

# CS 4530: Fundamentals of Software Engineering

## Lecture 3: Code-Level Design Principles

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# Learning Objectives for this Lesson

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- By the end of this lesson you should be able to:
  - Describe the purpose of our design principles
  - List 5 code-level design principles with examples
  - Identify some violations of the principles and suggest ways to mitigate them

# Use Design As a Way of Communicating Organization

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- Software systems must be comprehensible by humans
- Which humans?
  - The other members of your team
  - The folks who will maintain and modify your system
  - Management
  - Your clients
  - and ...
  - You, a week from now or 6 weeks from now

# Use Design to Control Complexity

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- Software systems must be comprehensible by humans
- Why? Software needs to be maintainable
  - continuously adapted to a changing environment
  - Maintenance takes 50–80% of the cost
- Why? Software needs to be reusable
  - Economics: cheaper to reuse than rewrite!

# Three Scales of Design

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## The Structural Scale

- key questions: what are the pieces? how do they fit together to form a coherent whole?

## The Interaction Scale

- key questions: how do the pieces interact? how are they related?

## The Code Scale

- key question: how can I make the actual code easy to test, understand, and modify?

# Today's topic: design principles at the code scale

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# Coupling is the biggest source of complexity at the code level

- Two pieces of code are *coupled* if a change in one demands a change in the other.
- A coupling represents an agreement between the two pieces of code.
  - They may agree on:
    - names
    - order (e.g. of arguments)
    - meaning (e.g. meaning of data)
    - algorithms
- The more two pieces of code are coupled, the harder they are to understand and modify: you have to understand both to understand either of them.

There's a fancy word for this:  
*connascence*  
(meaning "born together")

More coupling means less readability, less modifiability

# Five general-purpose design principles

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## Five General Principles

1. Use Good Names
2. Make Your Data Mean Something
3. One Method/One Job
4. Don't Repeat Yourself
5. Don't Hardcode Things That Are Likely To Change



# Principle 1. Use Good Names

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- The name of a thing is a first clue to the reader about what the thing means.
  - often, it's the only clue 😞
- Use good names for
  - constants
  - variables
  - functions/methods
  - data types

# Use Good Names for Variables and Types

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```
var t : number  
var l : number
```



```
var temp : number  
var loc  : number
```



```
var temp : Temperature  
var loc  : SensorLocation
```

# Use Good Names for Functions and Methods

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```
function checkLine (line) : boolean
```



```
function LineIsTooLong (line) : boolean
```

# Use Good Names for Functions and Methods

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- Use noun-like names for functions or methods that return values, e.g.

```
let c = new Circle(initRadius)
let a = c.diameter()
```

- not:

```
let a = c.calculateDiameter()
```

- Reserve verb-like names for functions or methods that perform actions, like

```
table1.addItem(student1, grade1)
```

# Principle 2. Make Your Data Mean Something

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- You need to do three things:
  1. Decide **what part** of the information in the "real world" needs to be represented as data
  2. Decide **how** that information needs to be represented as data
  3. Document how to **interpret** the data in your computer as information about the real world

# Example:

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- Right now I am wearing a red shirt, and I've decided I need to represent that fact in my program.
- How should I represent that in my program?
- We need to decide:
  - how to represent shirts (including their color)
  - how to represent colors
  - how to represent **my** shirt

