Execution Control Structures

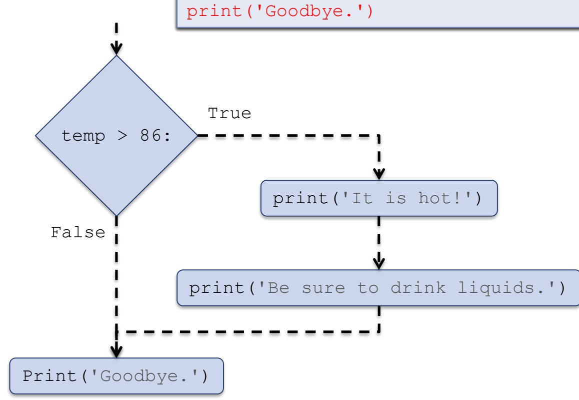
- Conditional Structures
- Iteration Patterns, Part I
- Two-Dimensional Lists
- `while` Loop
- Iteration Patterns, Part II

One-way if statement

```
if <condition>:
    <indented code block>
<non-indented statement>
```

```
if temp > 86:
    print('It is hot!')
    print('Be sure to drink liquids.')
print('Goodbye.')
```

The value of `temp` is 90.

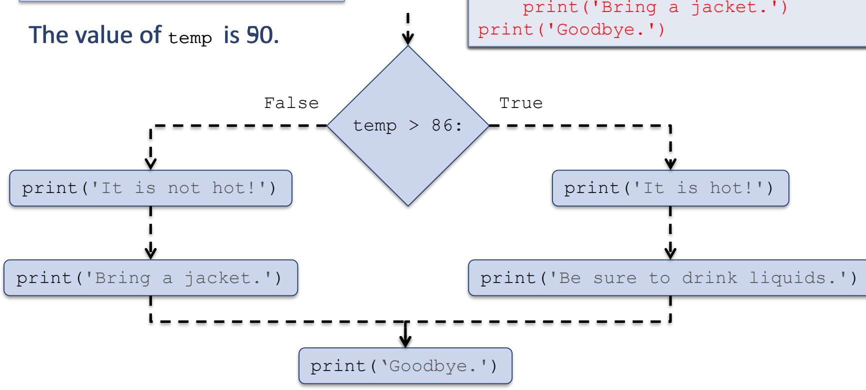


Two-way if statement

```
if <condition>:
    <indented code block 1>
else:
    <indented code block 2>
<non-indented statement>
```

```
if temp > 86:
    print('It is hot!')
    print('Be sure to drink liquids.')
else:
    print('It is not hot.')
    print('Bring a jacket.')
print('Goodbye.')
```

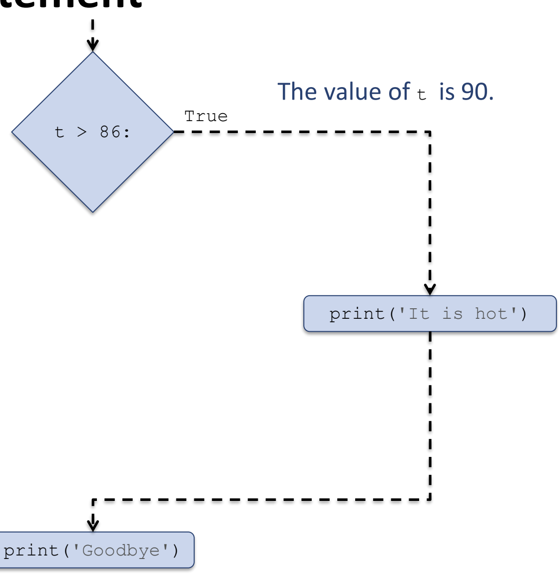
The value of `temp` is 90.



Multi-way if statement

The value of `t` is 90.

