

Booting into FP

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Our Tour

- Functions, everywhere!
- Understanding Referential Transparency
- What is a Lambda?
- Modularization
 - Building Abstractions with Higher-Order Functions
 - Lazy Evaluation
- Tackling Complexity using Function Composition
- Streams (Lazy Lists)
- De-structuring and Pattern Matching
- Currying
- Sequence/Chain Operations together using Monads - Dealing with absence of Values
- Overview of Upcoming Sessions

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- Immutability
 - No assignment statements, a variable value never changes.
- No side-effects
 - Eliminates major source of bugs, order of evaluation does not matter.
- Referential Transparency
 - Enables equational reasoning

Source: Why Functional Programming Matters - John Hughes

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 - Reusability of general-purpose modules.
 - Independent testing of modules.

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- Benefits
 - Small can be coded quickly and easily.
 - Reusability of general-purpose modules.
 - Independent testing of modules.
- The Glue
 - Lazy Evaluation.
 - Higher-Order Functions.

Functions Everywhere!

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- Co-Domain $\{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$

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- Function is a relation that maps the domain into co-domain such that there is exactly one input maps to a output (1:1 and not 1:n).

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- Range $\{0, 1, 4, 9\}$
- Function is a relation that maps the domain into co-domain such that there is exactly one input maps to a output (1:1 and not 1:n).
- Type of the function is $int \mapsto int$

A Pure Function

- Uses nothing other than i/p parameters (and its definition) to produce o/p $f: T \mapsto R$
- Neither modifies input arguments nor reads/modifies external state
- Call is substitutable by its body. To understand the code, you don't have to look elsewhere.

```
class Calculator {  
    // (int, int) -> int  
    public int add(final int x, final int y) {  
        return x + y;  
    }  
}
```

A Side-affecting Function

- Modifies or interacts with things outside of its scope (interaction with outside world), and may also return a value.
- Reading/Writing to disk, DB, Socket etc... anything that modifies external world.

```
class Calculator {  
    private int memory = 0;  
  
    public Calculator(final int memory) {  
        this.memory = memory;  
    }  
    public Integer add(final int x, final int y) { ... }  
  
    public Integer memoryPlus(final int n) {  
        memory = add(memory, n);  
        return memory;  
    }  
}
```

Outside of
its scope

Black-Hole like Side-affecting Function

- Write Side-effect...a typical Setter!

$$f : T \mapsto ()$$

```
class Calculator {  
    private int memory = 0;  
  
    public Calculator(final int memory) {  
        this.memory = memory;  
    }  
    // int -> ()  
    public void setMemory(final int memory) {  
        this.memory = memory;  
    }  
}
```

Mother's Love like Side-affecting Function

- Read Side-effect...a Getter! $f: () \mapsto R$

```
class Calculator {  
    private int memory = 0;  
  
    public Calculator(final int memory) {  
        this.memory = memory;  
    }  
    // () -> int  
    public int recallMemory() {  
        return memory;  
    }  
}
```

Politician like Side-affecting Function

- Read-Write Side-effect...a Printer! $f: () \mapsto ()$
- Neither consume anything, nor I return anything, because I do everything under the table.

```
class Calculator {  
    private int memory = 0;  
  
    public Calculator(final int memory) {  
        this.memory = memory;  
    }  
  
    public void printMemory() {  
        System.out.println(memory);  
    }  
}
```

Side-effects or Useful-effects?



Source: <https://channel9.msdn.com/Blogs/Charles/Simon-Peyton-Jones-Towards-a-Programming-Language-Nirvana>

Side-effects or Useful-effects?

