COMP 1023 Introduction to Python Programming

Collections - Container Data Types (Part I)

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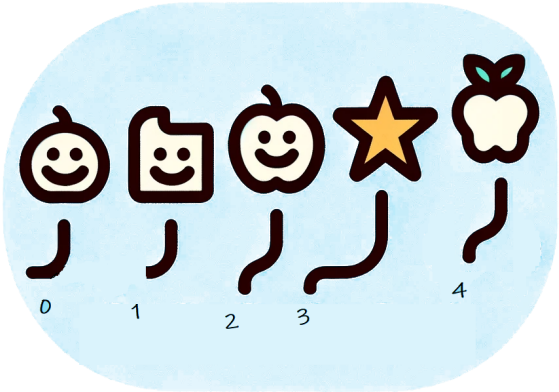
Collections in Python

- Collections are fundamental data structures in Python that allow you to store and manage multiple items efficiently.
- They provide ways to organize data, enabling easy access, modification, and manipulation.
- Different types of collections serve different purposes:
  - Lists: Ordered, mutable collections that can hold mixed data types.
  - Tuples: Ordered, immutable collections that are typically used to group related data.
  - Sets: Unordered collections of unique elements, useful for membership testing and eliminating duplicates. (Self-study)
  - Dictionaries: Ordered collections (i.e., those that preserve insertion order) of key-value pairs allow for fast lookups and data storage based on unique keys.
- Understanding these collections is crucial for effective programming in Python, as they provide the foundation for data organization and manipulation.

Lists



Introduction

- Programs often need to store a large number of values.
- For instance, suppose you need to read 100 numbers, compute their average, and find out how many of the numbers are above the average.
- Your program first reads the numbers, computes their average, and then compares each number with the average to determine whether it is above the average.
- To accomplish this task, all numbers must be stored in variables. This would require creating 100 variables and writing almost identical code 100 times.
- Writing a program this way is impractical. So, how do you solve this problem?
- Python provides a data type called a list that stores a sequential collection of elements.

Not a Good Idea!

```
def main():
    v1 = float(input("Enter the 1st number: "))
    v2 = float(input("Enter the 2nd number: "))
    v3 = float(input("Enter the 3rd number: "))
    ...
    v99 = float(input("Enter the 99th number: "))
    v100 = float(input("Enter the 100th number: "))

    avg = (v1 + v2 + v3 + v4 + v5
           + v6 + v7+ v8 + v9 + v10
           ...
           + v96 + v97 + v98 + v99 + v100) / 100
    print(f"The average is {avg}.")

if __name__ == "__main__":
    main()
```

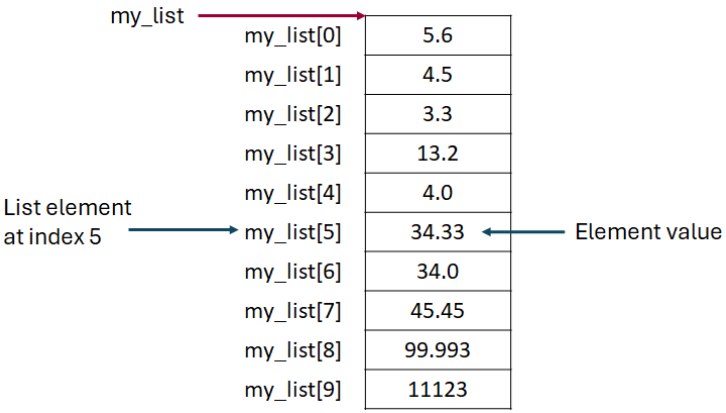
List Basics

- A list is a sequence of any elements (of any type).
- To create a list, you can use the following syntax:

```
list1 = []                          # Create an empty list
list2 = [2, 3, 4]                   # Create a list with elements 2, 3, 4
list3 = ["red", "green", "blue"]    # Create a list with strings
list4 = list(range(3, 6))           # Create a list with elements 3, 4, 5 using constructor
list5 = list("abcd")                # Create a list with characters a, b, c, d
                                    # using constructor
list6 = [2, "three", 4]             # Create a list with elements of mixed types
```

List Demonstration

```
my_list = [5.6, 4.5, 3.3, 13.2, 4.0, 34.33, 34.0, 45.45, 99.993, 11123]
```



- The list `my_list` has 10 elements with indexes from 0 to 9.

