Scientific Programming

Lecture A02 – Structured data types

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Strings

Strings

Strings are immutable objects containing text, represented as a sequence of characters.

- Strings are immutable: they can be read, but all operations that appear to modify them actually create a new string.
- Strings are a sequential collections of characters. This means that the individual characters that make up the string are assumed to be in a particular order from left to right.
- A string that contains no characters, often referred to as the empty string, is still considered to be a string.

How to define strings

```
>>> print('I am a single quoted string')
I am a single quoted string

>>> print("I am a double quoted string")
I am a double quoted string

>>> print("""I am a triple quoted string""")
I am a triple quoted string

>>> print("")
```

Escaped characters

Some characters cannot be represented directly, so they need to be escaped, i.e. prefixed with \ (backslash)

```
>>> print("So I said, \"You don’t know me!\"")
So I said, "You don’t know me!"

>>> print(’So I said, "You don\’t know me!"’)
So I said, "You don’t know me!"

>>> print("This will print only three backslashes: \\ \\ \\")
This will print only three backslashes: \ \ \

>>> print("""The double quotation mark (\") is used to...""")
The double quotation mark (") is used to...
```

Escaped characters

\\	Backslash
\n	ASCII linefeed (also known as newline)
\t	ASCII tab character
\'	Single quote
\"	Double quote
\xxxx	Unicode character xxxx (hexadecimal)

```
sad_joke = "Time flies like an arrow.\nFruit flies like a banana."
print(sad_joke)

sad_joke = """Time flies like an arrow.
Fruit flies like a banana."""
print(sad_joke)
```

String-number conversion

Built-in functions

`str(n)`	convert number **n** into a string
`int(s)`	convert string **s** into an integer
`float(s)`	convert string **s** into a float

```
n = 10
s = str(n)
print(n, type(n))
print(s, type(s))
```

```
10 <class ’int’>
10 <class ’str’>
```

```
n = int("123")
f = float("1.23")
print(n, type(n))
print(f, type(f))
```

```
123 <class ’int’>
1.23 <class ’float’>
```

String-number conversion

```
>>> print(int("3.14"))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError:  invalid literal for int() with base 10:  ’3.14’

>>> print(float("one"))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError:  could not convert string to float:  ’one’

>>> print(int("1,000"))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError:  invalid literal for int() with base 10:  ’1,000’
```

String operators

Result	Operator	Meaning
`int`	`len(str)`	Return the length of the string
`str`	`str + str`	Concatenate two strings
`str`	`str * int`	Replicate the string
`bool`	`str in str`	Check if a string is present in another string
`str`	`str[int]`	Read the character at specified index
`str`	`str[int:int]`	Extract a sub-string

Concatenation

```
s1 = "one" + " " + "string"
length = len(s1)
print("the string:", s1, "is", length, "characters long")

s2 = "hello,"*3
print("the string: ", s2, "is", len(s2), "characters long")
```

```
the string: one string is 10 characters long
the string: hello,hello,hello, is 21 characters long
```

Warning: Concatenation with integers

Python

```
>>> var = 123
>>> print("The value of var is " + var)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Can’t convert ’int’ object to str implicitly

>>> print("The value of var is " + str(var))
The value of var is 123
```

Java

```
System.out.println("The value of var is " + var)
```

in operator

```
s = "A beautiful journey"

print("A" in s)                True
print("beautiful" in s)        True
print("BEAUTIFUL" in s)        False
print("ul jour" in s)          True
print("Gengis Khan" in s)      False
print(" " in s)                True
print("  " in s)               False
print(s in s)                  True
print("" in s)                 True
```

String Indexing

Character extraction

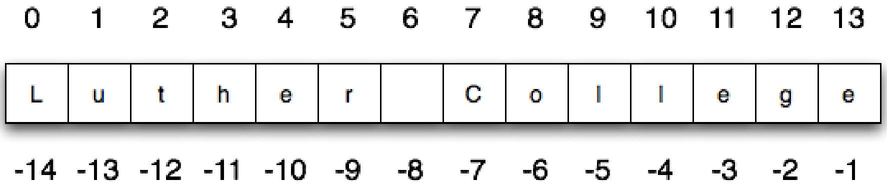
You can extract a character located at index `i` of string `s` with the expression `s[i]`

