CS 1
Introduction to Computer Programming

Lecture 5: October 10, 2012

Lists, etc.

Last time

- `raw_input()`
- Objects
- Method syntax (dot syntax)
- Modules
- Module syntax (dot syntax)

Today

- Documentation (docstrings)
- The `__main__` module
- Lists

Docstrings

- We've talked about comments already:

```
# This is a comment.
```

- Very common use of comments is to describe what a function does:

```
# Print out a hearty greeting.
def greet(name):
    print 'Hi there, %s' % name
```

Docstrings

- Comments describing the purpose of functions are very useful
- However, Python's `help()` function can't use them
- It would be cool if there were a special way to write comments so that they could be used by the `help()` function
- And there is! It's called a docstring
  - short for "documentation string"

Docstrings

- A docstring is just a regular Python string that is the first thing in any of:
  - a function body
  - a module
  - a class (later in course)
- When executing a function body, the docstring doesn't *do* anything
  - but Python stores it as part of the function
  - same is true for modules and classes

Docstrings

- **`greet`** function from last time, with a docstring:

```
def greet(name):
    '''Print out a hearty greeting.'''
    print 'Hi there, %s' % name
```

docstring

- Docstrings usually written using triple-quoted strings (multiline strings)
  - because docstrings often span more than 1 line

Docstrings

- Assume this is still part of module **`greetings`**
- Now can do this:

```
>>> help(greetings.greet)
Help on function greet in module
  greetings:

greet(name)
     Print out a hearty greeting.
```

Module docstrings

- Similarly, can have docstrings for entire module
- New version of file **`greetings.py`**:

```
'''Module: greetings
   Functions to print out greetings.'''

def greet(name):
    '''Print out a hearty greeting.'''
    print 'Hi there, %s!' % name

def insult(name):
    '''Print out a nasty insult.'''
    print 'Get lost, %s!' % name
```

module docstring

Module docstrings

```
>>> help(greetings)
FILE
    greetings.py
DESCRIPTION
    Module: greetings
    Functions to print out greetings.
FUNCTIONS
    greet(name)
        Print out a hearty greeting.
    insult(name)
        Print out a nasty insult.
```

The point of docstrings

- We will expect you to write docstrings for all your functions and modules
- Docstrings are good documentation
  - for you
  - for you in the future
  - for anyone else that wants to use your modules/ functions

What to put in docstrings

- For functions, a docstring should describe
  1. what the function does
  2. what the function arguments represent
  3. what the function return value represents

- For modules, a docstring should describe
  - the purpose of the module
  - general description of the kinds of functions in the module
    - but *not* a detailed description of the functions!
  - any other relevant information

Experiment

- Let's type in a function with a docstring into the Python shell:

```
>>> def double(x):
...     '''This function doubles its argument x.'''
...     return 2 * x
```

Experiment

- Now let's get some **`help()`**:

```
>>> help(double)
Help on function double in module __main__:

double(x)
    This function doubles its argument x.
```

- What's all this **`module __main__`** stuff?

The `__main__` module

- `__main__` is the name that Python gives to either
  - the interactive interpreter
  - the module which was directly invoked by Python
- All other modules are referred to by their own names
  - *e.g.* `greetings` module we defined before

`__name__`

- Python also defines a variable called `__name__` which contains the name of the currently-executing module
  - We'll see a good use for this later on

- Many "special names" in Python have the form `__xxx__` for some `xxx`
  - We'll see many more of these

__builtins__

- Python contains quite a few built-in functions
  - *e.g.* **abs**, **max**, **min**
- These functions actually live in a special module called **__builtins__**
- To get documentation on all of them:

```
>>> help(__builtins__)
```

- Can also call builtin functions with a qualified name:

```
>>> __builtins__.abs(-5)
5
```

Adminterlude

- Get registered if you aren't already!
- Problems with building access after hours:
  - Lisa Knox: lisa987@cms.caltech.edu
- You should be getting course-related emails from me
- Read the "Policies/FAQ" page on the web site before emailing me questions

Adminterlude

- Lab sections have been posted!
  - will start on Sunday afternoon
- People who filled out questionnaire very late may not be in initial list
  - I will fill in ASAP
- Some login names are missing
  - please email them to me!