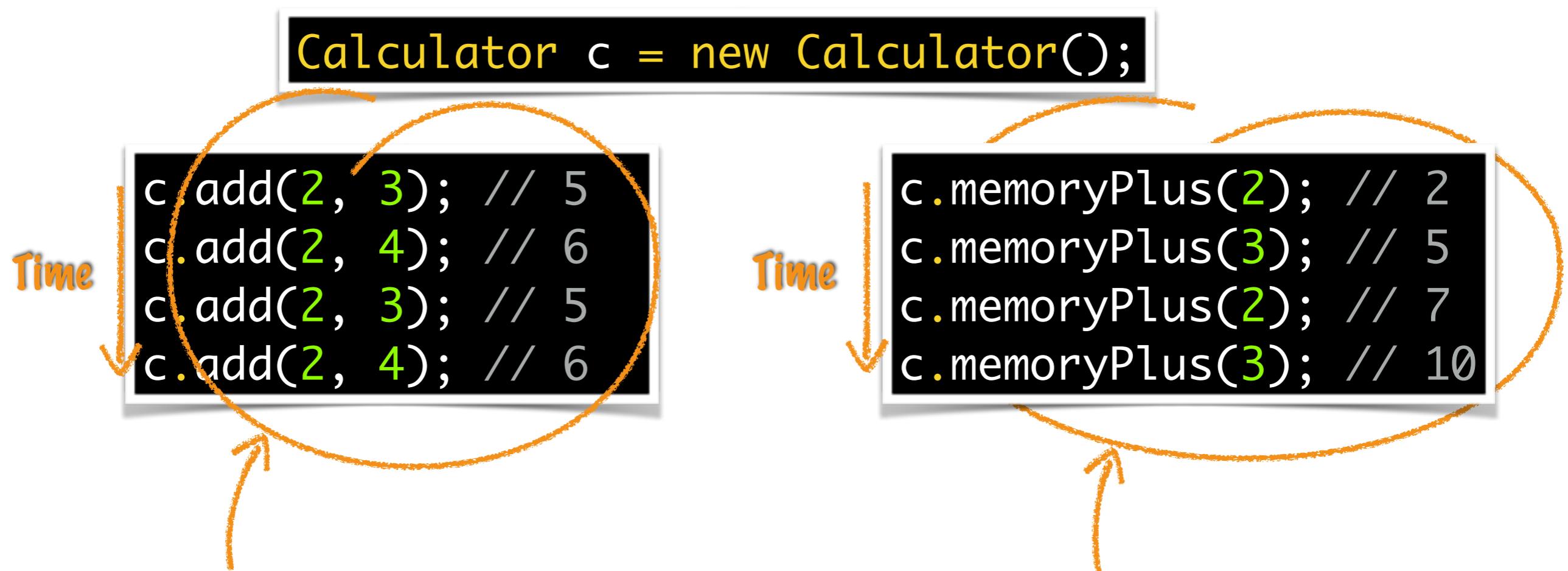


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Understanding Referential Transparency

```
class Calculator {  
  
    private int memory;  
  
    public Calculator(final int memory) {  
        this.memory = memory;  
    }  
  
    public Integer add(final int x, final int y) {  
        return x + y;  
    }  
  
    public Integer memoryPlus(final int n) {  
        memory = add(memory, n);  
        return memory;  
    }  
}
```

Understanding Referential Transparency



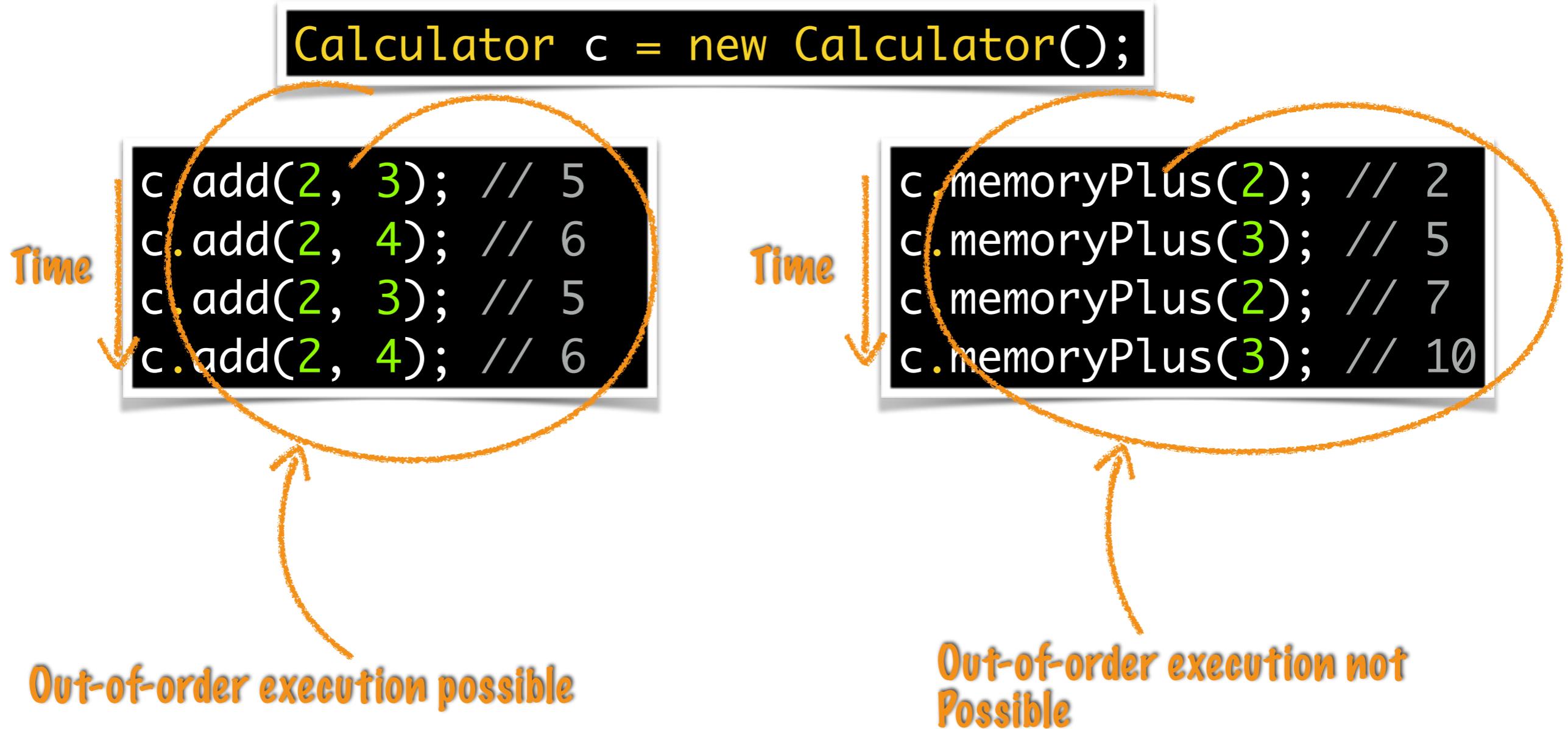
Referentially Transparent add :