# We need to write something like this:

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```
type Shirt = {  
    /** the color of the shirt */  
    color: Color  
}
```

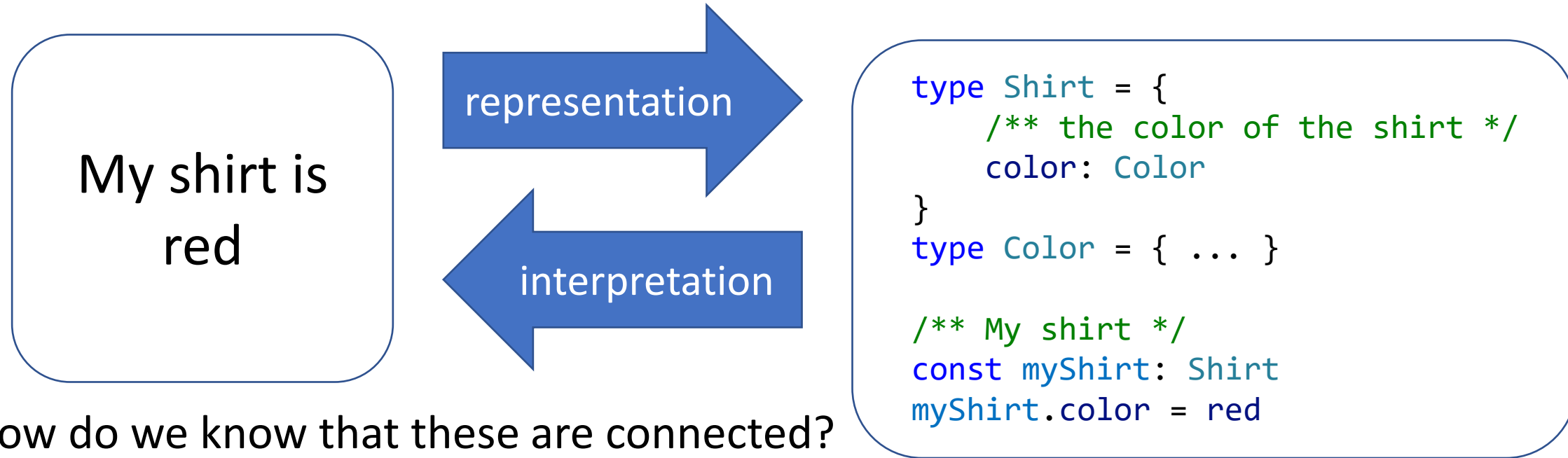
```
type Color = { ... }
```

```
/** My shirt */  
const myShirt: Shirt
```

```
myShirt.color = red
```

# The Big Picture

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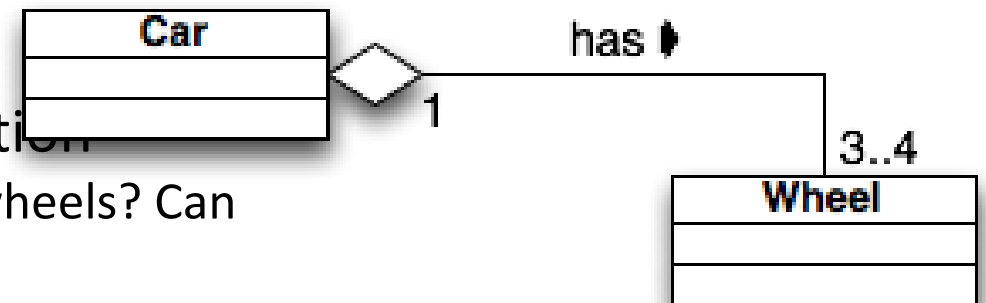


- How do we know that these are connected?
- Answer: we have to **write it down**.
- In our Typescript infrastructure, we do that with the comments.



# Another example: What does an object represent?

- What does an object of class Car represent?
  - a model of car (e.g. Dodge, Ford, Toyota)?
  - a particular car (my 2019 Toyota, VIN = 456789)?
- What does an object of class Wheel represent?
  - a model of tire? (Goodyear GoodGrips14)
  - a particular tire? (Goodyear GoodGrips14 SN = 345678)
- What does "has" represent?
  - depends on what Car and Wheel represent
  - this may affect the navigability of the association
    - (can you get from a car object to the associated wheels? Can you get from a wheel to the car that it's on?)



# Principle 3: One Method/One Job

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- Each class, and each method of that class, should have one job, and only one job
- If your method has more than one job, split it into 2 methods. Why?
  - You might want one part but not the other
  - It's easier to test a method that has only one job
- You call both of them if you need to.
  - or write a single method that calls them both
- Same thing for classes.

# Principle 4: Don't Repeat Yourself

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- If you have some quantity that you use more than once, give it a name and use the name.
- That way you only need to change it in one place!
- And of course you should use a good name
- If you have some task that you do in many places, make it into a procedure.
- If the tasks are slightly different, turn the differences into parameters.

# A real example

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```
function testequal <T> (testname: string, actualVal: T, correctVal: T) {  
    test(testname,  
        function () { expect(actualVal).toBe(correctVal) })  
}  
  
describe('tests for countOfLocalMorks', function () {  
    testequal('empty crew',countOfLocalMorks(ship1),0)  
    testequal('just Mork',countOfLocalMorks(ship2),1)  
    testequal('just Mindy',countOfLocalMorks(ship3),0)  
    testequal('two Morks',countOfLocalMorks(ship4),2)  
    testequal('drone has no Morks',countOfLocalMorks(drone1),0)  
})
```