Adminterlude

- Let's choose ombudspersons for each Caltech house!
- Get to have lunch with me every other Thursday at noon at the Athenaeum
  - starting tomorrow!
- Bring comments/criticism/praise/vilification from your house (anonymous feedback)

Movie clip

- More Python!

Lists

- A *list* is a sequence of Python values
  - a way to take multiple values and create a single value that contains all the other values
  - Recall: strings are a sequence of characters
  - Lists are a sequence of *any* kind of value

Why lists?

- Often have many related values that you'd like to store in a single object
  - *e.g.* average temperature each day for the last week
- Could define separate variables for each value
  - but it would quickly become tedious

Without lists

```
temp_sunday    = 59.6
temp_monday    = 72.4
temp_tuesday   = 68.5
temp_wednesday = 79.0
temp_thursday  = 66.4
temp_friday    = 77.1
temp_saturday  = -126.0  # new ice age?
```

- Hard to use this for anything

Without lists

```
avg_temp = (temp_sunday + ...) / 7.0
```

- Tedious, inflexible

With lists

```
temps = [59.6, 72.4, 68.5, 79.0,
         66.4, 77.1, -126.0]
```

- Much simpler, easier to work with:

```
avg_temp = sum(temps) / 7.0
```

- Makes working with multiple values as easy as working with single ones
- Lists are used everywhere in Python code!

Creating lists

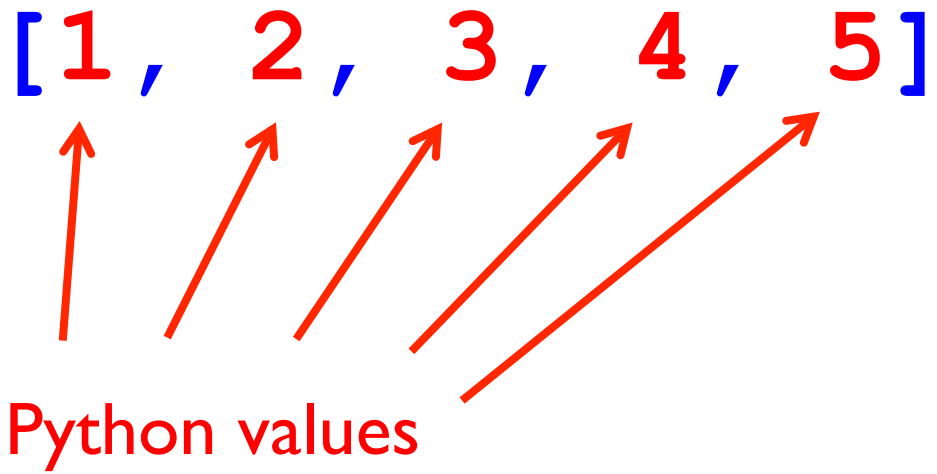
- Create lists by putting Python values or expressions inside square brackets, separated by commas:

```
[1, 2, 3, 4, 5]
```

- Items inside list are called the *elements* of the list

Creating lists

- Create lists by putting Python values or expressions inside square brackets, separated by commas:



Creating lists

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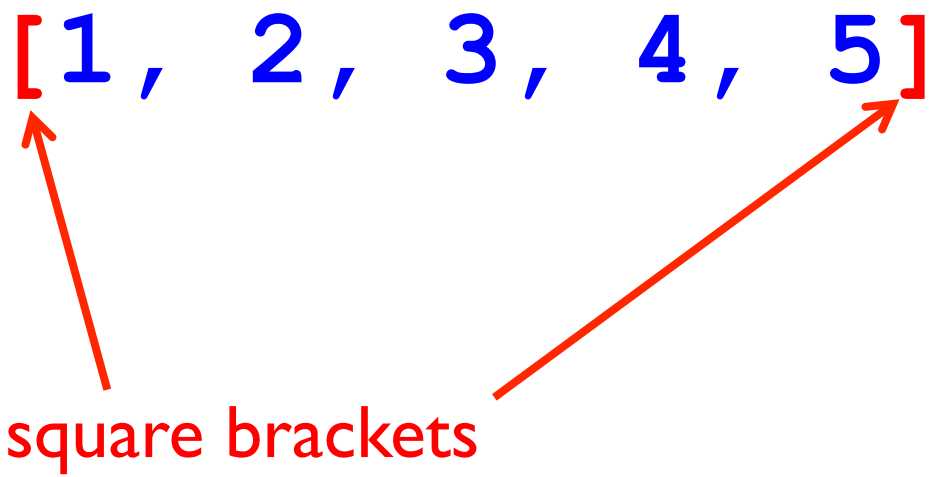
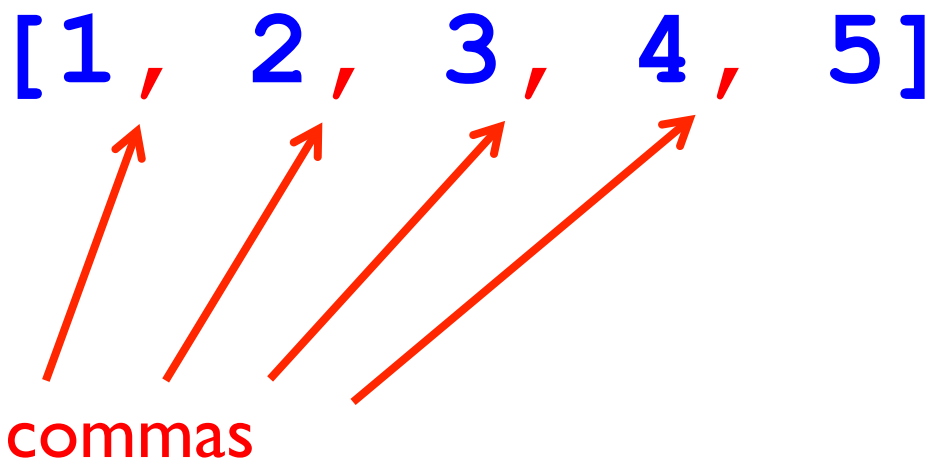


Creating lists

- Create lists by putting Python values or expressions inside square brackets, separated by commas:



Creating lists

- Any Python expression can be inside a list:

```
[1 + 3, 2 * 2, 4]
```

- The expressions get evaluated when the list as a whole gets evaluated
  - so this list becomes `[4, 4, 4]`

Creating lists

- Lists can contain expressions with variables:

```
>>> a = 10
>>> [a, 2*a, 3*a]
[10, 20, 30]
```

Creating lists

- Lists can contain expressions with function calls:

```
>>> a = 4
>>> [a, 2*a, 3 * math.sqrt(a)]
[4, 8, 6.0]
```

- (or any other Python expression)

Creating lists

- Lists can contain other lists:

```
>>> a = 4
>>> [[a, 2*a], [3*a, 4*a]]
[[4, 8], [12, 16]]
```

- This is called a *nested list*

Creating lists

- Lists can contain values of different types:

```
[1, 3.14, 'foobar', [0, 1]]
```

- But most of the time they have values of the same type:

```
[1, 2, 3, 4, 5]
[3.14, 2.718, 1.618]
['foo', 'bar', 'baz']
```

Accessing list elements

- Once a list is created, need to be able to get elements of list:

```
>>> temps = [59.6, 72.4, 68.5, 79.0,
             66.4, 77.1, -126.0]
>>> temps[0]
59.6
>>> temps[2]
68.5
```

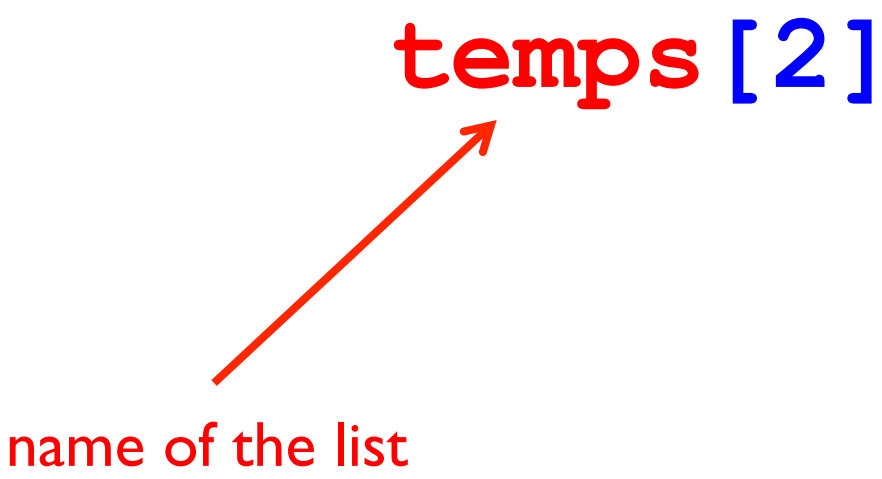
Accessing list elements

- Syntax:

```
temps[2]
```

Accessing list elements

- Syntax:



Accessing list elements

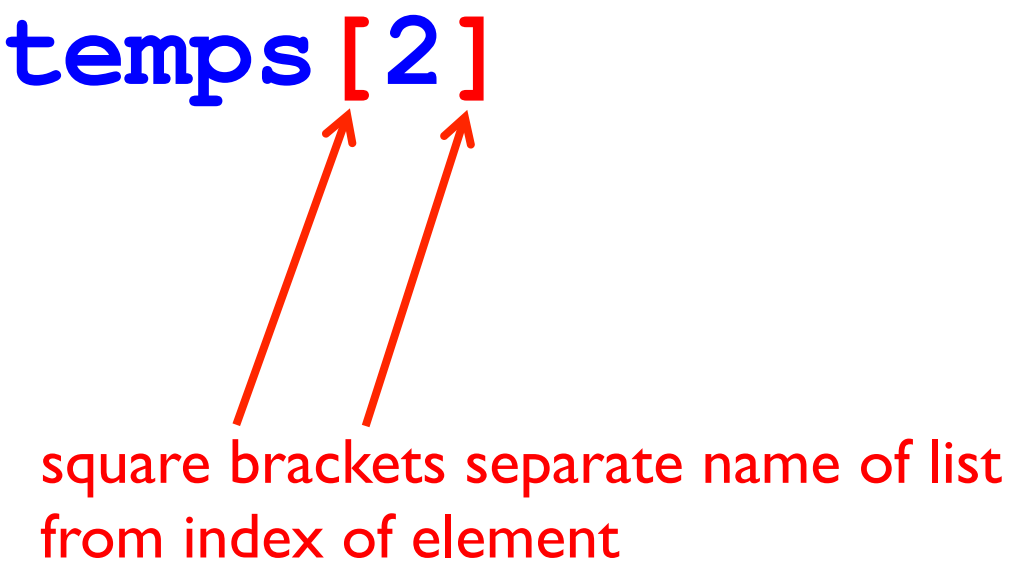
- Syntax:

```
temps[2]
```

location (index) of desired element

Accessing list elements

- Syntax:



Accessing list elements

- NOTE: square brackets are being used for two distinct things:
  1. *creating* lists: `[1, 2, 3, 4, 5]`
  2. *accessing elements* of lists: `temps[2]`
- These are *completely different!*
  - Recall: Python likes to 'overload' syntax to mean different (but sometimes related) things

Accessing list elements

- Can even have both meanings in one expression:

```
>>> [1, 2, 3, 4, 5][2]
3
```

- (almost never see this in practice)

Accessing list elements

- List indices start at `0`, not `1`

```
>>> nums = [12, 42, 31, 51, -32]
>>> nums[0]  # first element of nums
12
>>> nums[1]  # second element of nums
42
```

- This is common in computer languages
  - but easy to make mistakes if not careful

Accessing list elements

- Can also access from the end of a list!

```
>>> nums = [12, 42, 31, 51, -32]
>>> nums[-1]  # last element
-32
>>> nums[-2]  # second-last element
51
```

- (but can't "wrap around")

Accessing list elements

- Accessing off the ends of the list is an error:

```
>>> nums = [12, 42, 31, 51, -32]
>>> nums[5]    # last element: nums[4]
IndexError: list index out of range
>>> nums[-6]   # first element: nums[-5]
IndexError: list index out of range
```

Empty list

- The empty list is written `[]`

```
>>> empty = []
>>> empty[0]
IndexError: list index out of range
```

- We'll see uses for this later

Modifying lists

- Recall: Python strings are *immutable*
  - means: can't change them after making them
- Lists are *mutable*
  - means: *can* change them after making them

Modifying lists

- Example:

```
>>> nums = [4, 6, 19, 2, -3]
>>> nums
[4, 6, 19, 2, -3]
>>> nums[2] = 501
>>> nums
[4, 6, 501, 2, -3]
```

Modifying lists

- Syntax:

```
nums[2] = 501
```

Modifying lists

- Syntax:

```
nums[2] = 501
```

element being modified

Modifying lists

- Syntax:

```
nums[2] = 501
```

new value at that location in list

Modifying lists

- Evaluation rule:
  - evaluate right-hand side expression
  - assign to location in list on left-hand side

```
>>> nums[2] = 3 * nums[2]
```