Common Error

- Accessing a list out of bounds is a common programming error that results in a runtime 'IndexError'.
- To avoid this error, ensure that you do not use an index beyond `len(my_list) - 1`.
- Here is an example of an out-of-bounds error:

```
# Filename: list_out_of_bounds_error.py

def main():
    my_list = [5.6, 4.5, 3.3, 13.2, 4.0, 34.33, 34.0, 45.45, 99.993, 11123]
    i = 0
    while i <= len(my_list):
        print(my_list[i])
        i += 1

if __name__ == "__main__":
    main()
```

How to fix it?

Operations for Sequences

- The following shows some common operations for sequences such as lists, ranges, tuples (to be discussed), and strings (to be covered in the labs).

Operation	Description
x in s	True if element x is in sequence s.
x not in s	True if element x is not in sequence s.
s1 + s2	Concatenates two sequences s1 and s2.
s * n, n * s	n copies of sequence s concatenated.
s[i]	ith element in sequence s.
s[i:j]	Slice of sequence s from index i to j - 1.
len(s)	Length of sequence s, i.e., the number of elements in s.
min(s)	Smallest element in sequence s.
max(s)	Largest element in sequence s.
sum(s)	Sum of all numbers in sequence s.
for loop	Traverses elements from left to right in a for loop.
$<$, $<=$, $>$, $>=$, $==$, $!=$	Compares two sequences

Comparison Operators for Lists

- Equality (==):
  - Checks if two lists have the same elements in the same order.

```
[1, 2, 3] == [1, 2, 3]  # True
[1, 2, 3] == [3, 2, 1]  # False
```

- Inequality (!=):
  - Checks if two lists are not equal.

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

- Less Than (<) and Greater Than (>):
  - Compares lists lexicographically (like dictionary order).
  - Compares element by element until a difference is found.

```
[1, 2, 3] < [1, 2, 4]   # True
[1, 2] < [1, 2, 0]      # True
```

- Less Than or Equal To (<=) and Greater Than or Equal To (>=):
  - Similar to < and >, but include equality.

```
[1, 2, 3] <= [1, 2, 3]  # True
[1, 2] >= [1, 2, 0]     # False
```

Functions for Lists

```python
def main():  # Filename: functions_for_lists.py
    my_list1 = [1, 2, 3, 4, 5]
    my_list2 = [4, 5, 6, 7, 8]

    print("4 in my_list1:", 4 in my_list1)
    print("4 not in my_list1:", 4 not in my_list1)
    print("my_list1 + my_list2:\n", my_list1 + my_list2)
    print("my_list1 * 2:", my_list1 * 2)
    print("2 * my_list1:", 2 * my_list1)
    print("my_list1[3]:", my_list1[3])
    print("my_list1[3:5]:", my_list1[3:5])
    print("len(my_list1):", len(my_list1))
    print("min(my_list1):", min(my_list1))
    print("max(my_list1):", max(my_list1))
    print("sum(my_list1):", sum(my_list1))

    for i in my_list1:
        print(i, end=" ")
    print()

    print("my_list1 < my_list2:", my_list1 < my_list2)

if __name__ == "__main__":
    main()
```

Output:

```
4 in my_list1: True
4 not in my_list1: False
my_list1 + my_list2:
 [1, 2, 3, 4, 5, 4, 5, 6, 7, 8]
my_list1 * 2: [1, 2, 3, 4, 5, 1, 2, 3, 4, 5]
2 * my_list1: [1, 2, 3, 4, 5, 1, 2, 3, 4, 5]
my_list1[3]: 4
my_list1[3:5]: [4, 5]
len(my_list1): 5
min(my_list1): 1
max(my_list1): 5
sum(my_list1): 15
1 2 3 4 5
my_list1 < my_list2: True
```

Index Operator [ ]

- An element in a list can be accessed through the index operator, using the following syntax:

  `my_list[index]`

- List indexes are 0-based, meaning they range from `0` to `len(my_list) - 1`.
- `my_list[index]` can be used just like a variable, so it is also known as an indexed variable.
- For example, the following code adds the values in `my_list[0]` and `my_list[1]` to `my_list[2]`:

  `my_list[2] = my_list[0] + my_list[1]`

- The following loop assigns `0` to `my_list[0]`, `1` to `my_list[1]`, ..., `9` to `my_list[9]`:

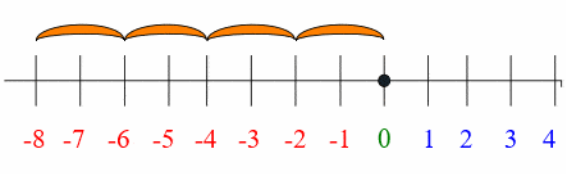
```
for i in range(len(my_list)):
    my_list[i] = i
```