## Principle 5: Don't Hardcode Things That Are Likely To Change

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- "No magic numbers" and "Don't Repeat Yourself" are already examples of this.
- General strategy: If there something that might change, give it a name
  - if it's not already a "thing", refactor to make it a "thing"
- Let's look at a couple of examples.

# Replace magic numbers with good names

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- Replace magic numbers with good names

```
let salesprice = netPrice * 1.06
```



```
const salesTaxRate = 1.06  
let salesPrice = netPrice * salesTaxRate
```

# Example

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- Imagine we are computing income tax in a state where there are four rates:
  - One on incomes less than \$10,000
  - One on incomes between \$10,000 and \$20,000
  - One on incomes between \$20,000 and \$50,000
  - One on incomes greater than \$50,000
- You might write something like

# You might write something like

---

```
function grossTax(income: number): number {  
  if ((0 <= income) && (income <= 10000)) { return 0 }  
  else if ((10000 < income) && (income <= 20000))  
  { return 0.10 * (income - 10000) }  
  else if ((20000 < income) && (income <= 50000))  
  { return 1000 + 0.20 * (income - 20000) }  
  else { return 7000 + 0.25 * (income - 50000) }  
}
```

- What might change?
  - The boundaries of the tax brackets might change
  - The number of brackets might change



# So let's represent our data differently

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```
// defines the tax bracket for income lower < income <= upper.  
// if upper is null, then lower < income (no upper bound)
```

```
type TaxBracket = {  
    lower: number,  
    upper: number | null,  
    base : number  
    rate : number  
}
```

```
let brackets : TaxBracket[] = [  
    {lower:0,      upper:10000, base:0,    rate:0},  
    {lower:10000,  upper:20000, base:0,    rate:0.10},  
    {lower:20000,  upper:50000, base:1000,  rate:0.20},  
    {lower:50000,  upper: null,  base:7000,  rate:0.25}  
]
```

# And now it's easy to rewrite our function

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```
// defines the incomes covered by a bracket
function isInBracket(income:number, bracket:TaxBracket) : boolean {
  if (bracket.upper == null)
  { return (bracket.lower <= income) }
  else
  { return ((bracket.lower <= income) && (income < bracket.upper)) }
}

function income2bracket(income: number, brackets: Bracket[]): Bracket {
  return brackets.find(b0 => isInBracket(income, b0))
}

function taxByBracket(income:number,bracket:TaxBracket) : number {
  return bracket.base + bracket.rate * (income - bracket.lower)
}

function grossTax2 (income:number, brackets: TaxBracket[] ) : number {
  return taxByBracket(income,income2bracket(income,brackets))
}
```

# Review: Learning Objectives for this Lesson

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- You should now be able to:
  - Describe the purpose of our design principles
  - List 5 general design principles and illustrate their expression in code
  - Identify some violations of the principles and suggest ways to mitigate them

# Additional Material

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# Examples of Design at the Structural Scale

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- Object-Oriented
- Pipeline
- Pipeline + Database
- Layered

