5. Sequences: Lists and Tuples

Objectives

In this chapter, you'll:

- Create and initialize lists and tuples.
- Refer to elements of lists, tuples and strings.
- Sort and search lists, and search tuples.
- Pass lists and tuples to functions and methods.

Objectives (cont.)

- Use list methods to perform common manipulations, such as searching for items, sorting a list, inserting items and removing items.
- Use additional Python functional-style programming capabilities, including lambdas and the operations filter, map and reduce.

Objectives (cont.)

- Use functional-style list comprehensions to create lists quickly and easily, and use generator expressions to generate values on demand.
- Use two-dimensional lists.
- Enhance your analysis and presentation skills with the Seaborn and Matplotlib visualization libraries.

Outline

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- 5.2 Lists (05_02.html)
- 5.3 Tuples (05_03.html)
- 5.4 Unpacking Sequences (05_04.html)
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- 5.7 Passing Lists to Functions (05_07.html)

Outline (cont.)

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5.1 Introduction

- **Collections** are prepackaged data structures consisting of related data items.
- Examples of collections:
  - Favorite songs on your smartphone
  - Contacts list
  - A library’s books
  - Cards in a card game
  - Favorite sports team’s players
  - Stocks in an investment portfolio
  - Patients in a cancer study
  - Shopping list.
- Lists (which are modifiable) and tuples (which are not) have many common capabilities.
- Each can hold items of the same or different types.
- Lists can **dynamically resize** as necessary.
- The Intro to Data Science section uses the visualization libraries Seaborn and Matplotlib to interactively develop static bar charts containing the die frequencies.

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5.2 Lists

- Many of the capabilities shown in this section apply to all sequence types.

Creating a List

- **Lists** typically store **homogeneous data**, but may store **heterogeneous data**.

In [1]:

```
c = [-45, 6, 0, 72, 1543]
```

In [2]:

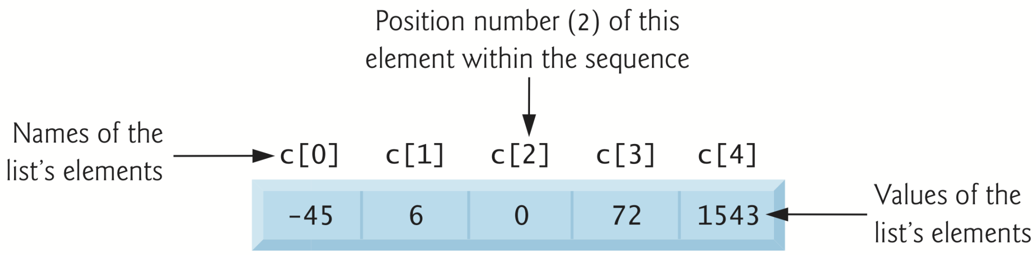
```
c
```

Out[2]:

```
[-45, 6, 0, 72, 1543]
```

Accessing Elements of a List

- Reference a list element by writing the list’s name followed by the element’s **index** enclosed in `[]` (the **subscription operator**).


Position number (2) of this element within the sequence
Names of the list’s elements
c[0]
c[1]
c[2]
c[3]
c[4]
-45
6
0
72
1543
Values of the list’s elements

In [3]:

```
c[0]
```

Out[3]:

```
-45
```

In [4]:

```
c[4]
```

Out[4]:

```
1543
```

Determining a List’s Length

In [5]:

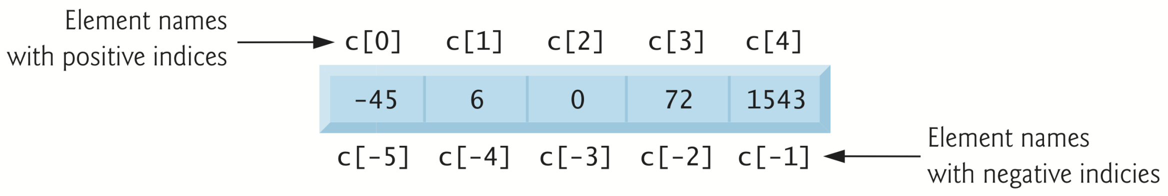
```
len(c)
```

Out[5]:

```
5
```

Accessing Elements from the End of the List with Negative Indices

- Lists can be accessed from the end by using *negative indices*:



In [6]:

```
c[-1]
```

Out[6]:

```
1543
```

In [7]:

```
c[-5]
```

Out[7]:

```
-45
```

Indices Must Be Integers or Integer Expressions

In [8]:

```
a = 1
```

In [9]:

```
b = 2
```

In [10]:

```
c[a + b]
```

Out[10]:

```
72
```

Lists Are Mutable

In [11]:

```
c[4] = 17
```

In [12]:

```
c
```

Out[12]:

```
[-45, 6, 0, 72, 17]
```

Some Sequences Are Immutable

- Python’s string and tuple sequences are immutable.

