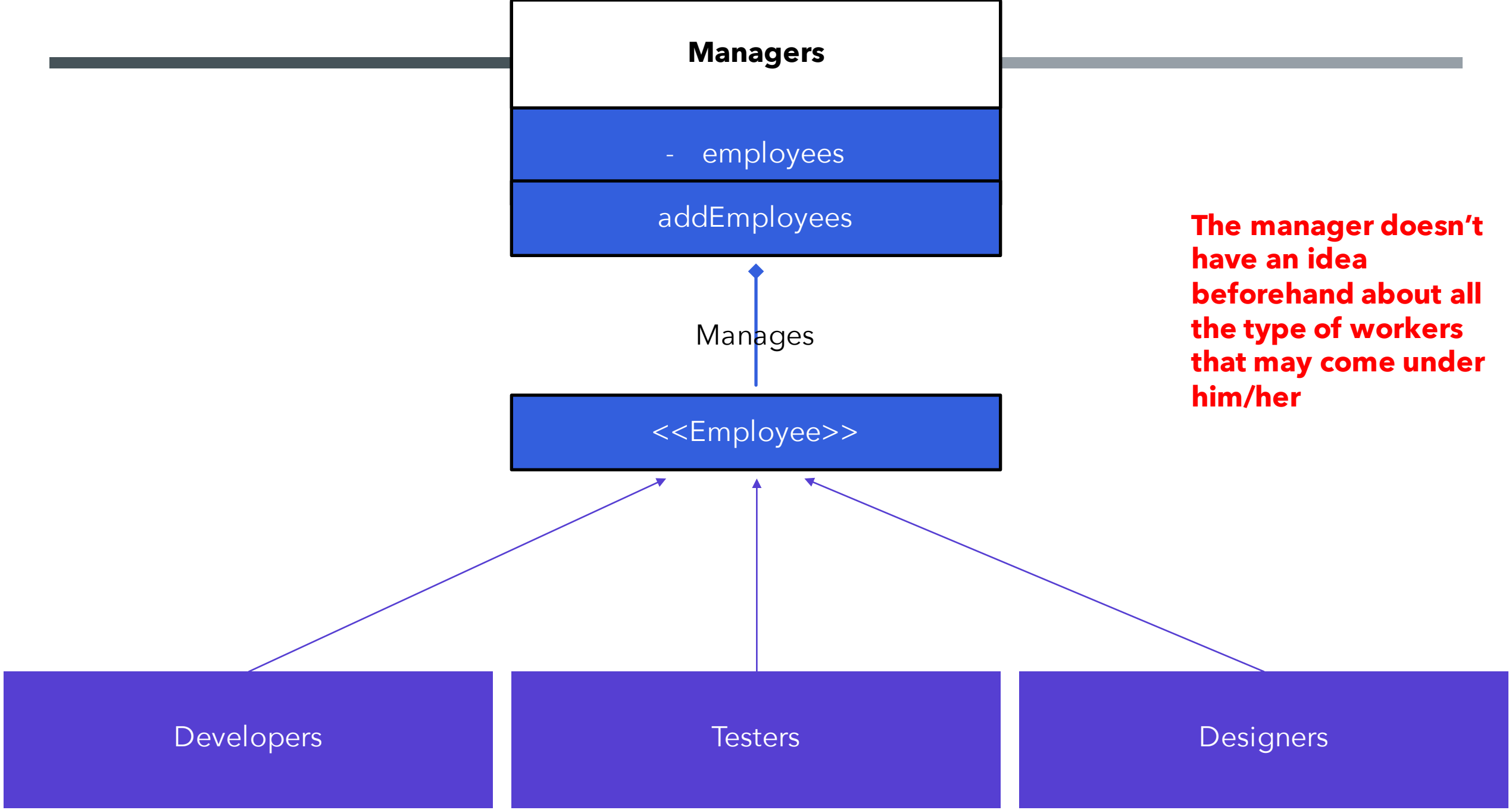

<<Automobile>>
start ( )
stop ( )
receiveOil ( )
<<Convert>>
topUp( )
topDown ( )
<<Speed>>
turbo( )
Ferrari
Fiat 500

DEPENDENCY INVERSION PRINCIPLE

- HIGH LEVEL OBJECTS SHOULD NOT DEPEND ON LOW LEVEL IMPLEMENTATIONS
- Higher classes are not dependent on the lower classes instead depend upon the abstraction of the lower classes



Manager always need to have concern over who employees are and what they do



The manager doesn't have an idea beforehand about all the type of workers that may come under him/her

DEPENDENCY INJECTION

ONE OBJECT SUPPLIES THE DEPENDENCIES OF ANOTHER OBJECT

DEPENDENCY INVERSION & DEPENDENCY INJECTION

```
class FlyingCreatureHouse  {
    FlyingCreature * myCreature;
 public:
    FlyingCreatureHouse(): myCreature(new Cardinal()) {}
};
```

- Does FlyingCreatureHouse follow Dependency Inversion?
  - Does it depend on an interface or a concrete implementation?
- What about Open/Closed Principle?

DEPENDENCY INVERSION & DEPENDENCY INJECTION

```
class FlyingCreatureHouse  {
    FlyingCreature * myCreature;
 public:
    FlyingCreatureHouse(): myCreature(new Cardinal()) {}
};
```

- Does BirdHouse follow Dependency Inversion? Depends on a concrete implementation (CardinalBird)
  - Does it depend on an interface or a concrete implementation?
- What about Open/Closed Principle? No: cannot make this work with other bird types!

DEPENDENCY INVERSION & DEPENDENCY INJECTION

```
15 class FlyingCreatureHouse  {
16     FlyingCreature * myCreature;
17  public:
18     FlyingCreatureHouse(FlyingCreature * fc): myCreature(fc) {}
19 };
```

Dependency Injection: we pass in the object we should depend on.

- Does BirdHouse follow Dependency Inversion? Depends only on FlyingCreature interface
  - Does it depend on an interface or a concrete implementation?
- What about Open/Closed Principle? Yes, can pass in any type of FlyingCreature

DESIGNING FOR TESTING

- **Controllability**: how well can my test code control the state of the module I want to test?
- **Observability**: how well can my test code inspect the state (to see if correct) of the module I want to test?
- **Isolatability**: how well can I separate out the module I want to test it by itself?

TESTING AND SRP

HOW DOES FOLLOWING THE SINGLE RESPONSIBILITY PRINCIPLE HELP WITH TESTING?