Negative Numbers as Indexes

- Python allows the use of negative numbers as indexes to reference positions relative to the end of the list.
- The actual position is obtained by adding the length of the list to the negative index.
- For example:

```
my_list = [2, 3, 5, 2, 33, 21]
print(my_list[-1])  # Print 21
print(my_list[-3])  # Print 2
```

  - `my_list[-1]` is the same as `my_list[-1 + len(my_list)]` (i.e., `my_list[-1 + 6]`).
  - `my_list[-3]` is the same as `my_list[-3 + len(my_list)]` (i.e., `my_list[-3 + 6]`).



List Slicing

- The slicing operator returns a slice of the list using the syntax:

  `my_list[start : end : step]`

- The slice is a sublist from index `start` to index `end - 1` with the specified `step`.
  - By default, `step` is 1.

```
my_list = [2, 3, 5, 7, 9, 1]
print(my_list[2 : 4])      # Print [5, 7]
print(my_list[0 : 5 : 2]) # Print [2, 5, 9]
```

List Slicing

- You can use a negative index in slicing.

```
my_list = [2, 3, 5, 7, 9, 1]
print(my_list[1 : -3])   # Print [3, 5]
print(my_list[-4 : -2])  # Print [5, 7]
```

  - `my_list[1 : -3]` is the same as `my_list[1 : -3 + len(my_list)]`.
  - `my_list[-4 : -2]` is the same as `my_list[-4 + len(my_list) : -2 + len(my_list)]`.

- You can assign values to a slice of a list.

```
my_list = [2, 3, 5, 7, 9, 1]
my_list[1 : 3] = [91, 92, 93, 94]
print(my_list) # Print [2, 91, 92, 93, 94, 7, 9, 1]
```

  - `my_list[1 : 3] = [91, 92, 93, 94]` replaces `[3, 5]` in `my_list` with `[91, 92, 93, 94]`.

List Slicing: Default Values and Edge Cases

- The starting index or ending index may be omitted. Then, default values will be used.
  - Positive step (i.e., step > 0):
    - If you omit the start index: Default is 0 (start from the beginning).
    - If you omit the end index: Default is the length of the list (i.e., len(my_list)).
    - If start index $\geq$ end index, the result will be an empty list.
  - Negative step (i.e., step < 0):
    - If you omit the start index: Default is the last index (i.e., len(my_list)-1).
    - If you omit the end index: Default is None (will go until the start of the list).
    - If end index $\leq$ start index, the result will be an empty list.
  - If you omit the step: Default is 1.
- If `start` or `end` specifies a position beyond the end of the list, Python will use the length of the list for `start` or `end` instead.

List Slicing Examples

- Positive steps (i.e., step > 0):

```
my_list = [2, 3, 5, 7, 9, 1]
print(my_list[  : 2 : 1])  # Equivalent to print(my_list[0 : 2 : 1]), Print [2, 3]
print(my_list[3 :   : 1])  # Equivalent to print(my_list[3 : 6 : 1]), Print [7, 9, 1]
print(my_list[3 : 1 : 1])  # Empty list
```

- Negative steps (i.e., step < 0):

```
my_list = [2, 3, 5, 7, 9, 1]
print(my_list[  : 2 : -1])  # Equivalent to print(my_list[5 : 2 : -1]), Print [1, 9, 7]
print(my_list[3 :   : -1])  # Equivalent to print(my_list[3 : None : -1]), Print [7, 5, 3, 2]
print(my_list[1 : 3 : -1])  # Empty list
```

- start or end specifies a position beyond the end of the list:

```
my_list = [2, 3, 5, 7, 9, 1]
print(my_list[3 : 8]) # Equivalent to print(my_list[3 : 6]), Print [7, 9, 1]
print(my_list[7 : 5]) # Equivalent to print(my_list[6 : 5]), Print []
print(my_list[7 : 8]) # Equivalent to print(my_list[6 : 6]), Print []
```

Slicing handles out-of-range indices gracefully!