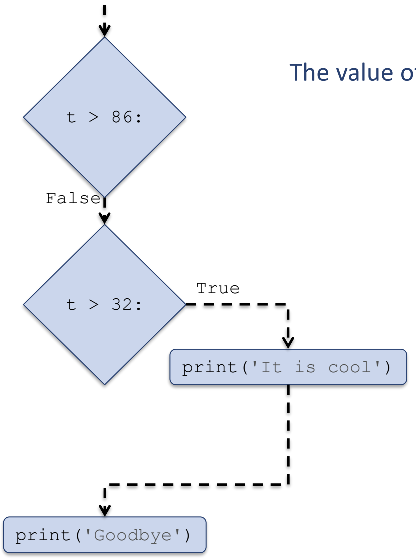
```
def temperature(t):
    if t > 86:
        print('It is hot')
    elif t > 32:
        print('It is cool')
    else:
        print('It is freezing')
    print('Goodbye')
```



Multi-way if statement

The value of `t` is 50.

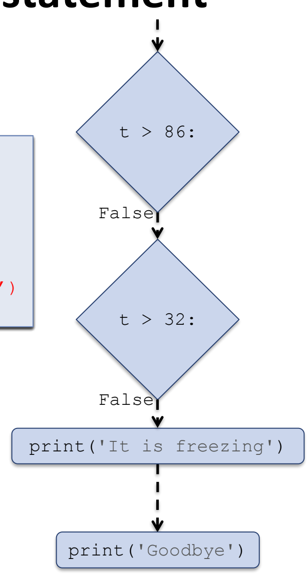
```
def temperature(t):
    if t > 86:
        print('It is hot')
    elif t > 32:
        print('It is cool')
    else:
        print('It is freezing’)
    print('Goodbye')
```



Multi-way if statement

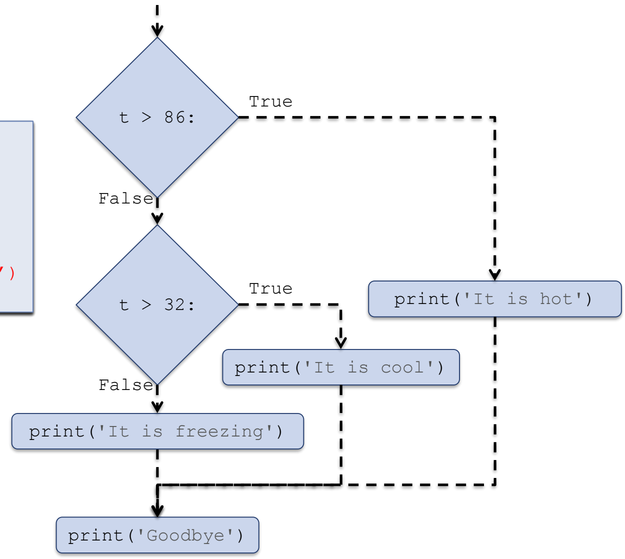
The value of `t` is 20.

```
def temperature(t):
    if t > 86:
        print('It is hot')
    elif t > 32:
        print('It is cool')
    else:
        print('It is freezing’)
    print('Goodbye')
```



Multi-way if statement

```
def temperature(t):
    if t > 86:
        print('It is hot')
    elif t > 32:
        print('It is cool')
    else:
        print('It is freezing’)
    print('Goodbye')
```



Ordering of conditions

What is the wrong with this re-implementation of `temperature()`?

```
def temperature(t):
    if t > 32:
        print('It is cool')
    elif t > 86:
        print('It is hot')
    else: # t <= 32
        print('It is freezing')
    print('Goodbye')
```

```
def temperature(t):
    if 86 >= t > 32:
        print('It is cool')
    elif t > 86:
        print('It is hot')
    else: # t <= 32
        print('It is freezing')
    print('Goodbye')
```

The conditions must be
mutually exclusive,
either explicitly or implicitly

```
def temperature(t):
    if t > 86:
        print('It is hot')
    elif t > 32: # 86 >= t > 32
        print('It is cool')
    else: # t <= 32
        print('It is freezing')
    print('Goodbye')
```

Exercise

Write function `BMI()` that:

- takes as input a person's height (in inches) and weight (in pounds)
- computes the person's BMI and *prints* an assessment, as shown below

The function does not return anything.

