# Strictness and Laziness

06016415 Functional Programming

พระจอมเกล้าลาดกระบัง

## Outline

- Evaluation Strategies
  - Strict / Non-strict Evaluation
- Lambda Calculus Example
- Strict and Non-strict Functions

- In programming language, an **evaluation strategy** is a set of rules for evaluating expressions.

- Example

**(1-x)(1+x)**

when x is very close to 1 might be better evaluated as 1-2x-x*x.

$$\boldsymbol{f(x) = \frac{a(x)}{b(x)}}$$

Our lazy value is a(x), and this is the point of a lazy variable.

Where evaluation strategies are important, say in numerical computation, we need to know a lot about how the compiler works.

- **Strict evaluation** means to evaluate all the arguments to a function before evaluating the function.
  - *When we compute a function we usually assume that all arguments have a value before the function evaluation begins*

- **Non-strict evaluation** arguments need not be evaluated until they are actually required. **(call-by-need)**
  - ***Lazy evaluation*** *is a form of non-strict evaluation in which arguments are not evaluated until required.*

## Table of evaluation strategies

| Evaluation strategy | Representative Languages | Year first introduced |
|---|---|---|
| Call by value | ALGOL, C, Scheme, MATLAB | 1960 |
| Call by name | ALGOL 60, Simula | 1960 |
| Call by unification | Prolog | 1965 |
| Call by need | SASL, Haskell, R | 1971 |
| Call by sharing | CLU, Java, Python, Ruby, Julia | 1974 |
| Call by reference parameters | C++, PHP, C#, Visual Basic .NET | 1985 |
| Call by reference to const | C++, C | 1985 |

Scott, Michael Lee (2016). *Programming language pragmatics* (Fourth ed.). Waltham, MA: Elsevier.

# Laziness in the real world

*Find odd numbers of an array of numbers from 1 to 6.*

## Lambda Calculus Example

- In the λ-calculus, all reduction orders that terminate give the same result.
- Changing the evaluation strategy only changes whether the program terminates, not the final result of the computation.

```
(define X 2)
(define Y 3)
```

```
(if test-expr then-expr else-expr)
```

```
(if (< X Y)
        (+ X X)
        (* Y Y)
    )
```

```
(list (< X Y)
        (print "true")
        (print "false")
      )
```

```
(or (and condition consequent) alternate)
```

```
(or (and (< X Y)
         (+ X X)
    )
    (* Y Y)
)
```

```
(or (and (< X Y)
         (print "true")
    )
    (print "false")
)
```

- ***Nonstrictness*** is a property of a function. To say that a function is nonstrict just means the function may choose not to evaluate one or more of its arguments. In contrast, a *strict* function always evaluates its arguments.

- **Strict functions** are the norm in most programming languages, and indeed, most languages only support functions that expect their arguments fully evaluated.

```
def square(x: Double): Double = x * x
```

# A nonstrict if function

```scala
def if1[A](cond: Boolean, onTrue: () => A, onFalse: () => A): A =
  if cond then onTrue() else onFalse()

def if2[A](cond: Boolean, onTrue: => A, onFalse: => A): A =
  if (cond) onTrue else onFalse
```

The **onTrue** and **onFalse** arguments use some new syntax we have not encountered yet: the type () => A. A value of type () => A is a function that accepts zero arguments and returns an A.

```
scala> if2(false, sys.error("fail"), 3)
val res0: Int = 3

scala> if2(true, sys.error("fail"), 3)
java.lang.RuntimeException: fail
  at scala.sys.package$.error(package.scala:27)
  at rs$line$3$.$init$$$anonfun$1(rs$line$3:1)
  at Main$package$.if2(Main.scala:11)
  ... 62 elided
```

