Basic Programming

Lesson 09-10

Functional Programming

Higher-order Functions in Python

A higher-order function is one that takes a function as a parameter or returns a function as a result, or both.

```python
def f(x):
    return x + 2

def g(h, x):
    return h(x) * 2

print(g(f, 42))
```

Composition

```python
def addx(x):
    def _(y):
        return x + y
    return _

add2 = addx(2)
add3 = addx(3)

print(add2(2), add3(3))
```

Closure

```python
def f(x, y):
    return x*y

def f2(x):
    def _(y):
        return f(x, y)
    return _

print(f2(2))
print(f2(2)(3))
```

Currying

One Function or Three?

```python
def get_ints(ints, odd=True, even=True):
    if odd and even:
        return [i for i in ints]
    elif odd:
        return [i for i in ints if i % 2]
    elif even:
        return [i for i in ints if not i % 2]
    else:
        return []
```

Do it all function

```python
def get_even_ints(ints):
    return [i for i in ints if not i % 2]

def get_odd_ints(ints):
    return [i for i in ints if i % 2]

def get_all_ints(ints):
    return list(ints)
```

Split them!

```python
def g(h, x):
    return h(x) * 2

print(g(lambda x: x + 2, 42))
```

Lambdas in Python

Import the dis module

Define a simple test function

Disassemble it

Trouble in Mutable Town

```python
pi = 3.14159

def change_pi(pi):
    pi = 2.71828

print(pi)
change_pi(pi)
print(pi)
```

Try to change pi

```python
pi = 3.14159

def change_pi(*args, **kwargs):
    global pi
    pi = 2.71828

print(pi)
change_pi(pi)
print(pi)
```

Really change pi!

Conditional expressions

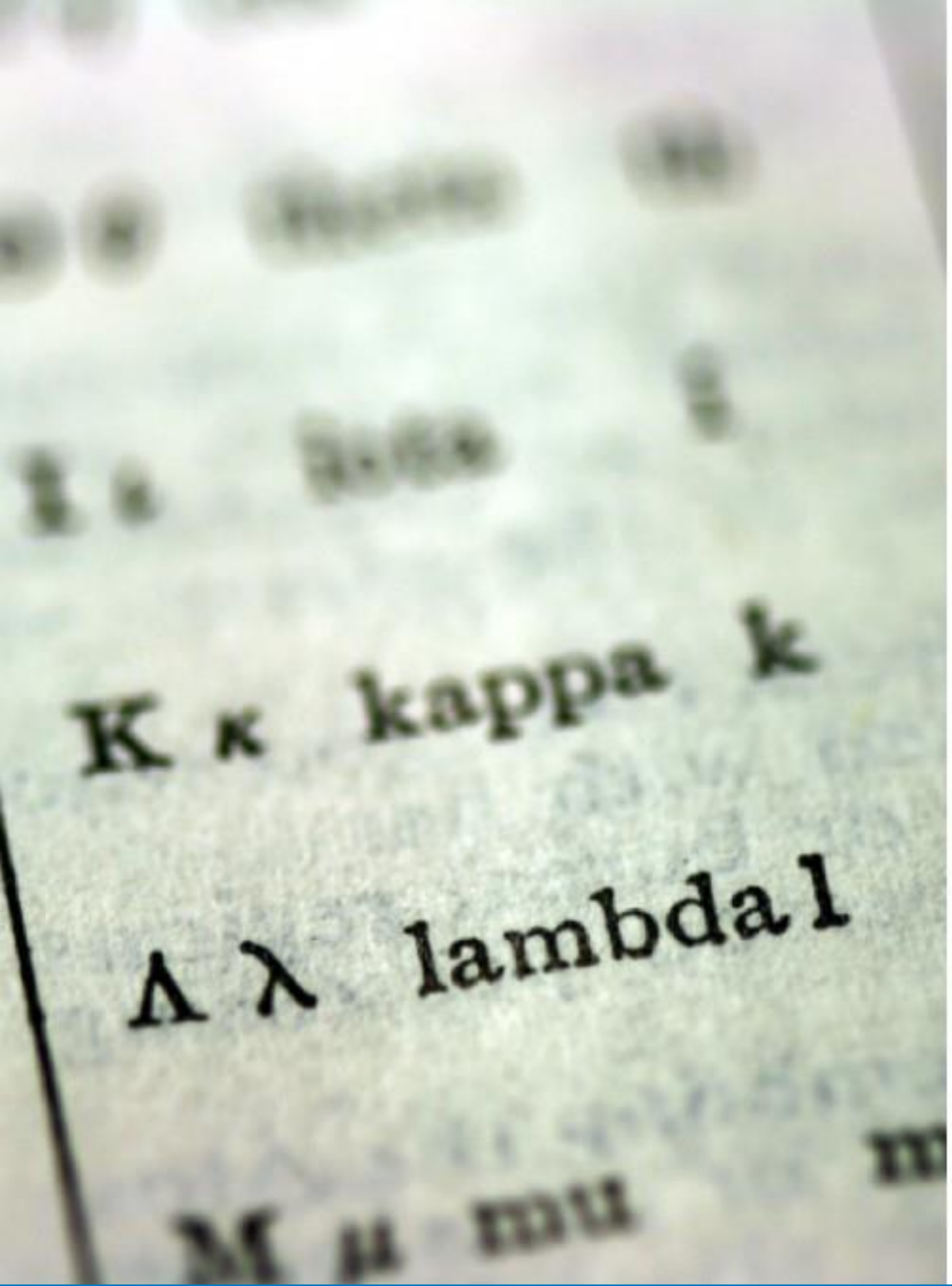
Evaluates to one of two expressions depending on a boolean.

```
result = true_value if condition else false_value
```

