

61A Lecture 12

Announcements

Objects

(Demo)

Objects

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- In Python, every value is an object
 - All **objects** have **attributes**

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 - A lot of data manipulation happens through object **methods**

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 - A metaphor for organizing large programs
 - Special syntax that can improve the composition of programs
- In Python, every value is an object
 - All **objects** have **attributes**
 - A lot of data manipulation happens through object **methods**
 - Functions do one thing; objects do many related things

Example: Strings

(Demo)

Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

ASCII Code Chart

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2		!	"	#	\$	%	&	'	()	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{		}	~	DEL

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2		!	"	#	\$	%	&	'	()	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
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6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
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"Line feed" (\n)

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Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

"Bell" (\a)

ASCII Code Chart

"Line feed" (\n)

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
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2		!	"	#	\$	%	&	'	()	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	_
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健	腓	腳	腓	股	股	膈	腸
8171	8172	8173	8174	8175	8176	8177	8178
艱	色	艷	艷	艷	艷	艷	艸
8271	8272	8273	8274	8275	8276	8277	8278
菟	菟	荳	菰	葱	苣	荷	葶
8371	8372	8373	8374	8375	8376	8377	8378
葱	菰	葦	葦	葵	葶	葶	蔥

http://ian-albert.com/unicode_chart/unichart-chinese.jpg

Representing Strings: the Unicode Standard

- 109,000 characters

聾	聾	聾	聽	聵	聶	職	聵
8071	8072	8073	8074	8075	8076	8077	8078
健	腓	腳	腓	股	股	膈	腸
8171	8172	8173	8174	8175	8176	8177	8178
艱	色	艷	艷	艷	艷	艷	艸
8271	8272	8273	8274	8275	8276	8277	8278
菟	菟	荳	菰	葱	苳	荷	葶
8371	8372	8373	8374	8375	8376	8377	8378
葱	菰	葦	葦	葵	葶	葶	蔥

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Representing Strings: the Unicode Standard

- 109,000 characters
- 93 scripts (organized)

聾	聾	聾	聾	聾	聾	聾	聾
8071	8072	8073	8074	8075	8076	8077	8078
健	腓	腳	腓	腓	腓	腓	腸
8171	8172	8173	8174	8175	8176	8177	8178
艱	色	艷	艷	艷	艷	艷	艸
8271	8272	8273	8274	8275	8276	8277	8278
菟	菟	荳	菰	菰	菰	荷	菴
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- Enumeration of character properties, such as case

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Representing Strings: the Unicode Standard

- 109,000 characters
- 93 scripts (organized)
- Enumeration of character properties, such as case
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健	腓	腳	腓	腓	腓	腓	腸
8171	8172	8173	8174	8175	8176	8177	8178
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Representing Strings: the Unicode Standard

- 109,000 characters
- 93 scripts (organized)
- Enumeration of character properties, such as case
- Supports bidirectional display order
- A canonical name for every character

聾	聾	聾	聾	聾	聾	聾	聾
8071	8072	8073	8074	8075	8076	8077	8078
健	腓	腳	腓	腓	腓	腓	腸
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8171	8172	8173	8174	8175	8176	8177	8178
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U+0058 LATIN CAPITAL LETTER X

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U+263a WHITE SMILING FACE

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U+263a WHITE SMILING FACE

U+2639 WHITE FROWNING FACE

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8171	8172	8173	8174	8175	8176	8177	8178
艱	色	艷	艷	艷	艷	艷	艷
8271	8272	8273	8274	8275	8276	8277	8278
菟	菟	荳	菰	菰	菰	荷	菰
8371	8372	8373	8374	8375	8376	8377	8378
葱	菰	菰	菰	葵	菰	菰	菰

http://ian-albert.com/unicode_chart/unichart-chinese.jpg

U+0058 LATIN CAPITAL LETTER X

U+263a WHITE SMILING FACE

U+2639 WHITE FROWNING FACE



(Demo)

Mutation Operations

Some Objects Can Change

[Demo]

Some Objects Can Change

[Demo]

First example in the course of an object changing state

Some Objects Can Change

[Demo]