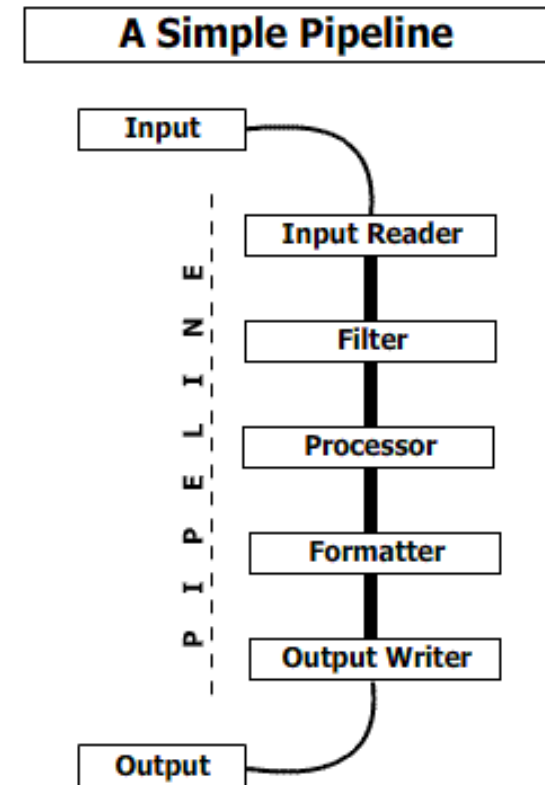
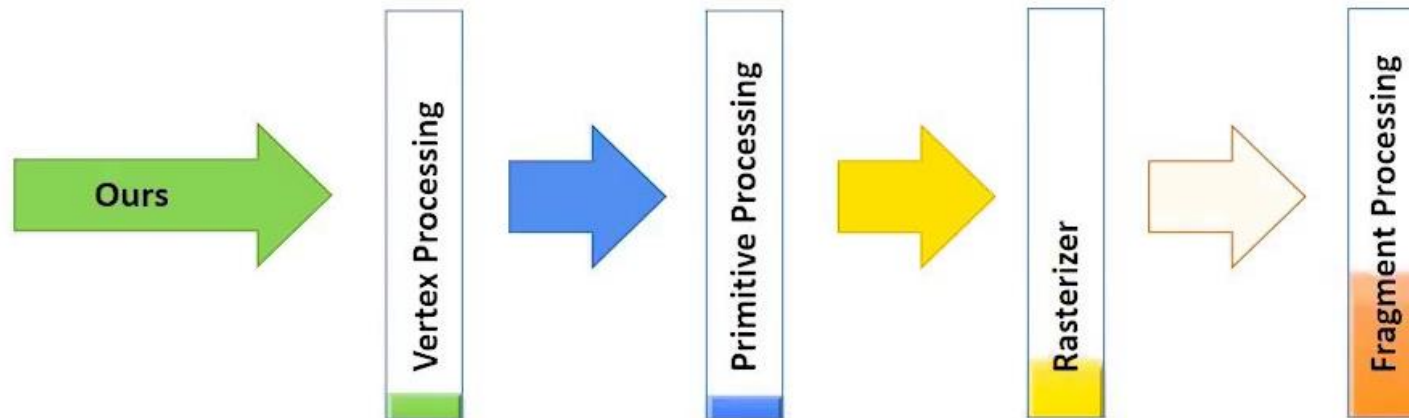
# Object-Oriented Architecture

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- The entities in the program correspond to entities in the real world.
- Example: a library system might have classes for
  - A holding (several books, eg: “7 copies of Moby-Dick”)
  - An individual item (“copy #3 of Moby-Dick”)
  - A card-holder (“Avery Fischer, library card #12345, ...”)
  - A borrowing (“Avery Fischer borrowed copy #3 of Moby-Dick on 9/1/22”)