String extraction (slicing)

You can extract a substring of a string `s` with the expressions:

`s[start:end]`	Returns the characters located between index `start` (included) and index `end` (excluded)
`s[:end]` (prefix)	Returns the characters located between the beginning of the string and index `end` (excluded)
`s[start:]` (suffix)	Returns the characters located between index `start` (included) and the end of the string

Single characters

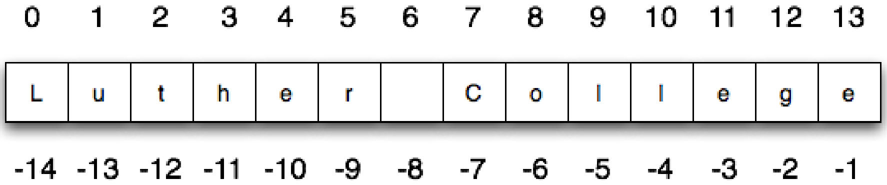


0	1	2	3	4	5	6	7	8	9	10	11	12	13
L	u	t	h	e	r		C	o	l	l	e	g	e
-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1

```
s = "Luther College"
print(s[0], s[2], s[len(s)-1])
print(s[-1], s[-3], s[-5])
print(s[len(s)])
```

```
L t e
e e l
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: string index out of range
```

Extraction (Slicing)



0	1	2	3	4	5	6	7	8	9	10	11	12	13
L	u	t	h	e	r		C	o	l	l	e	g	e
-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1

```
s = "Luther College"
print(s[0:1])                L
print(s[0:2])                Lu
print(s[0:5])                Luthe
print(s[:5])                 Luthe
print(s[-5:-1])              lleg
print(s[-5:])                llege
print(s[3:-3])               her Coll
print(s[:])                  Luther College
```

Methods

Result	**Method**	**Meaning**
`str`	`str.upper()`	Return the string in upper case
`str`	`str.lower()`	Return the string in lower case
`str`	`str.strip(str)`	Remove strings from the sides
`str`	`str.lstrip(str)`	Remove strings from the left
`str`	`str.rstrip(str)`	Remove strings from the right
`str`	`str.replace(str, str)`	Replace substrings
`bool`	`str.startswith(str)`	Check if the string starts with another
`bool`	`str.endswith(str)`	Check if the string ends with another
`int`	`str.find(str)`	Return the first position of a substring starting from the left
`int`	`str.rfind(str)`	Return the position of a substring starting from the right
`int`	`str.count(str)`	Count the number of occurrences of a substring

Stripping and replacing

Stripping removes the specified characters from the beginning or the end of the string. If not specified, removes spaces

```
text = "    one piece    "
print("|" + text.strip()  + "|")         |one piece|
print("|" + text.lstrip() + "|")         |one piece    |
print("|" + text.rstrip() + "|")         |    one piece|

text = "xoxo -one piece- xoox"
print("|" + text.strip(" xo")  + "|")    |-one piece-|
print("|" + text.lstrip(" xo") + "|")    |-one piece- xoox|
print("|" + text.rstrip(" xo") + "|")    |xoxo -one piece-|

print(text.replace("xo", "*"))           ** -one piece- **
```

Analyzing strings

```
text = """Ti che te tachi i tachi, tacame i me tachi.
Mi no che no te taco i tachi, tachete ti i to tachi!"""

print(text.startswith("Ti"))           True
print(text.startswith("Mi"))           False

print(text.endswith("achi!"))          True
print(text.endswith("Tachi!"))         False

print(text.find("tachi"))              10
print(text.rfind("tachi"))             93
print(text.find("tacchi"))             -1

print(text.count("tac"))               8
print(text.count("tachi"))             5
```

Strings are immutable

Whenever you apply any of the operators or methods seen before, a new string is created. The original one is left unchanged.

```
>>> name = "luciano’’
>>> othername = name.replace("no", "")
>>> together = name + othername
>>> print(name, othername, together)
luciano lucia lucianolucia
```

Strings are immutable

Differently from C/C++, but like Java, you cannot modify a character inside a string using the [] notation

```
>>> name[0] = "A"
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError:  'str' object does not support item assignment
```