First example in the course of an object changing state


The same object can change in value throughout the course of computation

Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation

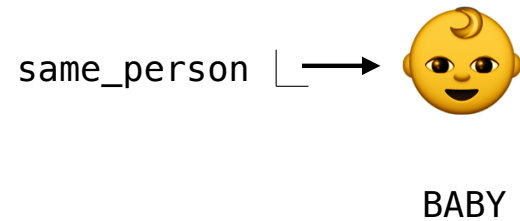
same_person \mapsto 

Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation

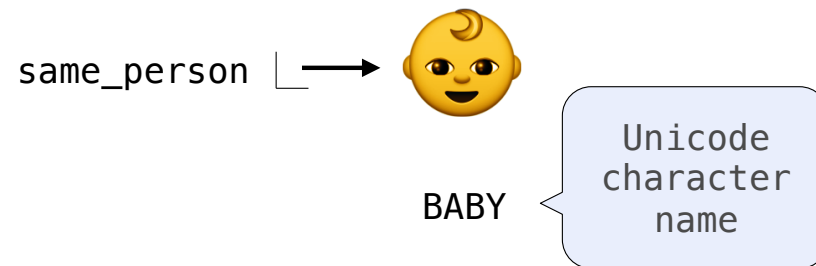


Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation

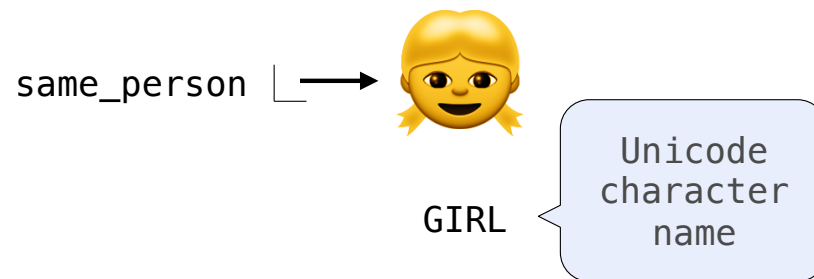


Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation

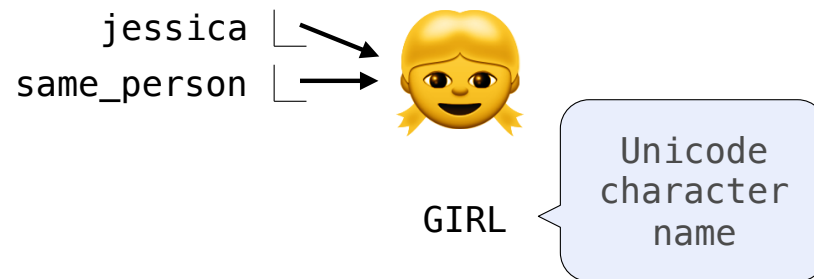


Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation

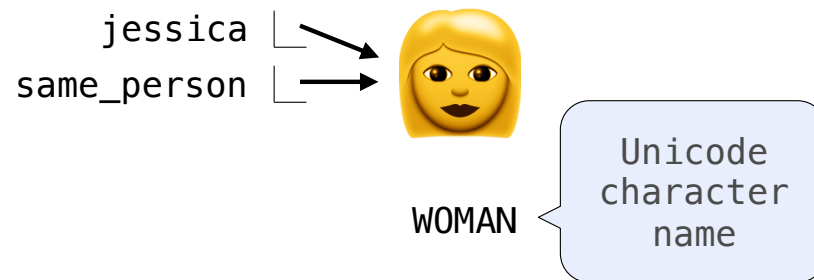


Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation

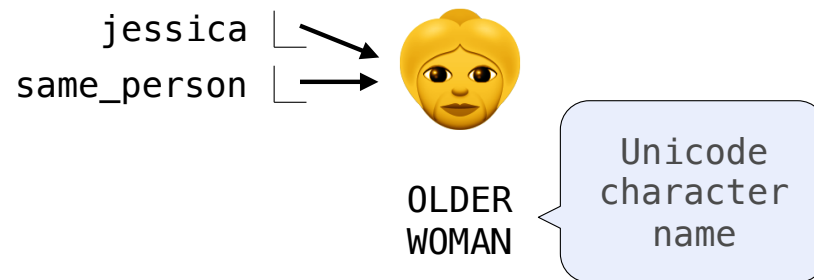


Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation

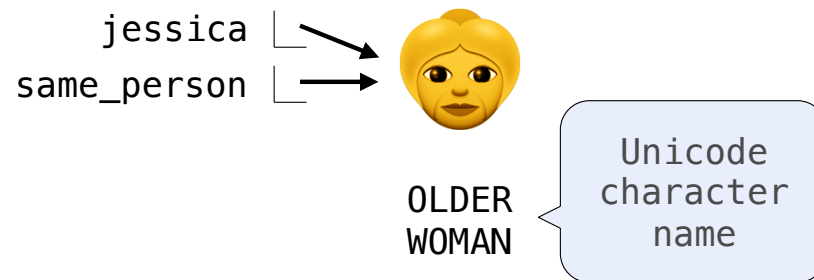


Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation



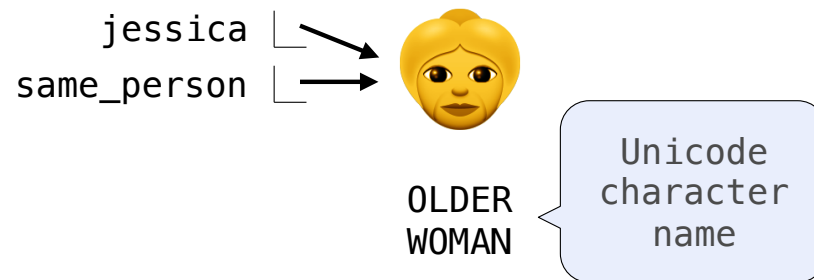
All names that refer to the same object are affected by a mutation

Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation



All names that refer to the same object are affected by a mutation

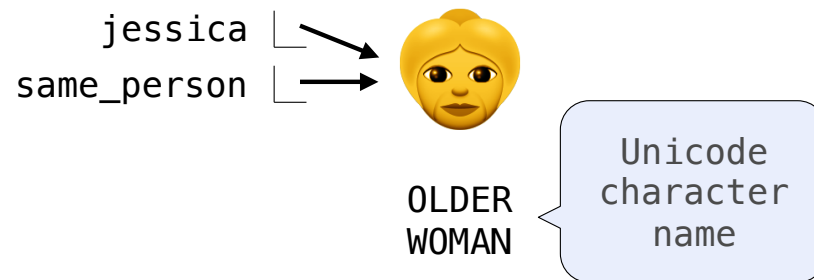
Only objects of *mutable* types can change: lists & dictionaries

Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation



All names that refer to the same object are affected by a mutation

Only objects of *mutable* types can change: lists & dictionaries

{Demo}

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
```


Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
def mystery(s):
    s.pop()
    s.pop()
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
def mystery(s):      or    def mystery(s):
    s.pop()           s[2:] = []
    s.pop()
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
def mystery(s):      or    def mystery(s):
    s.pop()           s[2:] = []
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```

```
>>> four = [1, 2, 3, 4]
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
```

```
def mystery(s):      or    def mystery(s):
    s.pop()           s[2:] = []
    s.pop()
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
def mystery(s):      or    def mystery(s):
    s.pop()           s[2:] = []
    s.pop()
```

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> another_mystery() # No arguments!
```

