Mutability
Class outline:

- List diagrams
- Objects & methods
- List mutation & methods
- Tuples
- Mutability
- Beware of mutation
List diagrams
Lists in environment diagrams

Lists are represented as a row of index-labeled adjacent boxes, one per element.

\[ \text{pair} = [1, 2] \]

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Nested lists in environment diagrams

Each box either contains a primitive value or points to a compound value.

```python
matrix = [ [1, 2, 0, 4], [0, 1, 3, -1], [0, 0, 1, 8] ]
```
Nested lists in environment diagrams

A very nested list:

```
worst_list = [ [1, 2], [], [ [3, False, None], [4, lambda: 5]]]
```

View in PythonTutor
Objects
Objects

An **object** is a bundle of data and behavior.

A type of object is called a **class**.

Every value in Python is an object.

- All objects have attributes
- Objects often have associated methods
Strings as objects

```python
name = 'PamelamaDingDong'
```

What kind of object is it?

```python
type(name)
```

What data is inside it?

```python
name[0]
name[8:]
```

What methods can we call?

```python
name.upper()
name.lower()
```
Lists as objects

```
names = ['Pamela', 'Spamela', 'Pammyla', 'Ela']
```

What kind of object is it?
```
type(names)
```

What data is inside it?
```
names[0]
names[-1]
```

What methods can we call?
```
names.index("Spamela")
names.copy()
```
List mutation
Mutating lists with methods

**append()** adds a single element to a list:

```python
s = [2, 3]
t = [5, 6]
s.append(4)
s.append(t)
t = 0
```

Try in PythonTutor.

**extend()** adds all the elements in one list to a list:

```python
s = [2, 3]
t = [5, 6]
s.extend(4)
s.extend(t)
t = 0
```

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Mutating lists with methods

**append()** adds a single element to a list:

```python
s = [2, 3]
t = [5, 6]
s.append(4)
s.append(t)
t = 0
```

**Try in PythonTutor.**

**extend()** adds all the elements in one list to a list:

```python
s = [2, 3]
t = [5, 6]
s.extend(4)  # Error: 4 is not an iterable!
s.extend(t)
t = 0
```

**Try in PythonTutor. (After deleting the bad line)**
**Mutating lists with methods**

`pop()` removes and returns the last element:

```python
s = [2, 3]
t = [5, 6]
t = s.pop()
```

![Try in PythonTutor.](image)

`remove()` removes the first element equal to the argument:

```python
s = [6, 2, 4, 8, 4]
s.remove(4)
```

![Try in PythonTutor.](image)
## Mutating lists with slicing

We can do a lot with just brackets/slice notation:

```python
L = [1, 2, 3, 4, 5]
L[2] = 6
L[1:3] = [9, 8]
L[2:4] = []  # Deleting elements
L[1:1] = [2, 3, 4, 5]  # Inserting elements
L[len(L):] = [10, 11]  # Appending
L = L + [20, 30]
L[0:0] = range(-3, 0)  # Prepending
```

Try in PythonTutor.
Dictionary mutation
Dictionary mutation

Starting with an empty dict:

```python
users = {}  
```

Add values:

```python
users["profpamela"] = "b3stp@ssEvErDontHackMe"
```

Change values:

```python
users["profpamela"] += "its LongerSoItsMoreSecure!!"
```

```python
>>> users["profpamela"]
```

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Dictionary mutation

Starting with an empty dict:

```python
users = {}
```

Add values:

```python
users["profpamela"] = "b3stp@ssEvErDontHackMe"
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Change values:

```python
users["profpamela"] += "itsLongerSoItsMoreSecure!!"
```

```python
>>> users["profpamela"]
'b3stp@ssEvErDontHackMeitsLongerSoItsMoreSecure!!'
```
Tuples
Tuples

A **tuple** is an immutable sequence. It's like a list, but no mutation allowed!

An empty tuple:

```python
empty = ()
# or
golden = tuple()
```

A tuple with multiple elements:

```python
conditions = ('rain', 'shine')
# or
conditions = 'rain', 'shine'
```

A tuple with a single element: 🐱
Tuples

A **tuple** is an immutable sequence. It's like a list, but no mutation allowed!

An empty tuple:

```python
empty = ()
# or
def = tuple()
```

A tuple with multiple elements:

```python
conditions = ('rain', 'shine')
# or
def = 'rain', 'shine'
```

A tuple with a single element: 😼

```python
oogly = (61,)
# or
def = 61
```
Tuple operations

Many of list's read-only operations work on tuples.

Combining tuples into a new tuple:

('come', '☂') + ('or', '⋆')

Checking containment:

'wally' in ('wall-e', 'wallace', 'waldo')

Slicing:

rainbow = ('red', 'orange', 'yellow', 'green', 'blue', 'indigo')
roy = rainbow[:3]
Tuple operations

Many of list's read-only operations work on tuples.

Combining tuples into a new tuple:

```
('come', '☂') + ('or', '☼')  # ('come', '☂', 'or', '☼')
```

Checking containment:

```
'wally' in ('wall-e', 'wallace', 'waldo')
```

Slicing:

```
rainbow = ('red', 'orange', 'yellow', 'green', 'blue', 'indigo', 'violet')
roy = rainbow[:3]
```
Tuple operations

Many of list's read-only operations work on tuples.

Combining tuples into a new tuple:

```
('come', '☂') + ('or', '☼')  # ('come', '☂', 'or', '☼')
```

Checking containment:

```
'wally' in ('wall-e', 'wallace', 'waldo')  # True
```

Slicing:

```
rainbow = ('red', 'orange', 'yellow', 'green', 'blue', 'indigo')
roy = rainbow[:3]
```
Tuple operations

Many of list's read-only operations work on tuples.

Combining tuples into a new tuple:

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('come', '☂') + ('or', '☼')  # ('come', '☂', 'or', '☼')
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Checking containment:

```
'wally' in ('wall-e', 'wallace', 'waldo')  # True
```

Slicing:

```
rainbow = ('red', 'orange', 'yellow', 'green', 'blue', 'indigo', 'violet')
roy = rainbow[:3]  # ('red', 'orange', 'yellow')
```
Immutability vs. Mutability
Immutable vs. Mutable

An **immutable** value is unchanging once created.

Immutable types (that we've covered): int, float, string, tuple

```python
a_tuple = (1, 2)
a_tuple[0] = 3
a_string = "Hi y'all"
a_string[1] = "I"
a_string += ", how you doing?"
an_int = 20
an_int += 2
```

A **mutable** value can change in value throughout the course of computation. All names that refer to the same object are affected by a mutation.

Mutable types (that we've covered): list, dict

```python
grades = [90, 70, 85]
grades_copy = grades
grades[1] = 100
words = {"agua": "water"}
words["pavo"] = "turkey"
```
**Immutable vs. Mutable**

An *immutable* value is unchanging once created.

Immutable types (that we've covered): int, float, string, tuple

```python
a_tuple = (1, 2)
a_tuple[0] = 3  # Error! Tuple items cannot be set.
a_string = "Hi y'all"
a_string[1] = "I"  # Error! String elements cannot be set.
a_string += ", how you doing?"
an_int = 20
an_int += 2
```

A *mutable* value can change in value throughout the course of computation. All names that refer to the same object are affected by a mutation.

Mutable types (that we've covered): list, dict

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Immutable types (that we've covered): int, float, string, tuple

```python
a_tuple = (1, 2)
a_tuple[0] = 3  # Error! Tuple items cannot be set.
a_string = "Hi y'all"
a_string[1] = "I"  # Error! String elements cannot be set.
a_string += ", how you doing?"  # How does this work?
an_int = 20
an_int += 2  # And this?
```

A **mutable** value can change in value throughout the course of computation. All names that refer to the same object are affected by a mutation.

Mutable types (that we've covered): list, dict

```python
grades = [90, 70, 85]
grades_copy = grades
grades[1] = 100
words = {"agua": "water"}
words["pavo"] = "turkey"
```
Name change vs. mutation

The value of an expression can change due to either changes in names or mutations in objects.

Name change:

\[ x + x \]

\[ x + x \]

Object mutation:

\[ x + x \]

\[ x + x \]

\[ x + x \]
Name change vs. mutation

The value of an expression can change due to either changes in names or mutations in objects.

Name change:

\[
x = 2
\]
\[
x + x \# 4
\]
\[
x + x
\]

Object mutation:

\[
x + x
\]
\[
x + x
\]
\[
x + x
\]
Name change vs. mutation

The value of an expression can change due to either changes in names or mutations in objects.

Name change:

\[
\begin{align*}
x &= 2 \\
x + x &= 4 \\
x &= 3 \\
x + x &= 6
\end{align*}
\]

Object mutation:

\[
\begin{align*}
x + x \\
x + x
\end{align*}
\]
Name change vs. mutation

The value of an expression can change due to either changes in names or mutations in objects.

Name change:

```
x = 2
x + x # 4
x = 3
x + x # 6
```

Object mutation:

```
x = ['A', 'B']
x + x  # ['A', 'B', 'A', 'B']
x + x
```
Name change vs. mutation

The value of an expression can change due to either changes in names or mutations in objects.

Name change:

```python
x = 2
x + x  # 4
x = 3
x + x  # 6
```

Object mutation:

```python
x = ['A', 'B']
x + x  # ['A', 'B', 'A', 'B']
x.append('C')
x + x  # ['A', 'B', 'C', 'A', 'B', 'C']
```
Mutables inside immutables

An immutable sequence may still change if it contains a mutable value as an element.

```python
# immutable sequence with a mutable list

t = (1, [2, 3])
t[1][0] = 99
t[1][1] = "Problems"
```

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Equality of contents vs. Identity of objects

```python
list1 = [1, 2, 3]
list2 = [1, 2, 3]
```

**Equality:** \(\text{exp0 == exp1}\) evaluates to \text{True} if both \text{exp0} and \text{exp1} evaluate to objects containing equal values

```python
list1 == list2
```
Equality of contents vs. Identity of objects

```python
list1 = [1, 2, 3]
list2 = [1, 2, 3]
```

**Equality:** `exp0 == exp1`
evaluates to `True` if both `exp0` and `exp1` evaluate to objects containing equal values

```python
list1 == list2  # True
```
Equality of contents vs. Identity of objects

```python
list1 = [1,2,3]
list2 = [1,2,3]
```

**Equality:** `exp0 == exp1` evaluates to `True` if both `exp0` and `exp1` evaluate to objects containing equal values.

```python
list1 == list2  # True
```

**Identity:** `exp0 is exp1` evaluates to `True` if both `exp0` and `exp1` evaluate to the same object. Identical objects always have equal values.

```python
list1 is list2
```

Try in PythonTutor.
Equality of contents vs. Identity of objects

```
list1 = [1, 2, 3]
list2 = [1, 2, 3]
```

**Equality:** \( \text{exp0} == \text{exp1} \)
evaluates to \textbf{True} if both \textbf{exp0} and \textbf{exp1} evaluate to objects containing equal values

```
list1 == list2  # True
```

**Identity:** \( \text{exp0} \text{ is } \text{exp1} \)
evaluates to \textbf{True} if both \textbf{exp0} and \textbf{exp1} evaluate to the same object

```
list1 is list2  # False
```

Try in PythonTutor.
Beware, Mutation!
An function can change the value of any object in its scope.

```python
four = [1, 2, 3, 4]
print(four[0])
do_stuff_to(four)
print(four[0])
```

**Try in PythonTutor**

Even without arguments:

```python
four = [1, 2, 3, 4]
print(four[3])
do_other_stuff()
print(four[3])
```

**Try in PythonTutor**
Immutability in function calls

Immutable values are protected from mutation.

<table>
<thead>
<tr>
<th>Tuple</th>
<th>List</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>turtle = (1, 2, 3)</code></td>
<td><code>turtle = [1, 2, 3]</code></td>
</tr>
<tr>
<td><code>ooze()</code></td>
<td><code>ooze()</code></td>
</tr>
<tr>
<td><code>turtle # (1, 2, 3)</code></td>
<td><code>turtle # [1, 2, 'Mwahaha']</code></td>
</tr>
</tbody>
</table>
Mutable default arguments 🐱

A default argument value is part of a function value, not generated by a call.

```python
def f(s=[]):
    s.append(3)
    return len(s)
```

f() # 1
f() # 2
f() # 3

Each time the function is called, `s` is bound to the same value.

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Python Project of The Day!
Anki

Anki: An open-source desktop application for studying flash cards.

Technologies used: Python. (Github repository)