Conditional Expressions

```
>>> def sequence_class(immutable):
...     return tuple if immutable else list
...
>>> seq = sequence_class(immutable=False)
>>> s = seq("Nairobi")
>>> s
['N', 'a', 'i', 'r', 'o', 'b', 'i']
>>> type(s)
<class 'list'>
>>>
```

Lambdas

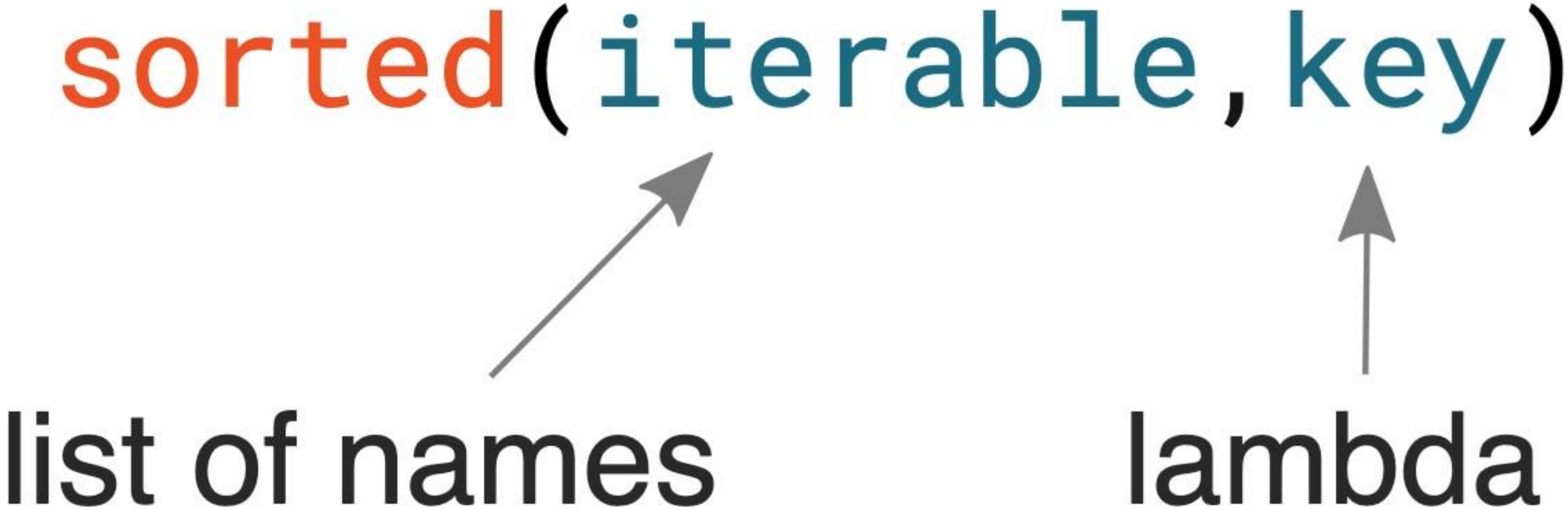


In many cases anonymous callable objects will suffice.