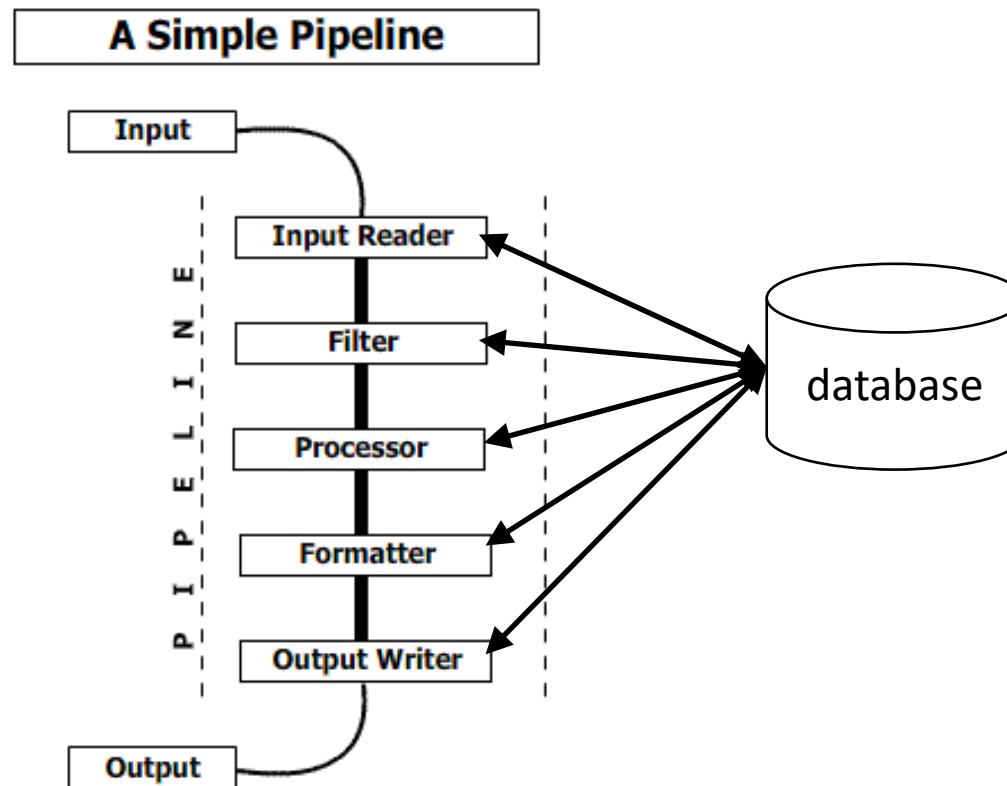
# Pipeline Architecture

- The pieces correspond to stages in the transformation of data in the system
- Good for complex straight-line processes, e.g. image processing



# Pipeline + Database

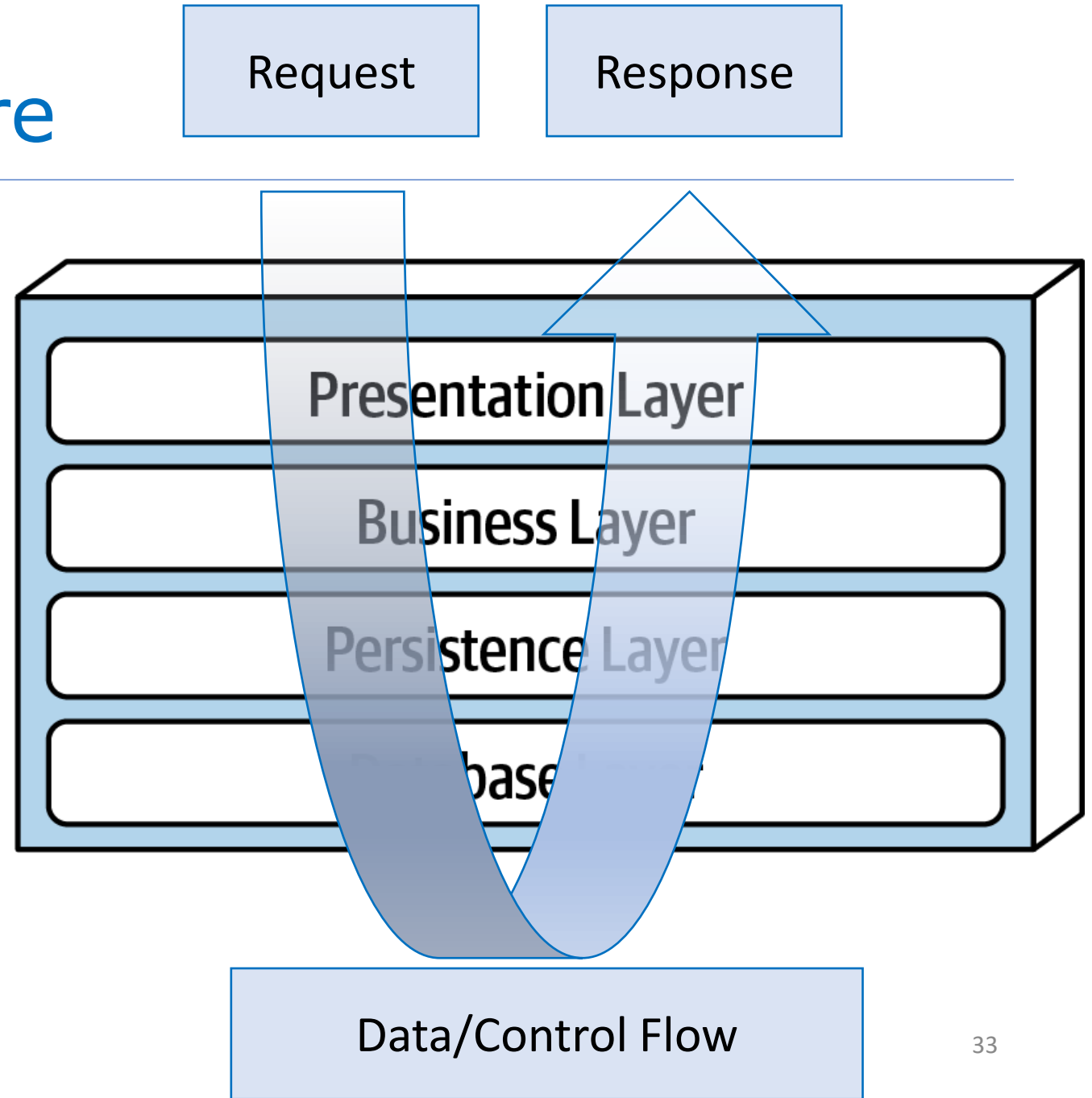
- Stages in the pipeline share data through a database