Example

Given an unformatted string of aminoacids, we want to remove the character >, remove spaces and convert everything to upper case

```
sequence = ">MAnlFKLgaENIFLGrKW    "

s1 = sequence.lstrip(">")
s2 = s1.rstrip(" ")
s3 = s2.upper()
print(s3)
```

Alternatively

Example

Given an unformatted string of aminoacids, we want to remove the character >, remove spaces and convert everything to upper case

```
sequence = ">MAnlFKLgaENIFLGrKW    "

s1 = sequence.lstrip(">")
s2 = s1.rstrip(" ")
s3 = s2.upper()
print(s3)
```

Alternatively

```
print(sequence.lstrip(">").rstrip(" ").upper())
```

How this is possible?

Example

Given an unformatted string of aminoacids, we want to remove the character >, remove spaces and convert everything to upper case

```
sequence = ">MAnlFKLgaENIFLGrKW    "

s1 = sequence.lstrip(">")
s2 = s1.rstrip(" ")
s3 = s2.upper()
print(s3)
```

Alternatively

```
print("MAnlFKLgaENIFLGrKW    ".rstrip(" ").upper())
```

Example

Given an unformatted string of aminoacids, we want to remove the character >, remove spaces and convert everything to upper case

```
sequence = ">MAnlFKLgaENIFLGrKW    "

s1 = sequence.lstrip(">")
s2 = s1.rstrip(" ")
s3 = s2.upper()
print(s3)
```

Alternatively

```
print("MAnlFKLgaENIFLGrKW".upper())
```

Example

Given an unformatted string of aminoacids, we want to remove the character >, remove spaces and convert everything to upper case

```
sequence = ">MAnlFKLgaENIFLGrKW    "

s1 = sequence.lstrip(">")
s2 = s1.rstrip(" ")
s3 = s2.upper()
print(s3)
```

Alternatively

```
print("MANLFKLGAENIFLGRKW")
```

Testing for equality

Result	Operator	Meaning
`bool`	`==, !=`	Check if two strings are equal
`bool`	`is, not is`	Check if two strings are the same object
`str`	`<, >`	Check for lexigraphic order

```
a1 = "casa"
a2 = "casata"
a3 = "casta"
print(a1 == a2)                         False
print(a1 < a2)                          True
print(a1 < a3)                          True
```

Operator ==: equality

Python

```
a1 = "banana"
a2 = "banana"
b1 = "ba"+"na"
b2 = "ba"+"na"
c1 = b1+"na"
c2 = b2+"na"
print(a1==a2)
print(b1==b2)
print(c1==c2)
```

```
True
True
True
```

Java

```
String a1 = "banana";
String a2 = "banana";
String b1 = "ba"+"na";
String b2 = "ba"+"na";
String c1 = b1+"na";
String c2 = b2+"na";
System.out.println(a1 == a2);
System.out.println(b1 == b2);
System.out.println(c1 == c2);
```

```
true
true
false
```

Operator is: identity

Python

```python
a1 = "banana"
a2 = "banana"
b1 = "ba"+"na"
b2 = "ba"+"na"
c1 = b1+"na"
c2 = b2+"na"
print(a1 is a2)
print(b1 is b2)
print(c1 is c2)
```

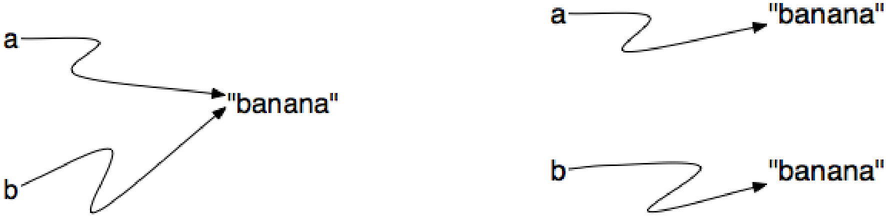
```
True
True
False
```

Java

```java
String a1 = "banana";
String a2 = "banana";
String b1 = "ba"+"na";
String b2 = "ba"+"na";
String c1 = b1+"na";
String c2 = b2+"na";
System.out.println(a1.equals(a2));
System.out.println(b1.equals(b2));
System.out.println(c1.equals(c2));
```

```
true
true
true
```

How strings are stored



In one case, `a` and `b` refer to two different string objects that have the same value. In the second case, they refer to the same object. Remember that an object is something a variable can refer to.

