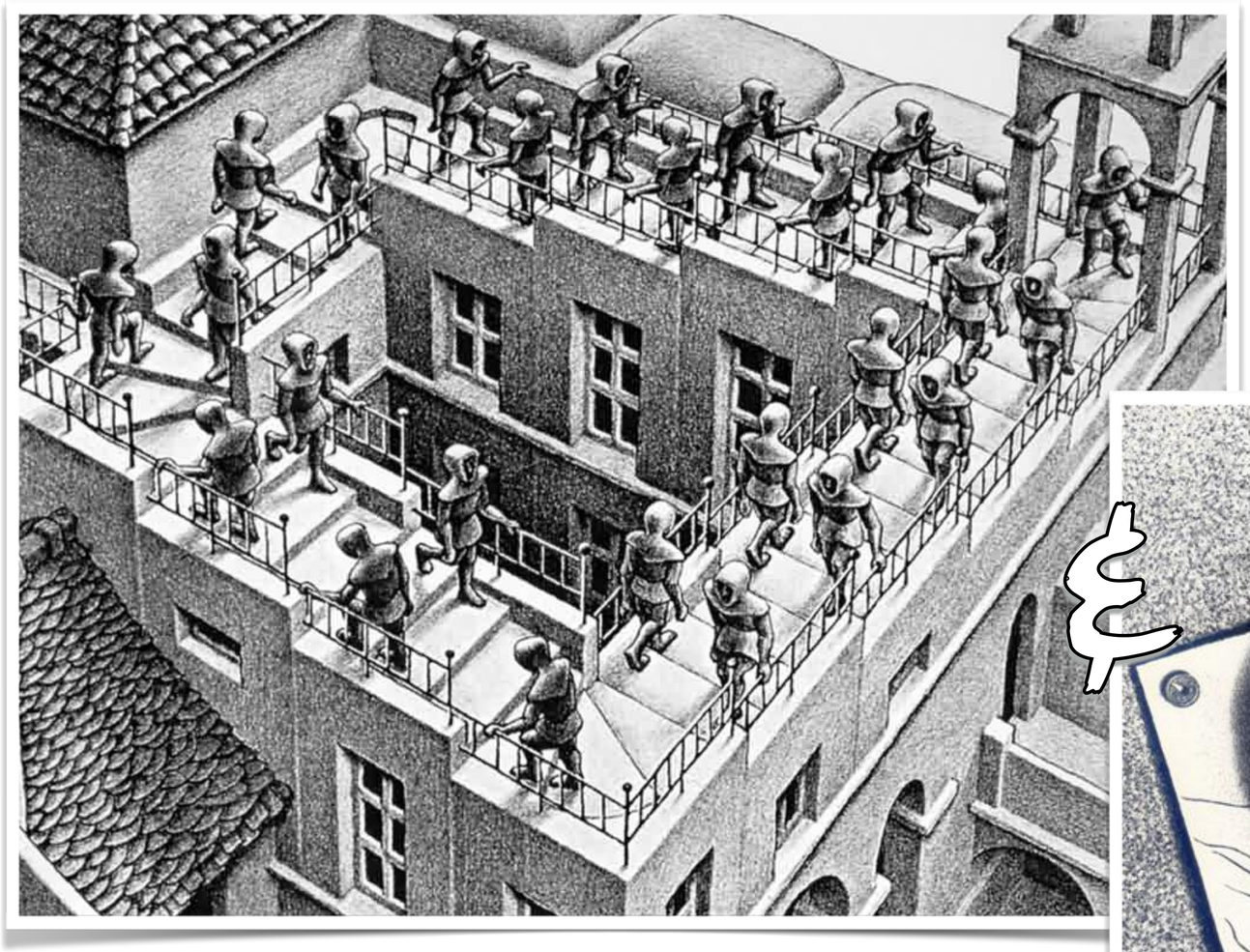
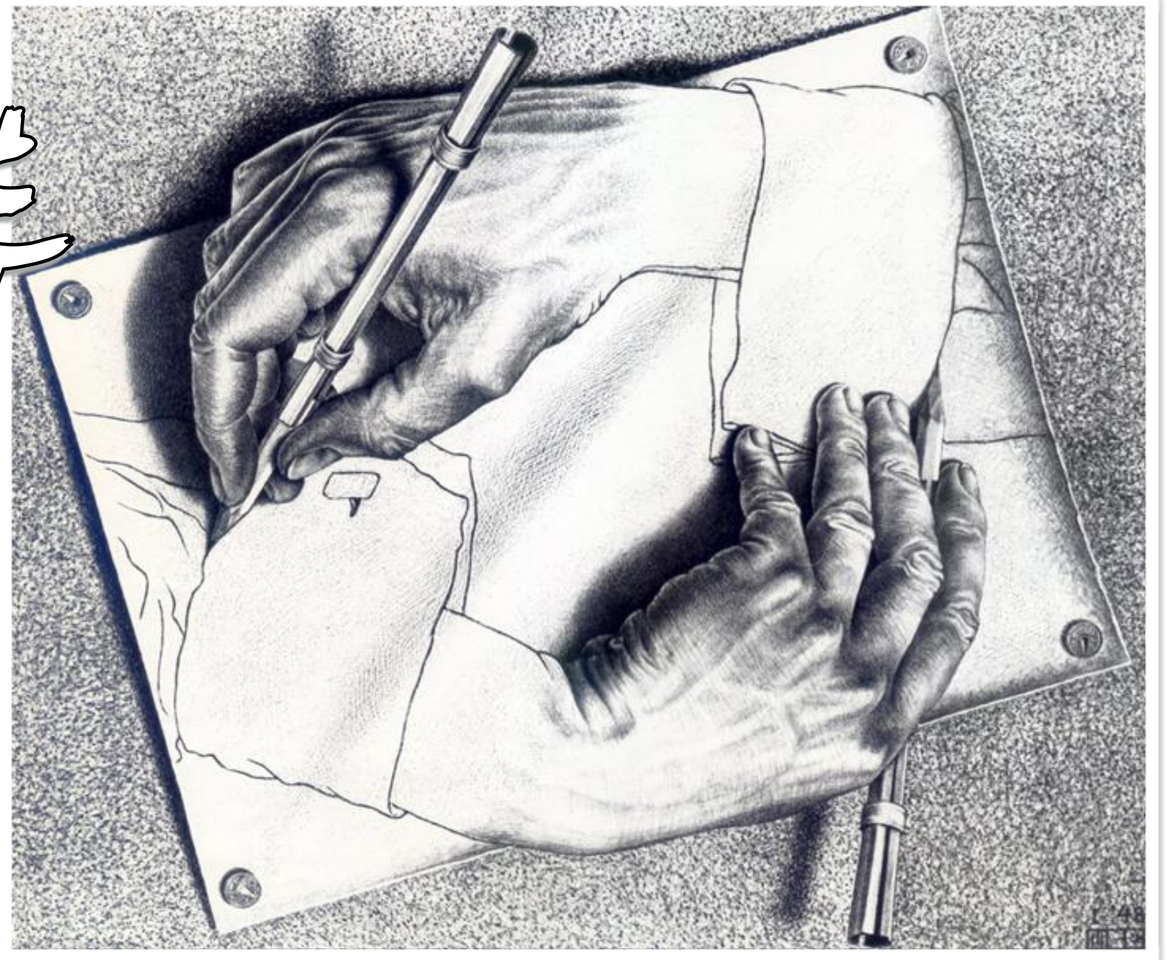
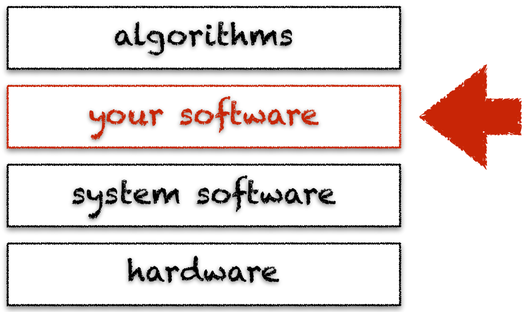