In [13]:

```
s = 'hello'
```

In [14]:

```
s[0]
```

Out[14]:

```
'h'
```

In [15]:

```
s[0] = 'H'
```

```
---------------------------------------------------------------------
----
TypeError                                 Traceback (most recent call l
ast)
<ipython-input-15-d6f3b193531a> in <module>
----> 1 s[0] = 'H'

TypeError: 'str' object does not support item assignment
```

Attempting to Access a Nonexistent Element

- Index values must be in range.

In [16]:

```
c[100]
```

```
---------------------------------------------------------------------
----
IndexError                                Traceback (most recent call l
ast)
<ipython-input-16-78fb4de297cc> in <module>
----> 1 c[100]

IndexError: list index out of range
```

Using List Elements in Expressions

In [17]:

```
c[0] + c[1] + c[2]
```

Out[17]:

```
-39
```

Appending to a List with +=

- Lists can grow dynamically to accommodate new items.

In [18]:

```
a_list = []
```

In [19]:

```
for number in range(1, 6):
    a_list += [number]
```

In [20]:

```
a_list
```

Out[20]:

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

- When the left operand of `+=` is a list, the right operand must be an *iterable*; otherwise, a `TypeError` occurs.

In [21]:

```
letters = []
```

In [22]:

```
letters += 'Python'
```

In [23]:

```
letters
```

Out[23]:

```
['P', 'y', 't', 'h', 'o', 'n']
```

Concatenating Lists with +

- Can **concatenate** two lists, two tuples or two strings using `+` to create a *new* sequence of the same type.

In [24]:

```
list1 = [10, 20, 30]
```

In [25]:

```
list2 = [40, 50]
```

In [26]:

```
concatenated_list = list1 + list2
```

In [27]:

```
concatenated_list
```

Out[27]:

```
[10, 20, 30, 40, 50]
```

Using `for` and `range` to Access List Indices and Values

In [28]:

```
for i in range(len(concatenated_list)):
    print(f'{i}: {concatenated_list[i]}')
```

```
0: 10
1: 20
2: 30
3: 40
4: 50
```

- We'll show a safer way to access element indices and values using built-in function `enumerate`.

Comparison Operators

- Can compare entire lists element-by-element.

In [29]:

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

In [30]:

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

In [31]:

```
c = [1, 2, 3, 4]
```

In [32]:

```
a == b
```

Out[32]:

```
True
```

In [33]:

```
a == c
```

Out[33]:

```
False
```

In [34]:

```
a < c
```

Out[34]:

```
True
```

In [35]:

```
c >= b
```

Out[35]:

```
True
```

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5.3 Tuples

Creating Tuples

- To create an empty tuple, use empty parentheses.

In [1]:

```
student_tuple = ()
```

In [2]:

```
student_tuple
```

Out[2]:

```
()
```

In [3]:

```
len(student_tuple)
```

Out[3]:

```
0
```

- Pack a tuple by separating its values with commas.

In [4]:

```
student_tuple = 'John', 'Green', 3.3
```

In [5]:

```
student_tuple
```

Out[5]:

```
('John', 'Green', 3.3)
```

In [6]:

```
len(student_tuple)
```

Out[6]:

```
3
```

- When you output a tuple, Python always displays its contents in parentheses.
- Parentheses are optional when creating a tuple.

In [7]:

```
another_student_tuple = ('Mary', 'Red', 3.3)
```

In [8]:

```
another_student_tuple
```

Out[8]:

```
('Mary', 'Red', 3.3)
```

- A comma is required to create a one-element tuple.

In [9]:

```
a_singleton_tuple = ('red',)  # note the comma
```

In [10]:

```
a_singleton_tuple
```

Out[10]:

```
('red',)
```

Accessing Tuple Elements

- You generally access tuple elements directly rather than iterating over them.

In [11]:

```
time_tuple = (9, 16, 1)
```

In [12]:

```
time_tuple
```

Out[12]:

```
(9, 16, 1)
```

In [13]:

```
time_tuple[0] * 3600 + time_tuple[1] * 60 + time_tuple[2]
```

Out[13]:

```
33361
```

Adding Items to a String or Tuple

- `+=` can be used with strings and tuples, even though they’re *immutable*.
- Creates new objects.

In [14]:

```
tuple1 = (10, 20, 30)
```

In [15]:

```
tuple2 = tuple1
```

In [16]:

```
tuple2
```

Out[16]:

```
(10, 20, 30)
```

In [17]:

```
tuple1 += (40, 50)
```

In [18]:

```
tuple1
```

Out[18]:

```
(10, 20, 30, 40, 50)
```

In [19]:

```
tuple2
```

Out[19]:

```
(10, 20, 30)
```

Appending Tuples to Lists

In [20]:

```
numbers = [1, 2, 3, 4, 5]
```

In [21]:

```
numbers += (6, 7)
```

In [22]:

```
numbers
```

Out[22]:

```
[1, 2, 3, 4, 5, 6, 7]
```

Tuples May Contain Mutable Objects

In [23]:

```
student_tuple = ('Amanda', 'Blue', [98, 75, 87])
```

In [24]:

```
student_tuple[2][1] = 85
```

In [25]:

```
student_tuple
```

Out[25]:

```
('Amanda', 'Blue', [98, 85, 87])
```

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5.4 Unpacking Sequences

- Can unpack any sequence’s elements by assigning the sequence to a comma-separated list of variables (of the appropriate length).