Traversing Elements in a List

- The elements in a Python list are iterable.
- Python supports a convenient `for` loop, which enables you to traverse the list sequentially without using an index variable.
- For example, the following code displays all the elements in the list `my_list`:

```
my_list = [5.6, 4.5, 3.3, 13.2, 4.0, 34.33, 34.0, 45.45, 99.993, 11123]
for u in my_list:
    print(u, end=' ')
# Print 5.6 4.5 3.3 13.2 4.0 34.33 34.0 45.45 99.993 11123
```

- You still have to use an index variable if you wish to traverse the list in a different order or change the elements in the list. For example, the following code displays the elements at even-numbered indices:

```
my_list = [5.6, 4.5, 3.3, 13.2, 4.0, 34.33, 34.0, 45.45, 99.993, 11123]
for i in range(0, len(my_list), 2):
    print(my_list[i], end=' ')
# Print 5.6 3.3 4.0 34.0 99.993
```

List Comprehensions

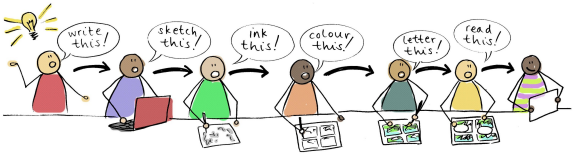
- List comprehensions provide a concise syntax to create a list by processing another sequence of data.
- A list comprehension consists of brackets containing an expression followed by a `for` clause, then zero or more `for` or `if` clauses.
- The list comprehension produces a list with the results from evaluating the expression.

```
list1 = [x for x in range(5)]
print(list1)  # Print [0, 1, 2, 3, 4]

list2 = [0.5 * x for x in list1]
print(list2)  # Print [0.0, 0.5, 1.0, 1.5, 2.0]

list3 = [x for x in list2 if x < 1.5]
print(list3)  # Print [0.0, 0.5, 1.0]
```

List Methods

- Lists are defined using the list class in Python. Once a list is created, you can use the list class's methods to manipulate the list.

Method	Description
append(x)	Adds an element `x` to the end of the list.
count(x)	Returns the number of times element `x` appears in the list.
extend(anotherList)	Appends all the elements in `anotherList` to the list.
index(x)	Returns the index of the first occurrence of element `x` in the list.
insert(index, x)	Inserts an element `x` at a given index. Note that the first element in the list has index 0.
pop(index)	Removes the element at the given index and returns it. The parameter index is optional. If it is not specified, `list.pop()` removes and returns the last element in the list.
remove(x)	Removes the first occurrence of element `x` from the list.
reverse()	Reverses the elements in the list.
sort()	Sorts the elements in the list in ascending order.



Examples

```
list1 = [2, 3, 4, 1, 32, 4]
list1.append(19)
print(list1)                # Print [2, 3, 4, 1, 32, 4, 19]
print(list1.count(4))       # Return the count for number 4, print 2
list2 = [99, 54]
list1.extend(list2)
print(list1)                # Print [2, 3, 4, 1, 32, 4, 19, 99, 54]
print(list1.index(4))       # Print 2
list1.insert(1, 25)
print(list1)                # Print [2, 25, 3, 4, 1, 32, 4, 19, 99, 54]
print(list1.pop(2))         # Print 3
print(list1)                # Print [2, 25, 4, 1, 32, 4, 19, 99, 54]
print(list1.pop())          # Print 54
print(list1)                # Print [2, 25, 4, 1, 32, 4, 19, 99]
list1.remove(32)            # Equivalent to del list1[4]
print(list1)                # Print [2, 25, 4, 1, 4, 19, 99]
list1.reverse()
print(list1)                # Print [99, 19, 4, 1, 4, 25, 2]
list1.sort()
print(list1)                # Print [1, 2, 4, 4, 19, 25, 99]
list1.sort(reverse=True)    # Sort the list in descending order
print(list1)                # Print [99, 25, 19, 4, 4, 2, 1]
del list1                   # Delete the whole list, so list1 no longer exists
```

Splitting a String into a List

- To split the characters in a string `s` into a list, use `list(s)`:

```
my_list = list("abc")
print(my_list)  # Print ['a', 'b', 'c']
```

- The `str` class contains the `split` method, which is useful for splitting items in a string into a list:

```
items1 = "COMP1023 is the best COMP course".split() # Delimited by spaces
print(items1)   # Print ['COMP1023', 'is', 'the', 'best', 'COMP', 'course']

items2 = "12/25/2025".split("/")  # Delimited by /
print(items2)   # Print ['12', '25', '2025']
```

Inputting Lists

- To read data from the console into a list, you can enter one data item per line and append it to a list in a loop.

```
# Filename: inputting_list.py

def main():
    total = 0.0
    counter = 0
    my_list = []  # Create an empty list
    print("Enter 10 numbers, one number per line: ")
    for i in range(10):
        my_list.append(float(input()))
        total += my_list[-1]
        counter += 1
    average = total / counter
    print("Average =", average)

if __name__ == "__main__":
    main()
```

