# [301] Advanced Functions

Tyler Caraza-Harter

1. Functions as Objects
2. Iterators/Generators

# Radical Claim:

# Functions are Objects

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# Functions are Objects

**implications:**

- variables can reference functions
- lists/dicts can reference functions
- we can pass function references to other functions
- we can pass lists of function references to other functions
- ...

# Function References (Part 1)

Outline

- functions as objects
- sort

```
x = [1,2,3]
y = x

def f():
    return "hi"

g = f

z = f()
```

your notes should probably include this example, with an explanation of what each of the 5 steps do!

*which line of code is most novel for us?*

```
x = [1,2,3]
y = x

def f():
    return "hi"

g = f

z = f()
```

**State:**

*references*

*objects*

```
x = [1,2,3]
y = x

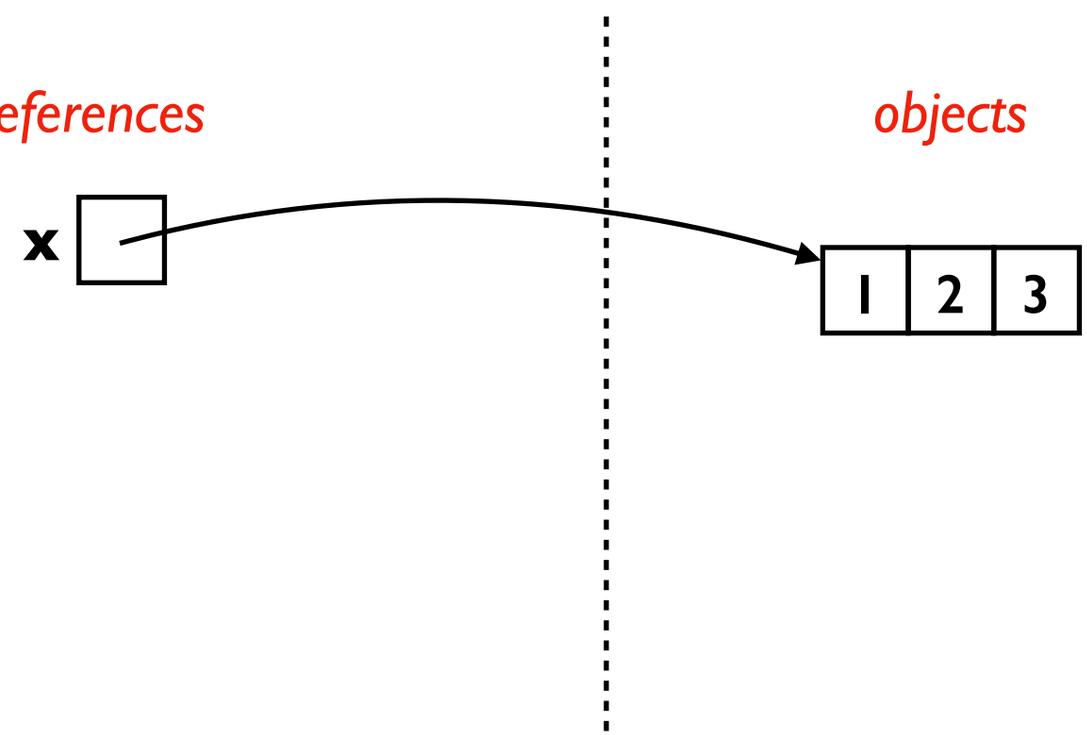
def f():
    return "hi"

g = f

z = f()
```

**Explanation:** x should reference a new list object

**State:**



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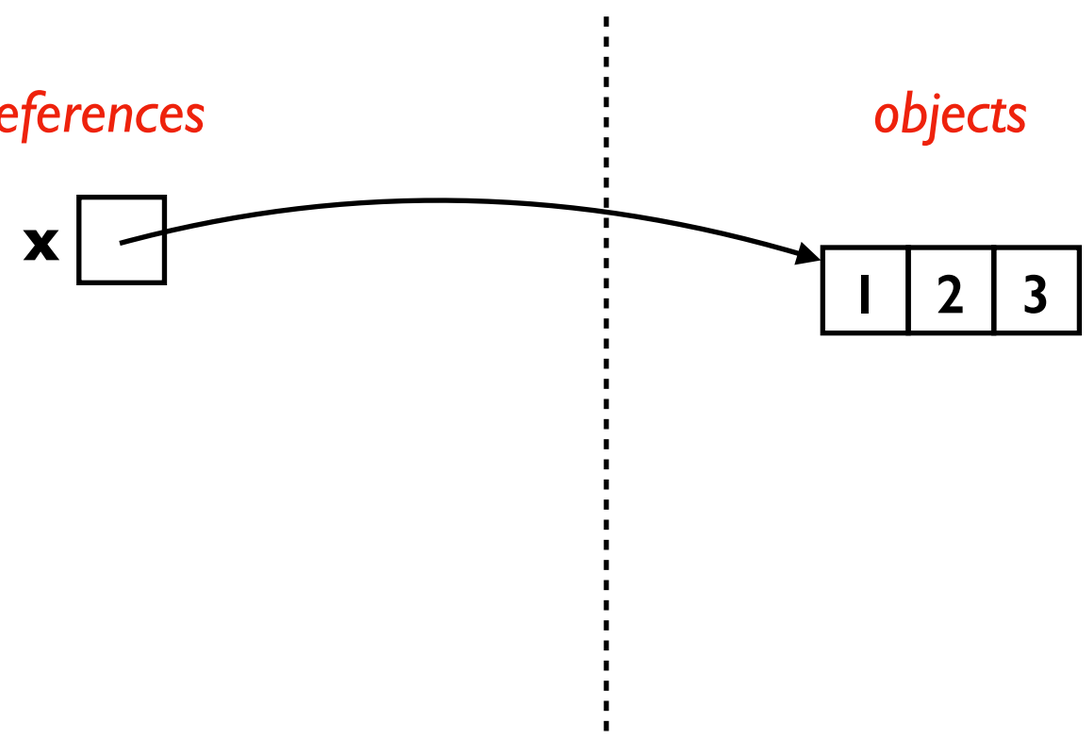