1. Substitute any expression with its resulting value.
2. Returns same results all the time, as behaviour does not depend on history.

Referentially Opaque memoryPlus :

1. Cannot replace it with resulting value.
2. Returns different results as time progresses, as behaviour depends on history.

Pure Functions, Side-Effects and Evaluation Order



**How can we make
memoryPlus
Referentially
Transparent?**

Ref. Transparent memoryPlus

Make memory
Immutable

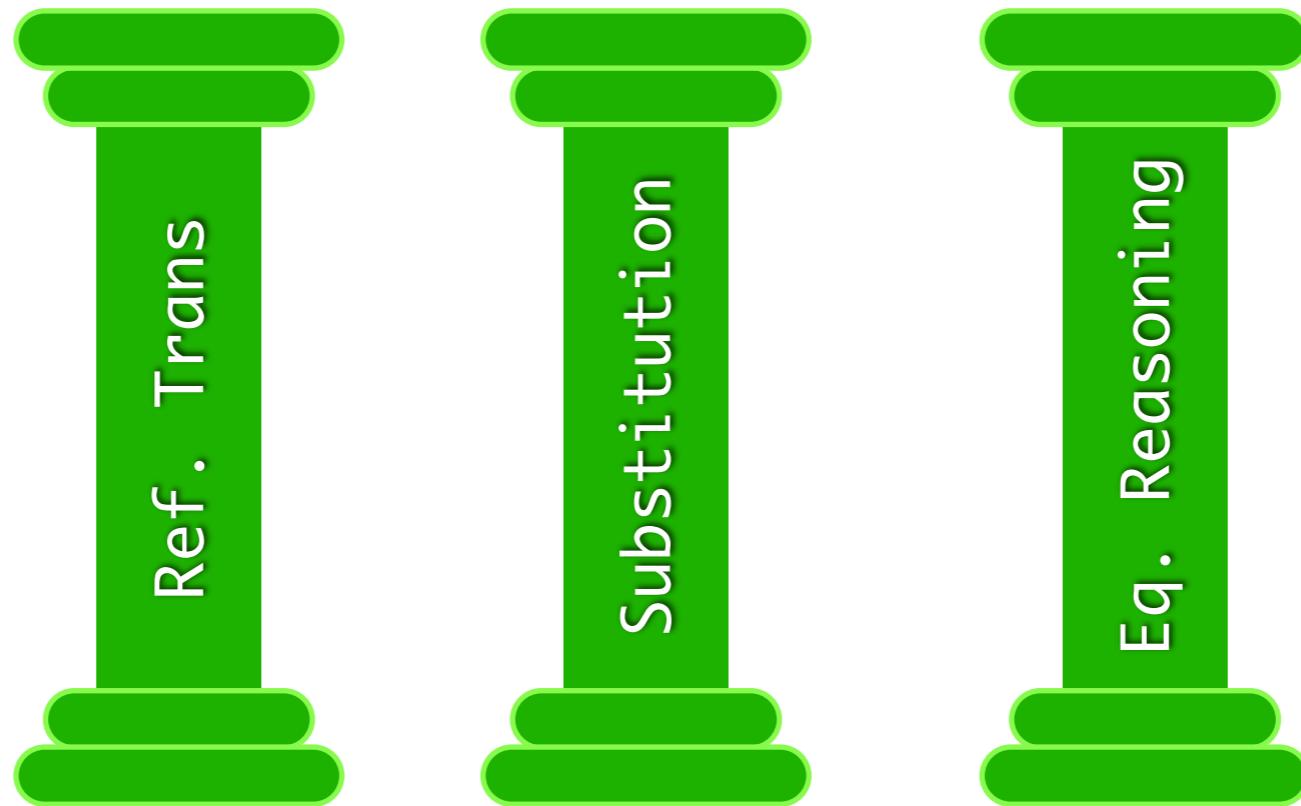
```
class Calculator {  
    private final int memory;  
  
    public Calculator(final int memory) {  
        this.memory = memory;  
    }  
  
    public int add { ... }  
  
    public Calculator memoryPlus(final int n) {  
        return new Calculator(add(memory, n));  
    }  
}
```

Return new instance from
operation.

