Creating Reusable Functions with Partial Application and Currying

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Closure

The ability of a method to reference a variable or another method in its enclosing context.

Closure Example

```
Integer a = 2;

Function<Integer, Integer> f = new Function<Integer, Integer>() {
        @Override
        public Integer apply(Integer x) {
                return x * a;
        }
};
```

Effectively final

A variable is not explicitly marked as final, but its initial value is never changed.

Closure Example

```
Integer a = 2;

Function<Integer, Integer> f = x -> x * a;

// Equivalent to f(x) = x * 2?
```

Closure Example

```
Integer a = Integer.parseInt(args[0]);

Function<Integer, Integer> f = x -> x * a;

// Equivalent to f(x) = x * 2?
```

Correct Way to Express the Function

$$f(x, a) = x * a$$

Reusing Is Harder

```
Integer a = Integer.parseInt(args[0]);

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

Should We Implement This?

```
f(x, a) = x * a
```

Function Interface

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

BiFunction Interface

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

BinaryOperator Interface

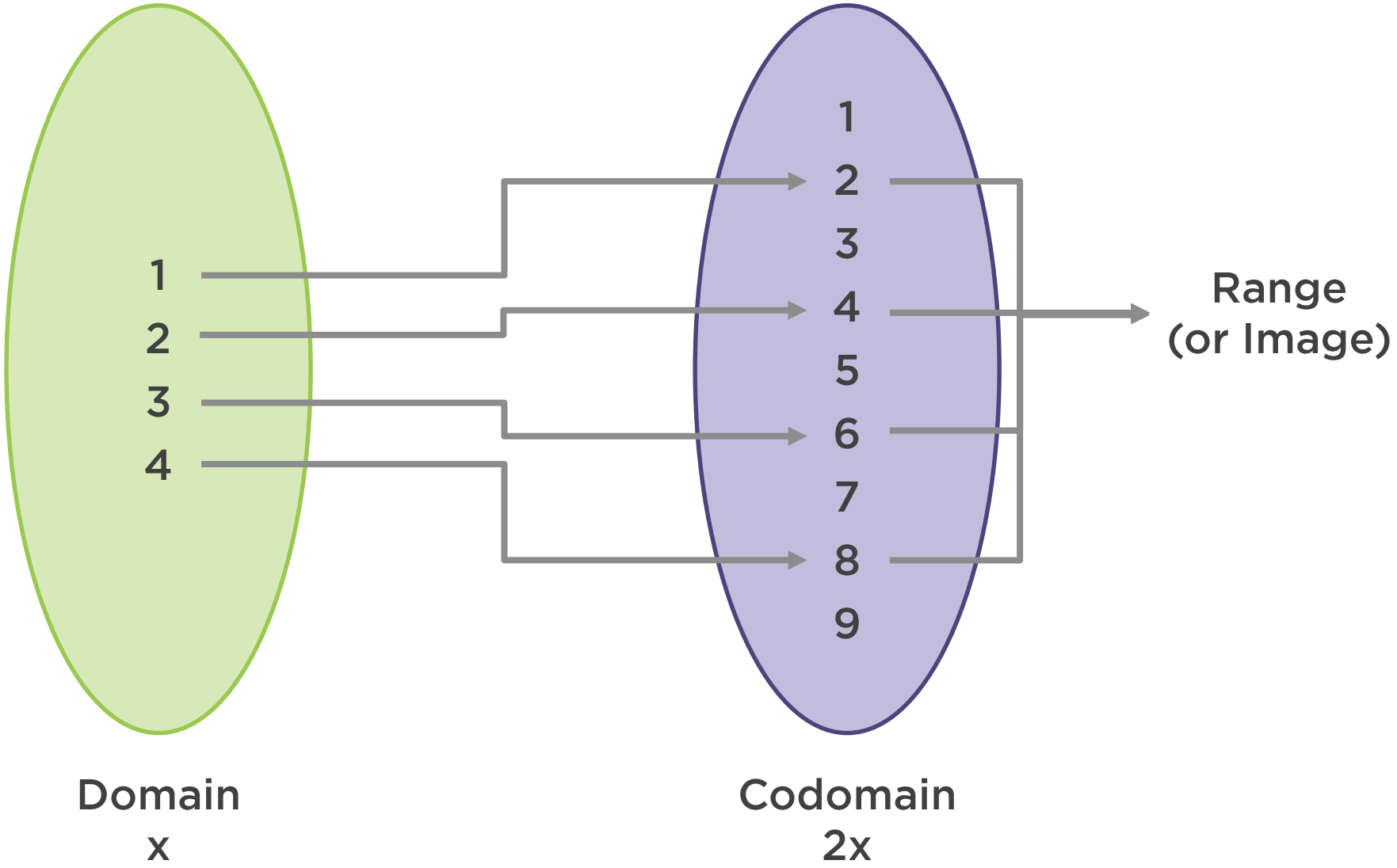
```
@FunctionalInterface
public interface BinaryOperator<T> extends BiFunction<T,T,T> {
}
```

Implement a QuaterFunction?

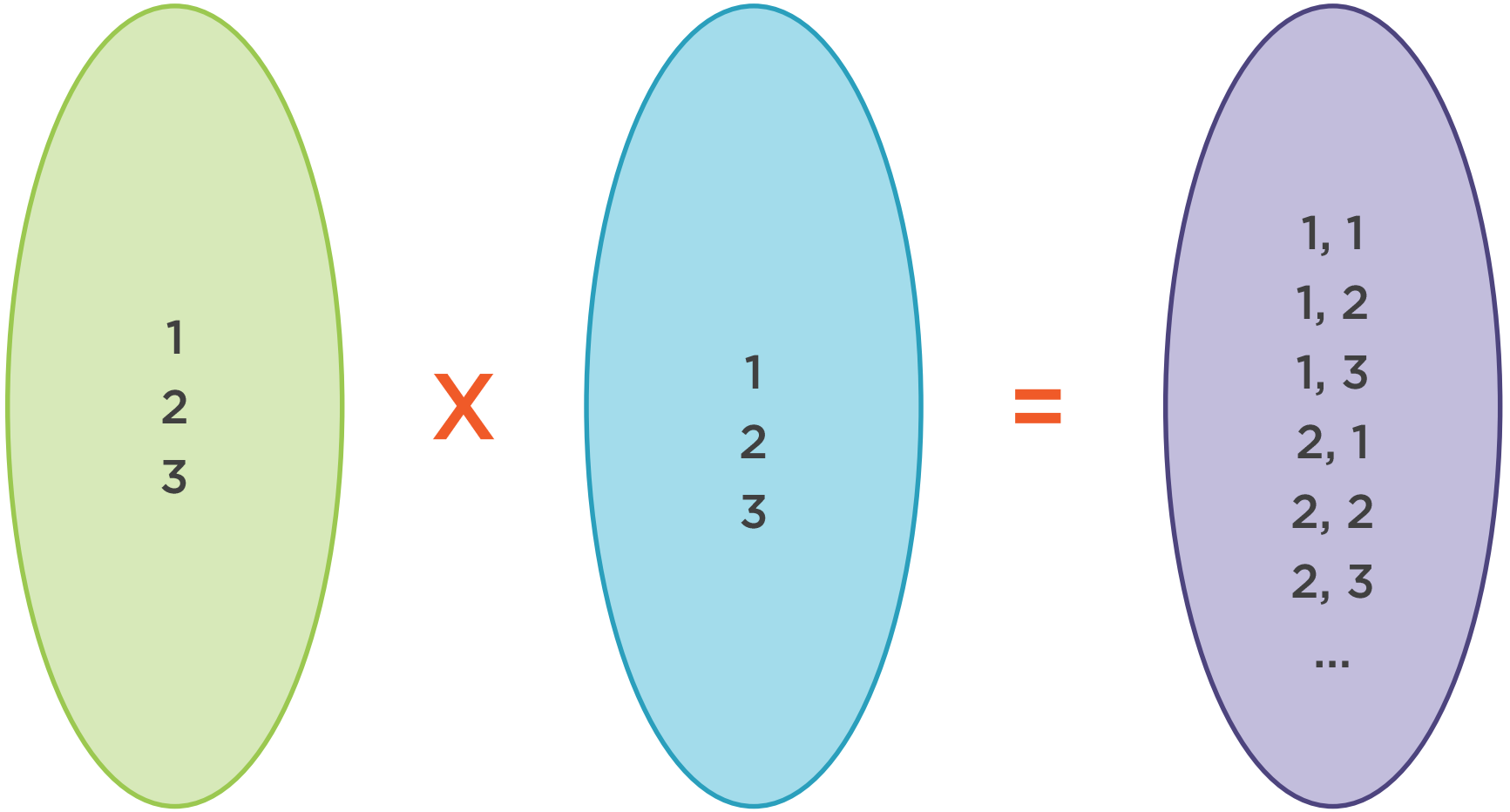
```
@FunctionalInterface
public interface QuaterFunction<T, U, V, W, R> {
    R apply(T t, U u, V v, W w);
}
```

Thinking About Functions of Multiple Arguments

Mathematical Functions



Product of Two Sets



$$f(a, b) = a + b$$

Domain

$$A \times B$$

Tuples

(1, 2, 3, 4, ...)

$$f(a, b) = a + b$$