iteration



recursion

learning objectives



- learn about tuples, lists and maps
- learn about immutability and literals
- learn about iteration and recursion

notion of tuple

a tuple is finite ordered set of elements

```python
location = ("Museum of Mankind", 48.861166, 2.286826, 57)
```

```scala
var location = ("Museum of Mankind", 48.861166, 2.286826, 57)
```

```java
Object[] location = {"Museum of Mankind", 48.861166, 2.286826, 57};
```

an array, really

```swift
var location = ("Museum of Mankind", 48.861166, 2.286826, 57)
```

a n-tuple is an ordered set of n elements

- when n = 0 : we say it's an empty tuple or unit
- when n = 1 : we say it's single or singleton
- when n = 2 : we say it's double or couple or pair
- when n = 3 : we say it's triple or triplet or triad
- etc...

notion of tuple

accessing tuple elements

```python
print("latitude is {0}, longitude is {1}, altitude is {2}m".format(location[1],location[2],location[3]))
```

```scala
print(s"latitude is ${location._2}, longitude is ${location._3}, altitude is ${location._4}m")
```

```java
System.out.println("latitude is "  + location[1] + ", " +
                   "longitude is " + location[2] + ", " +
                   "altitude is "  + location[3]);
```

'+' is the string concatenation operator

```swift
print("latitude is \(location.1), longitude is \(location.2), altitude is \(location.3)m")
```

0	"Museum of Mankind"
1	48.861166
2	2.286826
3	57

1	"Museum of Mankind"
2	48.861166
3	2.286826
4	57

0	"Museum of Mankind"
1	48.861166
2	2.286826
3	57

0	"Museum of Mankind"
1	48.861166
2	2.286826
3	57

notion of tuple

accessing tuple elements

```
print("latitude is {0}, longitude is {1}, altitude is {2}m".format(location[1],location[2],location[3]))
```

```
print(s"latitude is ${location._2}, longitude is ${location._3}, altitude is ${location._4}m")
```

```
 System.out.println("latitude is "  + location[1] + ", " +
                    "longitude is " + location[2] + ", " +
                    "altitude is "  + location[3]);
```

'+' is the string concatenation operator

```
print("latitude is \(location.1), longitude is \(location.2), altitude is \(location.3)m")
```

```
location[1] = 3.14
```

```
location._2 = 3.14
```

in scala and in python, tuples are immutable

```
location[1] = 3.14;
```

```
location.1 = 3.14
```

in java and in swift, tuples are mutable ⇔ they can be changed

notion of tuple

naming tuple elements

```
case class Location(name: String, latitude: Double, longitude: Double, altitude: Int)
var location = Location("Museum of Mankind", 48.861166,2.286826, 57)
print(s"latitude is ${location.latitude}, longitude is ${location.longitude}, altitude is ${location.altitude}m")
```

```
location.latitude = 3.14
```


```
var location = (name:"Museum of Mankind", latitude:48.861166, longitude:2.286826, altitude:57)
print("latitude is \(location.latitude), longitude is \(location.longitude), altitude is \(location.altitude)m")
```

```
location.latitude = 3.14
```

named elements are not supported
out-of-the box in python and java

immutability

an immutable object is an object whose state cannot be modified after its initialization

```
location.latitude = 3.14
```

an mutable object is an object whose state can be modified after its initialization

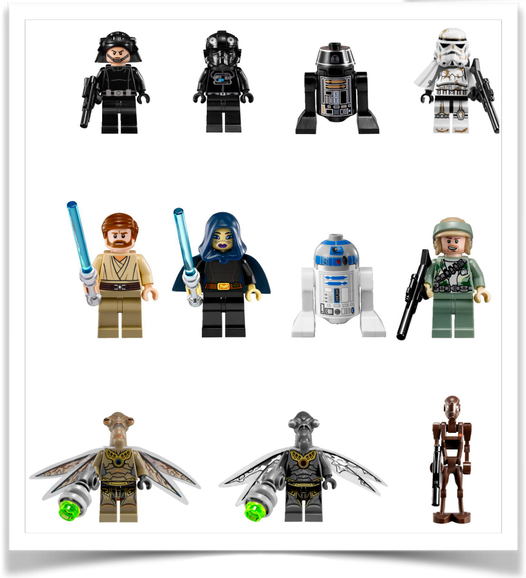
```
location.latitude = 3.14
```

immutable objects are easier to share across your code because they are immune to side effects

in addition, the compiler (or the interpreter) can perform optimization on immutable objects

collections

many programs rely on collections of objects



game elements

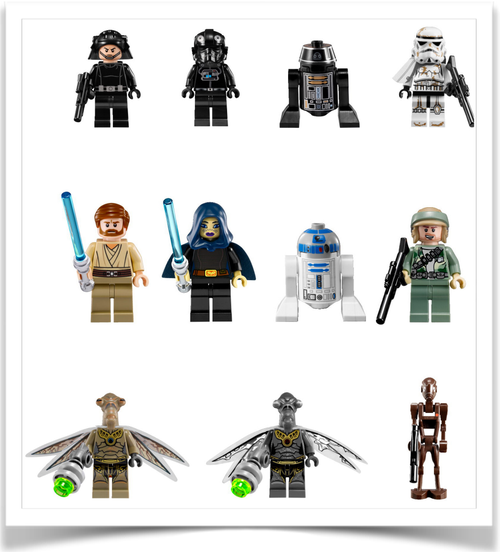
library catalog

notes in a notebook

collections

the number of items stored in a collection may vary over time

items added



items deleted

list creation & access

```
tour = ["Museum of Mankind", "Eiffel Tower", "Champs Elysée"]
```

```
var tour = List("Museum of Mankind", "Eiffel Tower", "Champs Elysée")
```

```
var tour = List.of("Museum of Mankind", "Eiffel Tower", "Champs Elysée");
```

```
var tour = ["Museum of Mankind", "Eiffel Tower", "Champs Elysée"]
```

```
print(tour[1])
```
→ **Eiffel Tower**

```
print(tour(1))
```
→ **Eiffel Tower**

```
System.out.println(tour.get(1));
```
→ **Eiffel Tower**

```
print(tour[1])
```
→ **Eiffel Tower**