In [1]:

```
student_tuple = ('Amanda', [98, 85, 87])
```

In [2]:

```
first_name, grades = student_tuple
```

In [3]:

```
first_name
```

Out[3]:

```
'Amanda'
```

In [4]:

```
grades
```

Out[4]:

```
[98, 85, 87]
```

In [5]:

```
first, second = 'hi'
```

In [6]:

```
print(f'{first}  {second}')
```

```
h  i
```

In [7]:

```
number1, number2, number3 = [2, 3, 5]
```

In [8]:

```
print(f'{number1}  {number2}  {number3}')
```

```
2  3  5
```

In [9]:

```
number1, number2, number3 = range(10, 40, 10)
```

In [10]:

```
print(f'{number1}  {number2}  {number3}')
```

```
10  20  30
```

Swapping Values Via Packing and Unpacking

In [11]:

```
number1 = 99
```

In [12]:

```
number2 = 22
```

In [13]:

```
number1, number2 = (number2, number1)
```

In [14]:

```
print(f'number1 = {number1}; number2 = {number2}')
```

```
number1 = 22; number2 = 99
```

Accessing Indices and Values Safely with Built-in Function enumerate

- Preferred way to access an element's index *and* value is the built-in function **`enumerate`**.
- Receives an iterable and creates an iterator that, for each element, returns a tuple containing the element's index and value.
- Built-in function **`list`** creates a list from a sequence.

In [15]:

```
colors = ['red', 'orange', 'yellow']
```

In [16]:

```
list(enumerate(colors))
```

Out[16]:

```
[(0, 'red'), (1, 'orange'), (2, 'yellow')]
```

- Built-in function **`tuple`** creates a tuple from a sequence.

In [17]:

```
tuple(enumerate(colors))
```

Out[17]:

```
((0, 'red'), (1, 'orange'), (2, 'yellow'))
```

In [18]:

```
for index, value in enumerate(colors):
    print(f'{index}: {value}')
```

```
0: red
1: orange
2: yellow
```

Creating a Primitive Bar Chart

```
# fig05_01.py
"""Displaying a bar chart"""
numbers = [19, 3, 15, 7, 11]

print('\nCreating a bar chart from numbers:')
print(f'Index{"Value":>8}   Bar')

for index, value in enumerate(numbers):
    print(f'{index:>5}{value:>8}   {"*" * value}')
```

In [19]:

```
run fig05_01.py
```

```
Creating a bar chart from numbers:
Index   Value   Bar
    0      19   *******************
    1       3   ***
    2      15   ***************
    3       7   *******
    4      11   ***********
```

- The expression `python "*" * value` creates a string consisting of `value` asterisks.
- When used with a sequence, the multiplication operator (`*`) *repeats* the sequence.

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5.5 Sequence Slicing

- Can **slice** sequences to create new sequences of the same type containing *subsets* of the original elements.
- Slice operations that do *not* modify a sequence work identically for lists, tuples and strings.

Specifying a Slice with Starting and Ending Indices

In [1]:

```
numbers = [2, 3, 5, 7, 11, 13, 17, 19]
```

In [2]:

```
numbers[2:6]
```

Out[2]:

```
[5, 7, 11, 13]
```

Specifying a Slice with Only an Ending Index

- Starting index `0` is assumed.

In [3]:

```
numbers[:6]
```

Out[3]:

```
[2, 3, 5, 7, 11, 13]
```

In [4]:

```
numbers[0:6]
```

Out[4]:

```
[2, 3, 5, 7, 11, 13]
```

Specifying a Slice with Only a Starting Index

- Assumes the sequence's length as the ending index.

In [5]:

```
numbers[6:]
```

Out[5]:

```
[17, 19]
```

In [6]:

```
numbers[6:len(numbers)]
```

Out[6]:

```
[17, 19]
```

Specifying a Slice with No Indices

In [7]:

```
numbers[:]
```

Out[7]:

```
[2, 3, 5, 7, 11, 13, 17, 19]
```

- Though slices create new objects, slices make **shallow copies** of the elements.
- In the snippet above, the new list's elements refer to the *same objects* as the original list's elements.

Slicing with Steps

In [8]:

```
numbers[::2]
```

Out[8]:

```
[2, 5, 11, 17]
```

Slicing with Negative Indices and Steps

In [9]:

```
numbers[::-1]
```

Out[9]:

```
[19, 17, 13, 11, 7, 5, 3, 2]
```

In [10]:

```
numbers[-1:-9:-1]
```

Out[10]:

```
[19, 17, 13, 11, 7, 5, 3, 2]
```

Modifying Lists Via Slices

- Can modify a list by assigning to a slice.

