61A Lecture 12

Friday, February 20
Announcements

• Homework 4 due Monday 2/23 @ 11:59pm (small)
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• Project 2 due Thursday 2/26 @ 11:59pm (BIG!)
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  ▪ Project party Tuesday 2/24 5pm–6:30pm in 2050 VLSB
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- Homework 4 due Monday 2/23 @ 11:59pm (small)
- Project 2 due Thursday 2/26 @ 11:59pm (BIG!)
  - Project party Tuesday 2/24 5pm–6:30pm in 2050 VLSB
  - Bonus point for early submission by Wednesday 2/25 @ 11:59pm!
Objects
Objects

(Demo)
Objects

(Demo)

- Objects represent information.
Objects

(Demo)

• Objects represent information.
• They consist of data and behavior, bundled together to create abstractions.
Objects

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• Objects can represent things, but also properties, interactions, & processes.
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• In Python, every value is an object.
  • All objects have attributes.
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Object-oriented programming:
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In Python, every value is an object.
- All objects have attributes.
- A lot of data manipulation happens through object methods.
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• Object-oriented programming:
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• 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
Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

**ASCII Code Chart**

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Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

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8 rows: 3 bits
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<td>O</td>
</tr>
<tr>
<td>5</td>
<td>P</td>
<td>Q</td>
<td>R</td>
<td>S</td>
<td>T</td>
<td>U</td>
<td>V</td>
<td>W</td>
<td>X</td>
<td>Y</td>
<td>Z</td>
<td>[</td>
<td>\</td>
<td>]</td>
<td>^</td>
<td>_</td>
</tr>
<tr>
<td>6</td>
<td>`</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>g</td>
<td>h</td>
<td>i</td>
<td>j</td>
<td>k</td>
<td>l</td>
<td>m</td>
<td>n</td>
<td>o</td>
</tr>
<tr>
<td>7</td>
<td>p</td>
<td>q</td>
<td>r</td>
<td>s</td>
<td>t</td>
<td>u</td>
<td>v</td>
<td>w</td>
<td>x</td>
<td>y</td>
<td>z</td>
<td>{</td>
<td></td>
<td></td>
<td>}</td>
<td>~</td>
</tr>
</tbody>
</table>

16 columns: 4 bits

- Layout was chosen to support sorting by character code
- Rows indexed 2–5 are a useful 6-bit (64 element) subset
- Control characters were designed for transmission

(Demo)
Representing Strings: the Unicode Standard
Representing Strings: the Unicode Standard

<table>
<thead>
<tr>
<th>ハ その だ  בש</th>
<th>8271 8072 8073 8074 8075 8076 8077 8078</th>
</tr>
</thead>
<tbody>
<tr>
<td>健 侀 脚 腕 腹</td>
<td>8171 8172 8173 8174 8175 8176 8177 8178</td>
</tr>
<tr>
<td>銀 色 艳 艳</td>
<td>8271 8272 8273 8274 8275 8276 8277 8278</td>
</tr>
<tr>
<td>苾 荻 仾 蕾 蕾</td>
<td>8371 8372 8373 8374 8375 8376 8377 8378</td>
</tr>
<tr>
<td>萌 萱 蕰 葵 菜</td>
<td>8371 8372 8373 8374 8375 8376 8377 8378</td>
</tr>
</tbody>
</table>

http://ian-albert.com/unicode_chart/unichart-chinese.jpg
Representing Strings: the Unicode Standard

- 109,000 characters
Representing Strings: the Unicode Standard

- 109,000 characters
- 93 scripts (organized)

http://ian-albert.com/unicode_chart/unichart-chinese.jpg
Representing Strings: the Unicode Standard

- 109,000 characters
- 93 scripts (organized)
- Enumeration of character properties, such as case

[Image: http://ian-albert.com/unicode_chart/unichart-chinese.jpg]
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- 109,000 characters
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- Enumeration of character properties, such as case
- Supports bidirectional display order

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

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U+0058 LATIN CAPITAL LETTER X
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(http://ian-albert.com/unicode_chart/unichart-chinese.jpg)

(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

First example in the course of an object changing state

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

same_person

[Demo]
Some Objects Can Change

First example in the course of an object changing state

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

same_person  ➔ BABY
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

```plaintext
same_person __→ BABY

Unicode character name
```
Some Objects Can Change

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

Jessica → same_person → GIRL

Unicode character name
Some Objects Can Change

First example in the course of an object changing state

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

[Demo]
Some Objects Can Change

First example in the course of an object changing state

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

[jDemo]

_unicode_character_name
**Some Objects Can Change**

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

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

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
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

```python
>>> four = [1, 2, 3, 4]
```
Mutation Can Happen Within a Function Call

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

```python
>>> 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

```python
>>> 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

```python
>>> 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

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

Interactive Diagram
Mutation Can Happen Within a Function Call

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

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

Interactive Diagram
Mutation Can Happen Within a Function Call

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

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

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

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

def mystery(s):
    s[2:] = []
```