literals

in a program, a literal is a notation for representing a value directly in the source code

	python	scala	swift	java
string	`"Museum of Mankind"` `'Museum of Mankind'`	`"Museum of Mankind"`		
double	`3.14`			
float		`3.14f`		`3.14f`
integer	`666`			
boolean	`True / False`	`true / false`		
tuple	`("Museum of Mankind", 48.861166, 2.286826, 57)`			`{"Museum", 48.86, 2.28, 57}`
list	`["Jan", "Feb", "Mar"]`	`List("Jan", "Feb", "Mar")`	`["Jan", "Feb", "Mar"]`	`List.of("Jan", "Feb", "Mar")`

adding & removing elements from a list

append

```
tour.append("Triumphal Arch")
```

```
tour = tour ::: List("Triumphal Arch")
```

```
tour.append("Triumphal Arch")
```

prepend

```
tour.insert(0,"Triumphal Arc")
```

```
tour = "Triumphal Arc"::tour
```

```
tour.insert("Triumphal Arch", at:0)
```

remove first element

```
del tour[0]
```

```
tour = tour.tail
```

```
tour.remove(at:0)
```

remove last element

```
tour.pop()
```

```
tour = tour.take(tour.size - 1)
```

```
tour.remove(at:tour.count - 1)
```

adding & removing elements from a list

in scala, lists are **immutable**, so we have to create **a new list for each modification**

```
tour = tour ::: List("Triumphal Arch")
```

```
tour = "Triumphal Arc"::tour
```

```
tour = tour.tail
```

```
tour = tour.take(tour.size - 1)
```

---

if you need a **mutable list**, use a `ListBuffer`

```
import scala.collection.mutable.ListBuffer
var tour = ListBuffer("Museum of Mankind", "Eiffel Tower")
tour.append("Triumphal Arch")
tour.remove(0)
tour.prepend("Champs Elysée")
tour.trimEnd(1)
```

➡ ("Museum of Mankind", "Eiffel Tower")

➡ ("Museum of Mankind", "Eiffel Tower", "Triumphal Arch")

➡ ("Eiffel Tower", "Triumphal Arch")

➡ ("Champs Elysée", "Eiffel Tower", "Triumphal Arch")

➡ ("Champs Elysée", "Eiffel Tower")

adding & removing elements from a list

in java, lists are also **immutable** by default,
so we have to create **a mutable linked list**
if we need to modify its content

```
var immutableTour = List.of("Museum of Mankind", "Eiffel Tower", "Champs Elysée");
var tour = new LinkedList(immutableTour);
```

append

```
tour.addLast("Triumphal Arch");
```

prepend

```
tour.addFirst("Triumphal Arch");
```

---

remove first element

```
tour.removeFirst("Triumphal Arch");
```

remove last element

```
tour.removeLast("Triumphal Arch");
```

adding & removing elements from a list

in swift, a list is mutable, if and only if we are accessing it via a variable

```
var tour = ["Museum of Mankind", "Eiffel Tower", "Champs Elysée"]
tour.append("Triumphal Arch")
tour.remove(at:0)
```


```
let tour = ["Museum of Mankind", "Eiffel Tower", "Champs Elysée"]
tour.append("Triumphal Arch")
tour.remove(at:0)
```


```
var myTour = ["Museum of Mankind", "Eiffel Tower", "Champs Elysée"]
myTour.append("Triumphal Arch")
myTour.remove(at:0)

let yourTour = myTour
yourTour.append("Triumphal Arch")
yourTour.remove(at:0)
```

a copy of the list is performed, so no side effects impacts the list referenced via yourTour

associative arrays

in a program, an **associative array** (also called a **dictionary** or simply a **map**) is a collection composed of a set of **(key, value) pairs**, where **each key appears at most once** in the collection

```
mountains = {"jungfrau": 4158, "eiger": 0}          ➡ {'eiger': 0, 'jungfrau': 4158}
height = mountains["eiger"]                         ➡ 0
mountains["eiger"] = 3950                           ➡ {'eiger': 3950, 'jungfrau': 4158}
mountains["moench"] = 4099                          ➡ {'eiger': 3950, 'jungfrau': 4158, 'moench': 4099}
mountains.pop("jungfrau")                           ➡ {'eiger': 3950, 'moench': 4099}
```

```
var mountains = ["jungfrau": 4158, "eiger": 0]      ➡ ["eiger": 0, "jungfrau": 4158]
height = mountains["eiger"]                         ➡ 0
mountains["eiger"] = 3950                           ➡ ["eiger": 3950, "jungfrau": 4158]
mountains["moench"] = 4099                          ➡ ["moench": 4099, "eiger": 3950, "jungfrau": 4158]
mountains.removeValue(forKey:"jungfrau")            ➡ ["eiger": 3950, "moench": 4099]
```