In [11]:

```
numbers[0:3] = ['two', 'three', 'five']
```

In [12]:

```
numbers
```

Out[12]:

```
['two', 'three', 'five', 7, 11, 13, 17, 19]
```

In [13]:

```
numbers[0:3] = []
```

In [14]:

```
numbers
```

Out[14]:

```
[7, 11, 13, 17, 19]
```

In [15]:

```
numbers = [2, 3, 5, 7, 11, 13, 17, 19]
```

In [16]:

```
numbers[::2] = [100, 100, 100, 100]
```

In [17]:

```
numbers
```

Out[17]:

```
[100, 3, 100, 7, 100, 13, 100, 19]
```

In [18]:

```
id(numbers)
```

Out[18]:

```
4391419592
```

In [19]:

```
numbers[:] = []
```

In [20]:

```
numbers
```

Out[20]:

```
[]
```

In [21]:

```
id(numbers)
```

Out[21]:

```
4391419592
```

- Deleting `numbers`' contents is different from assigning `numbers` a *new* empty list `[]`.
- Identities are different, so they represent separate objects in memory.

In [22]:

```
numbers = []
```

In [23]:

```
numbers
```

Out[23]:

```
[]
```

In [24]:

```
id(numbers)
```

Out[24]:

```
4391542152
```

- When you assign a new object to a variable, the original object will be **garbage collected** if no other variables refer to it.

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5.6 del Statement

Deleting the Element at a Specific List Index

In [1]:

```
numbers = list(range(0, 10))
```

In [2]:

```
numbers
```

Out[2]:

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

In [3]:

```
del numbers[-1]
```

In [4]:

```
numbers
```

Out[4]:

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

Deleting a Slice from a List

In [5]:

```
del numbers[0:2]
```

In [6]:

```
numbers
```

Out[6]:

```
[2, 3, 4, 5, 6, 7, 8]
```

In [7]:

```
del numbers[::2]
```

In [8]:

```
numbers
```

Out[8]:

```
[3, 5, 7]
```

Deleting a Slice Representing the Entire List

In [9]:

```
del numbers[:]
```

In [10]:

```
numbers
```

Out[10]:

```
[]
```

Deleting a Variable from the Current Session

In [11]:

```
del numbers
```

In [12]:

```
numbers
```

```
---------------------------------------------------------------------
----
NameError                                 Traceback (most recent call l
ast)
<ipython-input-12-6a54518a0c2c> in <module>
----> 1 numbers

NameError: name 'numbers' is not defined
```

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5.7 Passing Lists to Functions

Passing an Entire List to a Function

In [1]:

```
def modify_elements(items):
    """"Multiplies all element values in items by 2."""
    for i in range(len(items)):
        items[i] *= 2
```

In [2]:

```
numbers = [10, 3, 7, 1, 9]
```

In [3]:

```
modify_elements(numbers)
```

In [4]:

```
numbers
```

Out[4]:

```
[20, 6, 14, 2, 18]
```

Passing a Tuple to a Function

- When you pass a tuple to a function, attempting to modify the tuple’s immutable elements results in a `TypeError`.

In [5]:

```
numbers_tuple = (10, 20, 30)
```

In [6]:

```
numbers_tuple
```

Out[6]:

```
(10, 20, 30)
```

```
In [7]:
```

```
modify_elements(numbers_tuple)
```

```
--------------------------------------------------------------------
----
TypeError                              Traceback (most recent call l
ast)
<ipython-input-7-9339741cd595> in <module>
----> 1 modify_elements(numbers_tuple)

<ipython-input-1-aa30cff7ee99> in modify_elements(items)
      2     """"Multiplies all element values in items by 2."""
      3     for i in range(len(items)):
----> 4         items[i] *= 2

TypeError: 'tuple' object does not support item assignment
```

A Note Regarding Tracebacks

- A traceback shows code that led to an exception.
- When an exception occurs in a single-line snippet, it's always preceded by `---->  1` , indicating that line 1 (the snippet's only line) caused the exception.
- Multiline snippets like a function definition show consecutive line numbers starting at 1.
- The last line of code shown with `---->` caused the exception.

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5.8 Sorting Lists

Sorting a List in Ascending Order

- List method `sort` *modifies* a list.

In [1]:

```
numbers = [10, 3, 7, 1, 9, 4, 2, 8, 5, 6]
```

In [2]:

```
numbers.sort()
```

In [3]:

```
numbers
```

Out[3]:

```
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
```

Sorting a List in Descending Order

In [4]:

```
numbers.sort(reverse=True)
```

In [5]:

```
numbers
```

Out[5]:

```
[10, 9, 8, 7, 6, 5, 4, 3, 2, 1]
```

Built-In Function `sorted`

- Built-in function **`sorted`** *returns a new list* containing the sorted elements of its argument *sequence*—the original sequence is *unmodified*.