Exercises

- Check whether a string contains exactly five (arbitrary) characters
- Check whether a string contains at least one space
- Check whether the string `"12345"` begins with 1
- Check whether a string contains `x` at least three times at the beginning and/or at the end. For instance, the following strings satisfy the desideratum: `"x....xx"`, `"xx....x"`, `"xxxx..."`.

Exercises

```
chain_a = """SSSVPSQKTYQGSYGFRLGFLHSGTAKSVTCTYSPALNKM
FCQLAKTCPVQLWVDSTPPPGTRVRAMAIYKQSQHMTEVV
RRCPHHERCSDSDGLAPPQHLIRVEGNLRVEYLDDRNTFR
HSVVVPYEPPEVGSDCTTIHYNYMCNSSCMGGMNRRPILT
IITLEDSSGNLLGRNSFEVRVCACPGRDRRTEEENLRKKG
EPHHELPPGSTKRALPNNT"""
```

This string represents the aminoacid sequence of the DNA-binding domain of the Tumor Suppressor Protein TP53.

- How many lines does it hold?
- How long is the sequence? (Without special characters!)
- Create a new variable `sequence` with all newlines removed.
- How many cysteines `"C"` and histidines `"H"` are there in the sequence?
- Does the chain contain the sub-sequence `"NLRVEYLDDRN"`? Where?
- How can I use `find()` and the sub-string extraction `[i:j]` operators to extract the first line from `chain_a`?

Lists

Lists

Lists are ordered sequences of arbitrary elements (objects).

- Lists are mutable: it is possible to change an element inside a list.
- Lists are a sequential collections of elements. This means that the individual elements that make up the list are assumed to be in a particular order from left to right.
- A list that contains no element, often referred to as the empty list, is still considered to be a list.

How to define lists

Lists are defined using square brackets, as follows:

```
# A list of integers (notice that the 1 appears twice)
integers = [1, 2, 3, 1]

# A list of strings
uniprot_proteins = ["Y08501", "Q95747"]

# A list of heterogeneous objects
things = ["Y08501", 0.13, "Q95747", 0.96]

# An empty list
empty = []
```

How to define lists

```
# A list of lists
two_level_list = [
    ["Y08501", 120, 520],
    ["Q95747", 550, 920],
]

# A list containing two empty lists
a_weird_list = [ [], [] ]
```

List operators

All these operators work exactly as in strings

Result	**Operator**	**Meaning**
`bool`	`==, !=`	Check if two lists are equal or different
`int`	`len(list)`	Return the length of the list
`list`	`list + list`	Concatenate two lists (returns a new list)
`list`	`list * int`	Replicate the list (returns a new list)
`list`	`list[int:int]`	Extract a sub-list

New and slightly different operators

Result	Operator	Meaning
`bool`	`obj in list`	Check if an element is present in a list

```
food = ["apple", "orange", "banana", "cherry",
  ["blueberry", "strawberry", "raspberry"]]
print("apple" in food)
print("pear" in food)
print([] in food)
print(["apple", "orange"] in food)
print("blueberry" in food)
print(["blueberry", "strawberry", "raspberry"] in food)
```

```
True / False / False / False / False / True
```

New and slightly different operators

Result	Operator	Meaning
`obj`	`list[int]`	Read/write an element at a specified index

```python
food = ["apple", "orange", "banana", "cherry"]
food[1]="pear"
print(food[1])
print(food[2]=="banana")
food[4] = "pineapple"
```

```
pear
True
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: list assignment index out of range
```

Notes on lists

Lists are ordered

```
[1,2,3] != [3,2,1]
```

Lists are not sets

```
[3, 3, "a", "a"] != [3, "a"]
```

Matrix

```
matrix = [
    [1, 2, 3],          # <-- 1st row
    [4, 5, 6],          # <-- 2nd row
    [7, 8, 9],          # <-- 3rd riga
]
#    ^  ^  ^
#    |  |  |
#    |  |  +-- 3rd column
#    |  +----- 2nd column
#    +-------- 1st column

print(matrix[0])                   [1, 2, 3]
print(matrix[1][1])                5
print(matrix[-1][-1])              9
```