`lambda` allows you to create such anonymous callable objects.

Use `lambda` with care to avoid creating inscrutable code.

Effective Use of Lambdas



Sorting with a Lambda

```
>>> scientists = ['Marie Curie', 'Albert Einstein', 'Rosalind Franklin',
...               'Niels Bohr', 'Dian Fossey', 'Isaac Newton',
...               'Grace Hopper', 'Charles Darwin', 'Lise Meitner']
>>>
>>> sorted(scientists, key=lambda name: name.split()[-1])
['Niels Bohr', 'Marie Curie', 'Charles Darwin', 'Albert Einstein', 'Dian Fossey'
, 'Rosalind Franklin', 'Grace Hopper', 'Lise Meitner', 'Isaac Newton']
>>> last_name = lambda name: name.split()[-1]
>>> last_name
<function <lambda> at 0x10e630f70>
>>> last_name("Nikola Tesla")
'Tesla'
>>> def first_name(name):
...     return name.split()[0]
...
>>>
```

Functions vs. Lambdas

`def name(args): body`	`lambda args: expr`
Statement which defines a function and binds it to a name	Expression which evaluates to a function
Must have a name	Anonymous
Arguments delimited by parentheses, separated by commas	Argument list terminated by a colon, separated by commas
Zero or more arguments supported - zero arguments ⇒ empty parentheses	Zero or more arguments supported - zero arguments ⇒ `lambda:`
Body is an indented block of statements	Body is a single expression
A `return` statement is required to return anything other than `None`	The return value is given by the body expression; no `return` statement is permitted
Regular functions can have docstrings	Lambdas cannot have docstrings
Easy to access for testing	Awkward or impossible to test

Extended Argument Syntax

Extended Argument Syntax

```
>>> print()

>>> print("one")
one
>>> print("one", "two")
one two
>>> print("one", "two", "three")
one two three
>>> "{a}<===>{b}".format(a="Oslo", b="Stavanger")
'Oslo<===>Stavanger'
>>>
```

Hypervolume

```
>>> hypervolume(3, 4, 5)
(3, 4, 5)
<class 'tuple'>
>>> def hypervolume(*lengths):
...     i = iter(lengths)
...     v = next(i)
...     for length in i:
...         v *= length
...     return v
...
>>> hypervolume(2, 4)
8
>>> hypervolume(2, 4, 6)
48
>>> hypervolume(2, 4, 6, 8)
384
>>> hypervolume(1)
1
>>> hypervolume()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 3, in hypervolume
StopIteration
>>>
```

Extended Call Syntax

Extended Call Syntax

```
>>> def print_args(arg1, arg2, *args):
...     print(arg1)
...     print(arg2)
...     print(args)
...
>>> t = (11, 12, 13, 14)
>>> print_args(*t)
11
12
(13, 14)
>>>
```

Extended Call Syntax for Mappings

```
>>> def color(red, green, blue, **kwargs):
...     print("r =", red)
...     print("g =", green)
...     print("b =", blue)
...     print(kwargs)
...
>>> k = {'red':21, 'green':68, 'blue':120, 'alpha':52 }
>>> color(**k)
r = 21
g = 68
b = 120
{'alpha': 52}
>>> k = dict(red=21, green=68, blue=120, alpha=52)
>>>
```

Argument Forwarding

```
>>> def trace(f, *args, **kwargs):
...     print("args =", args)
...     print("kwargs =", kwargs)
...     result = f(*args, **kwargs)
...     print("result =", result)
...     return result
...
>>> trace(int, "ff", base=16)
args = ('ff',)
kwargs = {'base': 16}
result = 255
255
>>>
```