In [6]:

```
numbers = [10, 3, 7, 1, 9, 4, 2, 8, 5, 6]
```

In [7]:

```
ascending_numbers = sorted(numbers)
```

In [8]:

```
ascending_numbers
```

Out[8]:

```
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
```

In [9]:

```
numbers
```

Out[9]:

```
[10, 3, 7, 1, 9, 4, 2, 8, 5, 6]
```

In [10]:

```
letters = 'fadgchjebi'
```

In [11]:

```
ascending_letters = sorted(letters)
```

In [12]:

```
ascending_letters
```

Out[12]:

```
['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j']
```

In [13]:

```
letters
```

Out[13]:

```
'fadgchjebi'
```

In [14]:

```
colors = ('red', 'orange', 'yellow', 'green', 'blue')
```

In [15]:

```
ascending_colors = sorted(colors)
```

In [16]:

```
ascending_colors
```

Out[16]:

```
['blue', 'green', 'orange', 'red', 'yellow']
```

In [17]:

```
colors
```

Out[17]:

```
('red', 'orange', 'yellow', 'green', 'blue')
```

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5.9 Searching Sequences

- **Searching** is the process of locating a particular **key** value.

List Method index

- Searches through a list from index 0 and returns the index of the *first* element that matches the search key.
- `ValueError` if the value is not in the list.

In [1]:

```
numbers = [3, 7, 1, 4, 2, 8, 5, 6]
```

In [2]:

```
numbers.index(5)
```

Out[2]:

```
6
```

Specifying the Starting Index of a Search

In [3]:

```
numbers *= 2
```

In [4]:

```
numbers
```

Out[4]:

```
[3, 7, 1, 4, 2, 8, 5, 6, 3, 7, 1, 4, 2, 8, 5, 6]
```

In [5]:

```
numbers.index(5, 7)
```

Out[5]:

```
14
```

Specifying the Starting and Ending Indices of a Search

- Look for the value `7` in the range of elements with indices `0` through `3`.

In [6]:

```
numbers.index(7, 0, 4)
```

Out[6]:

```
1
```

Operators `in` and `not in`

- Operator `in` tests whether its right operand's iterable contains the left operand's value.

In [7]:

```
1000 in numbers
```

Out[7]:

```
False
```

In [8]:

```
5 in numbers
```

Out[8]:

```
True
```

- Operator `not in` tests whether its right operand's iterable does *not* contain the left operand's value.

In [9]:

```
1000 not in numbers
```

Out[9]:

```
True
```

In [10]:

```
5 not in numbers
```

Out[10]:

```
False
```

Using Operator `in` to Prevent a `ValueError`

In [11]:

```
key = 1000
```

In [12]:

```
if key in numbers:
    print(f'found {key} at index {numbers.index(search_key)}')
else:
    print(f'{key} not found')
```

```
1000 not found
```

Built-In Functions `any` and `all`

- Built-in function **`any`** returns `True` if any item in its iterable argument is `True`.
- Built-in function **`all`** returns `True` if all items in its iterable argument are `True`.
- Nonzero values are `True` and 0 is `False`.
- Non-empty iterable objects also evaluate to `True`, whereas any empty iterable evaluates to `False`.

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5.10 Other List Methods

In [1]:

```
color_names = ['orange', 'yellow', 'green']
```

Inserting an Element at a Specific List Index

In [2]:

```
color_names.insert(0, 'red')
```

In [3]:

```
color_names
```

Out[3]:

```
['red', 'orange', 'yellow', 'green']
```

Adding an Element to the End of a List

In [4]:

```
color_names.append('blue')
```

In [5]:

```
color_names
```

Out[5]:

```
['red', 'orange', 'yellow', 'green', 'blue']
```

Adding All the Elements of a Sequence to the End of a List

- Equivalent to `+=` .

In [6]:

```
color_names.extend(['indigo', 'violet'])
```

In [7]:

```
color_names
```

Out[7]:

```
['red', 'orange', 'yellow', 'green', 'blue', 'indigo', 'violet']
```

In [8]:

```
sample_list = []
```

In [9]:

```
s = 'abc'
```

In [10]:

```
sample_list.extend(s)
```

In [11]:

```
sample_list
```

Out[11]:

```
['a', 'b', 'c']
```

In [12]:

```
t = (1, 2, 3)
```

In [13]:

```
sample_list.extend(t)
```

In [14]:

```
sample_list
```

Out[14]:

```
['a', 'b', 'c', 1, 2, 3]
```

- Parentheses are required for the tuple argument below, because `extend` expects **one iterable argument**.

In [15]:

```
sample_list.extend((4, 5, 6))  # note the extra parentheses
```

In [16]:

```
sample_list
```

Out[16]:

```
['a', 'b', 'c', 1, 2, 3, 4, 5, 6]
```

Removing the First Occurrence of an Element in a List

- `ValueError` occurs if `remove`'s argument is not in the list.