Reflections

- Referential Transparency is about replacing any expression (or function) with its resulting value.
- To be referentially transparent, function will require to work with immutable data.
- To be referentially transparent, a function will require to be pure.
- To be referentially transparent, a function will require to be deterministic.
- Referentially transparent functions are context-free and the context is time.

3 Pillars of FP



- Referential Transparency - enforces invariant expressions or functions are pure.
- Substitution Model - RT enables simple and natural mode of reasoning about program evaluation.
- Equational Reasoning - Computation proceeds like solving an algebraic equation, where we substitute and reduce to its simplest form.

Good Deeds Happen Anonymously

- Naming is one of the hardest problem in software.
- Alleviate using an anonymous function - Lambda λ .

Drop all
inessentials



```
public int add(final int x, final int y) {  
    return x + y;  
}
```

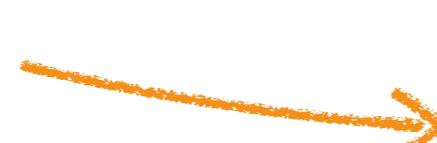


```
public int add(final int x, final int y) {  
    return x + y;  
}
```



```
(final int x, final int y) -> { x + y; }
```

what remains
are essentials,
parameters and
body



```
(x, y) -> x + y;
```

SAMs Become...

Drop all inessentials

```
new Button().addActionListener(new ActionListener() {  
    public void actionPerformed(ActionEvent e) {  
        System.out.print("essence");  
    }  
});
```



```
new Button().addActionListener(new ActionListener() {  
    public void actionPerformed(ActionEvent e) {  
        System.out.println("essence");  
    }  
});
```



```
new Button().addActionListener(e -> System.out.print("essence"));
```

what remains
are essentials,
parameters and
body

OR

```
new Button().addActionListener(System.out::print);
```

Lambda

- Compiled as interface implementation with synthesised method having signature of the abstract method in that interface.
- An interface with single abstract method (SAM).
- @FunctionalInterface - Though optional annotation, its better to have it so that it ensures that it stays as a lambda and not become something more.

```
Function<Integer, Integer> twice = x -> 2 * x;
```

```
twice.apply(3); // 6
```

Instead of

twice(3);

It would be have been nice if
some more syntactic sugar
was added by Java8 to make
this happen

Functional Interfaces

```
@FunctionalInterface
public interface Function<T, R> {
    R apply(T t);
    ...
}

Function<Float, Float> twice = x -> 2 * x;
twice.apply(3); // 6

// A function returns its argument unchanged
Function<Float, Float> identity = x -> x;

@FunctionalInterface
public interface BiFunction<T, U, R> {
    R apply(T t, U u);
    ...
}

BiFunction<Float, Float, Float> add = (x, y) -> x + y;
add.apply(2, 3); // 5
```

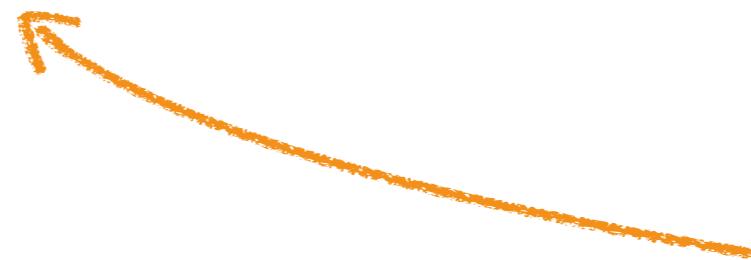
A Black-Hole like Functional Interface

```
@FunctionalInterface
public interface Consumer<T> {
    void accept(T t);
    ...
}

corrupt.accept(100.34);
@FunctionalInterface
public interface BiConsumer<T, U> {
    void accept(T t, U u);
    ...
}
BiConsumer<Celestial, Celestial> blackHole =
        (planet, asteroid) -> { }
blackHole.accept(planet, asteriod);
```

A Mother's Love like Functional Interface

```
@FunctionalInterface  
public interface Supplier<T> {  
    T get();  
}  
  
Supplier<String> mother = () -> "Love";  
  
mother.get(); // Love
```



Things Emerge
without
consuming anything

Mr. Spock like Functional Interface

```
@FunctionalInterface
public interface Predicate<T> {
    boolean test(T t);
    ...
}

Predicate<T> affirmative = x -> true;
affirmative.test(1); // true

Predicate<T> negative = x -> false;
negative.test(1); // false

Predicate<Integer> isEven = x -> x % 2 == 0;
isEven.test(2); // true
isEven.test(3); // false
```

Politician like Functional Interface

- Neither consume anything, nor I return anything, because I do everything under the table.

```
@FunctionalInterface  
public interface Runnable {  
    void run();  
}
```

Every“thing” is a Lambda

- Like Object, a Function is also a thing, so
 - Pass a function to a function
 - Return a function from within a function
- A function that produces or consumes a function is called as Higher Order Function - HOF
 - Either pass existing method reference (static or instance) or write an in-place lambda where a method expects a function parameter.
- Modularization - Build abstractions with HOFs.