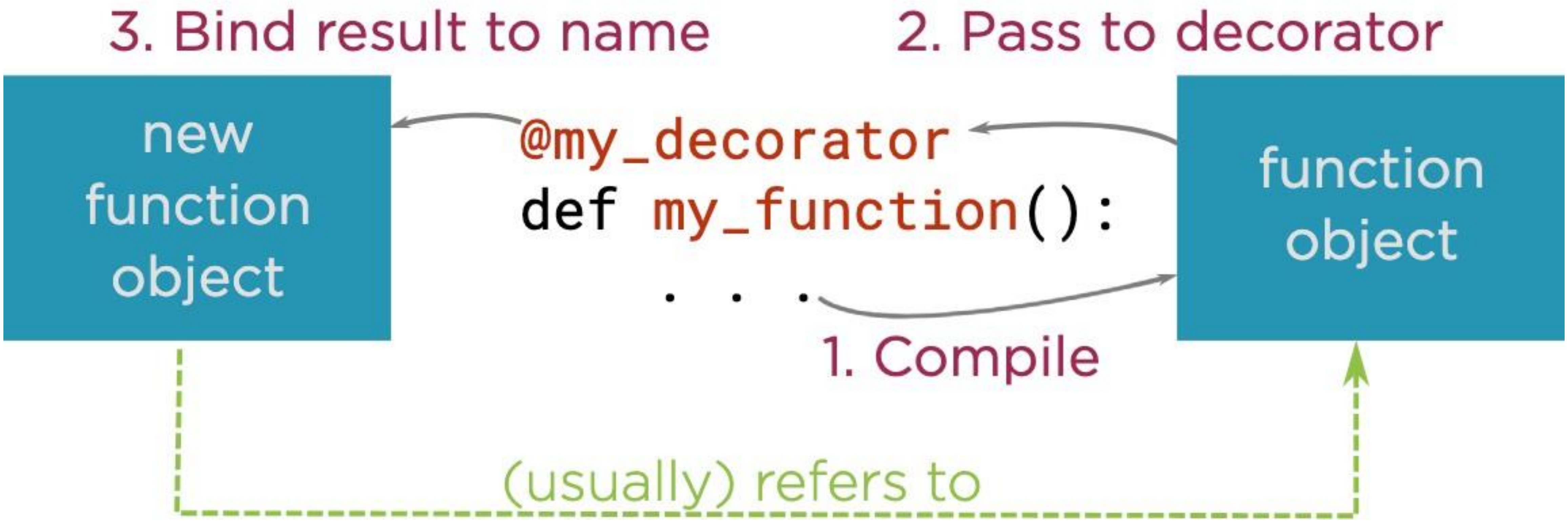
Function Decorators

Decorator Syntax

Applies decorator

```
@my_decorator
def my_function():
    . . .
```

Decorator Application



Decorators allow you to modify existing functions without changing their definition.
Callers don't need to change when decorators are applied.

Decorator Example

```
>>> def escape_unicode(f):
...     def wrap(*args, **kwargs):
...         x = f(*args, **kwargs)
...         return ascii(x)
...     return wrap
...
>>> def northern_city():
...     return 'Tromsø'
...
>>> print(northern_city())
Tromsø
>>> @escape_unicode
... def northern_city():
...     return 'Tromsø'
...
>>> print(northern_city())
'Troms\xf8'
>>>
```

Classes as Decorators

Classes as Decorators

1. Classes are callable objects
2. Functions decorated with a class are replaced by an instance of the class
3. These instances must themselves be callable