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x = [1,2,3]
y = x

def f():
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g = f

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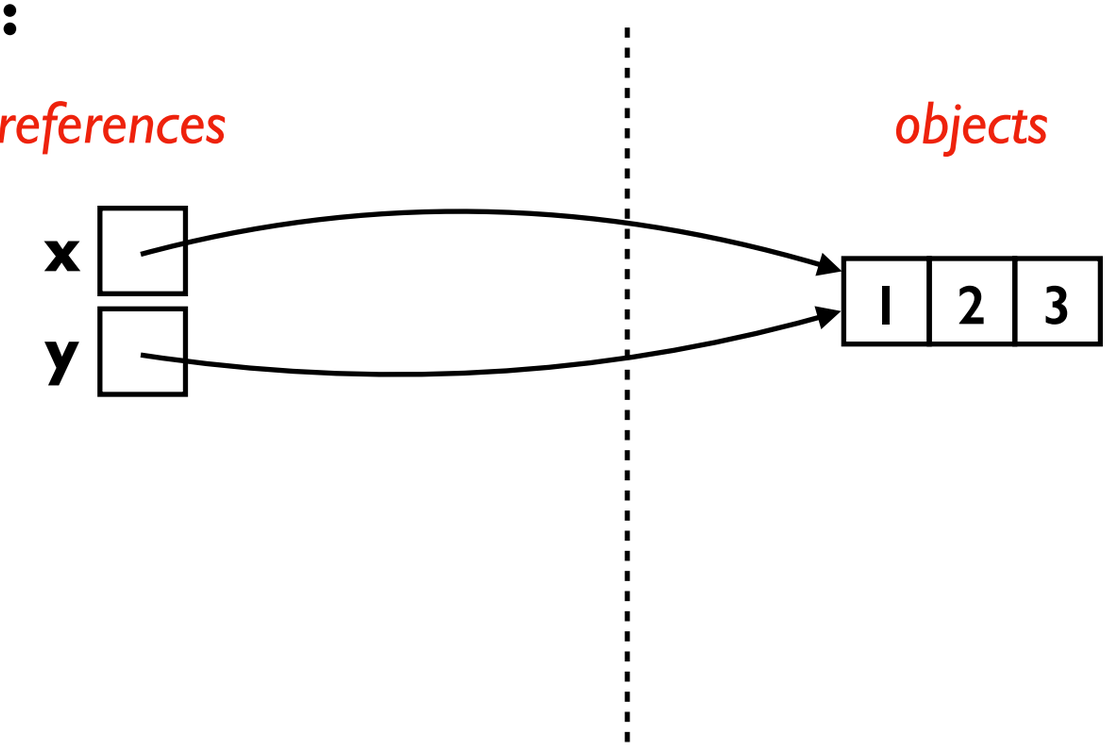
```

**Explanation:** x should reference a new list object

**Explanation:** y should reference whatever x references

**State:**



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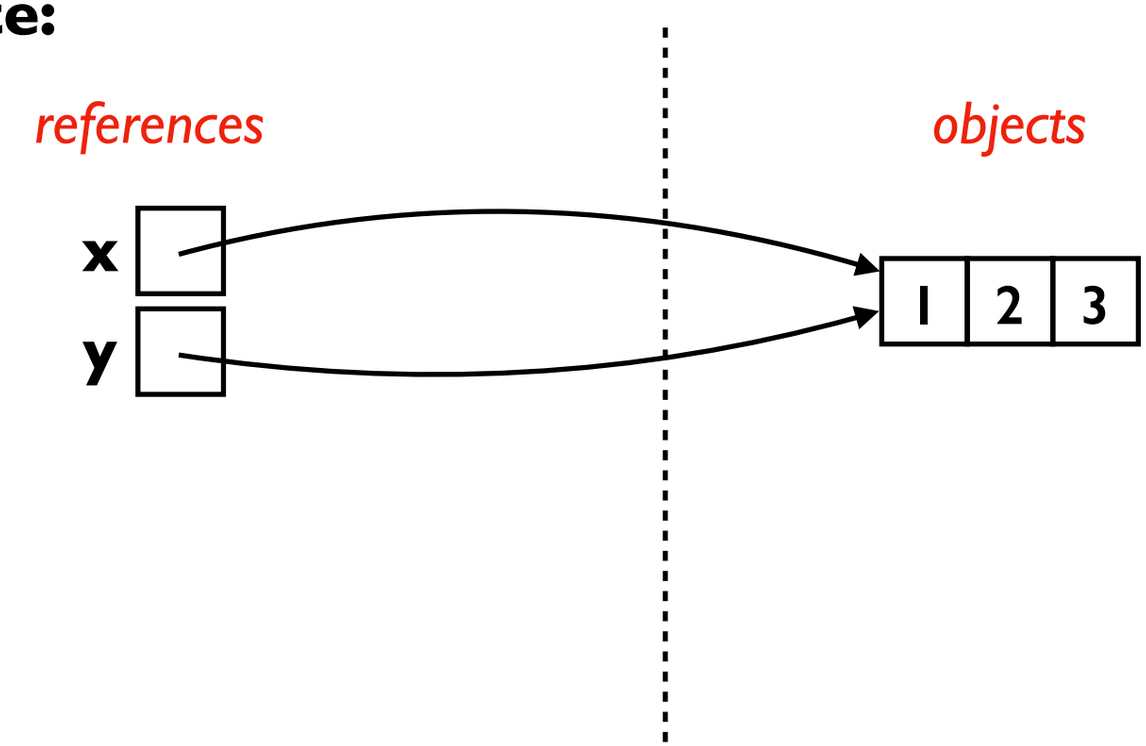

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y = x