List methods

Return	Method	Meaning
`None`	`list.append(obj)`	Add a new element at the end of the list
`None`	`list.extend(list)`	Add several new elements at the end of the list
`None`	`list.insert(int,obj)`	Add a new element at some given position
`None`	`list.remove(obj)`	Remove the first occurrence of an element
`None`	`list.reverse()`	Invert the order of the elements
`None`	`list.sort()`	Sort the elements
`int`	`list.count(obj)`	Count the occurrences of an element

List methods

```
L = [1,2,3]
print(L)                 [1, 2, 3]
L.append(4)
print(L)                 [1, 2, 3, 4]
L.extend([7,6,5])
print(L)                 [1, 2, 3, 4, 7, 6, 5]
L.insert(3, 3.5)
print(L)                 [1, 2, 3, 3.5, 4, 7, 6, 5]
L.remove(3.5)
print(L)                 [1, 2, 3, 4, 7, 6, 5]
L.sort()
print(L)                 [1, 2, 3, 4, 5, 6, 7]
L.reverse()
print(L)                 [7, 6, 5, 4, 3, 2, 1]
```

List methods

All list methods (except `count()`):

- Modify the input list
- Do not have a return value (they return `None`)

```
L = [0, 1, 2, 3, 4, 5]
print(L)                 [0, 1, 2, 3, 4, 5]
result = L.append(6)
print(L)                 [0, 1, 2, 3, 4, 5, 6]
print(result)            None
L.append(7).append(8)    Traceback (most recent call last):
                           File "<stdin>", line 1, in <module>
                         AttributeError: 'NoneType' object
                         has no attribute 'append'
```

Compare them with similar methods for strings

Append,extend vs concatenation

Unless you really want to create a new list, avoid concatenation whenever possible. The following code produces the same result, but concatenation is way more inefficient.

```
a = [0,1,2,3,4,5]
a.append(6)
a.extend([7,8,9])
```

```
a = [0,1,2,3,4,5]
a = a + [6]
a = a + [7,8,9]
```

Consequences of mutability

Recall that lists are mutable, and that (like all variables) they contain references to objects, not the objects themselves.

```
L1 = [1,2,3]
L2 = [4,5]
LL = [L1,L2]
print(LL)                 [[1, 2, 3], [4, 5]]
L1[2] = 10
print(LL)                 [[1, 2, 10], [4, 5]]
L2.append(6)
print(LL)                 [[1, 2, 10], [4, 5, 6]]
LL[1][1] = 0
print(L2)                 [4, 0, 6]
```

Consequences of mutability

Recall that lists are mutable, and that (like all variables) they contain references to objects, not the objects themselves.

```
original = [1,2,3,4]
copy = original
copy.append(5)
print(original)              [1, 2, 3, 4, 5]
print(copy)                  [1, 2, 3, 4, 5]
```

Consequences of mutability

Recall that lists are mutable, and that (like all variables) they contain references to objects, not the objects themselves.

```
original = [1,2,3,4]
copy = original[:]
copy.append(6)
print(original)          [1, 2, 3, 4, 5]
print(copy)              [1, 2, 3, 4, 5, 6]
```

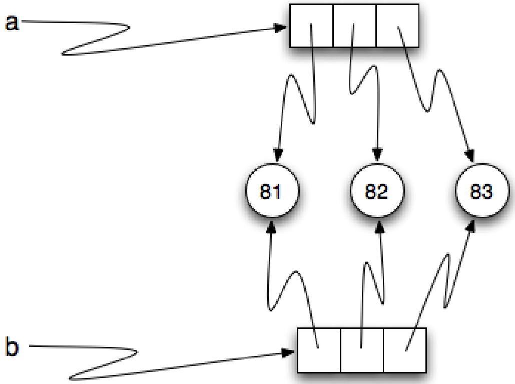
Equality and identity

```
a = [81, 82, 83]
b = [81, 82, 83]
print(a is b)             False
print(a == b)             True
```

Even though they are initialized with the same value, the two objects references by variables `a` and `b` are not identical.