- `nums[2]` is `501`, so `3 * nums[2]` is `1503`

```
>>> nums
[4, 6, 1503, 2, -3]
```

Modifying lists

- Can change an element to an element with a different type:

```
>>> nums
[4, 6, 1503, 2, -3]
>>> nums[2] = 'foobar'
[4, 6, 'foobar', 2, -3]
>>> nums[0] = [42, 'hello']
>>> nums
[[42, 'hello'], 6, 'foobar', 2, -3]
```

Very quick demo

- Making music with Python!

List operators

- Operators on lists behave much like operators on strings
- The + operator on lists means list concatenation
  - (like + with strings means string concatenation)

```
>>> [1, 2, 3] + [4, 5, 6]
[1, 2, 3, 4, 5, 6]
>>> [1, 2, 3] + []
[1, 2, 3]
```

List operators

- The * operator on lists means list replication
  - (like * with strings means string replication)

```
>>> [1, 2, 3] * 3
[1, 2, 3, 1, 2, 3, 1, 2, 3]
>>> 0 * [1, 2, 3]
[]
>>> [1, 2, 3] * -1
[]
```

List functions

- Some built-in functions work on lists
- The **`len`** function returns the length of a list:

```
>>> len([1, 2, 3, 4, 5])
5
```

- The **`list`** function converts other sequences to lists, if possible:

```
>>> list('foobar')
['f', 'o', 'o', 'b', 'a', 'r']
```

List methods

- *Lots* of useful methods on lists
- **`append`**

```
>>> lst = [1,2,3,4,5]
>>> lst.append(6)
>>> lst
[1,2,3,4,5,6]
```

- **`append`** adds a new element to the end of a list

List methods

- Note that **`append`** changes the list it acts on
- Can use this to build up lists, starting from empty list

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

List methods

- To find an element's index (location) in a list, use the **`index`** method:

```
>>> lst = [1, 2, 3]
>>> lst.index(2)
1
>>> lst.index(42)
ValueError: list.index(x): x not
  in list
```

List methods

- If an element has multiple copies in a list, **`index`** returns the index of first copy:

```
>>> lst = [1, 2, 3, 2, 4]
>>> lst.index(2)
1    # index of 1st 2 in list
```

List methods

- To remove an element from a list, use the **`remove`** method:

```
>>> lst = [1, 2, 3]
>>> lst.remove(2)
>>> lst
[1, 3]
```

- Only removes first occurrence of element in list
- Error if element not found in list

List methods

- To reverse a list, use the **`reverse`** method:

```
>>> lst = [1, 2, 3, 4, 5]
>>> lst.reverse()
>>> lst
[5, 4, 3, 2, 1]
```

- NOTE: the **`reverse`** method doesn't return the reversed list!
  - it reverses the list 'in-place' and doesn't return anything

Pitfall: Aliasing

- *Aliasing* is a subtle issue which can come up when assigning lists to variables

```
>>> nums
[4, 6, 1503, 2, -3]
>>> nums2 = nums    # copy of nums?
>>> nums2[0] = 0
>>> nums2
[0, 6, 1503, 2, -3]
>>> nums
[0, 6, 1503, 2, -3]    # !!!
```

