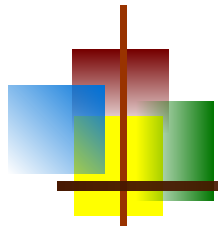


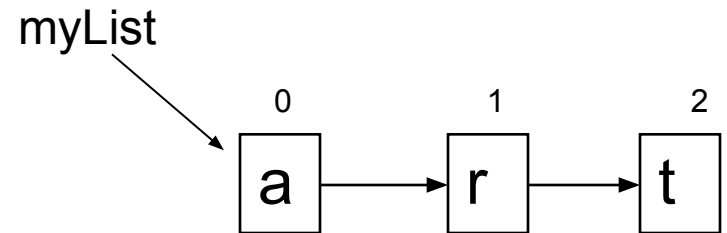
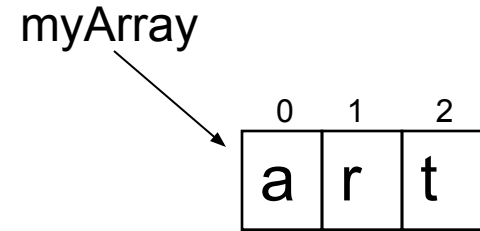
Lists

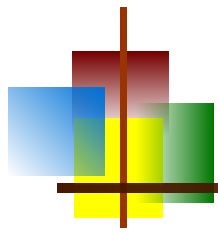




Arrays and Lists

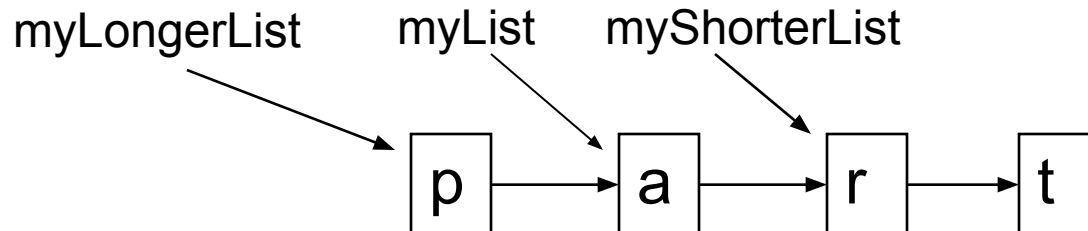
- Arrays are a fixed length and occupy sequential locations in memory
 - This makes random access (for example, getting the 37th element) very fast-- $O(1)$
- Lists are composed of values linked together
 - All access starts from the head (first element) and follows links
 - Random access takes linear time





Lists are immutable

- Lists, like Strings, are immutable
- Because all access is via the head, creating a “new” list is a fast operation



- myLongerList looks like List("p", "a", "r", "t"); the "p" is not visible from myList
- myShorterList looks like List("r", "t")
- myList has not been changed--it is *immutable*



List operations

- Basic *fast* (constant time) operations
 - *list.head* (or *list head*) returns the first element in the list
 - *list.tail* (or *list tail*) returns a list with the first element removed
 - *value :: list* returns a list with *value* appended to the front
 - *list.isEmpty* (or *list isEmpty*) tests whether the list is empty
- Some *slow* (linear time) operations
 - *list(i)* returns the i^{th} element (starting from 0) of the list
 - *list.last* (or *list last*) returns the last element in the list
 - *list.init* (or *list init*) returns a list with the last element removed
 - This involves making a complete copy of the list
 - *list.length* (or *list length*) returns the number of elements in the list
 - *list.reverse* (or *list reverse*) returns a new list with the elements in reverse order
- In practice, the slow operations are hardly ever needed



Stepping through a list

- ```
def printList1(myList: List[Any]) {
 for (i <- 0 until myList.length) {
 println(myList(i))
 }
}
```

  - What is the time complexity of this method?
- ```
def printList2(myList: List[Any]) {  
  if(! myList.isEmpty) { // the dot is required here  
    println(myList head)  
    printList2(myList tail)  
  }  
}
```

 - What is the time complexity of this method?

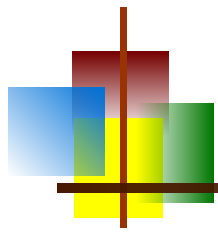


List construction with :: and Nil

- Lists are homogeneous: All elements have the same type
 - However,

```
scala> "abc" :: List(1, 2, 3)
res15: List[Any] = List(abc, 1, 2, 3)
```

 - The newly-created list has a type which is the least upper bound
- An empty list has “nothing” in it
 - ```
scala> List()
res16: List[Nothing] = List()
```
- The “name” of the empty list is Nil
  - ```
scala> Nil
res17: scala.collection.immutable.Nil.type = List()
```
- Lists are built from Nil and the :: operator (which is **right-associative**)
 - ```
scala> 1 :: 2 :: 3 :: Nil
res18: List[Int] = List(1, 2, 3)
```
  - ```
scala> 1 :: (2 :: (3 :: Nil))
res19: List[Int] = List(1, 2, 3)
```