Why this difference with strings?   Lists are mutable

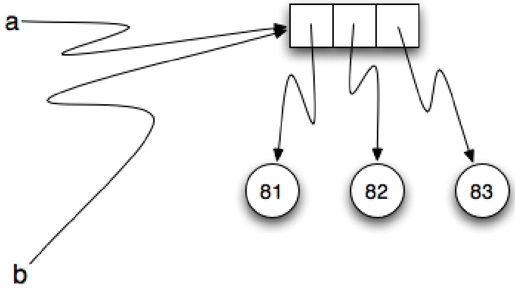
Equality and identity



Equality and identity

```
a = [81, 82, 83]
a = b
c = [81, 82, 83]
b[1] = 85
print(a)                 [81, 85, 83]
print(b)                 [81, 85, 83]
print(c)                 [81, 82, 83]
```

Equality and identity



Exotic slicing

```
L = [1, 2, 3, 4, 5, 6]
L[1:3] = [7, 8]
print(L)                             [1, 7, 8, 4, 5, 6]
L = [1, 2, 3, 4, 5, 6]
L[1:3] = []
print(L)                             [1, 4, 5, 6]
L = [1, 4, 6]
L[1:1] = [2, 3]
print(L)                             [1, 2, 3, 4, 6]
L[4:4] = [5]
print(L)                             [1, 2, 3, 4, 5, 6]
```

String-list methods

Result	**Operator**	**Meaning**
`list-of-str`	`str.split(str)`	Split a string into a list of strings (words)

`s.split(sep)` returns a list of the words of the string `s`. If the optional argument `sep` is absent or None, the words are separated by arbitrary strings of whitespace characters (space, tab, newline, return, formfeed). Otherwise, `sep` specifies a string to be used as the word separator.

String-list methods

```
terzina = """Nel mezzo del cammin di nostra vita
mi ritrovai per una selva oscura,
che la diritta via era smarrita."""
versi = terzina.split("\n")
print(versi)
print(versi[0].split())
print(versi[1].split(" "))
print(versi[2].split("via"))
```

```
['Nel mezzo del cammin di nostra vita',
'mi ritrovai per una selva oscura,',
'che la diritta via era smarrita.']
['Nel', 'mezzo', 'del', 'cammin', 'di', 'nostra', 'vita']
['mi', 'ritrovai', 'per', 'una', 'selva', 'oscura,']
['che la diritta ', ' era smarrita.']
```

Exercises

What is the difference between these two pieces of code? How long is `list` in the two cases?

```
L = []
L.append([1,2,3])
L.append([4,5,6])
print(L)
print(len(L))
```

```
[ [1, 2, 3], [4, 5, 6] ]
2
```

```
L = []
L.extend([1,2,3])
L.extend([4,5,6])
print(L)
print(len(L))
```

```
[1,2,3,4,5,6]
6
```

Tuples

Tuples

Tuples are the immutable version of lists.

- Tuples are immutable: it is not possible to change an element inside a tuple.
- Tuples are a sequential collections of elements. This means that the individual elements that make up the tuple are assumed to be in a particular order from left to right.
- Tuples with zero or one elements are possible, but not really interesting.

How to define tuples

Tuples are defined using paranthesis, as follows:

```
# A tuple of integers (notice that the 1 appears twice)
integers = (1, 2, 3, 1)

# A tuple of strings
uniprot_proteins = ("Y08501", "Q95747")

# A tuple of heterogeneous objects
things = ("Y08501", 0.13, "Q95747", 0.96)

# This is not a tuple, is a variable initialized to
# an expression evaluated to 1
single = (1)
```

How to define tuples

```
# A tuple containing a single element
single = (1,)

# A tuple of tuples
two_level_list = (
    ("Y08501", 120, 520),
    ("Q95747", 550, 920),
)
```

Why tuples?

- Tuples are needed whenever an immutable version of lists is needed. E.g., tuples can be used as keys in *dictionaries*, yet another data structure that associates immutable keys to objects.
- Tuples are used to associate objects that are treated as a single entity in the program. E.g., functions may return tuples in order to return multiple objects at the same time.
- Whenever a sequence of objects cannot change over time, immutable tuples are more efficient than mutable lists.