In [17]:

```
color_names.remove('green')
```

In [18]:

```
color_names
```

Out[18]:

```
['red', 'orange', 'yellow', 'blue', 'indigo', 'violet']
```

Emptying a List

In [19]:

```
color_names.clear()
```

In [20]:

```
color_names
```

Out[20]:

```
[]
```

Counting the Number of Occurrences of an Item

In [21]:

```
responses = [1, 2, 5, 4, 3, 5, 2, 1, 3, 3,
             1, 4, 3, 3, 3, 2, 3, 3, 2, 2]
```

In [22]:

```
for i in range(1, 6):
    print(f'{i} appears {responses.count(i)} times in responses')
```

```
1 appears 3 times in responses
2 appears 5 times in responses
3 appears 8 times in responses
4 appears 2 times in responses
5 appears 2 times in responses
```

Reversing a List’s Elements

- Method **`reverse`** reverses the contents of a list in place.

In [23]:

```
color_names = ['red', 'orange', 'yellow', 'green', 'blue']
```

In [24]:

```
color_names.reverse()
```

In [25]:

```
color_names
```

Out[25]:

```
['blue', 'green', 'yellow', 'orange', 'red']
```

Copying a List

- Method `copy` returns a *new* list containing a *shallow* copy.

In [26]:

```
copied_list = color_names.copy()
```

In [27]:

```
copied_list
```

Out[27]:

```
['blue', 'green', 'yellow', 'orange', 'red']
```

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5.11 Simulating Stacks with Lists

- Python does not have a built-in stack type.
- Can think of a stack as a constrained list.
- *Push* using list method `append` .
- *Pop* using list method **`pop`** with no arguments to get items in last-in, first-out (LIFO) order.

In [1]:

```
stack = []
```

In [2]:

```
stack.append('red')
```

In [3]:

```
stack
```

Out[3]:

```
['red']
```

In [4]:

```
stack.append('green')
```

In [5]:

```
stack
```

Out[5]:

```
['red', 'green']
```

In [6]:

```
stack.pop()
```

Out[6]:

```
'green'
```

In [7]:

```
stack
```

Out[7]:

```
['red']
```

In [8]:

```
stack.pop()
```

Out[8]:

```
'red'
```

In [9]:

```
stack
```

Out[9]:

```
[]
```

In [10]:

```
stack.pop()
```

```
--------------------------------------------------------------------
----
IndexError                                Traceback (most recent call l
ast)
<ipython-input-10-415460d3b717> in <module>
----> 1 stack.pop()

IndexError: pop from empty list
```

- Also can use a list to simulate a **queue**.
- Items are retrieved from queues in **first-in, first-out (FIFO) order**.

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5.12 List Comprehensions

- Concise way to create new lists.
- Replaces using `for` to iterate over a sequence and create a list.

In [1]:

```
list1 = []
```

In [2]:

```
for item in range(1, 6):
    list1.append(item)
```

In [3]:

```
list1
```

Out[3]:

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

Using a List Comprehension to Create a List of Integers

In [4]:

```
list2 = [item for item in range(1, 6)]
```

In [5]:

```
list2
```

Out[5]:

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

- **`for` clause** iterates over the sequence produced by `range(1, 6)`.
- For each `item`, the list comprehension evaluates the expression to the left of the `for` clause and places the expression's value in the new list.

Mapping: Performing Operations in a List Comprehension's Expression

- Mapping is a common functional-style programming operation that produces a result with the *same* number of elements as the original data being mapped.

In [6]:

```
list3 = [item ** 3 for item in range(1, 6)]
```

In [7]:

```
list3
```

Out[7]:

```
[1, 8, 27, 64, 125]
```

Filtering: List Comprehensions with `if` Clauses

- Another common functional-style programming operation is **filtering** elements to select only those that match a condition.
- Typically produces a list with *fewer* elements than the data being filtered.

In [8]:

```
list4 = [item for item in range(1, 11) if item % 2 == 0]
```

In [9]:

```
list4
```

Out[9]:

```
[2, 4, 6, 8, 10]
```

List Comprehension That Processes Another List’s Elements

- The `for` clause can process any iterable.

In [10]:

```
colors = ['red', 'orange', 'yellow', 'green', 'blue']
```

In [11]:

```
colors2 = [item.upper() for item in colors]
```

In [12]:

```
colors2
```

Out[12]:

```
['RED', 'ORANGE', 'YELLOW', 'GREEN', 'BLUE']
```

In [13]:

```
colors
```

Out[13]:

```
['red', 'orange', 'yellow', 'green', 'blue']
```

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5.13 Generator Expressions

- Like list comprehensions, but create iterable **generator objects** that produce values **on demand**.
- Known as **lazy evaluation**.
- For large numbers of items, creating lists can take substantial memory and time.
- **Generator expressions** can reduce memory consumption and improve performance if the whole list is not needed at once.