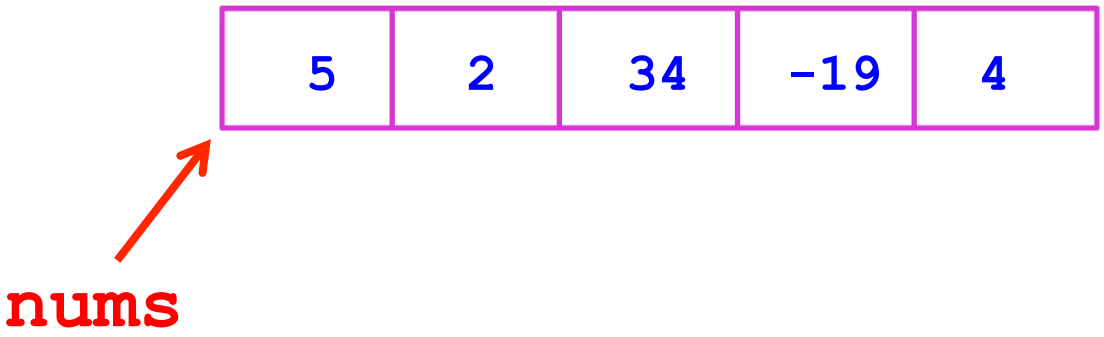
Aliasing

- The point: assigning a list to a variable *does not copy the list!*
- Python variables are not 'locations' or 'boxes' where stuff can be copied into
  - (unlike many other programming languages)
- Instead, after the assignment the variable name simply refers to the value on the right-hand side
  - we say that it's a *reference* to that value
  - so assigning doesn't copy anything (just get a new reference to the same value)

Aliasing

- Visually:

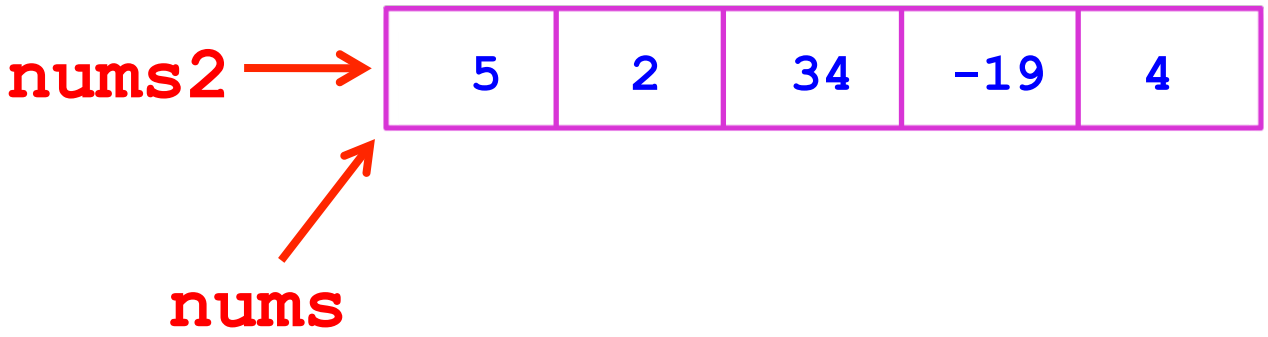
```
>>> nums = [5, 2, 34, -19, 4]
```



Aliasing

- Visually:

```
>>> nums2 = nums
```

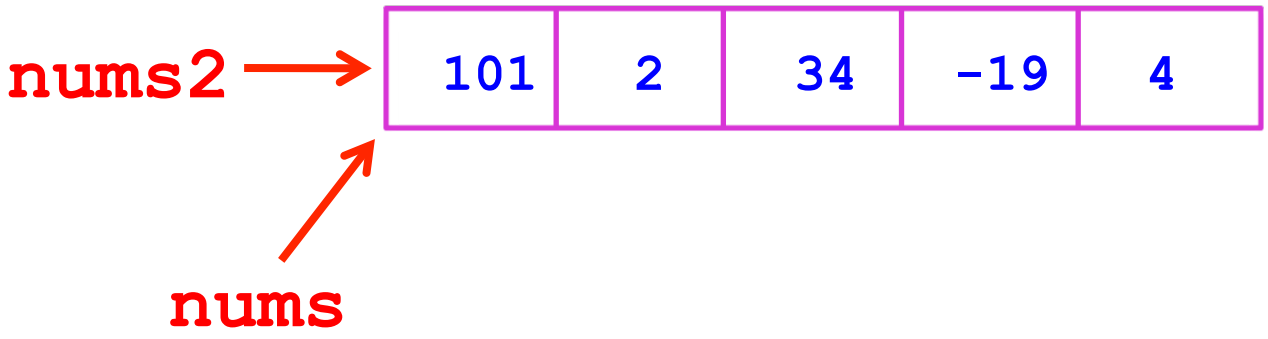


- **nums2** now refers to the same list as **nums**

Aliasing

- Visually:

```
>>> nums2[0] = 101
```



- **nums** and **nums2** are the *same* list!
- So when **nums2[0]** changes, so does **nums[0]**

Aliasing

- Aliasing does *not* happen with numbers or strings
  - only with container-like objects such as lists
- If we want to force Python to copy a list, we can do that too (see how later)

Next time

- Loops!
- Loops!
- Loops!
- Loops!
- Loops!