```
f((1, 2)) = a + b
```

```
f((1, 2)) = 1 + 2
```

$$f(1, 2) = 1 + 2$$

Implementation of a Tuple

```
class Tuple<T, U> {
    public final T _1;
    public final U _2;

    public Tuple(T _1, U _2) {
        this._1 = _1;
        this._2 = _2;
    }
}
```

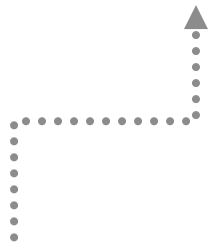
```
Function< Tuple< Integer, Integer >, Integer > f =
                                    tuple -> tuple._1 + tuple._2;

Integer i = f.apply( new Tuple<>(2, 1) ); // 3
```

Currying

Converting a function of multiple arguments to a function of one argument each step at a time.

$$f(a, b) = a + b$$

$$f(a) = g(b) = a + b$$



The range of f consists of functions

$$f(1) = g(b) = 1 + b$$

$$f(1) = g(2) = 1 + 2$$

In Java

```
int i = add( 1, 2 )
```

With currying,
the arguments of
a function are evaluated
at different times.

Partial application

Supplying fewer arguments than the ones required by the function.

```
add( 1, 2, 3, 4, 5 )
     ‾‾‾‾‾‾
      add3( 3, 4, 5 )
            ‾‾‾
       add6( 4, 5 )
```

```
add( 1, 2, 3, 4, 5 )
     ↳
  add1( 2, 3, 4, 5 )
        ↳
    add3( 3, 4, 5 )
```

All currying is partial application, but not all partial application is currying.

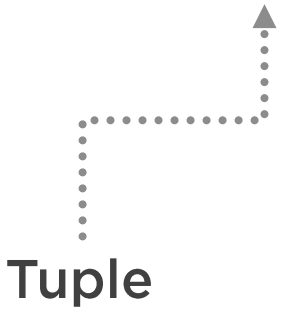
Using Currying in Java

In Mathematics

$$f(a, b) = a + b$$

In Mathematics

$$f((a, b)) = a + b$$



Curried Version

```
f(a)(b) = g(b)
```

```
g(b) = a + b
```

```
Integer -> (Integer -> Integer)
```

<Integer, <Integer, Integer>>

Curried Function in Java

```
Function<Integer, Function<Integer, Integer>>
```

Curried Function in Java

```
Function<Integer, Function<Integer, Integer>> add =
                                        a -> b -> a + b;
```

Curried Function in Java

```
Function<Integer, Function<Integer, Integer>> add =
  new Function<Integer, Function<Integer, Integer>>() {
      return new Function<Integer, Integer> apply(Integer a) {
            @Override
            public Integer apply(Integer b) {
              return a + b;
            }
        };
  }
```

Curried Function in Java

```
Function<Integer, Function<Integer, Integer>> add =
                                        a -> b -> a + b;
```

Apply a Curried Function in Java

```
Integer i = add.apply(1).apply(2); // 3
```

Curried Function Syntax in Java

```
Function<Integer, Function<Integer, Integer>> add =
                                        a -> b -> a + b;
```

Curried Function Syntax in Java

```
Function<
```

Curried Function Syntax in Java

```
Function<Integer,
```

Curried Function Syntax in Java

```
Function<Integer, Function<Integer, Integer>> add =
                                        a -> b -> a + b;
```

The Importance of the Order of Arguments

Order Doesn't Matter Here

$$f(x, y) = x + y$$

$$f(y, x) = x + y$$

But What About Curried Functions?

```
f(x)(y) = x + y
```

```
f(y)(x) = x + y
```

In curried functions,
the order does matter.

Things to Remember

Closures

- Using them as if they were implicit parameters of a function is not recommended

There are no functions with several arguments

Functions that appear to have several arguments are either:

- Functions of tuples
- Functions returning functions

Things to Remember

Currying

- Converting a function with many arguments into a series of one-argument functions

Partial application

- Supplying fewer arguments than the ones required by the function

Things to Remember

Function: (A, B, C) -> D

Curried function: A -> B -> C -> D

```
Function<A,
        Function<B,
                 Function<C,
                          Integer
                 >
        >
>
```

Things to Remember

Argument order

- From the most specific to the least specific

In the Next Module

Abstract control structures