Output:

```
Enter 10 numbers, one number per line:
52
79
67
21
56
11
99
41
69
47
Average = 54.2
```

Inputting Lists

- You can enter the data in one line, separated by spaces.
- The following code demonstrates how to read the input and calculate the average:

```
# Filename: inputting_list_comprehension.py
def main():
    s = input("Enter 10 numbers separated by spaces: ")
    items = s.split()                          # Extract items from the string
    my_list = [float(x) for x in items]        # Convert items to numbers
    average = sum(my_list) / len(my_list)      # Calculate average
    print("Average =", average)

if __name__ == "__main__":
    main()
```

Output:

```
Enter 10 numbers separated by spaces: 52 79 67 21 56 11 99 41 69 47
Average = 54.2
```

Good Use of List

- Suppose you want to prompt the user to enter a month number and display its month name.
- A simple approach might look like this:

```
if monthNumber == 1:
   print("The month is January")
elif monthNumber == 2:
   print("The month is February")
...
else:
   print("The month is December")
```

- A "better" way to do this is as follows:

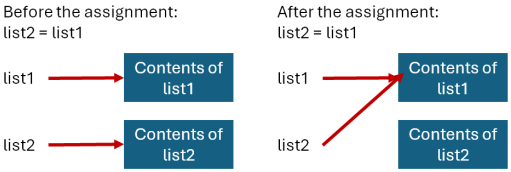
```
months = ["January", "February", "March", "April", "May", "June",
          "July", "August", "September", "October", "November", "December"]
monthNumber = int(input("Enter a month number (1 to 12): "))
if 1 <= monthNumber <= 12:
    print("The month is", months[monthNumber - 1])
else:
    print("Invalid month number! Please enter a number between 1 and 12.")
```

Copying Lists

Question

Does `list2 = list1` duplicate a list?

- The statement `list2 = list1` does not copy the contents of the list referenced by `list1` to `list2`.
- Instead, it copies the reference from `list1` to `list2`.
- After this statement, `list1` and `list2` refer to the same list.




```
list1 = [1, 2]
list2 = [3, 4, 5]
print(id(list1))  # Print 140415885168576
print(id(list2))  # Print 140415896311744
list2 = list1
print(id(list2))  # Print 140415885168576
```

- The list previously referenced by `list2` is no longer referenced. The memory space occupied by that list will be automatically collected and reused by the Python interpreter.

How can you duplicate a list?

Deep Copy vs. Shallow Copy in Python

- Shallow Copy
  - Creates a new object, but inserts references to the objects found in the original.
  - Changes to mutable objects in the copied list affect the original list.
- Deep Copy
  - Creates a new object and recursively adds copies of nested objects found in the original.
  - Changes to mutable objects in the copied list do not affect the original list.

```python
# Filename: shallow_vs_deep_copy.py

import copy

# Original list with a nested mutable object
original_list = [[1, 2], [3, 4]]

# Shallow Copy
shallow_copied_list = original_list.copy()
# Modifies original_list as well
shallow_copied_list[0][0] = 99

# Deep Copy
deep_copied_list = copy.deepcopy(original_list)
# Does not affect original_list
deep_copied_list[1][0] = 88

print(original_list)       # Print [[99, 2], [3, 4]]
print(shallow_copied_list) # Print [[99, 2], [3, 4]]
print(deep_copied_list)    # Print [[99, 2], [88, 4]]
```

Copying Lists

- Shallow Copy
  - List Constructor
    ```
    list1 = [1, 2]
    list2 = list(list1)
    ```
  - List Comprehension
    ```
    list1 = [1, 2]
    list2 = [x for x in list1]
    ```
  - List Concatenation
    ```
    list1 = [1, 2]
    list2 = [] + list1
    ```
  - List Splicing
    ```
    list1 = [1, 2]
    list2 = list1[:]
    ```
- Deep Copy
  - `copy.deepcopy()`
    ```
    import copy
    list1 = [1, 2]
    list2 = copy.deepcopy(list1)
    ```

Two-Dimensional Lists

- A two-dimensional list consists of rows.
- Each row is a list that contains values.
- The rows can be accessed using an index, called a row index.
- The values in each row can be accessed through another index, called a column index.