# Layered Architecture

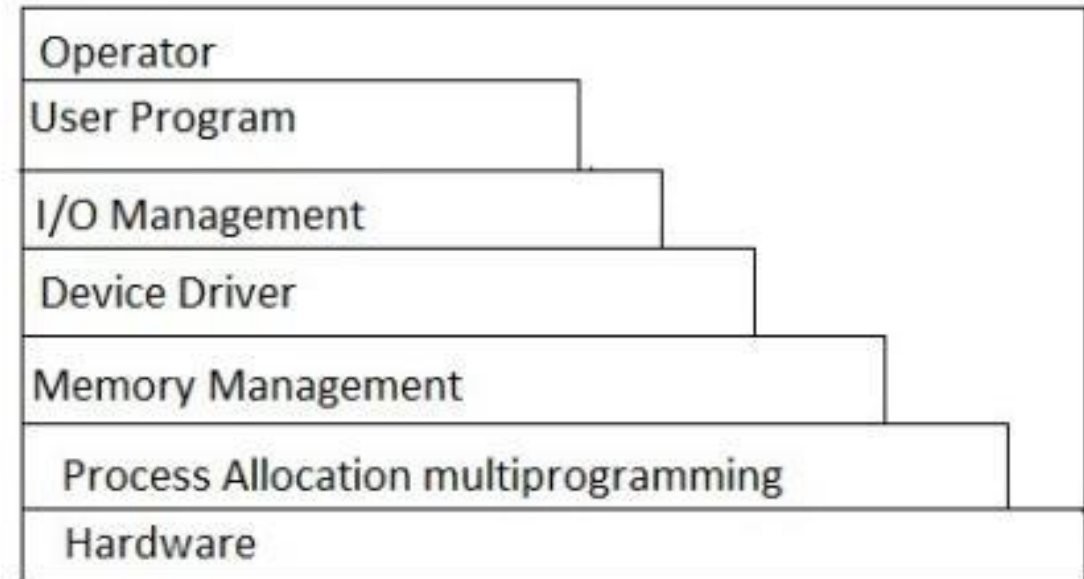
- The pieces correspond to level of concern.
- Each layer depends on services from the layer or layers below



# Layered Architecture (contd)

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- Typical organization for operating systems
- Layers communicate through procedure calls and callbacks (sometimes called "up-calls")



# Design at the Interaction Scale

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- Roughly what's typically called “Design Patterns”
- We'll talk about some OO Design Patterns in the next lecture.
- But we'll see interaction-scale patterns in many domains, not just OOP.