Pass a function to a function

- Subsumed ‘for’ loop.
 - Repetitive behaviour using Recursion.

No need for
explicit looping
constructs!
Just a function!

```
void iterate(int times, Runnable body) {  
    if (times <= 0) {  
        return;  
    }  
    body.run();  
    iterate(times - 1, body);  
}  
  
iterate(2, () -> System.out.println("Hello"));  
// Hello  
// Hello
```

Return a function from a function

- Subsumed Factory Method.

```
Function<Double, Double> power(double raiseTo) {  
    return x -> Math.pow(x, raiseTo);  
}  
  
Function<Double, Double> square = power(2.0);  
square.apply(2.0); // 4.0  
  
Function<Double, Double> cube = power(3.0);  
cube.apply(2.0); // 8.0
```

Subsumed Aspect

- AOP - Around style

```
public<T, R> Function<T, R> time(Function<T, R> fn) {  
    return t -> {  
        long startTime = System.currentTimeMillis();  
        R result = fn.apply(t);  
        long timeTaken = System.currentTimeMillis() - startTime;  
        System.out.println("Time: " + timeTaken + " ms");  
        return result;  
    }  
}
```

Composition Pipeline

- Compose a function from other functions by aligning types.

```
// T -> U
Function<T, U> f;

// U -> R
Function<U, R> g;

// T -> U . U -> R = T -> R
Function<T, R> h = f . g;
```

- Function composition is not commutative.

- $f \circ g \neq g \circ f$

Why Composition?

- Tackle complexity by composing behaviors.
- Compose larger functions from smaller ones.
- Smaller functions can be tested independently.
- If the parts are correct, we can then trust the correctness of the whole.
- Every part of the larger function can be reasoned about easily.

Composing Functions

- Using compose & andThen

```
Function<Integer, Integer> square = x -> x * x;
```

```
Function<Integer, Integer> twice = x -> 2 * x;
```

Read Left to Right →

```
square.compose(twice).apply(2); // 16
```

← Think Right to Left

Read Left to Right →

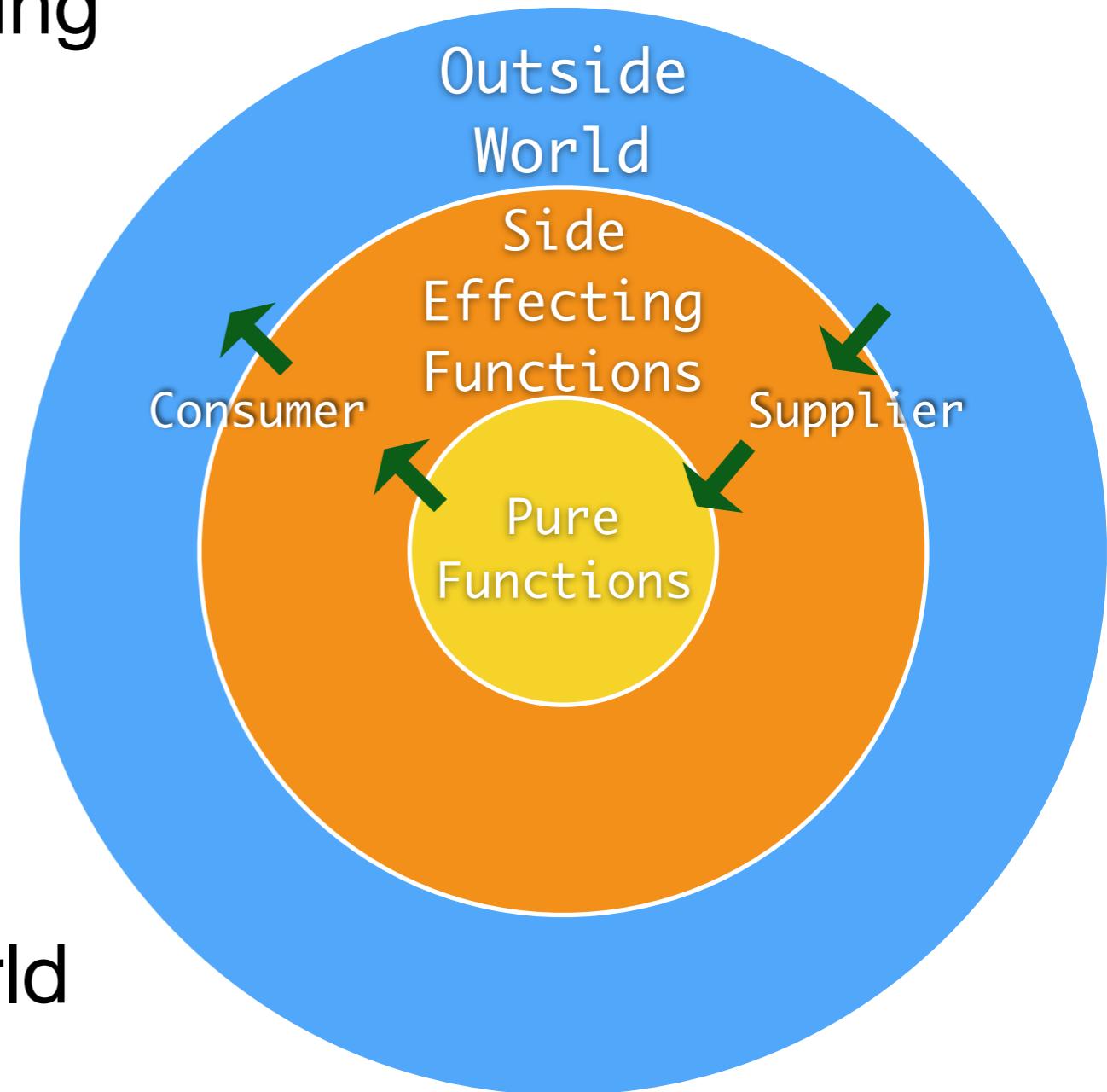
```
square.andThen(twice).apply(2); // 8
```

