Announcements
Objects

(Demo)
Objects
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  - 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

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Representing Strings: the ASCII Standard

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- Layout was chosen to support sorting by character code

8 rows: 3 bits

16 columns: 4 bits
Representing Strings: the ASCII Standard

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- Rows indexed 2–5 are a useful 6-bit (64 element) subset
Representing Strings: the ASCII Standard

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- Control characters were designed for transmission
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<td>DC3</td>
<td>DC4</td>
<td>NAK</td>
</tr>
<tr>
<td>4</td>
<td>SYN</td>
<td>ETB</td>
<td>CAN</td>
<td>EM</td>
<td>SUB</td>
<td>ESC</td>
</tr>
<tr>
<td>5</td>
<td>FS</td>
<td>GS</td>
<td>RS</td>
<td>US</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>&quot;Line feed&quot; (\n)</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
### Representing Strings: the ASCII Standard

#### American Standard Code for Information Interchange

<table>
<thead>
<tr>
<th>ASCII Code Chart</th>
<th>&quot;Bell&quot; (\a)</th>
<th>&quot;Line feed&quot; (\n)</th>
</tr>
</thead>
</table>

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<thead>
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<th>B</th>
<th>C</th>
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<td>SO</td>
<td>SI</td>
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<td>NAK</td>
<td>SYN</td>
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<td>GS</td>
<td>RS</td>
<td>US</td>
</tr>
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<td>!</td>
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<td>#</td>
<td>$</td>
<td>%</td>
<td>&amp;</td>
<td>(</td>
<td>)</td>
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<td>=</td>
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<td>C</td>
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<td>]</td>
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<td>6</td>
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<td>s</td>
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<td>v</td>
<td>w</td>
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<td>y</td>
<td>z</td>
<td>{</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- Layout was chosen to support sorting by character code
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#### Layout Characteristics
- 8 rows: 3 bits
- 16 columns: 4 bits
Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

<table>
<thead>
<tr>
<th>ASCII Code Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>---</td>
</tr>
<tr>
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<td>4</td>
</tr>
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</tr>
<tr>
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</tr>
<tr>
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(Demo)
Representing Strings: the Unicode Standard
Representing Strings: the Unicode Standard

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

- 109,000 characters

[Diagram with Chinese characters and corresponding Unicode codes]

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

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

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
Representing Strings: the Unicode Standard

• 109,000 characters
• 93 scripts (organized)
• Enumeration of character properties, such as case
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U+0058 LATIN CAPITAL LETTER X
Representing Strings: the Unicode Standard

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(Demo)
Mutation Operations
Some Objects Can Change

[Demo]
Some Objects Can Change

First example in the course of an object changing state
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

same_person ⟷ 😸
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 [ ] → BABY
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

First example in the course of an object changing state

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

same_person \[\rightarrow\] 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

```
jessica |___
same_person |___
          ▷Unicode character name
          GIRL
```
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]

Unicode character name

jessica → same_person → WOMAN

 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

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

```
jessica
same_person
```

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
generate_2d_table:
```
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()
```

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]

Interactive Diagram

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

```python
or
```
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):
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    s.pop()
```

```python
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4
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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):
    or
def mystery(s):
    s.pop()
    s.pop()
```

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

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

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

**Interactive Diagram**

---

Mutation Can Happen Within a Function Call
Mutation Can Happen Within a Function Call

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

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

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

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

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

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

Immutable values are protected from mutation

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

```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)
```

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Tuples are Immutable Sequences

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

```python
>>> 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!']
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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)
```

Next lecture: ooze can change turtle's binding

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

```python
>>> x + x
Name change:
>>> 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

>>> 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 + 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
```

```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()  # Next lecture: ooze can change turtle's binding
>>> 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
```
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
c

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

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)
```

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:  
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

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Name change:  
Object mutation:

```
Tuples are Immutable Sequences

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

Name change:

Object mutation:

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

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

Name change:

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

Object mutation:

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

Next lecture: ooze can change turtle’s binding

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

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

Object mutation:

```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
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]
```
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

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

Name change:

Object mutation:

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

Immutable values are protected from mutation

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

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
```

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

Object mutation:

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

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

Immutable values are protected from mutation

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

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Mutation
Sameness and Change
Sameness and Change

As long as we never modify objects, a compound object is just the totality of its pieces.
Sameness and Change

• As long as we never modify objects, a compound object is just the totality of its pieces
• A rational number is just its numerator and denominator
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```python
>>> a = [10]
```
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```python
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>>> b = a
```
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>>> a = [10]
>>> b = a
>>> a == b
True
```
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[10, 20]
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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]
>>> b
[10, 20]
```
Identity Operators
Identity Operators

**Identity**

\[
\text{<exp0> is <exp1>}
\]

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

**Identity**

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

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

**Equality**

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

evaluates to True if both \(<\text{exp0}\>\) and \(<\text{exp1}\>\) evaluate to equal values
Identity Operators

Identity

<exp0> is <exp1>

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

Equality

<exp0> == <exp1>

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

Identical objects are always equal values
Identity Operators

Identity

<exp0> is <exp1>

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

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<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
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)
...```
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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    ...     s.append(3)
    ...     return len(s)
    ...
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1
>>> f()
2
>>> f()
3
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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)
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...
>>> f()
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3
```

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