PROGRAMMING IN PYTHON I

Data Structures

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GROUPING VALUES

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- Group of values is a **data structure**

DATA STRUCTURES

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  - Python: Dictionary, . . .
- Python takes care of growing data structures for you

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- Important: **Indices in Python are integers and start at 0!**

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  → We can add, modify and delete the items in the list
- Python lists can contain all kinds of objects (also mixed)
- Python lists **can be nested**, i.e., contain other lists:

```
my_list = [23, "367", ["trh", 5], 6.35]
my_list[2]  # Returns ["trh", 5]
```

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- Tuples are created via a number of values, separated by commas

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my_tuple = 42, "a string", 346.345
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```

- Tuples are **similar to lists but immutable**
  - Once a tuple is created, it cannot be changed anymore!

    ```
    my_tuple[1] = 5  # This would fail
    ```

  - It is possible to create tuples with mutable objects, e.g., lists

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- Common set operations are supported:
  - Union: `set1 | set2`
  - Intersection: `set1 & set2`
  - Difference: `set1 - set2`
  - ...

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- Could use a second list of names with same order
  - $\rightarrow$ Tedious to use and maintain!
- It would be better to use the names as indices to the phone number, i.e., to have key-value pairs
  - $\rightarrow$ This is a map/associative array

Dictionaries in Python (1)

- Python dictionaries are **mappings/associative arrays**
  - Consist of **key-value pairs**, e.g., name $\rightarrow$ phone number
  - Any **hashable** object can be used as **key**
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  - Any **hashable** object can be used as **key**
  - Any object can be used as **value**
- **Mutable** and **ordered**[1] (insertion order is preserved)
- Created with syntax (keys can be anything)

  ```
  my_dict = {key1: value1, key2: value2}
  ```

  or syntax (keys must be identifiers and are automatically converted to type string)

  ```
  my_dict = dict(key1=value1, key2=value2)
  ```

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Dictionaries in Python (2)

- Phone book example (mapping string keys to string values):

  ```
  phone_book = {"sam": "01234", "alex": "98765"}
  ```

  or alternatively:

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  phone_book = dict(sam="01234", alex="98765")
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- The keys of dictionary entries have to be **unique**
- The following will overwrite the previous number for sam:

  ```
  phone_book["sam"] = "13579"
  ```

LIST COMPREHENSIONS

List Comprehensions

- Compact way to loop over an iterable (strings, lists, sets, ...), perform (optional) actions on the elements and store the results in a list:

```
lst = [code-to-be-executed for element in iterable]
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```

- Can optionally include conditions during iteration
- Can also store results in sets and dictionaries, in which case they are called set and dictionary comprehensions

Code Example

```python
my_list = ["a", "b", "c"]
upper_case_list = [item.upper() for item in my_list]
```

- Very compact way instead of a normal for loop (and typically also faster in terms of run-time performance)

SLICING, INDEXING DETAILS AND MORE EXAMPLES

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- Syntax for slicing: `sequence[start:end:stepsize]` with default values if not specified explicitly (0 for `start`, length of sequence for `end`, 1 for `stepsize`)

```
my_list[2:5]  # View on list at indices 2, 3, 4
my_list[2:5:1]  # Same with explicit step size
my_list[2:5:2]  # View on list at indices 2, 4
my_list[::-1]  # Entire list in reverse order
```

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- Negative numbers can also be used in indexing (starts from -1 for the last element, -2 for the second-last, etc.)

```
my_list[-2]  # Second-last element in list
```

UNPACKING

Unpacking

- If you have a sequence of values, you cannot only assign this sequence to some variable but also its contents. This is called **unpacking**

```
abc = [1, 2, 3]  # Regular assignment
a, b, c = [1, 2, 3]  # a -> 1, b -> 2, c -> 3
```

- Can improve code readability (examples see accompanying code file)

OBJECTS, ASSIGNMENTS AND (IM)MUTABILITY

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x = 3         # Integer object with constant 3
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- Mutability means that objects can be changed, e.g.:

```
x = [1, 2, 3]  # List object with items 1,2,3
x[0] = 7       # x -> [7, 2, 3]
```

Assignments + Immutability

- An **assignment to an existing object** does not copy the object, it will simply **reference the same object**, e.g.:

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- Since integers are immutable, there cannot be any side effects in this case

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- Since lists are mutable, there can be side effects in this case if you change the object, e.g., via `x[0] = 7`
- With this, the list changed; its content is now `[7, 2, 3]`
- Since `x` and `y` still reference the same object, this change is visible through both variables (alias effect):

```
x  # List object with items 7,2,3
y  # The same list object, which means the same
    items 7,2,3!
```

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- Often, you actually explicitly want this behavior, e.g., a sorting function that sorts a list **in-place**, i.e., makes changes directly within this list object
- If you do not want this behavior, you can make a copy of your object and perform the changes on the copy, e.g., a sorting function that sorts a list by first copying it, sorting the copy and then returning this copy, leaving the original list unchanged

EXCURSION: LINEAR ARRAY

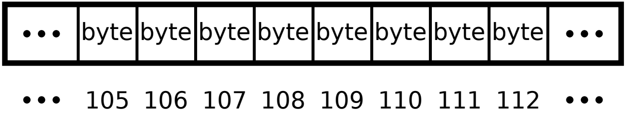
Excursion: Linear Array (1)

- Goal: We want to store a group of values of a fixed data type
  - E.g., 4 16-bit integer values
- Assumption: Our storage (=memory) consists of 1-byte large blocks with contiguous addresses
  - Byte 1 has address 0, byte 2 has address 1, etc.
- We know we need $m = 4 \cdot 16/8 = 8$ bytes to store our values
  - We can allocate 8 bytes of memory with contiguous addresses, starting at address x

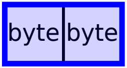
Excursion: Linear Array (2)

Memory:

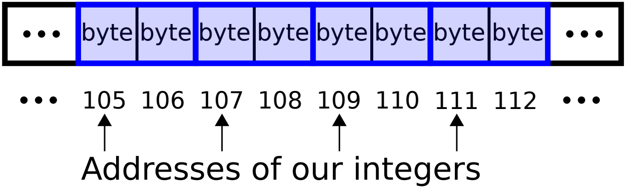
Address:



Memory to store a 16-bit integer:



Storing 4 16-bit integers in memory:



Excursion: Linear Array (3)

- Given the address of the first byte and the data type bytes (m), we can access one stored value via its index i:
  - 1st integer will be at address $x + 0 * m$
  - 2nd integer will be at address $x + 1 * m$
  - 3rd integer will be at address $x + 2 * m$
  - (i+1)th integer will be at address $x + i * m$
  - Note: Indices here are integers, starting at 0
- In our example: $x = 105$, $m = 2$

$\rightarrow$ 3rd integer will be at address $x + i * m = 105 + 2 * 2 = 109$

- This is the concept of a **linear array**

Excursion: Linear Array (4)

- Properties of linear arrays:
  - The cost of the indexing operation is independent of the size of the array or the value of the index (in contrast to linked lists[2])
  - Allocation of memory takes time and is therefore costly
  - If we want to increase the size of our linear array, we might have to copy the whole array to allocate enough contiguous space
  - → Increasing the number of elements is costly if done naively
- In Python, for instance, lists are implemented as linear, variable-length arrays

[2] Linked lists: https://realpython.com/linked-lists-python/