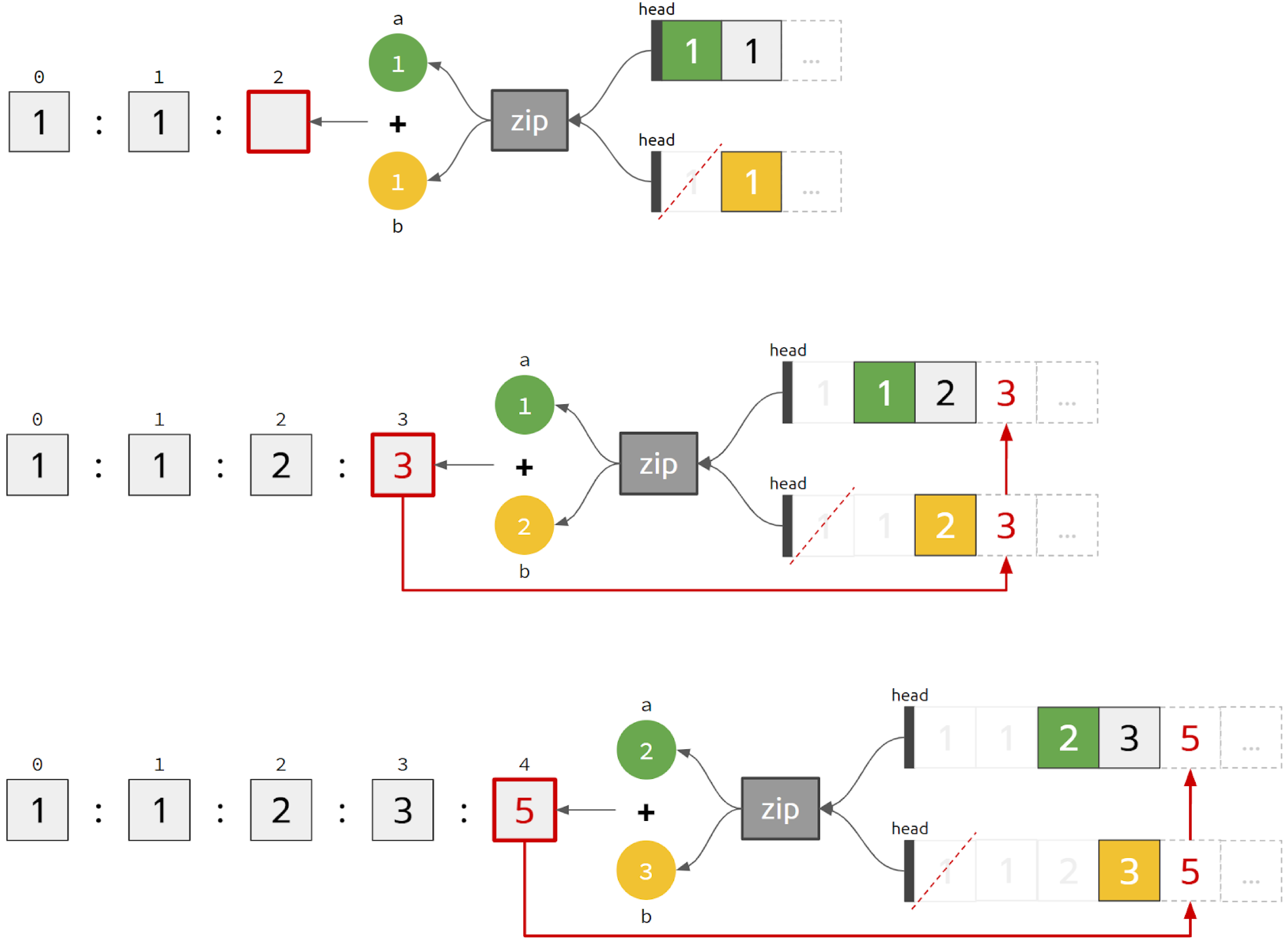
```
scala> if2(true, 1 , 3)
val res2: Int = 1

scala> if1(true, 1 , 3)
-- [E007] Type Mismatch Error: -------------------------------------------------
1 |if1(true, 1 , 3)
  |          ^
  |          Found:    (1 : Int)
  |          Required: () => Any
  |
  | longer explanation available when compiling with `-explain`
-- [E007] Type Mismatch Error: -------------------------------------------------
1 |if1(true, 1 , 3)
1 |if1(true, 1 , 3)
  |          ^
  |          Found:    (1 : Int)
  |          Required: () => Any
  |
  | longer explanation available when compiling with `-explain`
-- [E007] Type Mismatch Error: -------------------------------------------------
1 |if1(true, 1 , 3)
  |              ^
  |              Found:    (3 : Int)
  |              Required: () => Any
  |
  | longer explanation available when compiling with `-explain`
2 errors found
```

```
scala> List(1,2,3,4).map(_ + 10).filter(_ % 2 == 0).map(_ * 3)
val res0: List[Int] = List(36, 42)

scala> List(1,2,3,4).map(_ + 10)
val res1: List[Int] = List(11, 12, 13, 14)

scala> List(1,2,3,4).map(_ + 10).filter(_ % 2 == 0)
val res2: List[Int] = List(12, 14)

scala> List(1,2,3,4).map(_ + 10).filter(_ % 2 == 0).map(_ * 3)
val res3: List[Int] = List(36, 42)
```

Like many of the other data structures we've seen so far,
LazyList exists in the Scala standard library (see the API at https://mng.bz/M00D ).

```
import scala.math.BigInt
val fibs: LazyList[BigInt] = BigInt(0) #:: BigInt(1) #:: fibs.zip(fibs.tail).map{ n => n._1 + n._2 }
```

```
scala> fibs.take(1).foreach(println)
0

scala> fibs.take(5).foreach(println)
0
1
1
2
3
```