associative arrays

in a program, an **associative array** (also called a **dictionary** or simply a **map**) is a collection composed of a set of **(key, value) pairs**, where **each key appears at most once** in the collection

```
var mountains = scala.collection.mutable.Map("jungfrau" -> 4158, "eiger" -> 0)
```
➥ Map(jungfrau -> 4158, eiger -> 0)

```
var height = mountains("eiger")
```
➥ 0

```
mountains("eiger") = 3950
```
➥ Map(jungfrau -> 4158, eiger -> 3950)

```
mountains("moench") = 4099
```
➥ Map(jungfrau -> 4158, eiger -> 3950, moench -> 4099)

```
mountains.remove("jungfrau")
```
➥ Map(eiger -> 3950, moench -> 4099)

```
var mountains = new HashMap(Map.of("jungfrau", 4158, "eiger", 0));
```
➥ {eiger=0, jungfrau=4158}

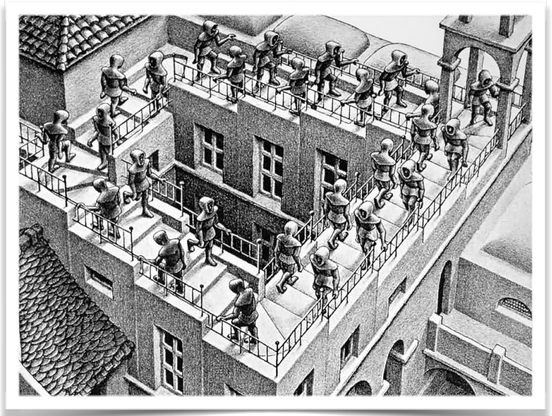
```
var height = mountains.get("eiger");
```
➥ 0

```
mountains.put("eiger", 3950);
```
➥ {eiger=3950, jungfrau=4158}

```
mountains.put("moench", 4099);
```
➥ {eiger=3950, jungfrau=4158, moench=4099}

```
mountains.remove("jungfrau");
```
➥ {eiger=3950, moench=4099}

iteration



we often want to perform some actions
an arbitrary number of times e.g.,

convert the height of a mountains from meters to feet

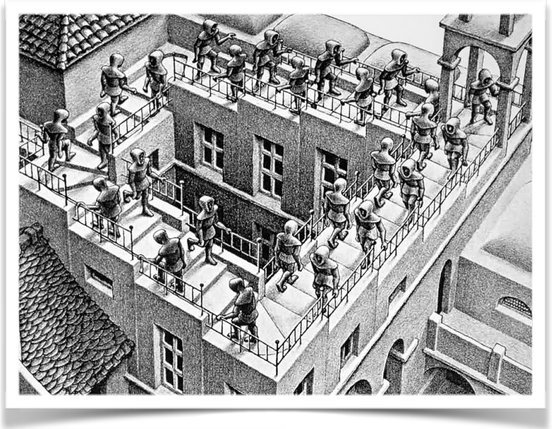
compute the list of 100 first prime numbers in sequence

print all the notes in a notebook

with collections in particular, we often want to repeat a sequence of actions once for each object in a given collection

programming languages include loop statements for this

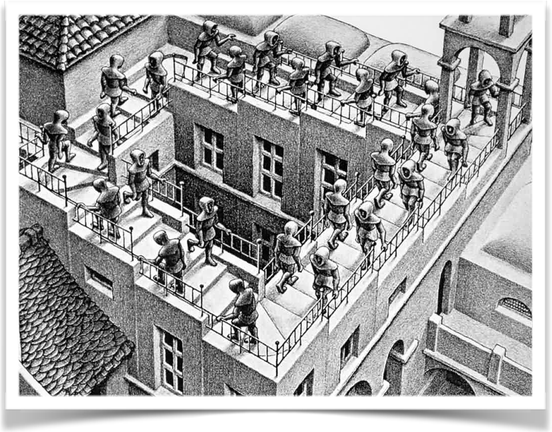
iteration



for each loop

while loop

for each loop



a for-each loop
repeats the loop body
for each and every
object in a collection

for each loop

python

iterating through a list

```
mountains = { "jungfrau", "eiger", "moench"}
for summit in mountains:
    print("I will climb to the summit of the {0}".format(summit))
```

iterating through a map

```
mountains = { "jungfrau":4158, "eiger":3950, "moench":4099}
height = 0
for summit in mountains.keys():
    print("I will climb to the summit of the {0} at {1} meters".format(summit,mountains[summit]))
    height = height + mountains[summit]
print("In total, I will climb {0} meters".format(height))
```