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**Explanation:** f should reference a new function object

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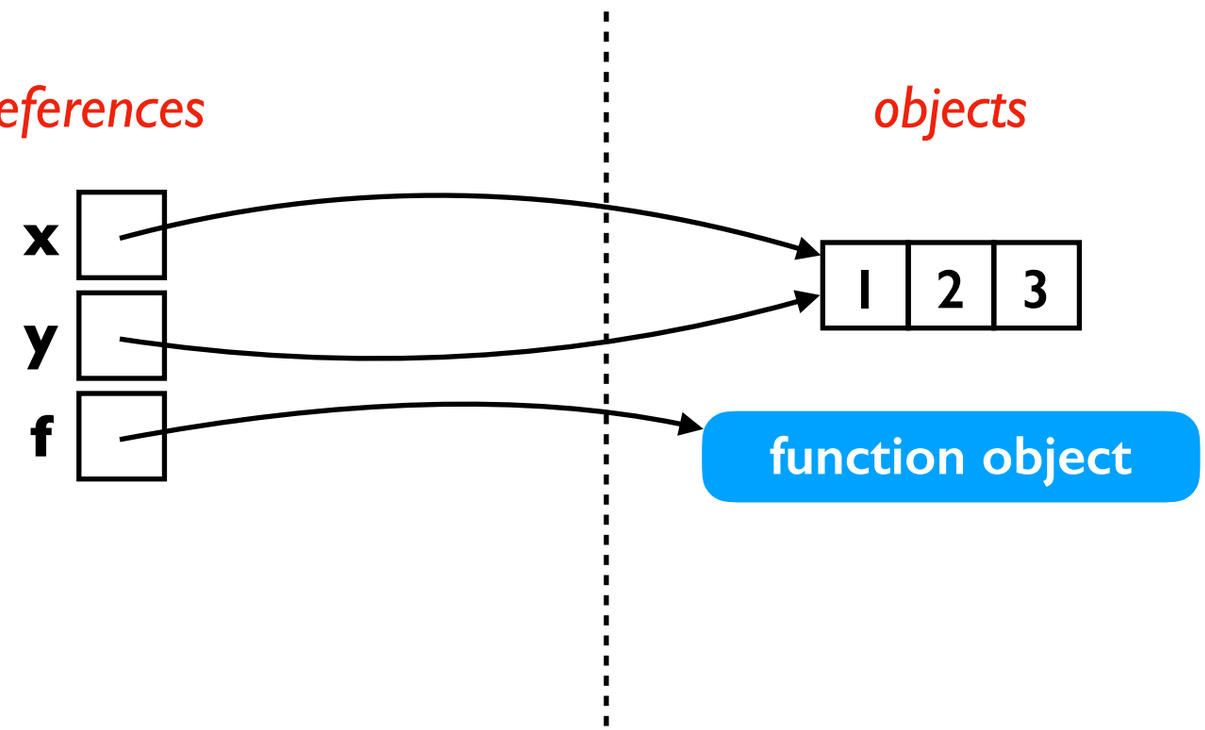

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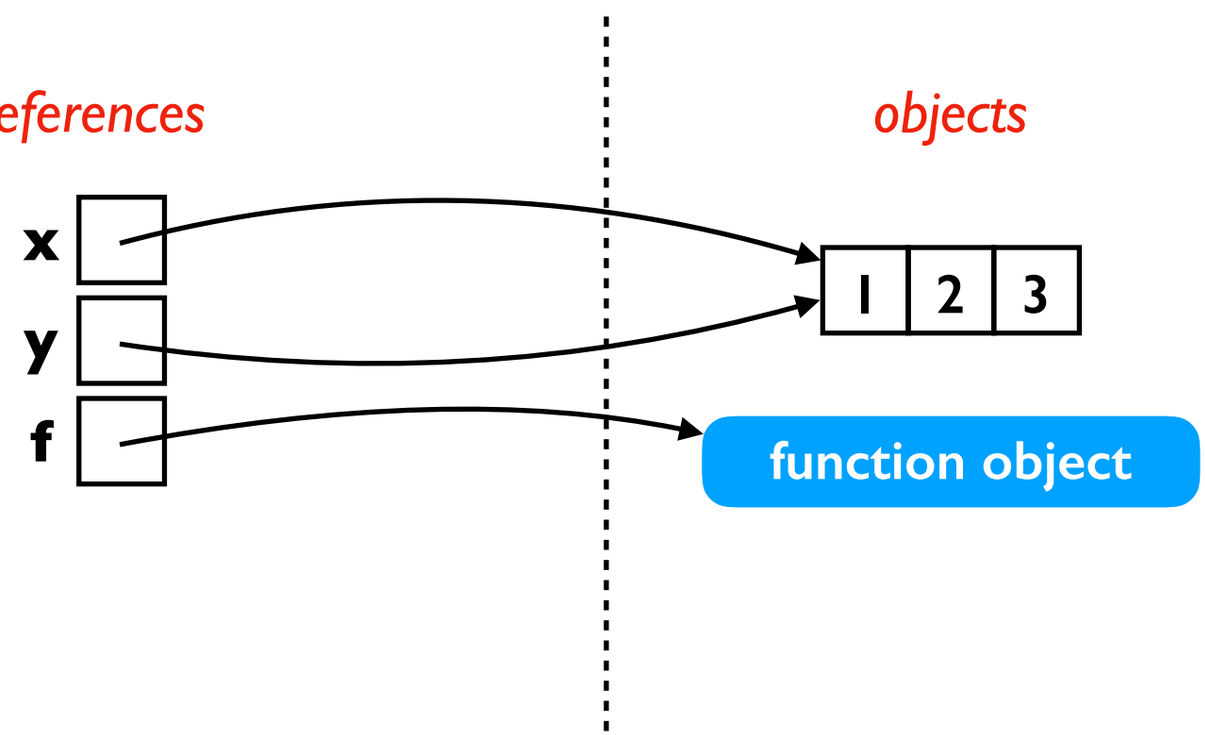

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**Explanation:** f should reference a new function object

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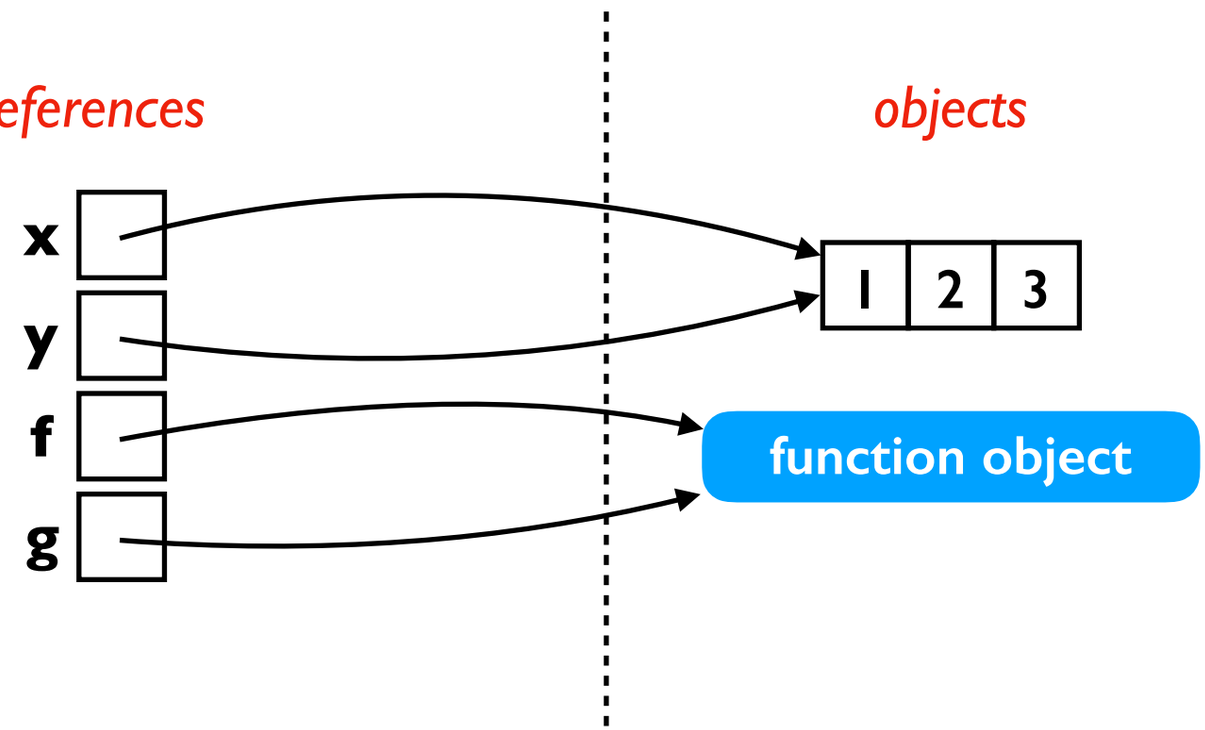