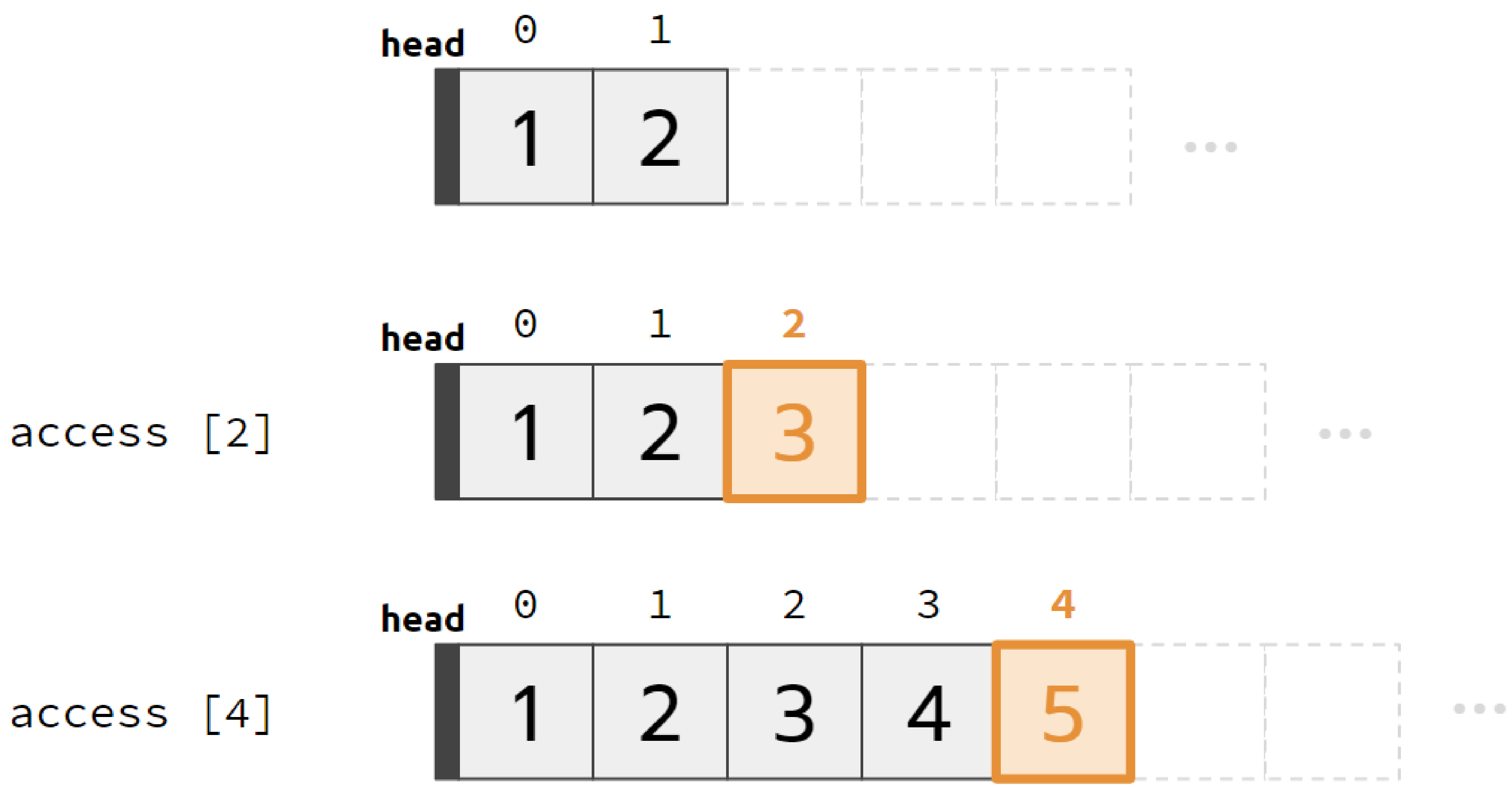
0 1 2
1 : 1 :
a
1
+
1
b
zip
head
1 1 ...
head
1 1 ...
0 1 2 3
1 : 1 : 2 : 3
a
1
+
2
b
zip
head
1 1 2 3 ...
head
1 1 2 3 ...
0 1 2 3 4
1 : 1 : 2 : 3 : 5
a
2
+
3
b
zip
head
1 1 2 3 5 ...
head
1 1 2 3 5 ...

evenNumbers = [1,2..1000]

evenNumbers = [1,2..]


static

lazy




- **LazyLists** are similar to lists, but their elements are evaluated only on demand.
- It is **"lazy"** because it computes its elements only when they are needed.