swift

iterating through a list

```
var mountains = ["jungfrau", "eiger", "moench"]
for summit in mountains {
    print("I will climb to the summit of the \(summit)")
}
```

iterating through a map

```
var mountains = ["jungfrau":4158, "eiger":3950, "moench":4099]
var height = 0
for summit in mountains.keys {
    print("I will climb to the summit of the \(summit) at \(mountains[summit]!) meters")
    height = height + mountains[summit]!
}
print("In total, I will climb \(height) meters")
```

for each loop

scala

iterating through a list

```
var mountains = List("jungfrau", "eiger", "moench")
for(summit <- mountains)
  println(s"I will climb to the summit of the $summit")
```

iterating through a map

```
var mountains = Map("jungfrau"->4158, "eiger"->3950, "moench"->4099)
var height = 0
for (summit <- mountains.keys) {
  println(s"I will climb to the summit of the $summit at ${mountains(summit)} meters");
  height = height + mountains(summit)
}
println(s"In total, I will climb $height meters")
```

java

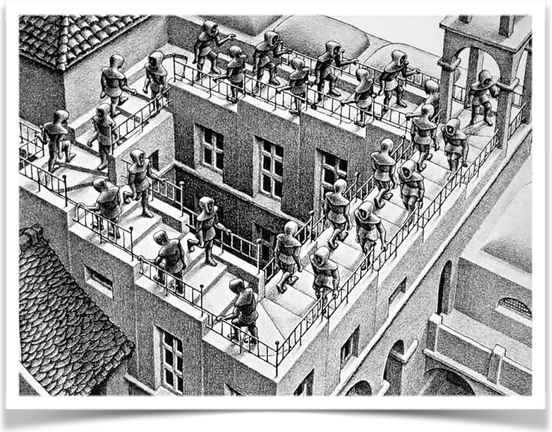
iterating through a list

```
var mountains = List.of("jungfrau", "eiger", "moench");
for (var summit : mountains) {
  System.out.println("I will climb to the summit of the " + summit);
}
```

iterating through a map

```
var mountains = Map.of("jungfrau", 4158, "eiger", 3950, "moench", 4099);
var height = 0;
for (var summit : mountains.keySet()) {
  System.out.println("I will climb to the summit of the " + summit + " at " +
mountains.get(summit) + " meters");
  height = height + mountains.get(summit);
}
System.out.println("In total, I will climb " + height +" meters");
```

while loop



a while loop uses a boolean condition to decide whether or not to continue the loop

while loop

python

```
numbers = [1,2,4,8,16,32,64, 128,256]
sum = 0
i = 0
while sum < 512 and i < len(numbers):
    sum = sum + numbers[i]
    i = i + 1
print("the sum is {0}".format(sum))
```

swift

```
var numbers = [1, 2, 4, 8, 16, 32, 64, 128, 256]
var sum = 0
var i = 0
while (sum < 512 && i < numbers.count) {
    sum = sum + numbers[i]
    i = i + 1
}
print("the sum is \(sum)")
```

while loop

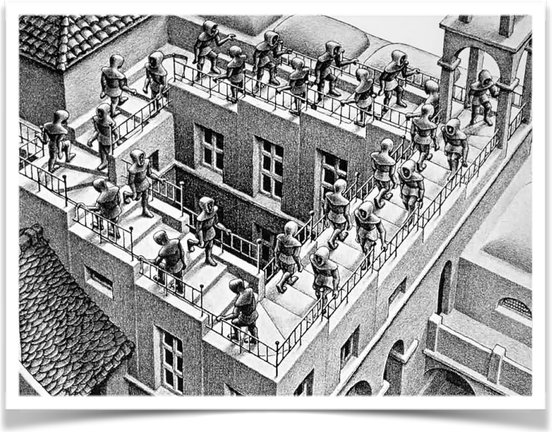
scala

```
var numbers = List(1, 2, 4, 8, 16, 32, 64, 128, 256)
var sum = 0
var i = 0
while (sum < 512 && i < numbers.length) {
  sum = sum + numbers(i)
  i = i + 1
}
print(s"the sum is $sum")
```

java

```
var numbers = List.of(1, 2, 4, 8, 16, 32, 64, 128, 256);
var sum = 0;
var i = 0;
while (sum < 512 && i < numbers.size()) {
    sum = sum + numbers.get(i);
    i = i + 1;
}
System.out.println("the sum is " + sum);
```