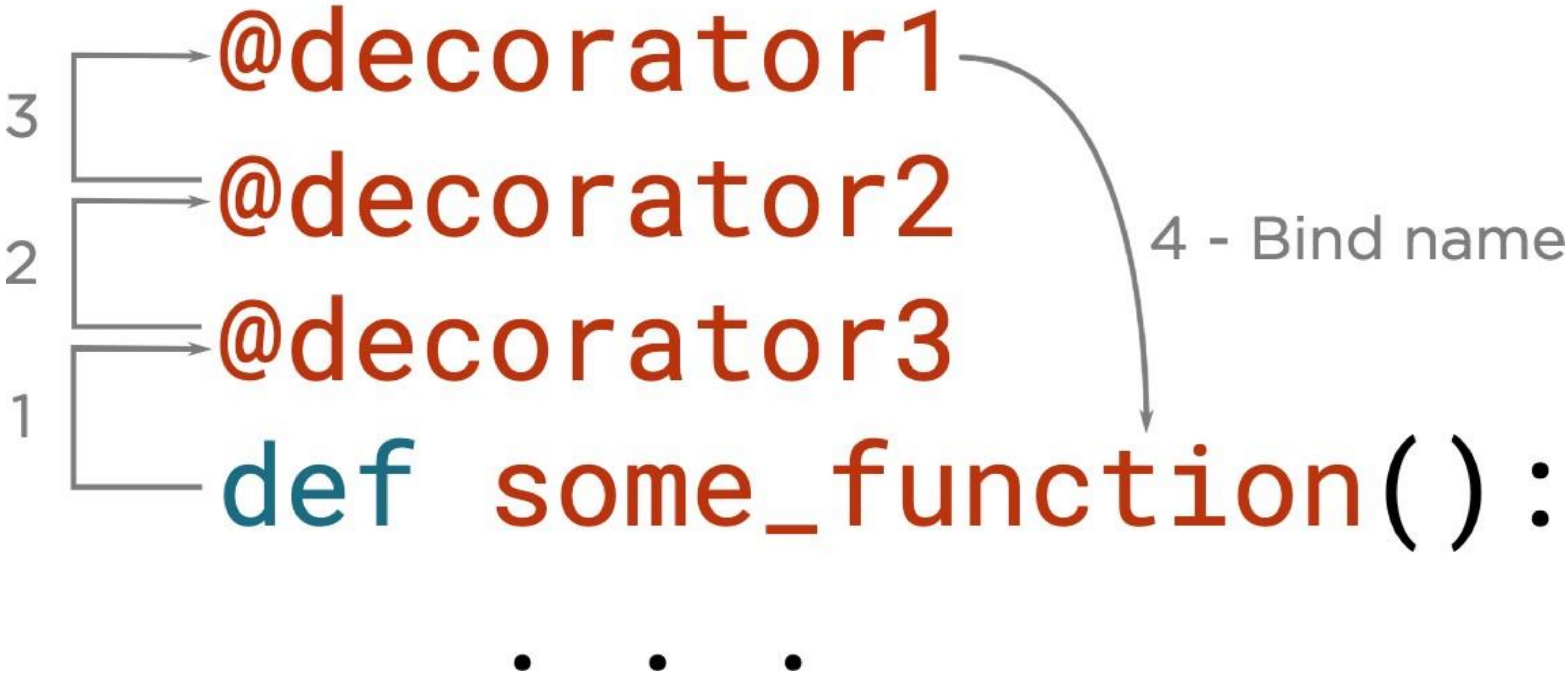
We can decorate with a class as long as instances of the class implement `__call__()`.

Classes as Decorators

```
>>> class CallCount:
...     def __init__(self, f):
...         self.f = f
...         self.count = 0
...     def __call__(self, *args, **kwargs):
...         self.count += 1
...         return self.f(*args, **kwargs)
...
>>> @CallCount
... def hello(name):
...     print('Hello, {}!'.format(name))
...
>>> hello('Fred')
Hello, Fred!
>>> hello('Wilma')
Hello, Wilma!
>>> hello('Betty')
Hello, Betty!
>>> hello('Barney')
Hello, Barney!
>>> hello.count
4
>>>
```

Multiple Decorators

Multiple Decorators



Decorating Methods

Decorating Methods

```
>>> class IslandMaker:
...     def __init__(self, suffix):
...         self.suffix = suffix
...     @tracer
...     def make_island(self, name):
...         return name + self.suffix
...
>>> im = IslandMaker(' Island')
>>> im.make_island('Python')
Calling <function IslandMaker.make_island at 0x10b4bc1f0>
'Python Island'
>>> im.make_island('Llama')
Calling <function IslandMaker.make_island at 0x10b4bc1f0>
'Llama Island'
>>>
```

map()

map( )