In [1]:

```
numbers = [10, 3, 7, 1, 9, 4, 2, 8, 5, 6]
```

In [2]:

```
for value in (x ** 2 for x in numbers if x % 2 != 0):
    print(value, end='  ')
```

```
9  49  1  81  25
```

In [3]:

```
squares_of_odds = (x ** 2 for x in numbers if x % 2 != 0)
```

In [4]:

```
squares_of_odds
```

Out[4]:

```
<generator object <genexpr> at 0x110430408>
```

- Output indicates that `square_of_odds` is a **generator object** that was created from a **generator expression (`<genexpr>`).**
- **Built-in function `next`** receives a generator or iterator and returns the next item.

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5.14 Filter, Map and Reduce

- Built-in `filter` and `map` functions also perform filtering and mapping.

Filtering a Sequence's Values with the Built-In `filter` Function

In [1]:

```
numbers = [10, 3, 7, 1, 9, 4, 2, 8, 5, 6]
```

In [2]:

```
def is_odd(x):
    """Returns True only if x is odd."""
    return x % 2 != 0
```

In [3]:

```
list(filter(is_odd, numbers))
```

Out[3]:

```
[3, 7, 1, 9, 5]
```

- Functions are objects that you can assign to variables, pass to other functions and return from functions.
- Functions that receive other functions as arguments are a functional-style capability called **higher-order functions**.
- `filter`'s first argument must be a function that receives one argument and returns `True` if the value should be included in the result.
- Higher-order functions may also return a function as a result.
- `filter` returns an iterator, so `filter`'s results are not produced until you iterate through them—lazy evaluation.

In [4]:

```
[item for item in numbers if is_odd(item)]
```

Out[4]:

```
[3, 7, 1, 9, 5]
```

Using a `lambda` Rather than a Function

- For simple functions like `is_odd` that `return` only a *single expression's value*, you can use a **lambda expression** (or simply a **lambda**) to define the function inline.

In [5]:

```
list(filter(lambda x: x % 2 != 0, numbers))
```

Out[5]:

```
[3, 7, 1, 9, 5]
```

- A lambda expression is an _anonymous function
- Begins with the **`lambda`** keyword followed by a comma-separated parameter list, a colon (**`:`**) and an expression.
- A `lambda` *implicitly* returns its expression’s value.

Mapping a Sequence’s Values to New Values

In [6]:

```
numbers
```

Out[6]:

```
[10, 3, 7, 1, 9, 4, 2, 8, 5, 6]
```

In [7]:

```
list(map(lambda x: x ** 2, numbers))
```

Out[7]:

```
[100, 9, 49, 1, 81, 16, 4, 64, 25, 36]
```

- Function `map` ’s first argument is a function that receives one value and returns a new value.
- equivalent list comprehension:

In [8]:

```
[item ** 2 for item in numbers]
```

Out[8]:

```
[100, 9, 49, 1, 81, 16, 4, 64, 25, 36]
```

Combining `filter` and `map`

In [9]:

```
list(map(lambda x: x ** 2,
         filter(lambda x: x % 2 != 0, numbers)))
```

Out[9]:

```
[9, 49, 1, 81, 25]
```

- Equivalent list comprehension:

In [10]:

```
[x ** 2 for x in numbers if x % 2 != 0]
```

Out[10]:

```
[9, 49, 1, 81, 25]
```

Reduction: Totaling the Elements of a Sequence with `sum`

- Reductions process a sequence’s elements into a single value.
    - E.g., `len`, `sum`, `min` and `max`.
- Can create custom reductions using the `functools` module (https://docs.python.org/3/library/functools.html)’s `reduce` function.

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5.15 Other Sequence Processing Functions

Finding the Minimum and Maximum Values Using a Key Function

In [1]:

```
'Red' < 'orange'
```

Out[1]:

```
True
```

- `'R'` “comes after” `'o'` in the alphabet, so you might expect `'Red'` to be less than `'orange'` and the condition above to be `False`.
- Strings are compared by their characters’ underlying *numerical values*, and lowercase letters have *higher* numerical values than uppercase letters.
- Confirm with built-in function **`ord`**:

In [2]:

```
ord('R')
```

Out[2]:

```
82
```

In [3]:

```
ord('o')
```

Out[3]:

```
111
```

In [4]:

```
colors = ['Red', 'orange', 'Yellow', 'green', 'Blue']
```

- Assume that we’d like to determine the minimum and maximum strings using *alphabetical* order.
- Can specify sort order with the `key` argument.

In [5]:

```
min(colors, key=lambda s: s.lower())
```

Out[5]:

```
'Blue'
```

In [6]:

```
max(colors, key=lambda s: s.lower())
```

Out[6]:

```
'Yellow'
```

Iterating Backwards Through a Sequence

In [7]:

```
numbers = [10, 3, 7, 1, 9, 4, 2, 8, 5, 6]
```

In [8]:

```
reversed_numbers = [item ** 2 for item in reversed(numbers)]
```

In [9]:

```
reversed_numbers
```

Out[9]:

```
[36, 25, 64, 4, 16, 81, 1, 49, 9, 100]
```

Combining Iterables into Tuples of Corresponding Elements

- Built-in function **`zip`** enables you to iterate over *multiple* iterables of data at the *same* time.
- Receives any number of iterables and returns an iterator that produces tuples containing the elements at the same index in each.