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
def mystery(s):      or    def mystery(s):
    s.pop()           s[2:] = []
    s.pop()
```

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> another_mystery() # No arguments!
>>> len(four)
2
```

Mutation Can Happen Within a Function Call

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```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
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>>> len(four)
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def mystery(s):      or    def mystery(s):
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```

```
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>>> len(four)
4
>>> another_mystery() # No arguments!
>>> len(four)
2
```

```
def another_mystery():
    four.pop()
    four.pop()
```


Tuples

(Demo)

Tuples are Immutable Sequences

Tuples are Immutable Sequences

Immutable values are protected from mutation

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```
>>> turtle = (1, 2, 3)
```

Tuples are Immutable Sequences

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```
>>> turtle = (1, 2, 3)
>>> ooze()
```

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(1, 2, 3)
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(1, 2, 3)
```

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
```

Tuples are Immutable Sequences

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```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
```

```
>>> ooze()
```

```
>>> turtle
```

```
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
```

```
>>> ooze()
```

```
>>> turtle
```

```
['Anything could be inside!']
```

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>>> turtle = (1, 2, 3)
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Next lecture: ooze can
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```
>>> turtle = [1, 2, 3]
```

```
>>> ooze()
```

```
>>> turtle
```

```
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
```

```
>>> ooze()
```

```
>>> turtle
```

```
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
```

```
>>> ooze()
```

```
>>> turtle
```

```
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
```

```
>>> ooze()
```

```
>>> turtle
```

```
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
```

```
>>> ooze()
```

```
>>> turtle
```

```
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