Tuple operators

All these operators work exactly as in lists

Result	Operator	Meaning
`bool`	`==, !=`	Check if two tuples are equal or different
`int`	`len(tuple)`	Return the length of the tuple
`tuple`	`tuple + tuple`	Concatenate two tuples (returns a new tuple)
`tuple`	`tuple * int`	Replicate the tuple (returns a tuple)
`tuple`	`tuple[int]`	Read an element of the tuple
`tuple`	`tuple[int:int]`	Extract a sub-tuple

Tuple methods

Return	Method	Meaning
`int`	`tuple.count(obj)`	Count the occurrences of an element
`int`	`tuple.index(obj)`	Return the index of the first occurrence of an object

Some comments

- Equality and identity for tuples work exactly as equality and identity for lists, not as in strings
- As tuples are immutable, there are no consequences of mutability (unlike lists)

List/tuple/string conversions

Return	Method	Meaning
list	list(obj)	Transform an object into a list
tuple	tuple(onj)	Transform an object into a tuple

```
T = (1,2,3)
S = "123"
LT = list(T)
LS = list(S)
print(LT)                      [1, 2, 3]
print(LS)                      [’1’, ’2’, ’3’]
print(LT == LS)                False
```

Warning

Why you shouldn’t call a list `list`, a string `string` and a tuple `tuple`

```
list = [1,2,3]
another_list = list("Goal")
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: ’list’ object is not callable
```

Your variable list substitutes the `list()` function; more on this in a future lecture.

Dictionary

Dictionary

A dictionary represents a map between objects: it maps from a key to the corresponding value.

- Dictionaries are mutable: it is possible to add/remove/change the associations between keys and values
- Dictionaries contains sequences of keys, but these keys are not necessarily ordered.
- A dictionary that contains no element is still considered to be a dictionary.

How to define dictionaries

Dictionaries are defined using curly brackets, listing associations key:values: `key1: value1, key2: value2, ...`

```
genetic_code = {
    "UUU": "F",     # phenilalanyne
    "UCU": "S",     # serine
    "UAU": "Y",     # tyrosine
    "UGU": "C",     # cysteine
    "UUC": "F",     # phenilalanyne
    "UCC": "S",     # serine
    "UAC": "Y",     # tyrosine
    # etc.
}
```

- Keys are unique: a key can be associated to a single value
- Values are not unique: different keys can map to the same value

How to define dictionaries

```
volume_of = {
    "A":  67.0, "C":  86.0, "D":  91.0,
    "E": 109.0, "F": 135.0, "G":  48.0,
    "H": 118.0, "I": 124.0, "K": 135.0,
    "L": 124.0, "M": 124.0, "N":  96.0,
    "P":  90.0, "Q": 114.0, "R": 148.0,
    "S":  73.0, "T":  93.0, "V": 105.0,
    "W": 163.0, "Y": 141.0,
}
```

- There are no restrictions on the type of the values
- In this case, values are floats

Reading a dictionary

```
>>> print(genetic_code["UCU"])
S
>>> print(genetic_code["UCC"])
S
>>> print(volume_of["C"])
86.0
>>> print(type(volume_of["C"]))
float
```

Keys must be immutable

The association works only in one direction: you can obtain values from keys, not viceversa

```
properties_of = {
    "A": [ 89.09,  67.0],
    "C": [121.15,  86.0],
    "D": [133.10,  91.0],
    # ...
}
print(properties_of["A"])
print(properties_of[89.09,  67.0])
```

```
[89.09, 67.0]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError:  (89.09, 67.0)
```

Keys must be immutable

Lists and dictionaries cannot be used as keys, because they are mutable.

```
reverse_properties_of = {
    [89.09,  67.0]: "A",
    [121.15,  86.0]: "C",
    [133.10,  91.0]: "D",
    # ...
}
```

```
Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
TypeError:  unhashable type:  'list'
```

Keys must be immutable

Use tuples instead!

```
reverse_properties_of = {
    (89.09,  67.0): "A",
    (121.15,  86.0): "C",
    (133.10,  91.0): "D",
    # ...
}
```