Think Left to Right →

- For languages that support function composition, look for a way to go with the grain of thought. In Java, prefer using andThen

Circle of Purity

- Compose behaviours using pure Functions.



- Data flows through composed pipes.
- Interact with outside world using Side-effecting functions.

Courtesy: Venkat

Reflections

- Enforce order of evaluation.
 - In imperative programming, statements enforce order of evaluation.
 - In FP, the order of composition determines the order of evaluation.
- Function composition (and not function application) is the default way to build sub-routines in Concatenative Programming Style, a.k.a Point Free Style.
- Functions neither contain argument types nor names, they are just laid out as computation pipeline.
- Lot of our domain code is just trying to do this!
- Makes code more succinct and readable.

Eager Evaluation

- Java uses eager evaluation for method arguments.
- Args evaluated before passing to the method.

```
public int first(int x, int y) {  
    System.out.println("Inside First...");  
    return x;  
}  
  
public int loop() {  
    System.out.println("Inside Loop...");  
    return loop();  
}  
  
System.out.println(first(10, 20));  
// Inside First...  
// 10  
System.out.println(first(10, loop())); // Stackoverflow  
System.out.println(first(loop(), 20)); // Stackoverflow
```

Lazy Evaluation

- Lazy means don't compute until there exists a demand.
- Haskell OTOH is lazy by default.
- Args not evaluated before passing to the method, instead evaluated upon use.

```
loop = loop

first x y = x

main :: IO ()
main = do
    print $ first 10 20    -- 10
    print $ first 10 loop -- 10
    print $ first loop 10 -- Infinite Loop
```

Lazy Evaluation

- Scala is eager by default like Java, and provides a “lazy” switch.

```
def loop: Int = loop

def first(x: Int, y: Int) = x

first(10, 20) // 10
first(loop, 20) // Non-termination
first(10, loop) // Non-termination

scala> lazy val x = loop
x: Int = <lazy>

scala> x // Non-termination
```

Simulating Lazy Evaluation

- To delay the evaluation of args (lazy), wrap them in lambda.
 - Call the lambda when we need to evaluate.
 - Immutability and Purity makes lazy evaluation possible.

```
public static int first(Supplier<Integer> x, Supplier<Integer> y) {  
    System.out.println("Inside First...");  
    return x.get();  
}
```

```
public static int loop() {  
    System.out.println("Inside Loop...");  
    return loop();  
}
```

```
System.out.println(first(10, 20)); // 10  
System.out.println(first(() -> 10, () -> loop())); // 10  
System.out.println(first(() -> loop(), () -> 20)); // Stackoverflow
```

Representation of computation and not the computation itself.

Imperative Filtering and Collecting

```
String sentence = "all mimsy were the borogoves and the momeraths";  
String [] words = sentence.split(" ");  
StringBuilder caps ← new StringBuilder();
```

```
for (var word : words) {  
    if (word.length() < 4) {  
        caps.append(word.toUpperCase());  
        caps.append(" ");  
    }  
}
```

Collector

Enumeration
and
Filtering
interleaved

```
String capitalized = caps.toString().trim();  
System.out.println(capitalized); // ALL THE AND THE
```

- One of the motivations of Streams is to make parallelism more accessible to developers.