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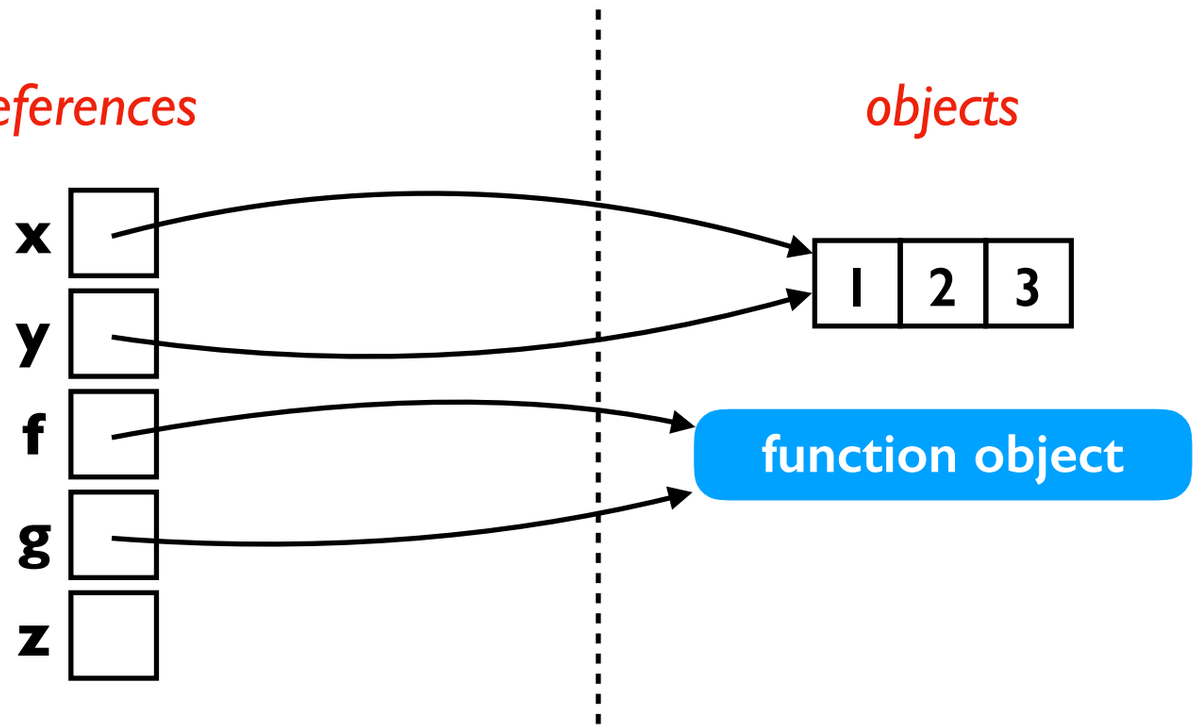

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def f():
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g = f

z = f()
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**Explanation:** x should reference a new list object

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**Explanation:** f should reference a new function object

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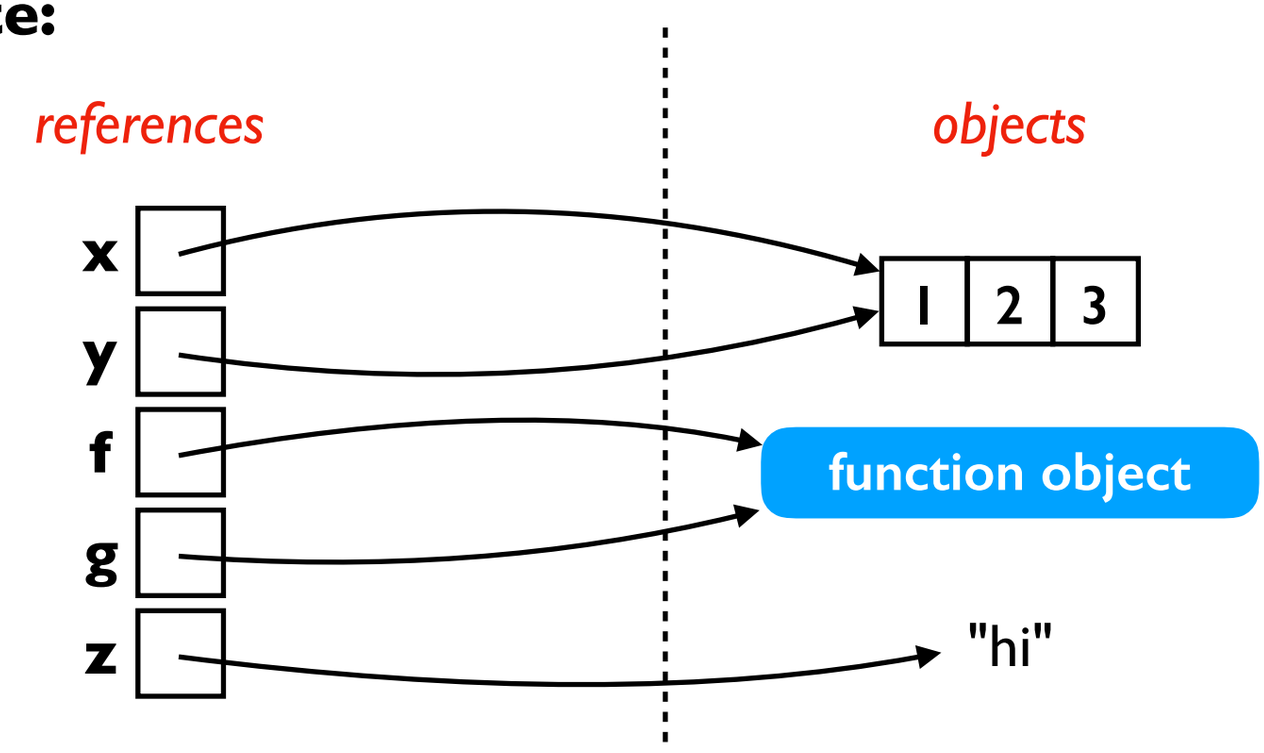