The Body Mass Index is the value (weight * 703)/height^2 . Indexes below 18.5 or above 25.0 are assessed as underweight and overweight, respectively; indexes in between are considered normal.

```
BMI(weight, height):
  'prints BMI report'

  bmi = weight*703/height**2

  if bmi < 18.5:
    print('Underweight')
  elif bmi < 25:
    print('Normal')
  else: # bmi >= 25
    print('Overweight')
```

```
>>> BMI(190, 75)
Normal
>>> BMI(140, 75)
Underweight
>>> BMI(240, 75)
Overweight
```


Iteration

The general format of a `for` loop statement is

```
for <variable> in <sequence>:
    <indented code block>
<non-indented code block>
```

`<indented code block>` is executed once for every item in `<sequence>`

- If `<sequence>` is a string then the items are its characters (each of which is a one-character string)
- If `<sequence>` is a list then the items are the objects in the list

`<non-indented code block>` is executed after every item in `<sequence>` has been processed

There are different `for` loop usage patterns

Iteration loop pattern

Iterating over every item of an explicit sequence

```
>>> name = 'Apple'
>>> for char in name:
        print(char)


A
p
p
l
e
```

```
name  =  'A  p  p  l  e'

char  =  'A'
char  =      'p'
char  =          'p'
char  =              'l'
char  =                  'e'
```


Introduction to Computing Using Python

Iteration loop pattern

Iterating over every item of an explicit sequence

```
for word in ['stop', 'desktop', 'post', 'top']:
    if 'top' in word:
        print(word)
```

```
word  =  'stop'
word  =      'desktop'
word  =          'post'
word  =              'top'
```

```
>>>
stop
desktop
top
```

Counter loop pattern

Iterating over an implicit sequence of numbers

```
>>> n = 10
>>> for i in range(n):
        print(i, end=' ')

0 1 2 3 4 5 6 7 8 9
```

```
>>> for i in range(7, 100, 17):
        print(i, end=' ')

7 24 41 58 75 92
```

```
>>> for i in range(len('world')):
         print(i, end=' ')

0 1 2 3 4
```

This example illustrates the most important application of the counter loop pattern

Counter loop pattern

Iterating over an implicit sequence of numbers

```
>>> pets = ['cat', 'dog', 'fish', 'bird']
```

```
>>> for animal in pets:
        print(animal, end=' ')

cat dog fish bird
```

```
>>> for i in range(len(pets)):
        print(pets[i], end=' ')

cat dog fish bird
```

animal = 'cat'	i = 0	`pets[0]` is printed
animal = 'dog'	i = 1	`pets[1]` is printed
animal = 'fish'	i = 2	`pets[2]` is printed
animal = 'bird'	i = 3	`pets[3]` is printed

Counter loop pattern

Iterating over an implicit sequence of numbers… But why complicate things?

Let's develop function `checkSorted()` that:

- takes a list of comparable items as input
- returns True if the sequence is increasing, False otherwise

```
>>> checkSorted([2, 4, 6, 8, 10])
True
>>> checkSorted([2, 4, 6, 3, 10])
False
>>>
```

Implementation idea:
check that adjacent pairs are correctly ordered

```
def checkSorted(lst):
    'return True if sequence lst is increasing, False otherwise'
    for i in range(0, len(lst)-1):
        # i = 0, 1, 2, ..., len(lst)-2
        if lst[i] > lst[i+1]:
            return False
    return True
```


Exercise

Write function `arithmetic()` that:

- takes as input a list of numbers
- returns True if the numbers in the list form an arithmetic sequence, False otherwise

```
>>> arithmetic([3, 6, 9, 12, 15])
True
>>> arithmetic([3, 6, 9, 11, 14])
False
>>> arithmetic([3])
True
```

```
def arithmetic(lst):
    '''return True if list lst contains an arithmetic sequence,
       False otherwise'''

    if len(lst) < 2: # a sequence of length < 2 is arithmetic
        return True

   # check that the difference between successive numbers is
   # equal to the difference between the first two numbers
    diff = lst[1] - lst[0]
    for i in range(1, len(lst)-1):
        if lst[i+1] - lst[i] != diff:
            return False

    return True
```