Calls a function for the elements in a sequence, producing a new sequence with the return values

It "maps" a function over a sequence

map()

```
map(ord, 'The quick brown fox')
```

T	h	e		q	u	i	c	k		b	r	o	w	n		f	o	x
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()	ord()
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
84	104	101	32	113	117	105	99	107	32	98	114	111	119	110	32	102	111	120

map()

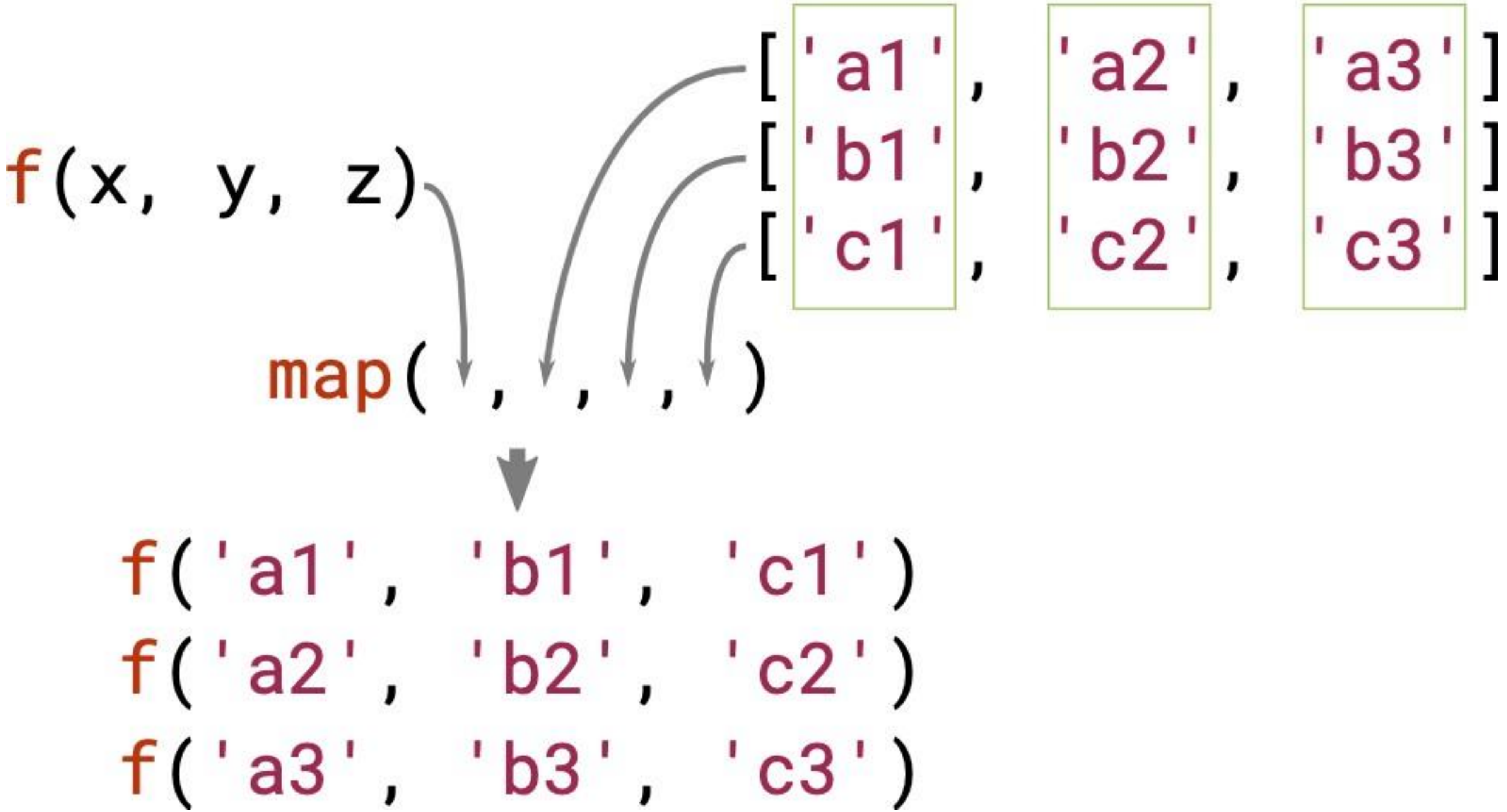
```
>>> map(ord, 'The quick brown fox')
<map object at 0x102ed20d0>
>>>
```