```
x = [1,2,3]
y = x

def f():
    return "hi"

g = f

z = f()
```

**Explanation:** x should reference a new list object

**Explanation:** y should reference whatever x references

**Explanation:** f should reference a new function object

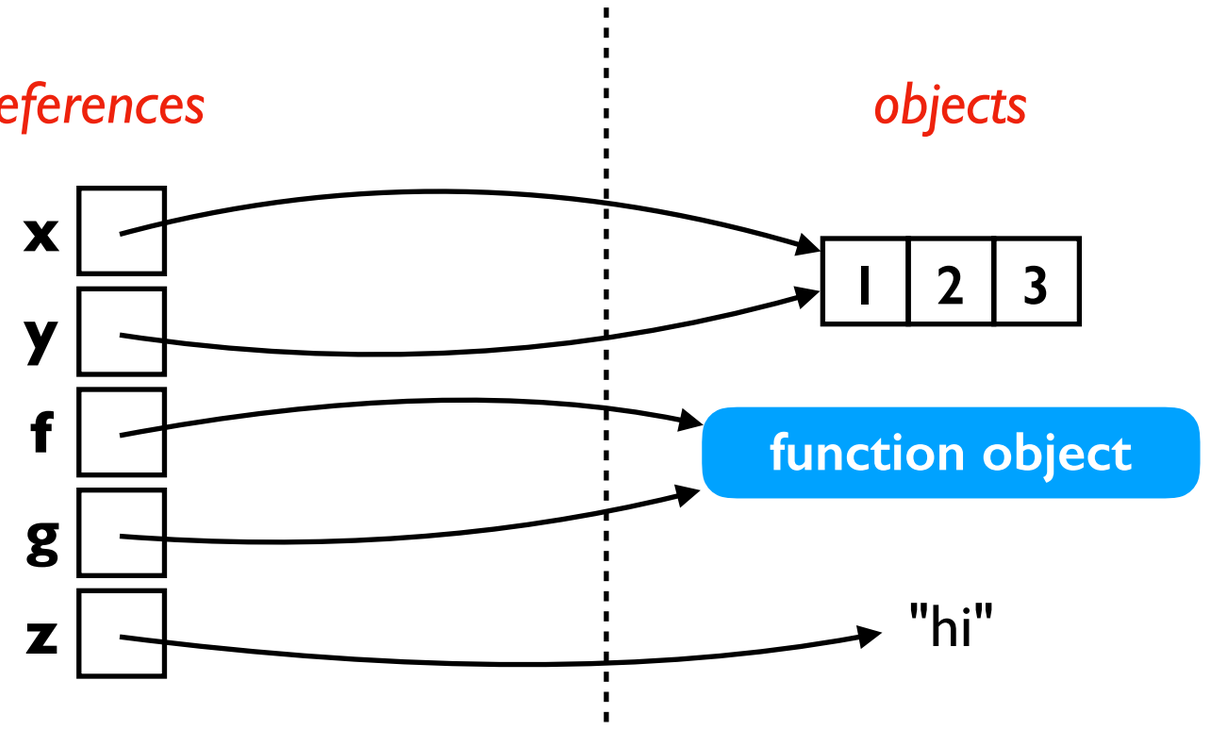
**Explanation:** g should reference whatever f references

**Explanation:** z should reference whatever f returns

both of these calls would have run the same code, returning the same result:

- `z = f()`
- `z = g()`

**State:**



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def f():
    return "hi"

g = f

z = f()
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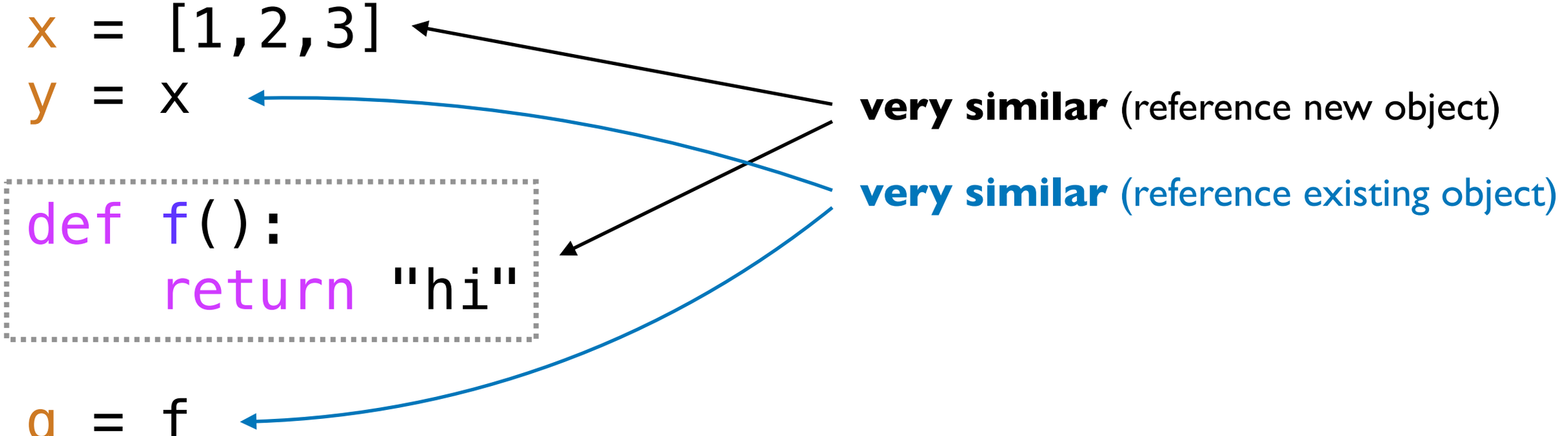

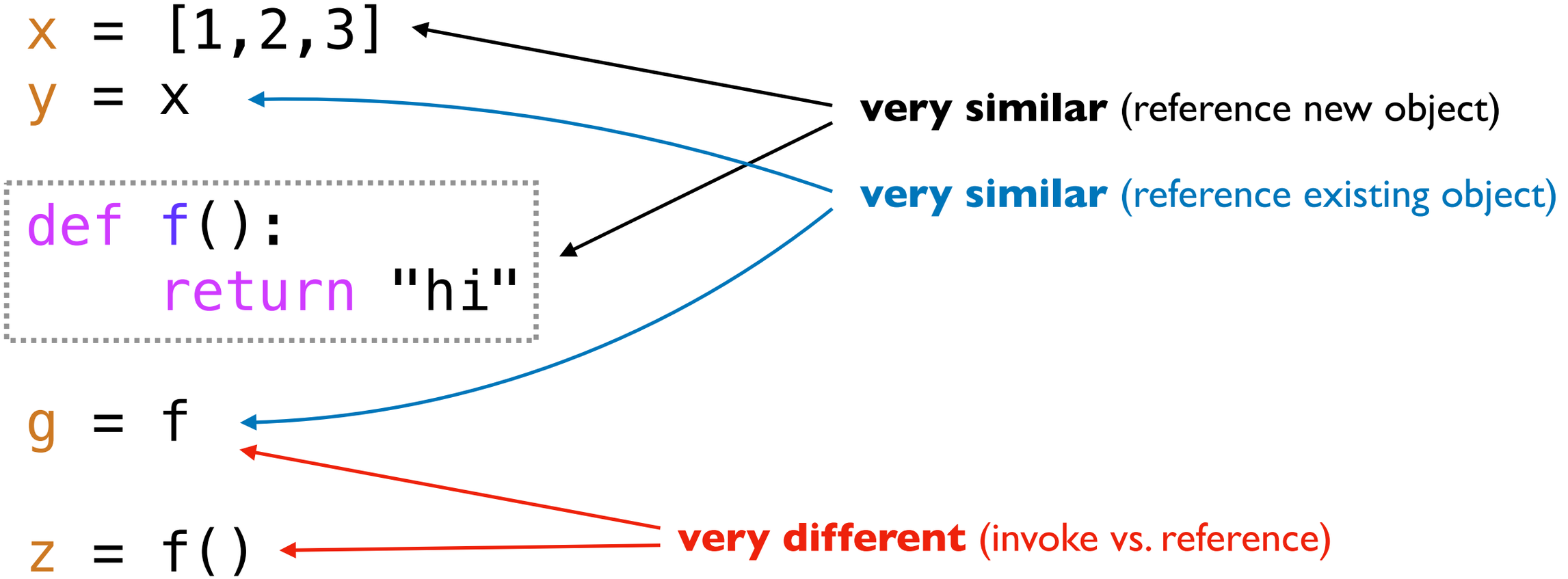
x = [1,2,3]
y = x
def f():
return "hi"
g = f
z = f()
very similar (reference new object)
very similar (reference existing object)
very different (invoke vs. reference)

# CODING DEMOS

# [Python Tutor]

# Function References (Part 1)

Outline

- functions as objects
- sort

# Example: Sorting Names

List of tuples:

```
names = [
     (“Catherine”, “Baker”),
     (“Alice”, “Clark”),
     (“Bob”, “Adams”),
]
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

# Example: Sorting Names

List of tuples:

```
names = [
      (“Catherine”, “Baker”),
      (“Alice”, “Clark”),
      (“Bob”, “Adams”),
]
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
names.sort()
```

**sorting tuples is done on first element**
(ties go to 2nd element)

| Alice | Clark |
|---|---|
| Bob | Adams |
| Catherine | Baker |

# Example: Sorting Names

List of tuples:

```
names = [
     (“Catherine”, “Baker”),
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]
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
names.sort()
```

**what if we want to sort by the last name?**

| Alice | Clark |
|---|---|
| Bob | Adams |
| Catherine | Baker |

# Example: Sorting Names

List of tuples:

```
names = [
     (“Catherine”, “Baker”),
     (“Alice”, “Clark”),
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]
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
names.sort()
```

**what if we want to sort by the last name?**

**or by the length of the name?**

| Alice | Clark |
|---|---|
| Bob | Adams |
| Catherine | Baker |

# Example: Sorting Names

List of tuples:

```
names = [
     (“Catherine”, “Baker”),
     (“Alice”, “Clark”),
     (“Bob”, “Adams”),
]
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
def extract(name_tuple):
     return name_tuple[1]

names.sort(key=extract)
```

# Example: Sorting Names

List of tuples:

```
names = [
     (“Catherine”, “Baker”),
     (“Alice”, “Clark”),
     (“Bob”, “Adams”),
]
```

```
def extract(name_tuple):
     return name_tuple[1]

names.sort(key=extract)
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

| Bob | Adams |
|---|---|
| Catherine | Baker |
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# Example: Sorting Names

List of tuples:

```
names = [
     (“Catherine”, “Baker”),
     (“Alice”, “Clark”),
     (“Bob”, “Adams”),
]
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
def extract(name_tuple):
     return len(name_tuple[0])

names.sort(key=extract)
```

# Example: Sorting Names

List of tuples:

```
names = [
     (“Catherine”, “Baker”),
     (“Alice”, “Clark”),
     (“Bob”, “Adams”),
]
```

| Catherine | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
def extract(name_tuple):
     return len(name_tuple[0])

names.sort(key=extract)
```

| Bob | Adams |
|---|---|
| Alice | Clark |
| Catherine | Baker |

# [301] Advanced Functions

Tyler Caraza-Harter

1. Functions as Objects
2. Iterators/Generators

# Iterators/Generators (Part 2)

Outline

- when normal functions aren't good enough
- yield keyword by example
- the scary vocabulary of iteration
- the open function
- demos

```
def get_one_digit_nums():
    print("START")
    nums = []
    i = 0
    while i < 10:
        nums.append(i)
        i += 1
    print("END")
    return nums

for x in get_one_digit_nums():
    print(x)
```

how many times is the word "START" printed?