Streams (Lazy List)

```
String sentence = "all mimsy were the borogoves and the momeraths";
String capitalized = Stream.of(sentence.split(" "))
    .filter(word -> word.length() < 4)
    .map(String::toUpperCase)
    .collect(Collectors.joining(" "));

System.out.println(capitalized);
```

- One Element at a time passes through the pipeline

```
String capitalized = Stream.of(sentence.split(" "))
    .peek(word -> System.out.println("Filter = " + word))
    .filter(word -> word.length() < 4)
    .peek(word -> System.out.println("Map = " + word))
    .map(String::toUpperCase)
    .collect(Collectors.joining(" "));

System.out.println(capitalized);
```

How can we improve this?

```
public static String capitalize(String s) {  
    try {  
        Thread.sleep(2000);  
    } catch (Exception e) {}  
    return s.toUpperCase();  
}  
  
String sentence = "all mimsy were the borogoves and the momeraths";  
long startTime = System.currentTimeMillis();  
String capitalized = Stream.of(sentence.split(" "))  
.filter(word -> word.length() < 4)  
.map(word -> capitalize(word))  
.collect(Collectors.joining(" "));  
long timeTaken = System.currentTimeMillis() - startTime;  
  
System.out.println(String.format("%s, Took %d(ms)", capitalized, timeTaken));  
// ALL THE AND THE, Took 8043(ms)
```

Parallelizing

- One of the motivations of Streams is to make parallelism more accessible to developers.

```
public static String capitalize(String s) {  
    try {  
        Thread.sleep(2000);  
    } catch (Exception e) {}  
    return s.toUpperCase();  
}  
  
String sentence = "all mimsy were the borogoves and the momeraths";  
long startTime = System.currentTimeMillis();  
String capitalized = Stream.of(sentence.split(" "))  
.parallel()  
.filter(word -> word.length() < 4)  
.map(word -> capitalize(word))  
.collect(Collectors.joining(" "));  
long timeTaken = System.currentTimeMillis() - startTime;  
  
System.out.println(String.format("%s, Took %d(ms)", capitalized, timeTaken));  
// ALL THE AND THE, Took 2027(ms)
```

Don't Parallelize everything

```
long startTime = System.currentTimeMillis();
long sum = Stream.iterate(0, x -> x + 1)
    .limit(10000)
    .filter(n -> n % 2 == 0)
    .reduce(0, (acc, elem) -> acc + elem);
long diff = System.currentTimeMillis() - startTime;
System.out.println(sum + " Took " + diff + "(ms)");
// 24995000 Took 36(ms)
```

- It takes time to create threads, scatter input and gather results.

```
long startTime = System.currentTimeMillis();
long sum = Stream.iterate(0, x -> x + 1)
    .limit(10000)
    .parallel()
    .filter(n -> n % 2 == 0)
    .reduce(0, (acc, elem) -> acc + elem);
long diff = System.currentTimeMillis() - startTime;
System.out.println(sum + " Took " + diff + "(ms)");
// 24995000 Took 56(ms)
```

Streams - Infinitely Lazy

- Streams are pull-based, consumer decides the pace of pull.
- With Streams, only essential space is allocated upon materialization, the rest is in ether :)
 - This reduces memory footprint (as you don't bring every item in memory).

```
Stream.iterate(22, x -> x + 1);
```

- Because of laziness `findFirst()` only runs till it finds the first matching element.

```
Stream.iterate(22, x -> x + 1)
    .filter(n -> n % 5 == 0)
    .findFirst()
    .ifPresent(System.out::println); // 25
```

De-structuring

- It is about extracting data from the innards of the Data-Structure.
- Gives us a short-hand way of naming parts of the data-structure.

```
val list = 1 :: 2 :: 3 :: 4 :: Nil  
val first :: second :: rest = list  
println(first) // 1  
println(second) // 2  
println(rest) // List(3, 4)
```

```
case class Name(first: String, last: String, salutation: String)  
  
val dd = Name("Dhaval", "Dalal", "Mr.")  
val Name(fName, lName, s) = dd  
println(fName) // Dhaval  
println(lName) // Dalal
```

Pattern Matching

- In Pattern Matching, we are not only matching on relative positions of elements in the data-structure, but also trying to dispatch to different definitions based on the value inside the data structure.
- This dispatch is a kind of conditional construct. So, it's about associating a definition with a particular set of i/ps.

```
val dd = Name("Dhaval", "Dalal", "Mr.")  
val nancy = Name("Nancy", "Drew", "Ms.")  
def greet(name: Name) = name match {  
    case Name("Nancy", "Drew", _) => s"Hello Ms. Drew"  
    case Name(f@"Dhaval", l, s) => s"Hey $f"  
    case name => s"Hi ${name.first.toUpperCase}"  
}  
  
println(greet(dd))                                // Hey Dhaval  
println(greet(nancy))                             // Hello Ms. Drew  
println(greet(Name("Peter", "Shmo", "Mr.")))     // Hi PETER
```

Implementing Recursion Using Pattern Matching In Erlang

```
sum(Acc, []) -> Acc;
sum(Acc, [X|XS]) -> sum(Acc + X, XS).

sum(List) -> sum(0, List).

main(_) ->
    io:format("~p~n", [sum([])]),
    io:format("~p~n", [sum([1, 2, 3, 4])]).
```