Map() Is Lazy

`map()` will not call its function or access its iterables until they're needed for output

A map object is itself iterable; iterate over it to produce output map( ) can be used with as many input sequences as your mapped function needs.

map( ) with Multiple Iterables



map( ) with Multiple Iterables

```
>>> sizes = ['small', 'medium', 'large']
>>> colors = ['lavender', 'teal', 'burnt orange']
>>> animals = ['koala', 'platypus', 'salamander']
>>> def combine(size, color, animal):
...     return '{} {} {}'.format(size, color, animal)
...
>>> list(map(combine, sizes, colors, animals))
['small lavender koala', 'medium teal platypus', 'large burnt orange salamander'
]
>>> def combine(quantity, size, color, animal):
...     return '{} x {} {} {}'.format(quantity, size, color, animal)
...
>>> import itertools
>>> list(map(combine, itertools.count(), sizes, colors, animals))
['0 x small lavender koala', '1 x medium teal platypus', '2 x large burnt orange
 salamander']
>>>
```

filter()

filter()

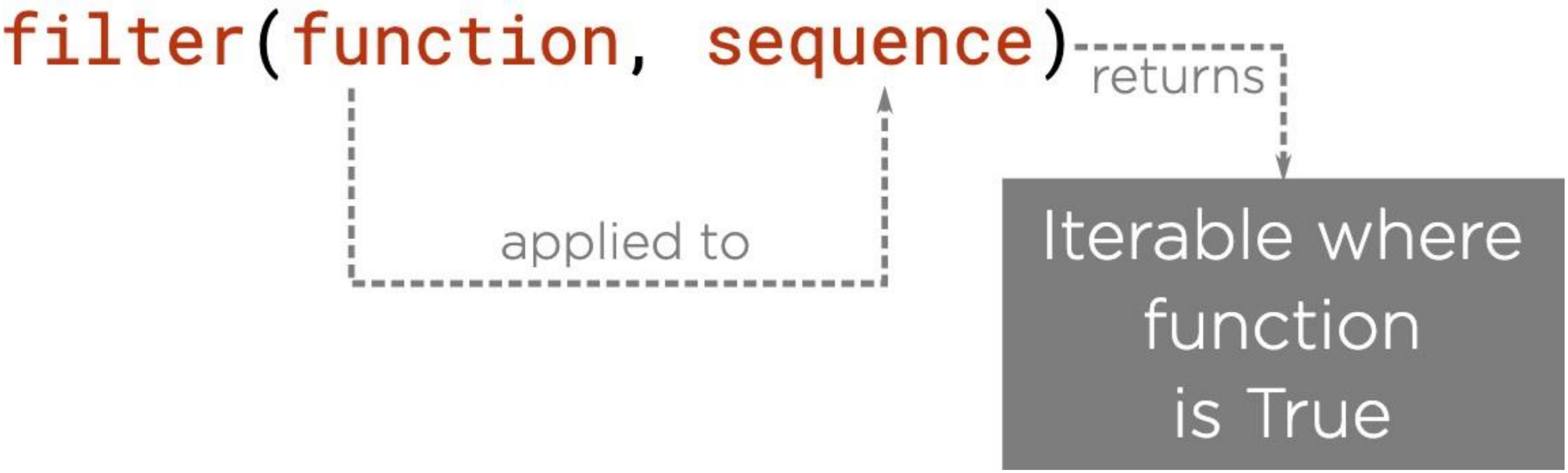
Removes elements from a sequence which don't meet some criteria

Applies a predicate function to each element

Produces its results lazily

Only accepts a single input sequence, and the function must accept only one argument

filter()


filter(function, sequence)
returns
applied to
Iterable where function is True

filter()

```
>>> positives = filter(lambda x: x > 0, [1, -5, 0, 6, -2, 8])
>>> positives
<filter object at 0x10fe9d490>
>>> list(positives)
[1, 6, 8]
>>>
```

Passing `None` as the first argument to `filter()` will filter out input elements which evaluate to `False`.