iteration



for-each

simpler: easier to write

safer: guaranteed to stop

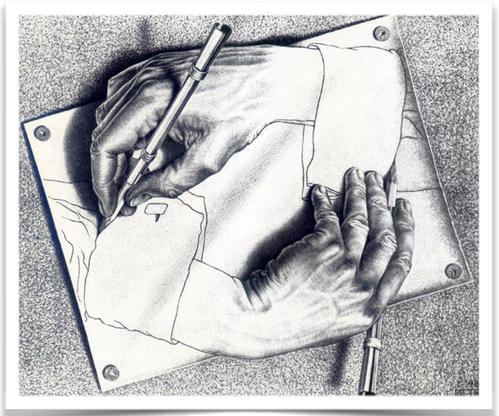
while

efficient: can process part of a collection

versatile: can be used for other purposes

be careful: could be an infinite loop

recursion



a classical way to solve a problem is to divide it into smaller and easier subproblems

if one of the subproblems is a less complex instance of the original problem, you might want to consider using recursion

for example, the factorial of n can be defined as

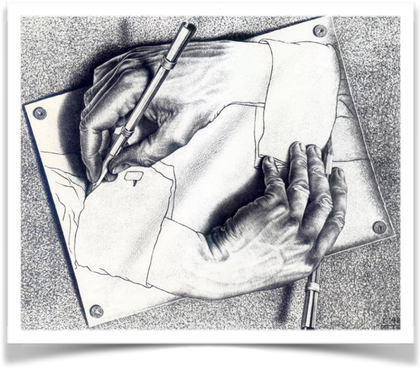
$n! = 1 \times 2 \times 3 \times .... \times (n-1) \times n$

but it can also be defined as:

$n! = (n - 1)! \times n$

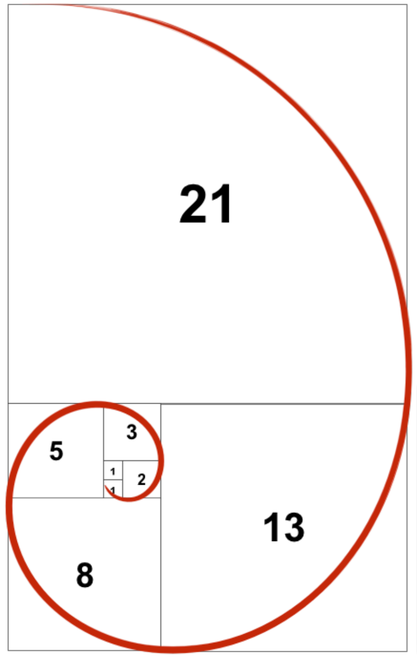
recursion

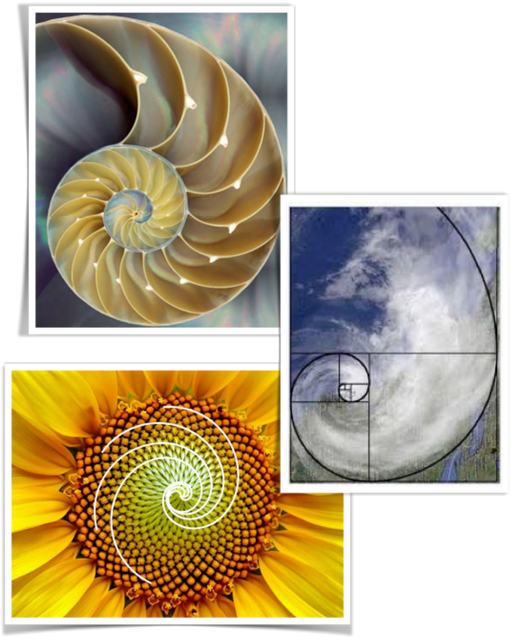
fibonacci numbers



$$F_n = \begin{cases} 0 & \text{if } n = 0 \\ 1 & \text{if } n = 1 \\ F_{n-1} + F_{n-2} & \text{if } n > 1 \end{cases}$$

n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	...
F_n	0	1	1	2	3	5	8	13	21	34	55	89	144	233	377	610	987	1597	2584	4181	...





fibonacci numbers

$$F_n = \begin{cases} 0 & \text{if } n = 0 \\ 1 & \text{if } n = 1 \\ F_{n-1} + F_{n-2} & \text{if } n > 1 \end{cases}$$

n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	...
F_n	0	1	1	2	3	5	8	13	21	34	55	89	144	233	377	610	987	1597	2584	4181	...

```scala
def fibonacci(n : Int) : Int = {
  if (n == 0 || n == 1)
    n
  else {
    var oldFib = 1;
    var newFib = 1;

    for (i <- 2 to n - 1) {
      val temp = newFib;
      newFib = oldFib + newFib;
      oldFib = temp;
    }
    newFib;
  }
}
```

iterative version

```scala
def fibonacci(n : Int) : Int = {
  if (n == 0 || n == 1)
    n
  else
    fibonacci(n - 1) + fibonacci(n - 2)
}
```