Currying

- Refers to the phenomena of rewriting a N-arg function to a nest of functions, each taking only 1-arg at a time

```
// (String, Integer) -> String
String merge(String x, Integer y) {
    return x + y.toString();
}

// String -> (Integer -> String)
Function<Integer, String> merge(String x) {
    return y -> x + y.toString();
}

// () -> (String -> (Integer -> String))
Function<String, Function<Integer, String>> merge() {
    return x -> y -> x + y.toString();
}

// (String -> (Integer -> String))
Function<String, Function<Integer, String>> merge = x -> y -> x + y.toString();
System.out.println(merge("Test#", 1)); // Test#1
System.out.println(merge("Test#").apply(2)); // Test#2
System.out.println(merge().apply("Test#").apply(3)); // Test#3
System.out.println(merge().apply("Test#").apply(4)); // Test#4
```

Currying

$$f: (T, U, V) \mapsto R$$

For each arg, there is another nested function, that takes a arg and returns a function taking the subsequent arg, until all the args are exhausted.



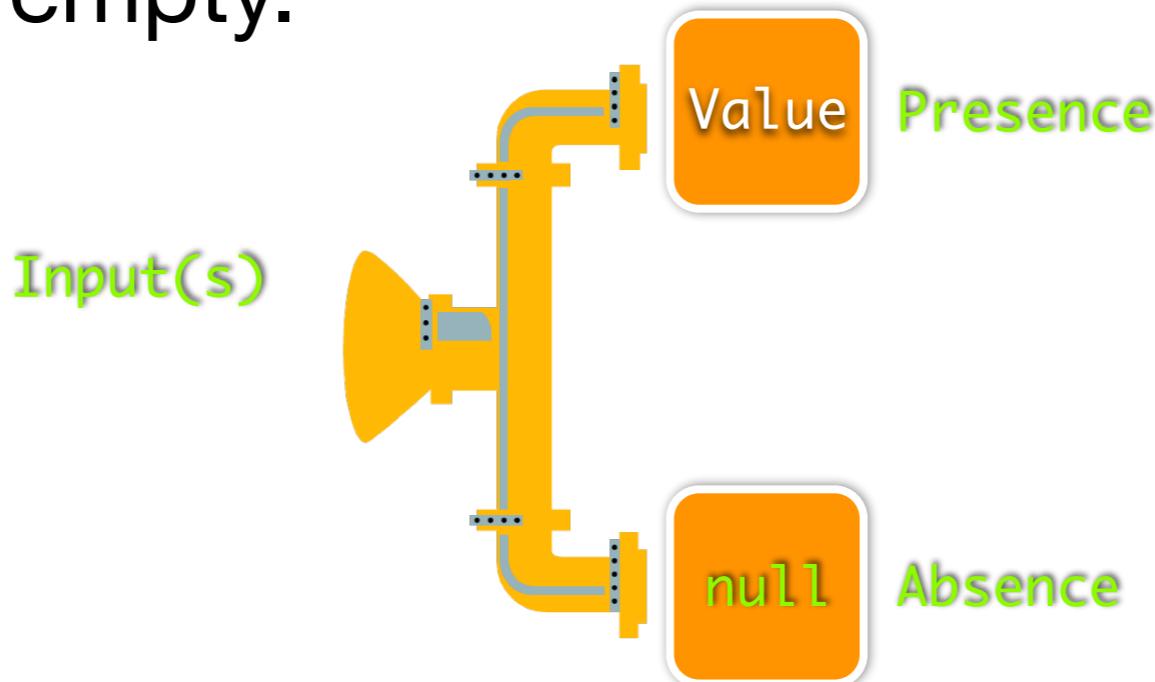
$$f': T \mapsto U \mapsto V \mapsto R$$

$$f = f'$$

Make Absence Explicit

Optional<T>

- Stop null abuse!
 - Don't return null, use Optional<T> so that it explicitly tells that in the type.
 - A container or view it as a collection containing single value or is empty.



Before

```
String frequentFlyerId = "123456789";
UserRepository userRepository = new UserRepository();
User user = userRepository.findBy(frequentFlyerId);
String targetPage = null;
int miles = 7000;
if (user != null) {
    int newPoints = user.addPointsUsing(miles);
    targetPage = "http://tierPage";
} else {
    targetPage = "http://loginPage";
}
System.out.println(targetPage);
```

After

```
String frequentFlyerId = "123456789";
int miles = 7000;
UserRepository userRepository = new UserRepository();
String targetPage = userRepository.findBy(frequentFlyerId)
    .map(user -> {
        int newPoints = user.addPointsUsing(miles);
        return "http://tierPage";
    })
    .orElse("http://loginPage");

System.out.println(targetPage);
```

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Thank - You!

<https://github.com/DhavalDalal/FunctionalConference-2019-Booting-Into-FP-Demo>