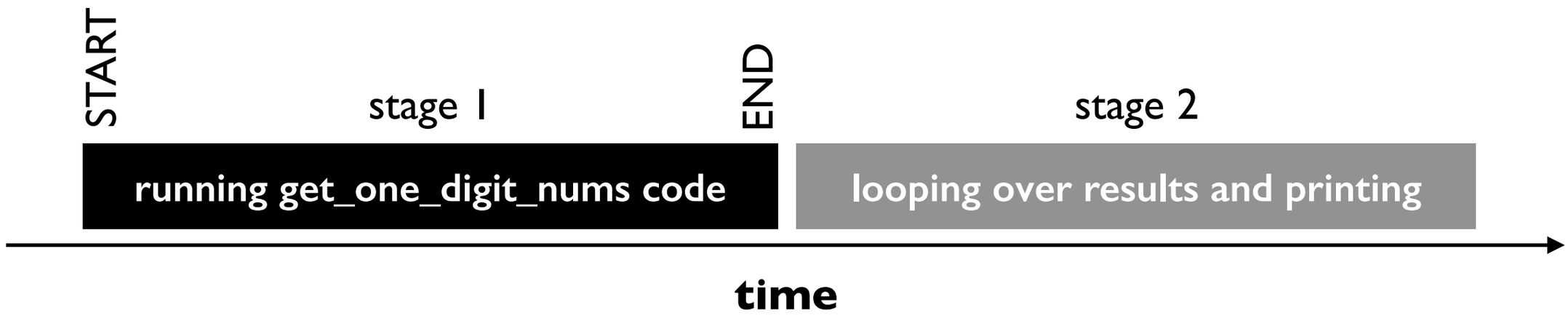
```
def get_one_digit_nums():
    print("START")
    nums = []
    i = 0
    while i < 10:
        nums.append(i)
        i += 1
    print("END")
    return nums
```

```
for x in ~~get_one_digit_nums()~~ [0,1,2,3,4,5,6,7,8,9]:
    print(x)
```

how many times is the word "START" printed?

```
def get_one_digit_nums():
    print("START")
    nums = []
    i = 0
    while i < 10:
        nums.append(i)
        i += 1
    print("END")
    return nums
```

```
for x in get_one_digit_nums():
    print(x)
```



```
def get_primes():
    print("START")
    nums = []
    i = 0
    while True:
        if is_prime(i):
            nums.append(i)
        i += 1
    print("END")
    return nums
```

```
for x in get_primes():
    print(x)
```

*what does this code do?*

assume there is an earlier `is_prime` function

```
def get_primes():
    print("START")
    nums = []
    i = 0
    while True:
        if is_prime(i):
            nums.append(i)
        i += 1
    print("END")
    return nums
```

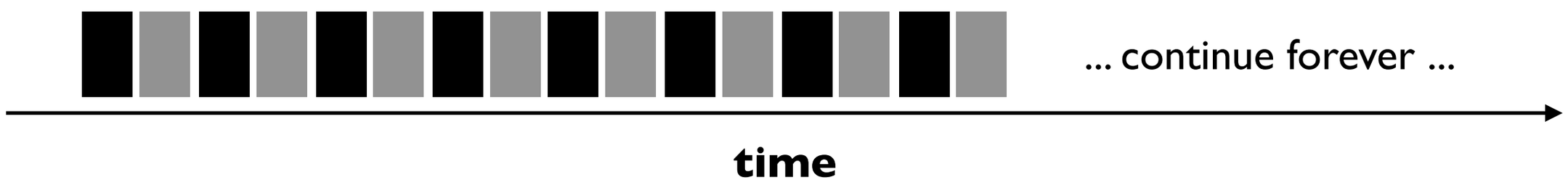
```
for x in get_primes():
    print(x)
```

to make this work, we'll need to learn a
completely new kind of function, the **generator**

```
def get_primes():
    ... 

for x in get_primes():
    print(x) 
```

what we want:

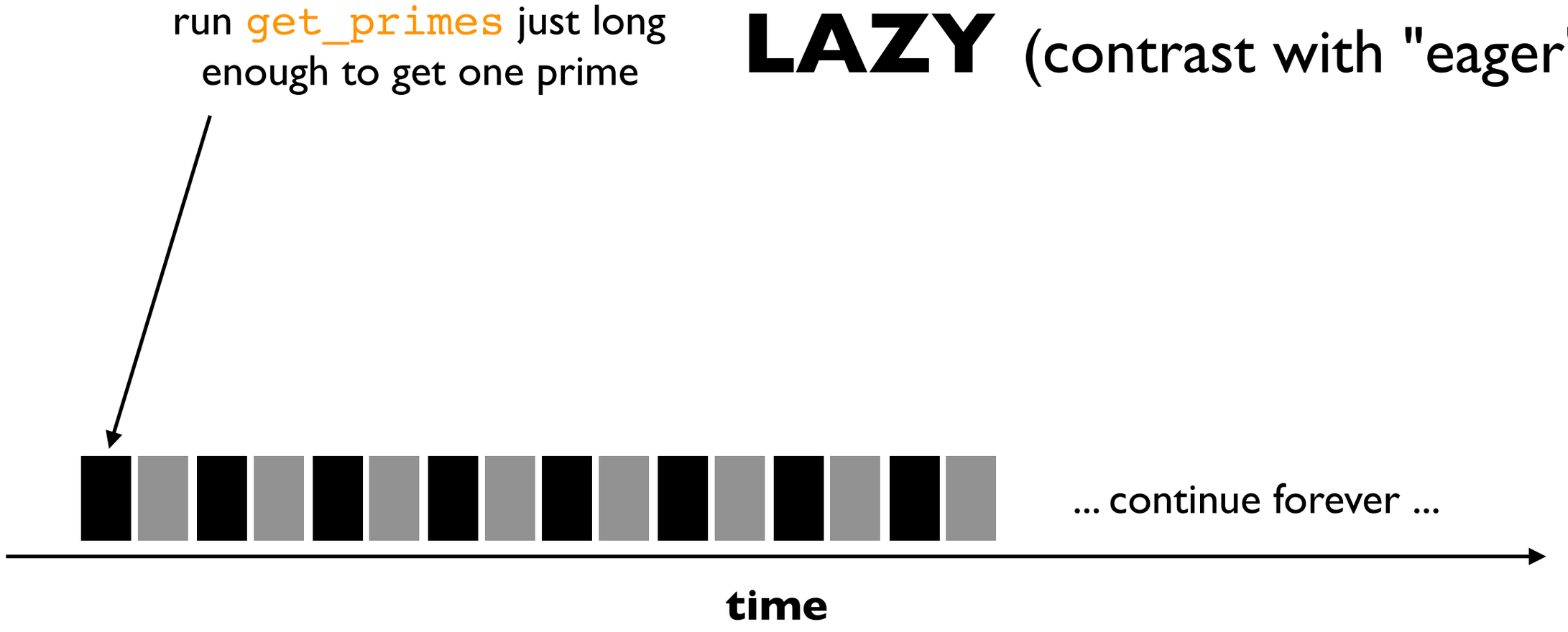


```
def get_primes():
    ... ■

for x in get_primes():
    print(x) ■
```