Basic recursion

- Recursion is when a method calls itself
- Here's the basic formula for working with a list:
 - if the list is empty
 return some initial value (often an empty list)
 - else
 process the head
 recur with the tail
- ```
def printList2(myList: List[Any]) {
 if(! myList.isEmpty) {
 println(myList head)
 printList2(myList tail)
 }
}
```



# Again, with pattern matching

---

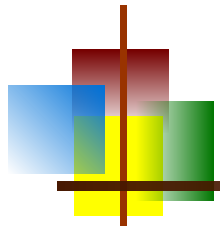
- Here's our same method again:

- ```
def printList2(myList: List[Any]) {  
  if(! myList.isEmpty) {  
    println(myList head)  
    printList2(myList tail)  
  }  
}
```

- Here it is with pattern matching:

- ```
def printList3(myList: List[Any]) {
 myList match {
 case h :: t =>
 println(myList head)
 printList3(myList tail)
 case _ =>
 }
}
```

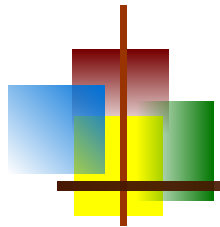




# map

---

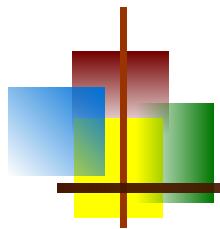
- `map` applies a one-parameter function to every element of a List, returning a new List
  - `scala> List(1, 2, 3, 4) map (n => 10 * n)`  
`res0: List[Int] = List(10, 20, 30, 40)`
- The result list doesn't have to be of the same type
  - `scala> List(1, 2, 3, 4) map (n => n % 2 == 0)`  
`res1: List[Boolean] = List(false, true, false, true)`
- Since an element of the list is the only parameter to the function, and it's only used once, you can abbreviate the function
  - `scala> List(1, 2, 3, 4) map (10 * _ + 6)`  
`res2: List[Int] = List(16, 26, 36, 46)`
- Of course, you don't have to use a literal function; you can use any previously defined function (yours or Scala's)
  - `scala> List(-1, 2, -3, 4) map (_ abs)`  
`res3: List[Int] = List(1, 2, 3, 4)`



# flatMap

---

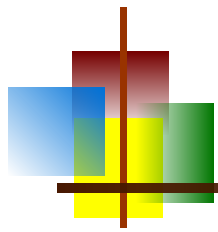
- **flatten** “flattens” a list (removes one level of nesting)
  - `scala> val nested = List(List(1, 2, 3), List(4, 5))`  
`nested: List[List[Int]] = List(List(1, 2, 3), List(4, 5))`
  - `scala> nested flatten`  
`res0: List[Int] = List(1, 2, 3, 4, 5)`
- **flatMap** is like **map**, but the function given to **flatMap** is expected to return a list of values; the resultant list of lists is then “flattened”
- Syntax:
  - `def map[B](f: (A) => B): List[B]`
  - `def flatMap[B](f: (A) => Traversable[B]): List[B]`
- Example:
  - `scala> val greeting = List("Hello".toList, "from".toList, "Scala".toList)`  
`greeting: List[List[Char]] = List(List(H, e, l, l, o), List(f, r, o, m), List(S, c, a, l, a))`
  - `scala> greeting map (word => word.toList)`  
`res2: List[List[Char]] = List(List(H, e, l, l, o), List(f, r, o, m), List(S, c, a, l, a))`
  - `scala> greeting flatMap (word => word.toList)`  
`res3: List[Char] = List(H, e, l, l, o, f, r, o, m, S, c, a, l, a)`



# filter

---

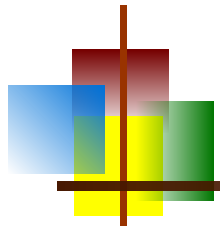
- **filter** is used to remove unwanted elements from a list, returning a new list
  - `scala> List(1, -2, 3, -4) filter (_ > 0)`  
`res3: List[Int] = List(1, 3)`
- There is a corresponding (less often used) **filterNot** method
  - `scala> List(1, -2, 3, -4) filterNot (_ > 0)`  
`res4: List[Int] = List(-2, -4)`



# foldl, foldr

---

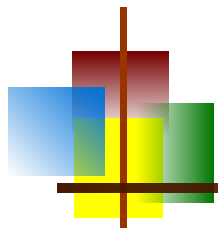
- The “fold” functions apply a binary operator to the values in a list, pairwise, starting from the left or starting from the right
  - `scala> val list = List(10, 1, 2, 3)`  
`list: List[Int] = List(10, 1, 2, 3)`
  - `scala> list.foldLeft(0)(_ - _)`  
`res3: Int = -16`
  - `scala> list.foldRight(0)(_ - _)`  
`res4: Int = 8`
  - `scala> (((0 - 10) - 1) - 2) - 3)`  
`res6: Int = -16`
  - `scala> (10 - (1 - (2 - (3 - 0))))`  
`res8: Int = 8`