In [10]:

```
names = ['Bob', 'Sue', 'Amanda']
```

In [11]:

```
grade_point_averages = [3.5, 4.0, 3.75]
```

In [12]:

```
for name, gpa in zip(names, grade_point_averages):
    print(f'Name={name}; GPA={gpa}')
```

```
Name=Bob; GPA=3.5
Name=Sue; GPA=4.0
Name=Amanda; GPA=3.75
```

- Shortest argument determines the number of tuples produced.

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5.16 Two-Dimensional Lists

- Lists can contain other lists as elements.
- Typical use is to represent **tables** of values consisting of information arranged in **rows** and **columns**.
- To identify a particular table element, we specify *two* indices—the first identifies the element's row, the second the element's column.

Creating a Two-Dimensional List

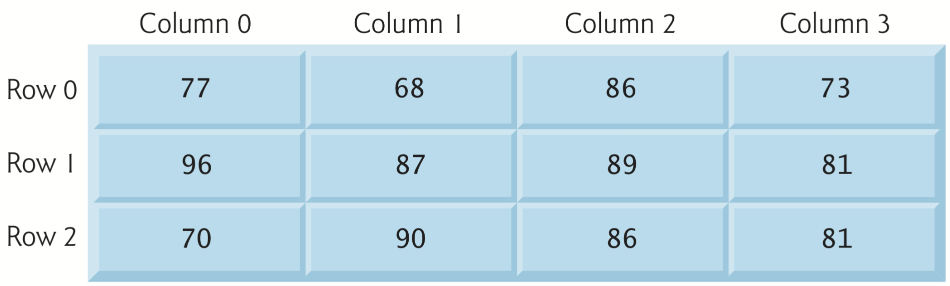
In [1]:

```
a = [[77, 68, 86, 73], [96, 87, 89, 81], [70, 90, 86, 81]]
```

Writing the list as follows makes its row and column tabular structure clearer:

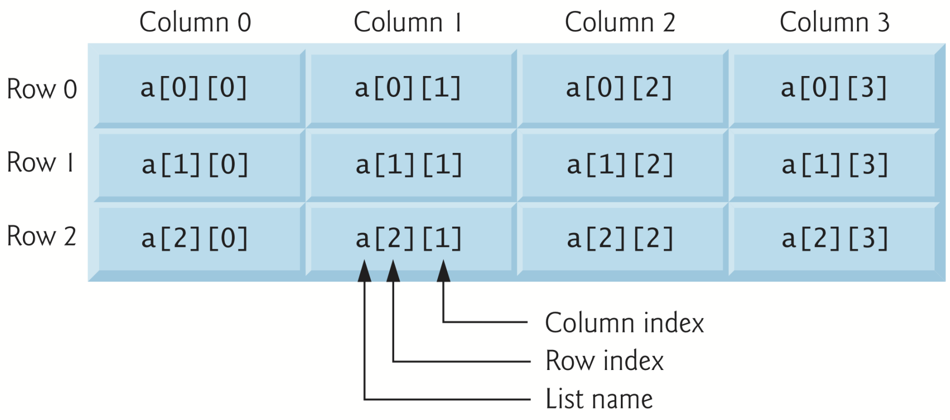
```
a = [[77, 68, 86, 73],  # first student's grades
     [96, 87, 89, 81],  # second student's grades
     [70, 90, 86, 81]]  # third student's grades
```

Illustrating a Two-Dimensional List



	Column 0	Column 1	Column 2	Column 3
Row 0	77	68	86	73
Row 1	96	87	89	81
Row 2	70	90	86	81

Identifying the Elements in a Two-Dimensional List



	Column 0	Column 1	Column 2	Column 3
Row 0	a[0][0]	a[0][1]	a[0][2]	a[0][3]
Row 1	a[1][0]	a[1][1]	a[1][2]	a[1][3]
Row 2	a[2][0]	a[2][1]	a[2][2]	a[2][3]

- Output the rows of the preceding two-dimensional list.

In [2]:

```
for row in a:
    for item in row:
        print(item, end=' ')
    print()
```

```
77 68 86 73
96 87 89 81
70 90 86 81
```

How the Nested Loops Execute

In [3]:

```
for i, row in enumerate(a):
    for j, item in enumerate(row):
        print(f'a[{i}][{j}]={item} ', end=' ')
    print()
```

```
a[0][0]=77  a[0][1]=68  a[0][2]=86  a[0][3]=73
a[1][0]=96  a[1][1]=87  a[1][2]=89  a[1][3]=81
a[2][0]=70  a[2][1]=90  a[2][2]=86  a[2][3]=81
```

- Outer `for` statement iterates over the list’s ows one row at a time.
- During each iteration of the outer `for` statement, the inner `for` statement iterates over *each* column in the current row.

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