Accumulator loop pattern

Accumulating something in every loop iteration

For example: the sum of numbers in a list

```
>>> lst = [3, 2, 7, 1, 9]
>>> res = 0
>>> for num in lst:
    res += num
>>> res
22
```

shorthand notation

```
lst = [3, 2, 7, 1, 9]        res = 0

num = 3                      res = res + num   (= 3)
num = 2                      res = res + num   (= 5)
num = 7                      res = res + num   (= 12)
num = 1                      res = res + num   (= 13)
num = 9                      res = res + num   (= 22)
```

accumulator

Accumulator loop pattern

Accumulating something in every loop iteration

What if we wanted to obtain the product instead?
What should `res` be initialized to?

```
>>> lst = [3, 2, 7, 1, 9]
>>> res = 1
>>> for num in lst:
    res *= num
```

```
lst = [3, 2, 7, 1, 9]        res = 1

num = 3                      res *= num   (= 3)
num = 2                      res *= num   (= 6)
num = 7                      res *= num   (= 42)
num = 1                      res *= num   (= 42)
num = 9                      res *= num   (= 378)
```

Exercise

Write function factorial() that:

- takes a non-negative integer n as input
- returns n!

$$n! = n \times (n-1) \times (n-2) \times (n-3) \times \ldots \times 3 \times 2 \times 1 \qquad \text{if} \quad n > 0$$
$$0! = 1$$

```
>>> factorial(0)
1
>>> factorial(1)
1
>>> factorial(3)
6
>>> factorial(6)
720
```

```
def factorial(n):
    'returns n! for input integer n'
    res = 1
    for i in range(2, n+1):
        res *= i
    return res
```


Exercise

Write function divisors() that:

- takes a positive integer n as input
- returns the list of positive divisors of n

```
>>> divisors(1)
[1]
>>> divisors(6)
[1, 2, 3, 6]
>>> divisors(11)
[1, 11]
```

```
def divisors(n):
    'return the list of divisors of n'

    res = []    # accumulator initialized to an empty list

    for i in range(1, n+1):
        if n % i == 0:    # if i is a divisor of n
            res.append(i) # accumulate i

    return res
```

Nested loop pattern

Desired Output

```
>>> n = 5
>>> nested(n)
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
```

Nesting a loop inside another

```
>>> n = 5
>>> nested(n)
0 1 2 3 4
>>>
```

```
def nested(n):
    for i in range(n):
        print(i, end=' ')
```


Nested loop pattern

Desired Output

```
>>> n = 5
>>> nested(n)
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
```

Nesting a loop inside another

```
>>> n = 5
>>> nested(n)
0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0 1 2 3 4
>>>
```

```
def nested(n):
    for j in range(n):
        for i in range(n):
            print(i, end=' ')
```

Nested loop pattern

Desired Output

```
>>> n = 5
>>> nested(n)
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
```

Nesting a loop inside another

```
>>> n = 5
>>> nested(n)
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
0 1 2 3 4
```

```
def nested(n):
    for j in range(n):
        for i in range(n):
            print(i, end=' ')
        print()
```


Nested loop pattern

Nesting a loop inside another

```
>>> n = 5
>>> nested2(n)
0
0 1
0 1 2
0 1 2 3
0 1 2 3 4
```

When `j` = `0` inner for loop should print `0`

When `j` = `1` inner for loop should print `0 1`

When `j` = `2` inner for loop should print `0 1 2`

When `j` = `3` inner for loop should print `0 1 2 3`

When `j` = `4` inner for loop should print `0 1 2 3 4`

```
def nested2(n):
    for j in range(n):
        for i in range(j+1):
            print(i, end=' ')
        print()
```

Two-dimensional lists

The list `[3, 5, 7, 9]` can be viewed as a 1-D table

`[3, 5, 7, 9]` =

3	5	7	9

How to represent a 2-D table?