Dictionary operators

Result	Operator	Meaning
`bool`	obj `in` dict	Return `True` if a key is present in the dictionary
`int`	`len(dict)`	Return the number of elements in the dictionary
`obj`	`dict[obj]`	Read the value associate with a key
`obj`	`dict[obj] = obj`	Add or modify the value associated with a key

```
code = {}           # Empty dictionary
code["UUU"] = "F"   # Phenylalanine
code["UCU"] = "M"   # Methionine
code["UCU"] = "S"   # Serine (methionine was a mistake!)
code["UAU"] = "Y"   # Tyrosine
print(len(code))                                3
print("Y" in code)                              False
```

Dictionary methods

Return	**Method**	**Meaning**
`list`	`dict.keys()`	Returns the list of the keys that are present in the dictionary
`list`	`dict.values()`	Returns the list of the values that are present in the dictionary
`list of tuples`	`list.items()`	Returns the list of pairs (key, value) that are present in the dictionary

Dictionary methods

```
code = {
    "UUU": "F",      # phenylalanine
    "UCU": "S",      # serine
    "UAU": "Y",      # tyrosine
    "UGU": "C",      # cysteine
    "UUC": "F",      # phenylalanine
    "UCC": "S",      # serine
    "UAC": "Y",      # tirosine
}
```

Dictionary methods

```
>>> print(code)
{’UCC’: ’S’, ’UCU’: ’S’, ’UUC’: ’F’, ’UUU’: ’F’, ’UGU’: ’C’,
’UAC’: ’Y’, ’UAU’: ’Y’}

>>> print(code.keys())
dict_keys([’UCU’, ’UAC’, ’UUU’, ’UUC’, ’UGU’, ’UAU’, ’UCC’])

>>> print(code.values())
dict_values([’S’, ’Y’, ’F’, ’F’, ’C’, ’Y’, ’S’])

>>> print(code.items())
dict_items([(’UCU’, ’S’), (’UAC’, ’Y’), (’UUU’, ’F’),
(’UUC’, ’F’), (’UGU’, ’C’), (’UAU’, ’Y’), (’UCC’, ’S’)])
```

Dictionary methods

```
>>> print(code)
{’UCC’: ’S’, ’UCU’: ’S’, ’UUC’: ’F’, ’UUU’: ’F’, ’UGU’: ’C’,
’UAC’: ’Y’, ’UAU’: ’Y’}

>>> print(list(code.keys())
[’UUU’, ’UGU’, ’UUC’, ’UAU’, ’UCU’, ’UAC’, ’UCC’]

>>> print(list(code.values()))
[’F’, ’C’, ’F’, ’Y’, ’S’, ’Y’, ’S’]

>>> print(list(code.items()))
[(’UUU’, ’F’), (’UGU’, ’C’), (’UUC’, ’F’), (’UAU’, ’Y’),
(’UCU’, ’S’), (’UAC’, ’Y’), (’UCC’, ’S’)]
```

Notes

- Associations are stored (and printed) in a random order, which is neither the order in which elements are inserted neither the alphabetical order
- Differences between 2.x and 3.x:
  - In 2.x, methods `keys()`, `values()` and `items()` returns lists
  - In 3.x, methods `keys()`, `values()` and `items()` return special iterable objects used in `for` loops

Example

```
seq = "GTCCCTGTTCGGGCGCCA"
num_A = seq.count("A")
num_T = seq.count("T")
num_C = seq.count("C")
num_G = seq.count("G")
histogram = {
    "A": num_A / len(seq),
    "T": num_T / len(seq),
    "C": num_C / len(seq),
    "G": num_G / len(seq),
}
print(histogram)
```

Exercise

Given:

```
translation_of = {"a": "ade", "c": "cyt",
    "g": "gua", "t": "tym"}
```

translate the list:

```
L = ["A", "T", "T", "A", "G", "T", "C"]
```

into the string:

```
"ade tym tym ade gua tym cyt"
```

Hint: note that dictionary keys are in lower case, while the elements of list are in upper case! Start assuming they are not, then modify the code in order to account for this difference.