Announcements

• Homework 4 due Tuesday 10/7 @ 11:59pm (It is small)
Announcements

* Homework 4 due Tuesday 10/7 @ 11:59pm (It is small)

* Project 2 due Thursday 10/9 @ 11:59pm (It is BIG)
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  • Project Party Monday 5pm–7pm in 271, 273, & 275 Soda
Announcements

- Homework 4 due Tuesday 10/7 @ 11:59pm (It is small)
- Project 2 due Thursday 10/9 @ 11:59pm (It is BIG)
  - Project Party Monday 5pm–7pm in 271, 273, & 275 Soda
  - Extra credit point for submitting your project at least 24 hours before the deadline
Encoding Strings

(Bonus Material)
Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

<table>
<thead>
<tr>
<th>ASCII Code Chart</th>
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<tr>
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| 6 | p  | q  | r  | s  | t  | u  | v  | w  | x  | y  | z  | {  | |  | }  | ~  | DEL |
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### Representing Strings: the ASCII Standard

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8 rows: 3 bits

16 columns: 4 bits
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- Layout was chosen to support sorting by character code
- Rows indexed 2–5 are a useful 6-bit (64 element) subset
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<td>&quot;Line feed&quot; (\n)</td>
</tr>
<tr>
<td>@</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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<td>w</td>
<td>x</td>
<td>y</td>
<td>z</td>
<td>{</td>
<td></td>
<td></td>
<td>~</td>
<td>DEL</td>
</tr>
</tbody>
</table>

- 8 rows: 3 bits
- 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>0</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tbody>
<tr>
<td>NUL</td>
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<td>ETX</td>
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<td>ENQ</td>
<td>ACK</td>
<td>BEL</td>
<td>BS</td>
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<td>SO</td>
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<td>DC3</td>
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<td>GS</td>
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<td>%</td>
<td>&amp;</td>
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(Demo)
Representing Strings: the Unicode Standard

- 109,000 characters

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

- **109,000 characters**
- **93 scripts (organized)**

![Unicode Chart](https://ian-albert.com/unicode_chart/unichart-chinese.jpg)
Representing Strings: the Unicode Standard

- 109,000 characters
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- Enumeration of character properties, such as case

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- 109,000 characters
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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
Representing Strings: the Unicode Standard

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U+0058 LATIN CAPITAL LETTER X
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(Demo)
Representing Strings: UTF-8 Encoding
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UTF (UCS (Universal Character Set) Transformation Format)
Representing Strings: UTF-8 Encoding

UTF (UCS (Universal Character Set) Transformation Format)

Unicode: Correspondence between characters and integers
Representing Strings: UTF-8 Encoding

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UTF-8: Correspondence between those integers and bytes
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A byte is 8 bits and can encode any integer 0–255.
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\begin{align*}
\text{bytes} & \quad \text{integers}
\end{align*}
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```
00000000      0
```

`bytes` `integers`
Representing Strings: UTF-8 Encoding

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A byte is 8 bits and can encode any integer 0–255.

\[
\begin{array}{c|c}
\text{00000000} & 0 \\
\text{00000001} & 1 \\
\end{array}
\]

bytes integers
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Variable-length encoding: integers vary in the number of bytes required to encode them.
Representing Strings: UTF-8 Encoding

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In Python: `string` length is measured in characters, `bytes` length in bytes.
Representing Strings: UTF-8 Encoding

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In Python: string length is measured in characters, bytes length in bytes.

(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

```latex
\texttt{same\_person} \xrightarrow{\text{___}}
```

![Image of a baby with a smiling face]
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

[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  ▸

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]

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 [Demo]

Unicode character name

```
jessica  ┌─┐
same_person └─┘
```
Some Objects Can Change

First example in the course of an object changing state

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[jDemo]
Some Objects Can Change

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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

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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

```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

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>>> 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
```

```python
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]
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```

---

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

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

Interactive Diagram
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

>>> another_mystery()  # No arguments!
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def mystery(s):
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or
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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(s):
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    four.pop()
```

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

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

Interactive Diagram
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

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```python
turtle
```
Tuples are Immutable Sequences

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

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>>> turtle
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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!']
```
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

```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
Tuples are Immutable Sequences

Immutable values are protected from mutation

```python
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle  # Change in names
(1, 2, 3)
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle  # Change in objects
['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)
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 + 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
```

Name change:

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

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

Next lecture: ooze can change turtle's binding

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>>> x = 2
>>> x + x
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Name change:

```python
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```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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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

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

Name change:
>>> x = 3
>>> 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:
Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> 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

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

Name change:

```
>>> x = 3
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Object mutation:

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

Object mutation:

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

Next lecture: ooze can change turtle's binding

['Anything could be inside!']
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[1, 2, 3, 1, 2, 3]
Object mutation:
```

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

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>>> 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

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Name change:
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>>> x + x
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Object mutation:

>>> 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)
```
Tuples are Immutable Sequences

Immutable values are protected from mutation

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

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>>> turtle = (1, 2, 3)
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Name change:
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[1, 2, 1, 2]
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Object mutation:

```python
>>> 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

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

Immutable values are protected from mutation

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>>> turtle
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Object mutation:
>>> 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

```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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>>> x = 2
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>>> x = 3
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Name change:  
```

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>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
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
>>> s = ([1, 2], 3)
>>> s[0][0] = 4
>>> s
([4, 2], 3)
```
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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• As long as we never modify objects, a compound object is just the totality of its pieces
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>>> a = [10]
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```python
>>> a = [10]
>>> b = a
```
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```python
>>> a = [10]
>>> b = a
>>> a == b
True
```
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>>> a = [10]
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```
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>>> a = [10]
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True
>>> a.append(20)
>>> a == b
True
>>> a
[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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```python
>>> a = [10]
>>> b = [10]
>>> a == b
True
>>> b.append(20)
>>> a
[10]
>>> b
[10, 20]
```
Identity Operators
Identity Operators

Identity

<exp0> is <exp1>

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

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
Mutable Default Arguments are Dangerous

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(5)
...     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(5)
...     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(5)
    ...     return len(s)
    ...
>>> f()
1
>>> f()
2
```
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(5)
...     return len(s)
...
>>> f()
1
>>> f()
2
>>> f()
3
```
Mutable Default Arguments are Dangerous

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

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

```python
>>> def f(s=[]):
...     s.append(5)
...     return len(s)
... >>> f()
1
>>> f()
2
>>> f()
3
```

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