	0	1	2	3
`[3, 5, 7, 9]` = 0	3	5	7	9
`[0, 2, 1, 6]` = 1	0	2	1	6
`[3, 8, 3, 1]` = 2	3	8	3	1

A 2-D table is just a list of rows (i.e., 1-D tables)

```
>>> lst = [[3,5,7,9],
           [0,2,1,6],
           [3,8,3,1]]
>>> lst
[[3, 5, 7, 9],
[0, 2, 1, 6],
[3, 8, 3, 1]]
>>> lst[0]
[3, 5, 7, 9]
>>>
```


Introduction to Computing Using Python

Two-dimensional lists

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`[3, 5, 7, 9]` =

3	5	7	9

How to represent a 2-D table?

	0	1	2	3
`[3, 5, 7, 9]` = 0	3	5	7	9
`[0, 2, 1, 6]` = 1	0	2	1	6
`[3, 8, 3, 1]` = 2	3	8	3	1

A 2-D table is just a list of rows (i.e., 1-D tables)

```
>>> lst = [[3,5,7,9],
           [0,2,1,6],
           [3,8,3,1]]
>>> lst
[[3, 5, 7, 9],
[0, 2, 1, 6],
[3, 8, 3, 1]]
>>> lst[0]
[3, 5, 7, 9]
>>> lst[1]
[0, 2, 1, 6]
>>>
```

Two-dimensional lists

The list `[3, 5, 7, 9]` can be viewed as a 1-D table

`[3, 5, 7, 9]` =

3	5	7	9

How to represent a 2-D table?

		0	1	2	3
`[3, 5, 7, 9]` =	0	3	5	7	9
`[0, 2, 1, 6]` =	1	0	2	1	6
`[3, 8, 3, 1]` =	2	3	8	3	1

A 2-D table is just a list of rows (i.e., 1-D tables)

```
>>> lst = [[3,5,7,9],
       [0,2,1,6],
       [3,8,3,1]]
>>> lst
[[3, 5, 7, 9],
[0, 2, 1, 6],
[3, 8, 3, 1]]
>>> lst[0]
[3, 5, 7, 9]
>>> lst[1]
[0, 2, 1, 6]
>>> lst[2]
[3, 8, 3, 1]
>>> lst[0][0]
3
>>> lst[1][2]
1
>>> lst[2][0]
3
>>>
```


Nested loop pattern and 2-D lists

A nested loop is often needed to access all objects in a 2-D list

```
def print2D(t):
    'prints values in 2D list t as a 2D table'
    for row in t:
        for item in row
            print(item, end=' ')
        print()
```

(Using the iteration loop pattern)

```
>>> table = [[3, 5, 7, 9],
             [0, 2, 1, 6],
             [3, 8, 3, 1]]
>>> print2D(table)
3 5 7 9
0 2 1 6
3 8 3 1
>>>
```

Nested loop pattern and 2-D lists

A nested loop is often needed to access all objects in a 2-D list

```
def print2D(t):
    'prints values in 2D list t as a 2D table'
    for row in t:
        for item in row
            print(item, end=' ')
        print()
```

(Using the iteration loop pattern)

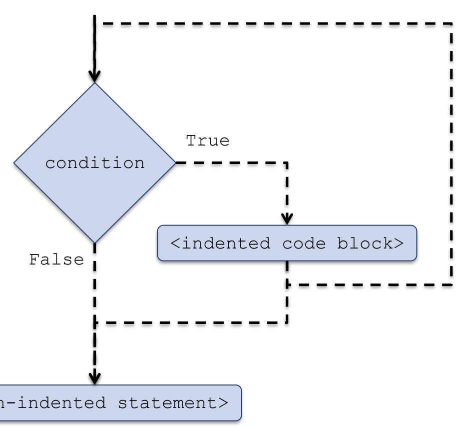
```
>>> table = [[3, 5, 7, 9],
             [0, 2, 1, 6],
             [3, 8, 3, 1]]
>>> print2D(table)
3 5 7 9
0 2 1 6
3 8 3 1
>>> incr2D(t)
>>> print2D(t)
4 6 8 10
1 3 2 7
4 9 4 2
>>>
```

```
def incr2D(t):
    'increments each number in 2D list t'
    # nrows = number of rows in t
    # ncols = number of columns in t

    for i in range(nrows):
        for j in range(ncols):
            t[i][j] += 1
```