Filtering with None

```
>>> trues = filter(None, [0, 1, False, True, [], [1, 2, 3], '', 'hello'])
>>> list(trues)
[1, True, [1, 2, 3], 'hello']
>>>
```

chain()

```python
from itertools import chain
l1 = [1, 2, 3]
l2 = [4, 5, 6]
l3 = [7, 8, 9]
for i in chain(l1, l2, l3):
    print(i) # 1,2,3,4,5,6,7,8,9
```

zip()

```python
lst1 = [1, 2, 3]
lst2 = [4, 5, 6]
lst3 = [7, 8, 9]
for i in zip(lst1, lst2, lst3):
    print(i)
```

```
Output:
(1, 4, 7)
(2, 5, 8)
(3, 6, 9)
```

reduce()

```python
from functools import reduce
numbers = [1, 2, 3, 4, 5, 6, 7, 8, 9]
res = reduce(lambda x, y: x + y, numbers)
print(res)
```

```
Output:
45
```

Multi-input Comprehensions

Comprehensions

```
>>> l = [i * 2 for i in range(10)]
>>> d = {i: i * 2 for i in range(10)}
>>> type(d)
<class 'dict'>
>>> s = {i for i in range(10)}
>>> type(s)
<class 'set'>
>>> g = (i for i in range(10))
>>> type(g)
<class 'generator'>
>>>
```

Comprehensions can have multiple input iterables and if-clauses.

Multi-input Comprehensions

```
>>> [(x, y) for x in range(5) for y in range(5)]
[(0, 0), (0, 1), (0, 2), (0, 3), (0, 4), (1, 0), (1, 1), (1, 2), (1, 3), (1, 4),
 (2, 0), (2, 1), (2, 2), (2, 3), (2, 4), (3, 0), (3, 1), (3, 2), (3, 3), (3, 4),
 (4, 0), (4, 1), (4, 2), (4, 3), (4, 4)]
>>> points = []
>>> for x in range(5):
...     for y in range(5):
...         points.append((x, y))
...
>>>
```

Multiple if-clauses

```
>>> values = [x / (x - y)
...           for x in range(100)
...           if x > 50
...           for y in range(100)
...           if x - y != 0]
>>> values = []
>>> for x in range(100):
...     if x > 50:
...         for y in range(100):
...             if x - y != 0:
...                 values.append(x / (x - y))
...
>>> [(x, y) for x in range(10) for y in range(x)]
[(1, 0), (2, 0), (2, 1), (3, 0), (3, 1), (3, 2), (4, 0), (4, 1), (4, 2), (4, 3),
 (5, 0), (5, 1), (5, 2), (5, 3), (5, 4), (6, 0), (6, 1), (6, 2), (6, 3), (6, 4),
 (6, 5), (7, 0), (7, 1), (7, 2), (7, 3), (7, 4), (7, 5), (7, 6), (8, 0), (8, 1),
 (8, 2), (8, 3), (8, 4), (8, 5), (8, 6), (8, 7), (9, 0), (9, 1), (9, 2), (9, 3),
 (9, 4), (9, 5), (9, 6), (9, 7), (9, 8)]
>>> result = []
>>> for x in range(10):
...     for y in range(x):
...         result.append((x, y))
...
>>>
```

Nested Comprehensions

Nested Comprehensions

```
>>> vals = [[y * 3 for y in range(x)] for x in range(10)]
>>> outer = []
>>> for x in range(10):
...     inner = []
...     for y in range(x):
...         inner.append(y * 3)
...     outer.append(inner)
...
>>> vals
[[], [0], [0, 3], [0, 3, 6], [0, 3, 6, 9], [0, 3, 6, 9, 12], [0, 3, 6, 9, 12, 15
], [0, 3, 6, 9, 12, 15, 18], [0, 3, 6, 9, 12, 15, 18, 21], [0, 3, 6, 9, 12, 15,
18, 21, 24]]
>>>
```