```
>>> x + x
```

Name change:

```
>>> x + x
```

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
```

```
>>> ooze()
```

```
>>> turtle
```

```
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
```

```
>>> ooze()
```

```
>>> turtle
```

```
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

```
>>> x = 2
```

```
>>> x + x
```

Name change:

```
>>> x + x
```


Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

```
>>> x = 2
>>> x + x
4
>>> x + x
```

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
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Name change:

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>>> turtle = (1, 2, 3)
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>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

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

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
```

```
>>> ooze()
```

```
>>> turtle
```

```
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
```

```
>>> ooze()
```

```
>>> turtle
```

```
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

```
>>> x = 2
```

```
>>> x + x
```

```
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```

```
>>> x = 3
```

```
>>> x + x
```

```
6
```

Object mutation:

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

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```

Object mutation:

```
>>> x + x
>>> x + x
```

Tuples are Immutable Sequences

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```
>>> turtle = (1, 2, 3)
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>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

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>>> turtle = [1, 2, 3]
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Object mutation:

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>>> x = [1, 2]
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[1, 2, 1, 2]
>>> x + x
[1, 2, 1, 2]
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```
>>> turtle = (1, 2, 3)
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```
(1, 2, 3)
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Next lecture: ooze can
change turtle's binding

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Object mutation:

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>>> x + x
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```
[1, 2, 1, 2]
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Tuples are Immutable Sequences

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```
>>> turtle = (1, 2, 3)
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Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
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['Anything could be inside!']
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The value of an expression can change because of changes in names or objects

Name change:

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

Object mutation:

```
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
```


Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

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[1, 2, 3, 1, 2, 3]
```

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
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Next lecture: ooze can
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The value of an expression can change because of changes in names or objects

Name change:

```
>>> x = 2
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6
```

Object mutation:

```
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```

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

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
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The value of an expression can change because of changes in names or objects

Name change:

```
>>> x = 2
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```
>>> x = [1, 2]
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[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```

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

```
>>> s = ([1, 2], 3)
```

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
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>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

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

Object mutation:

```
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```

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

```
>>> s = ([1, 2], 3)
>>> s[0] = 4
```

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

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

Object mutation:

```
>>> x = [1, 2]
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[1, 2, 1, 2]
>>> x.append(3)
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[1, 2, 3, 1, 2, 3]
```

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

```
>>> s = ([1, 2], 3)
>>> s[0] = 4
ERROR
```

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
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(1, 2, 3)
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Next lecture: ooze can
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>>> turtle = (1, 2, 3)
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>>> turtle
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```

Next lecture: ooze can
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```

Object mutation:

```
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[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```

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

```
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```
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>>> s[0][0] = 4
```

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```
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>>> s[0] = 4
ERROR
```

```
>>> s = ([1, 2], 3)
>>> s[0][0] = 4
>>> s
```


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```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can
change turtle's binding

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

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

Object mutation:

```
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```

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

```
>>> s = ([1, 2], 3)
>>> s[0] = 4
ERROR
```

```
>>> s = ([1, 2], 3)
>>> s[0][0] = 4
>>> s
([4, 2], 3)
```

Mutation

Sameness and Change

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>>> a = [10]
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(Demo)

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>>> def f(s=[]):  
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```

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>>> f()  
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```


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2
```