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

	[0]	[1]	[2]	[3]	[4]
[0]	1	2	3	4	5
[1]	6	7	0	0	0
[2]	0	1	0	0	0
[3]	1	0	0	0	8
[4]	0	0	9	0	3

```
matrix[0] is [1, 2, 3, 4, 5]
matrix[1] is [6, 7, 0, 0, 0]
matrix[2] is [0, 1, 0, 0, 0]
matrix[3] is [1, 0, 0, 0, 8]
matrix[4] is [0, 0, 9, 0, 3]

matrix[0][0] is 1
matrix[4][4] is 3
```

- Each value can be accessed using `matrix[i][j]`, where i and j are the row and column indexes.

Summing All Elements and Elements by Column

```python
# Filename: summing_elements.py

def main():
    matrix = [[1, 2, 3], [4, 5, 6], [7, 8, 9]]

    # Summing All Elements
    total = 0
    for row in matrix:
        for value in row:
            total += value
    print("Total is", total)  # Print the total

    # Summing Elements by Column
    for column in range(len(matrix[0])):
        total = 0
        for row in range(len(matrix)):
            total += matrix[row][column]
        print("Sum for column", column, "is", total)

if __name__ == "__main__":
    main()
```

Output:

```
Total is 45
Sum for column 0 is 12
Sum for column 1 is 15
Sum for column 2 is 18
```

Printing Two-Dimensional Lists

```python
def main():  # Filename: printing_two_dimensional_lists.py
    matrix = [[1, 2, 3], [4, 5, 6], [7, 8, 9]]

    # Method 1: Using indices
    for row in range(len(matrix)):
        for column in range(len(matrix[row])):
            print(matrix[row][column], end=" ")
        print()  # Print a new line

    print()  # Print another new line

    # Method 2: Using direct iteration
    for row in matrix:
        for value in row:
            print(value, end=" ")
        print()  # Print a new line

if __name__ == "__main__":
    main()
```

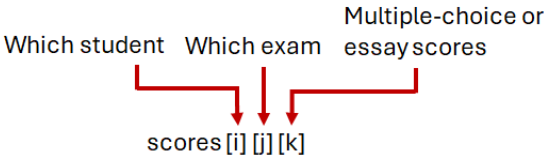
Output:

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

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

Multidimensional Lists

- Occasionally, you need to represent n-dimensional data, for any integer n.
- For example, you can use a three-dimensional list to store exam scores for a class of 6 students with 5 exams, where each exam has 2 parts (multiple-choice and essay).

```
scores = [
    [[11.5, 20.5], [11.0, 22.5], [15, 33.5], [13, 21.5], [15, 2.5]],
    [ [4.5, 21.5], [11.0, 22.5], [15, 34.5], [12, 20.5], [14, 11.5]],
    [ [6.5, 30.5], [11.4, 11.5], [11, 33.5], [11, 23.5], [10, 2.5]],
    [ [6.5, 23.5], [11.4, 32.5], [13, 34.5], [11, 20.5], [16, 11.5]],
    [ [8.5, 26.5], [11.4, 52.5], [13, 36.5], [13, 24.5], [16, 2.5]],
    [[11.5, 20.5], [11.4, 42.5], [13, 31.5], [12, 20.5], [16, 6.5]]
]
```



The expression `scores[0][1][0]` refers to the multiple-choice score for the first student's second exam.

Key Terms

- List
- List comprehension

Review Questions

Fill in the blanks in each of the following sentences about the Python environment.

1. You can use the Python built-in functions _____, _____, _____, and _____ to return the length of a numeric list, the maximum and minimum elements in a numeric list, and the sum of all the elements in a numeric list.
2. You can use the index operator [] with integer values to reference an individual element in a _____, and a _____.
3. Programmers often mistakenly reference the first element in a list or tuple with index 1, but it should be _____.
4. You can use the concatenation operator + to concatenate two _____, the repetition operator * to duplicate elements, the slicing operator [:] to get a _____, and the `in` and `not in` operators to check whether an element is in a _____.

Answer: 1. len; max; min; sum, 2. list; tuple, 3. 0, 4. lists; sublist; sequence.

Review Questions

Fill in the blanks in each of the following sentences about the Python environment.

5. A _____ object is mutable. You can use the methods _____, _____, _____, _____ to add and remove elements to and from a _____.
6. You can use the _____ method to split a string into a list.

Answer: 5. list; append; insert; pop; remove; list, 7. split.

Further Reading

- Read Chapters 7 & 14 of the textbook “Introduction to Python Programming and Data Structures”.

That's all!

Any question?