run `get_primes` just long enough to get one prime

**LAZY** (contrast with "eager")



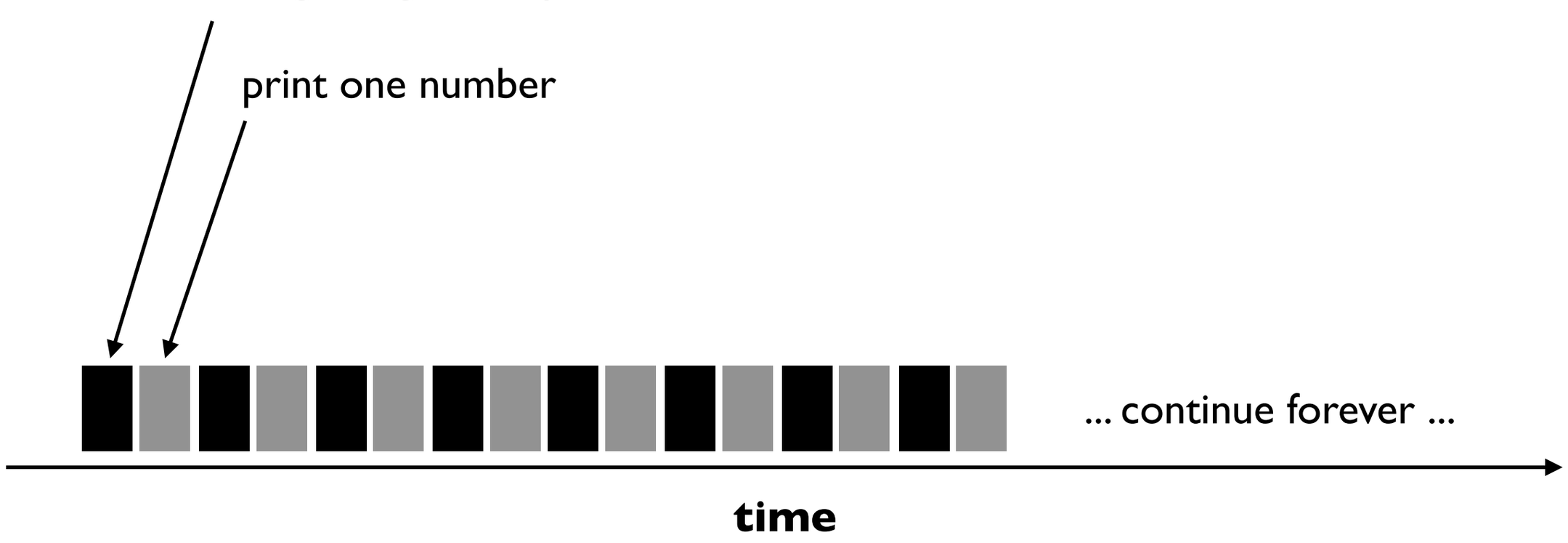
```
def get_primes():
    ... ■

for x in get_primes():
    print(x) ■
```

run `get_primes` just long enough to get one prime

print one number

**LAZY** (contrast with "eager")



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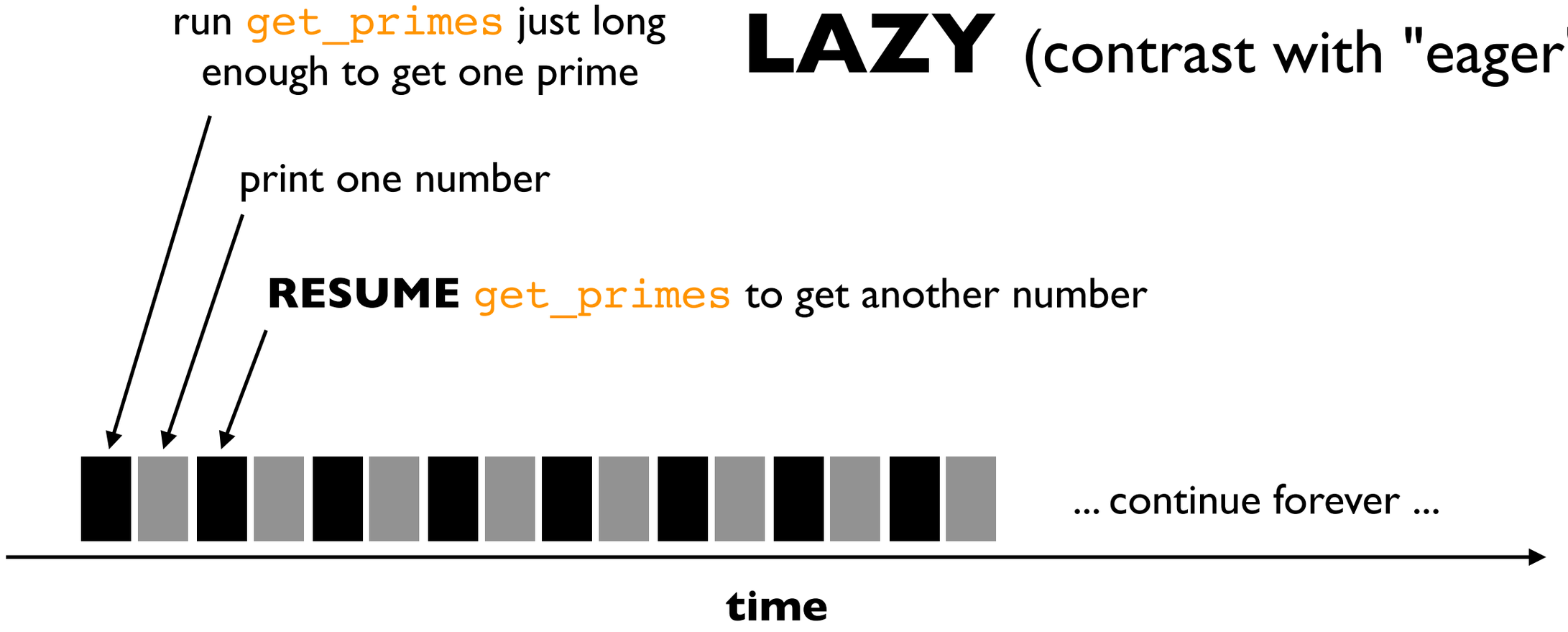


```
def get_primes():
    ...

for x in get_primes():
    print(x)
```

we will stop and resume running `get_primes` many times, even though we only call it once

**LAZY** (contrast with "eager")

run `get_primes` just long enough to get one prime

print one number

**RESUME** `get_primes` to get another number

... continue forever ...