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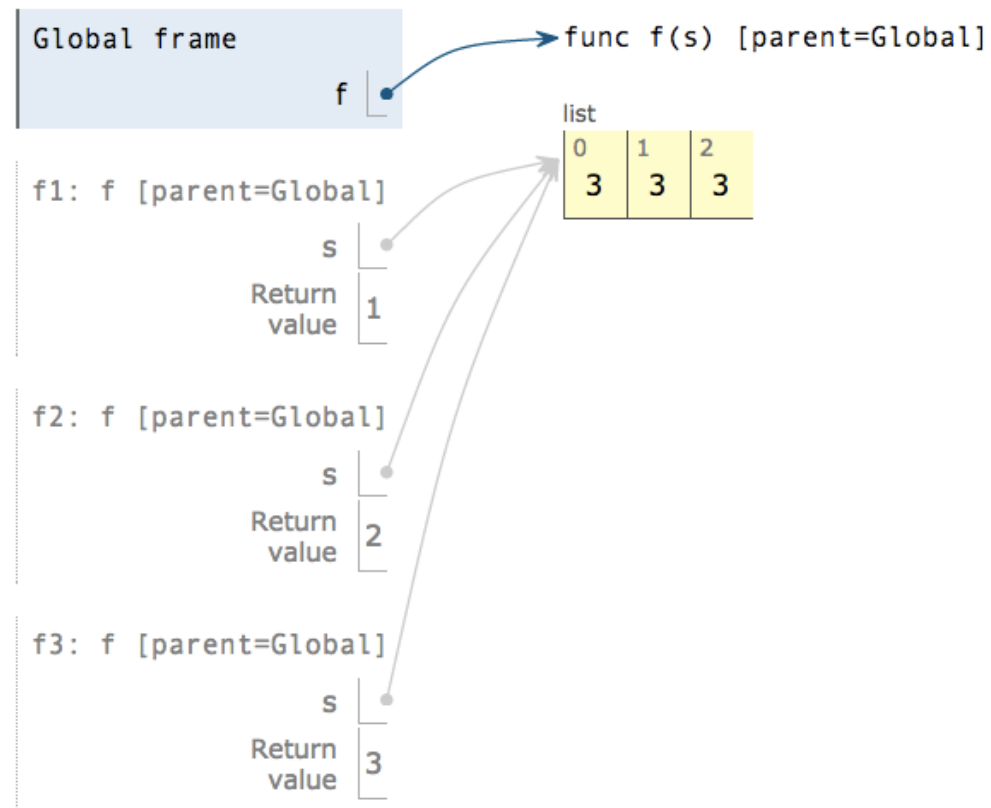
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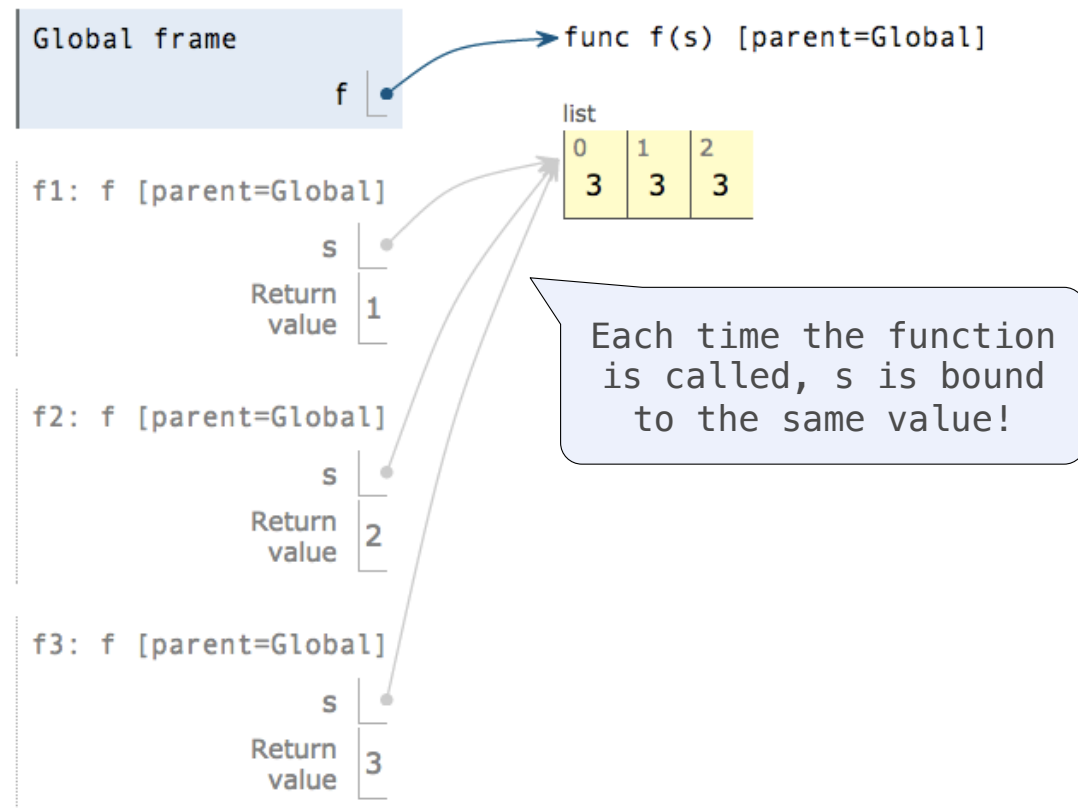


Interactive Diagram

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