Interactive Diagram
**Mutation Can Happen Within a Function Call**

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

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

```python
>>> 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

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

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

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

Interactive Diagram
Mutation Can Happen Within a Function Call

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

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

>>> another_mystery()  # No arguments!
```

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

def mystery(s):
    s[2:] = []
```

Interactive Diagram
Mutation Can Happen Within a Function Call

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

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

```  

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

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

```  

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

(Demo)
Tuples are Immutable Sequences
Tuples are Immutable Sequences

Immutable values are protected from mutation
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)
>>> ooze()
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)  # >>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
(1, 2, 3)
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)  # Mutable
>>> ooze()
>>> turtle
(1, 2, 3)
```

```python
>>> turtle = [1, 2, 3]  # Immutable
>>> ooze()
>>> turtle
[1, 2, 3]
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

Next lecture: ooze can change turtle's binding

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

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

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

```python
>>> x + x
Name change:
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

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

```python
>>> x = 2
>>> x + x

Name change:

```python
>>> x = 2
>>> x + x
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

Next lecture: `ooze` can change `turtle`'s binding

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

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

Name change:

```python
>>> x = 2
>>> x + x
4
```
Tuples are Immutable Sequences

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

Next lecture: ooze can change turtle's binding

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

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

Name change:
```
>>> x = 3
>>> x + x
```

```python
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
[1, 2, 3]
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

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

Next lecture: ooze can change turtle's binding

['Anything could be inside!']
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

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

Name change:

>>> x = 3
>>> x + x
6

Object mutation:
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

```python
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>>> x + x
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Next lecture: ooze can change turtle's binding
>>> turtle
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>>> ooze()
>>> turtle
['Anything could be inside!']
```

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

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>>> x + x
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Name change:
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>>> x + x
6
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>>> x = [1, 2]
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```

Object mutation:
Tuples are Immutable Sequences

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

Next lecture: ooze can change turtle's binding

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

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

Name change:

>>> x = 3
>>> x + x
6

Object mutation:

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

Immutable values are protected from mutation

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

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

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

- **Name change:**
- **Object mutation:**

Next lecture: ooze can change turtle's binding

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

Next lecture: ooze can change turtle's binding

```python
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 1, 2, 3]
```
**Tuples are Immutable Sequences**

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)
>>> ooze()  # Next lecture: ooze can change turtle's binding
(1, 2, 3)
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

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

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

**Name change:**

**Object mutation:**

```python
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```
Tuples are Immutable Sequences

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

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

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

Name change:

>>> x = 3
>>> x + x
6

Object mutation:

```python
>>> 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

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

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

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

Name change:  Object mutation:
```

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

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

```python
Next lecture: ooze can change turtle's binding
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

Name change:

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

Object mutation:

```python
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
```

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

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

Next lecture: ooze can change turtle's binding
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

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

**Name change:**

```python
>>> x = 3
>>> x + x
6
```

**Object mutation:**

```python
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
```

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

```python
>>> s = ([1, 2], 3)
>>> s[0] = 4
ERROR
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

Next lecture: ooze can change turtle's binding

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

```python
>>> x = 2
>>> x + x
4
>>> x = 3
>>> x + x
6
Name change:
```

```python
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
```

Object mutation:

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

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

```python
>>> s = ([1, 2], 3)
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

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

Next lecture: ooze can change turtle's binding

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

Object mutation:

```python
>>> 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

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

>>> s = ( [1, 2], 3 )
>>> s[0][0] = 4
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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

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

**Name change:**

Object mutation:

```python
>>> 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

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

Next lecture: ooze can change turtle's binding

```python
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

Next lecture: ooze can change turtle's binding

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

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

Name change:

```python
>>> x = 3
>>> x + x
6
```

Object mutation:

```python
>>> 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

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

>>> s = ([1, 2], 3)
>>> s[0][0] = 4
>>> s
([4, 2], 3)
```
Mutation
Sameness and Change
Sameness and Change

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• Conversely, we could have two lists that happen to have the same contents, but are different

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[10, 20]
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Identity Operators
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<exp0> is <exp1>

evaluates to True if both <exp0> and <exp1> evaluate to the same object
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Equality

<exp0> == <exp1>

evaluates to True if both <exp0> and <exp1> evaluate to equal values
Identity Operators

Identity

\(<\text{exp0}\> \text{ is } \text{exp1}\>

evaluates to True if both \(<\text{exp0}\> \text{ and } \text{exp1}\> \text{ evaluate to the same object}

Equality

\(<\text{exp0}\> == \text{exp1}\>

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Identical objects are always equal values
Identity Operators

**Identity**

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**Equality**

<exp0> == <exp1>

evaluates to True if both <exp0> and <exp1> evaluate to equal values

Identical objects are always equal values

(Demo)
Mutable Default Arguments are Dangerous
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A default argument value is part of a function value, not generated by a call
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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)
...```
Mutable Default Arguments are Dangerous

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
```
Mutable Default Arguments are Dangerous

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

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>>> f()
1
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```

Interactive Diagram
Mutable Default Arguments are Dangerous

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

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>>> def f(s=[]):
    ... s.append(3)
    ... return len(s)
    ...
>>> f()
1
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```

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