# for

---

- Scala's **for comprehension** can be used like Java's **for** loop
  - `scala> for (ch <- "abcde") print(ch + "*")`  
`a*b*c*d*e*`
- The `ch <- "abcde"` is a **generator**; you can have more than one
  - `scala> for { x <- 1 to 5`  
          |      `y <- 10 to 30 by 10 } print((x + y) + " ")`  
`11 21 31 12 22 32 13 23 33 14 24 34 15 25 35`
  - The above needs braces, `{ }`, not parentheses, `( )`
- You can have **definitions** (not the same as declarations):
  - `scala> for (i <- 1 to 10;`  
          |      `j = 100) print ((i + j) + " ")`  
`101 102 103 104 105 106 107 108 109 110`
  - `j = 100` is a definition
  - In this example, the semicolon preceding the definition is required
- You can also have **guards**:
  - `scala> for (i <- 1 to 10`  
          |      `if i != 7) print(i + " ")`  
`1 2 3 4 5 6 8 9 10`



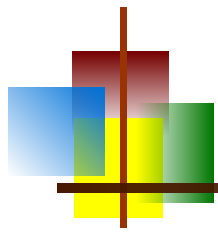
# Another for example

---

- You need to start with a generator, and after that you can have more generators, definitions, and guards

```
scala> for { i <- 1 to 5 if i % 2 == 0
 | k = 100
 | j <- 1 to 5
 | if j * k < 450 } print((k + 10 * i + j) + " ")
```

```
121 122 123 124 141 142 143 144
```



# for-yield

---

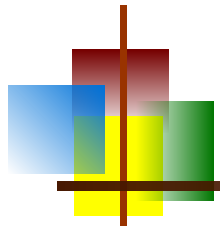
- The value of a **for** comprehension, without a **yield**, is **()**
- With a **yield**, the value is a list of results (one result for each time through the loop)
- The syntax is: **for** (*sequence*) **yield** *expression*
- Examples:
  - `scala> for (i <- 1 to 5) yield 10 * i`  
`res12: scala.collection.immutable.IndexedSeq[Int] = Vector(10, 20, 30, 40, 50)`
  - `scala> for (n <- List("one", "two", "three")) yield n.substring(0, 2)`  
`res2: List[java.lang.String] = List(on, tw, th)`



# Another for-yield example

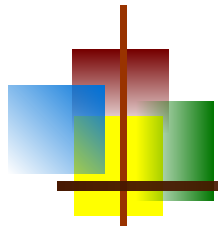
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- Here's a more complete example (Odersky, p. 125):
  - ```
val forLineLengths =  
  for {  
    file <- filesHere // 'filesHere' is an array of files  
    if file.getName.endsWith(".scala")  
    line <- fileLines(file) // get an Iterator[String]  
    trimmed = line.trim  
    if trimmed.matches(".*for.*")  
  } yield trimmed.length // get an Array[Int]
```
 - The above method:
 - gets each file from an array of files
 - considers only the file with the .scala extension
 - gets an iterator for the lines in the file
 - removes whitespace from the beginning and end of the line
 - looks for “for” within the line (using a regular expression)
 - counts the number of characters in the line
 - returns an array of line lengths of lines containing “for” in scala files



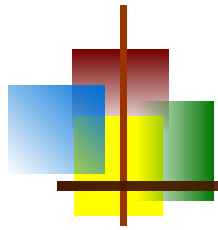
toList

- `scala> Array(1, 2, 3, 4) toList`
`res12: List[Int] = List(1, 2, 3, 4)`
- `scala> "abc" toList`
`res13: List[Char] = List(a, b, c)`
- `scala> Map("apple" -> "red", "banana" -> "yellow") toList`
`res14: List[(java.lang.String, java.lang.String)] = List((apple,red), (banana,yellow))`
- `scala> Set("abc", 123) toList`
`res16: List[Any] = List(abc, 123)`
- `scala> List(1, 2, 3) toList`
`res17: List[Int] = List(1, 2, 3)`
- Also: `toArray`, `toString`, `toSet`, `toMap`



Pattern matching

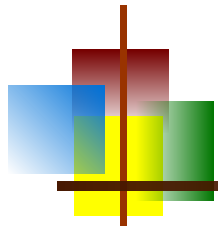
- Given this definition:
 - `scala> val myList = List("a", "b", "c")`
`myList: List[java.lang.String] = List(a, b, c)`
- This works:
 - `scala> val List(x, y, z) = myList`
`x: java.lang.String = a`
`y: java.lang.String = b`
`z: java.lang.String = c`
- But it's pretty useless unless you know the exact number of items in the list
- Here's a better way:
 - `scala> val hd :: tl = myList`
`hd: java.lang.String = a`
`tl: List[java.lang.String] = List(b, c)`



Example program

```
object EnglishToGerman {  
  
  def main(args: Array[String]) {  
    println(translate("Scala is a wonderful language !"))  
  }  
  
  def translate(english: String) = {  
    val dictionary = Map("a" -> "ein", "is" -> "ist",  
      "language" -> "Sprache", "wonderful" -> "wunderbar")  
    def lookup(word: String) = {  
      if (dictionary contains word) dictionary(word) else word  
    }  
    (english.split(" ") map (lookup(_))).mkString(" ")  
  }  
}
```

Output: Scala ist ein wunderbar Sprache !



The End