(Using the counter loop pattern)

while loop

```
while <condition>:
    <indented code block>
<non-indented statement>
```

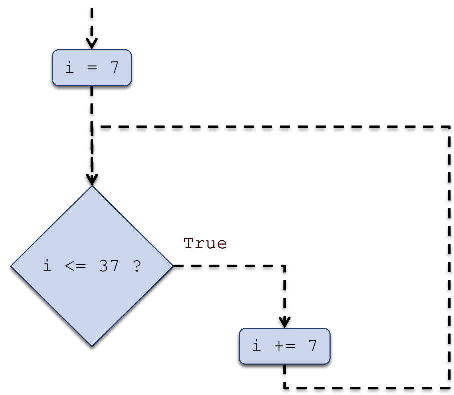


while loop

Example: compute the smallest multiple of 7 greater than 37.

Idea: generate multiples of 7 until we get a number greater than 37

```
>>> i = 7
>>> while i <= 37:
        i += 7
```

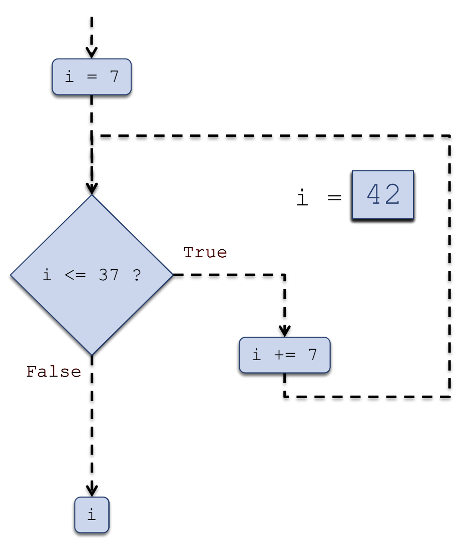


while loop

Example: compute the smallest multiple of 7 greater than 37.

Idea: generate multiples of 7 until we get a number greater than 37

```
>>> i = 7
>>> while i <= 37:
        i += 7

>>> i
42
```



Exercise

Write function `negative()` that:

- takes a list of numbers as input
- returns the index of the first negative number in the list or -1 if there is no negative number in the list

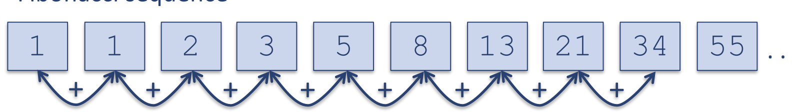
```
>>> lst = [3, 1, -7, -4, 9, -2]
>>> negative(lst)
2
>>> negative([1, 2, 3])
-1
```

```
def greater(lst):

    for i in range(len(lst)):
        if lst[i] < 0:
            return i

    return -1
```


Sequence loop pattern

Generating a sequence that reaches the desired solution

Fibonacci sequence



Goal: the first Fibonnaci number greater than some `bound`

```
def fibonacci(bound):
    'returns the smallest Fibonacci number greater than bound'
    previous = 1          # previous Fibonacci number
    current = 1           # current Fibonacci number
    while current <= bound:
        # current becomes previous, and new current is computed
        previous, current = current, previous+current
    return current
```

Exercise

Write function `approxE()` that approximates the Euler constant as follows:

- takes a number $error$ as input
- returns the approximation e_i such that $e_i - e_{i-1} < error$

$$e = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} \ldots = 2.71828183\ldots$$

$$e_0 = \frac{1}{0!} = 1$$

$$e_1 = \frac{1}{0!} + \frac{1}{1!} = 2 \qquad e_1 - e_0 = 1$$

$$e_2 = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} = 2.5 \qquad e_2 - e_1 = .5$$

$$e_3 = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} = 2.666\ldots \qquad e_3 - e_2 = .166..$$

$$e_4 = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} = 2.7083\ldots \qquad e_4 - e_3 = .04166\ldots$$

Exercise

Write function `approxE()` that approximates the Euler constant as follows:

- takes a number $error$ as input
- returns the approximation e_i such that $e_i - e_{i-1} < error$

```
>>> approxE(0.01)
2.7166666666666663
>>> approxE(0.000000001)
2.7182818284467594
```

$$e = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} \ldots = 2.71828183\ldots$$

```
def approxE(error):
    prev = 1        # approximation 0
    current = 2     # approximation 1
    i = 2           # index of next approximation
    while current - prev > error:
        prev, current = current, current + 1/factorial(i)
        i += 1    # index of next approximation
    return current
```

$$e_0 = \frac{1}{0!} = 1$$

$$e_1 = \frac{1}{0!} + \frac{1}{1!} = 2$$

$$e_2 = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} = 2.5$$

$$e_3 = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} = 2.666\ldots$$

$$e_4 = \frac{1}{0!} + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} = 2.7083\ldots$$

Infinite loop pattern

An infinite loop provides a continuous service

```
>>> hello2()
What is your name? Sam
Hello Sam
What is your name? Tim
Hello Tim
What is your name? Alex
Hello Alex
What is your name?
```

A greeting service

The server could instead be a time server, or a web server, or a mail server, or…

```
def hello2():
    '''a greeting service; it repeatedly requests the name
       of the user and then greets the user''’

    while True:
        name = input('What is your name? ')
        print('Hello {}'.format(name))
```


Loop-and-a-half pattern

Cutting the last loop iteration “in half”

Example: a function that creates a list of cities entered by the user and returns it

The empty string is a “flag” that indicates the end of the input

```
>>> cities()
Enter city: Lisbon
Enter city: San Francisco
Enter city: Hong Kong
Enter city:
['Lisbon', 'San Francisco', 'Hong Kong']
>>>
```

```
def cities():
    lst = []

    city = input('Enter city: ')

    while city != '':
        lst.append(city)
        city = input('Enter city: ')

    return lst
```

accumulator pattern

awkward and not quite intuitive

Loop-and-a-half pattern

Cutting the last loop iteration "in half"

Example: a function that creates a list of cities entered by the user and returns it

The empty string is a "flag" that indicates the end of the input

```
>>> cities()
Enter city: Lisbon
Enter city: San Francisco
Enter city: Hong Kong
Enter city:
['Lisbon', 'San Francisco', 'Hong Kong']
>>>
```

last loop iteration stops here

```
def cities2():
    lst = []

    while True:
        city = input('Enter city: ')

        if city == '':
            return lst

        lst.append(city)
```


The `break` statement

The `break` statement:

- is used inside the body of a loop
- when executed, it interrupts the current iteration of the loop
- execution continues with the statement that follows the loop body.

```
def cities2():
    lst = []

    while True:
        city = input('Enter city: ')

        if city == '':
            return lst

        lst.append(city)
```

```
def cities2():
    lst = []

    while True:
        city = input('Enter city: ')

        if city == '':
            break

        lst.append(city)

return lst
```

break and continue statements

The continue statement:

- is used inside the body of a loop
- when executed, it interrupts the current iteration of the loop
- execution continues with next iteration of the loop

In both cases (break and continue), only the innermost loop is affected

```
>>> before0(table)
2 3

4 5 6
```

```
>>> table = [
        [2, 3, 0, 6],
        [0, 3, 4, 5],
        [4, 5, 6, 0]]
```

```
>>> ignore0(table)
2 3 6
3 4 5
4 5 6
```

```
def before0(table):
    for row in table:
        for num in row:
            if num == 0:
                break
            print(num, end=' ')
        print()
```

```
def ignore0(table):
    for row in table:
        for num in row:
            if num == 0:
                continue
            print(num, end=' ')
        print()
```


Exercise

Write function bubbleSort() that:

- takes a list of numbers as input and sorts the list using BubbleSort

The function returns nothing

```
>>> lst = [3, 1, 7, 4, 9, 2, 5]
>>> bubblesort(lst)
>>> lst
[1, 2, 3, 4, 5, 7, 9]
```

```
def bubblesort(lst):

    for i in range(len(lst)-1, 0, -1):

        for j in range(i):

            if lst[j] > lst[j+1]:
                lst[j], lst[j+1] = lst[j+1], lst[j]
```