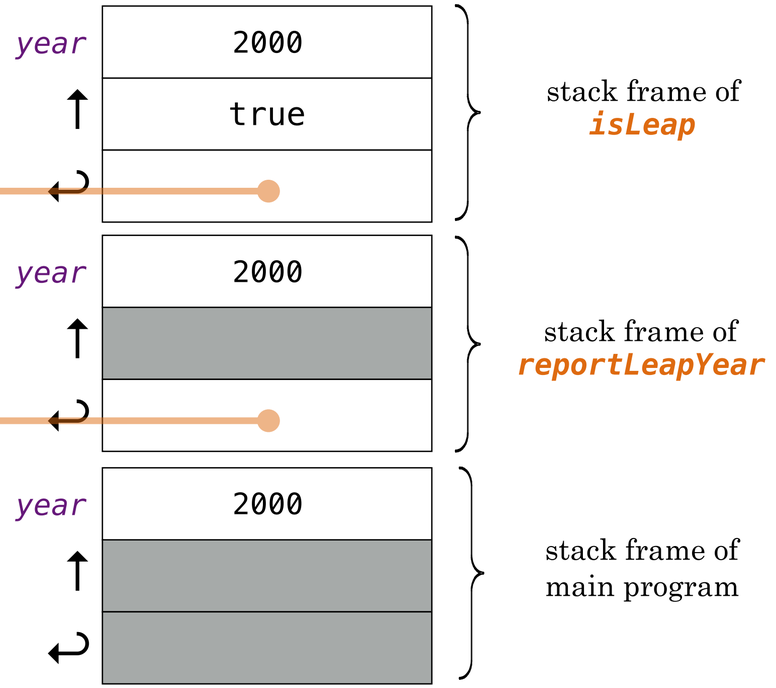
recursive version

examples given in scala

function calls

```scala
import scala.io.StdIn.readLine

object LeapYear extends App {

  def isLeap(year : Int) : Boolean = (year % 4 == 0) && (year % 100 != 0) || (year % 400 == 0)

  def reportLeapYear(year : Int) = {
    print(s"Is $year a leap year? ${if (isLeap(year))  "Yes, it is!" else "No, it's not!"}")
  }

  val year = readLine("Give us a year! ").toInt
  reportLeapYear(year)
}
```

breakpoint here



the call stack contains a stack frame for each function call currently active

a stack frame contains all the local variables and parameters of the function being called

↑ *returned value for the caller*

↩ *return address in the caller*

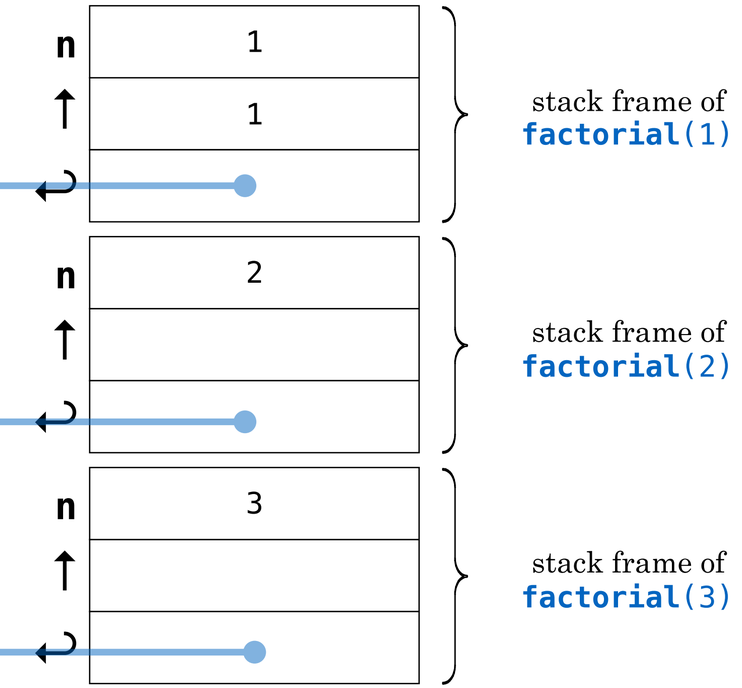
recursive function calls

```
def factorial(n: Int) : Int = {
  if (n == 0 || n == 1) {
    1
  }
  else {
    factorial(n-1) * n
  }
}
```

this is the **stop condition** of the recursion

```
factorial(3)
```

after calling `factorial(3)`, we have the following execution stack when the **stop condition** is reached:



↑ *returned value for the caller*

↩ *return address in the caller*

question

what happens if we pass `n = -1` ?