**time**

```
def get_primes():
    ... ■

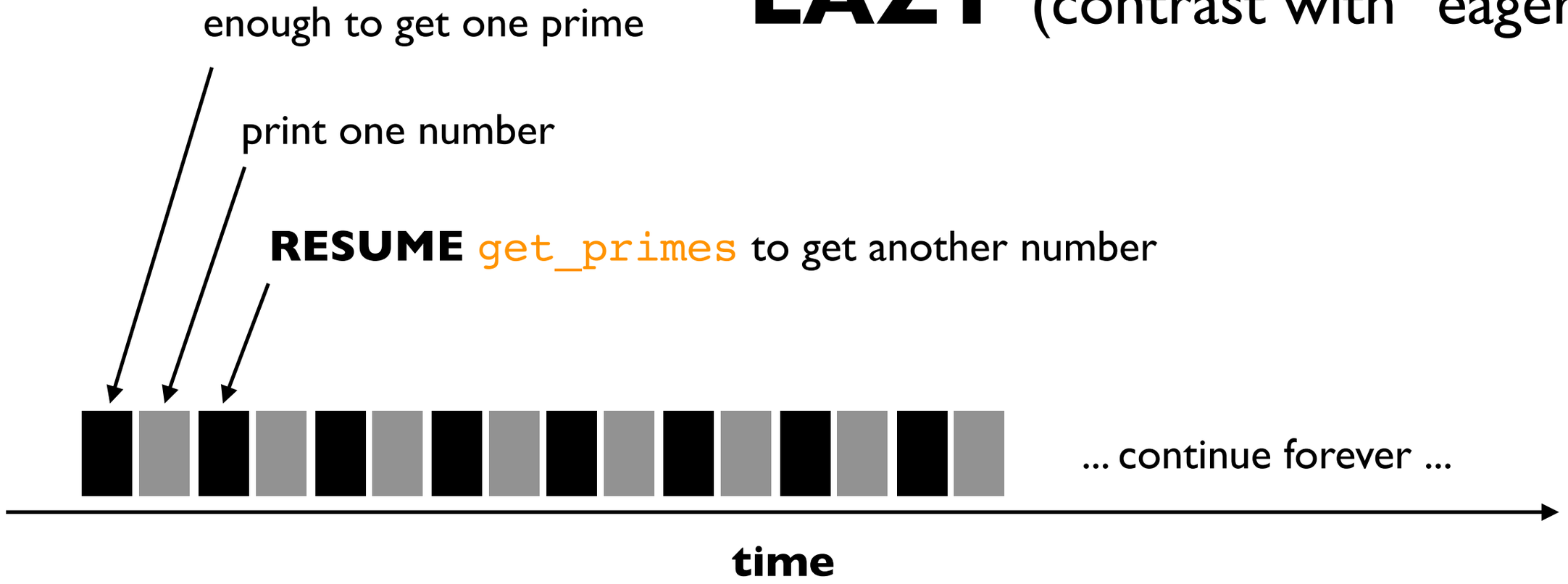
for x in get_primes():
    print(x) ■
```

we will stop and resume running `get_primes` many times, even though we only call it once

functions with this stop/resume behavior are called generators

run `get_primes` just long enough to get one prime

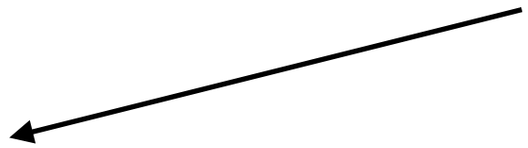
**LAZY** (contrast with "eager")



```
def get_primes():
    ... some code ...

    yield VALUE

    ... more code ...
```



any function containing the yield keyword anywhere is a generator

if you see this, all bets are off regarding how you currently understand functions to behave

?

```
gen def get_primes():
    ... some code ...

    yield VALUE

    ... more code ...
```

any function containing the yield keyword anywhere is a generator

if you see this, all bets are off regarding how you currently understand functions to behave

*should we even consider it a function?*

?

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gen def get_primes():
    ... some code ...

    yield VALUE

    ... more code ...
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*should we even consider it a function?*

**Guido van Rossum**

Python's Benevolent Dictator for Life
(until recently)

Should we "*introduce another new keyword (say, gen or generator) in place of def*"?

https://www.python.org/dev/peps/pep-0255/#bdfl-pronouncements

?

```
gen def get_primes():
    ... some code ...

    yield VALUE

    ... more code ...
```

any function containing the yield keyword anywhere is a generator

if you see this, all bets are off regarding how you currently understand functions to behave

*should we even consider it a function?*

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Argument for `gen`: "*a yield statement buried in the body is not enough warning that the semantics are so different*"

Argument for `def`: "*generators are functions, but with the twist that they're resumable*"

https://www.python.org/dev/peps/pep-0255/#bdfl-pronouncements

```
def get_primes():
    ... some code ...

    yield VALUE

    ... more code ...
```

*always scan a function for yields when trying to understand it*

**Guido van Rossum**

Python's Benevolent Dictator for Life (until recently)

Argument for `gen`: "*a yield statement buried in the body is not enough warning that the semantics are so different*"

Argument for `def`: "*generators are functions, but with the twist that they're resumable*"

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# Iterators/Generators (Part 2)

Outline

- when normal functions aren't good enough
- yield keyword by example
- the scary vocabulary of iteration
- the open function
- demos

# yield by example (note, PyTutor does a bad job showing generators)

```
def f():
    yield 1
    yield 2
    yield 3

for x in f():
    print(x)
```

```
def f():
    print("A")
    yield 1
    print("B")
    yield 2
    print("C")
    yield 3

for x in f():
    print(x)
```

```
def f():
    yield 1
    yield 2
    yield 3

for x in f():
    print(x)

for x in f():
    print(x)
```

```
def f():
    yield 1
    yield 2
    yield 3

for x in f():
    for y in f():
        print(x, y)
```

```
def f():
    yield 1
    yield 2
    yield 3

gen = f()
print(next(gen))
print(next(gen))
```

```
def f():
    yield 1
    yield 2
    yield 3

gen = f()
for x in gen:
    print(x)
```

# Iterators/Generators (Part 2)

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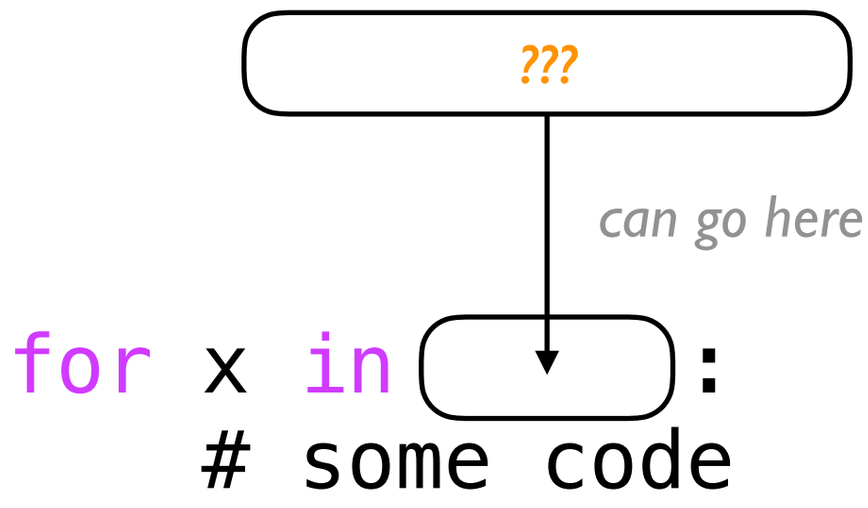
# The Vocabulary of Iteration



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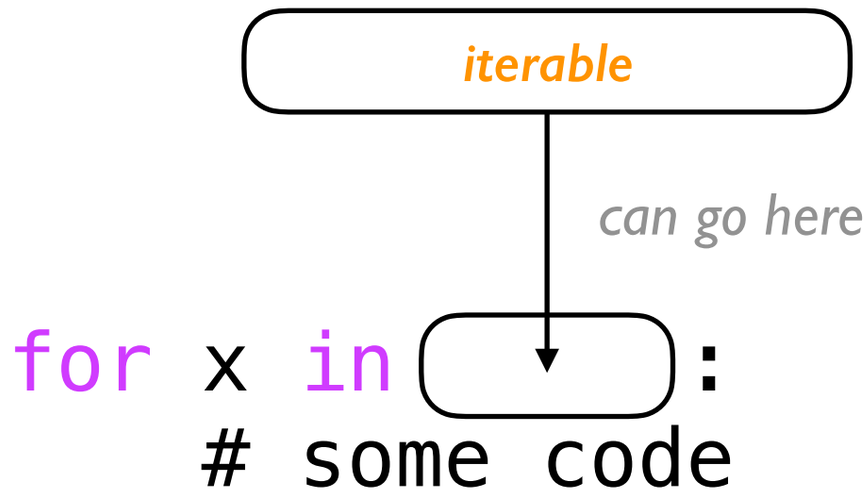

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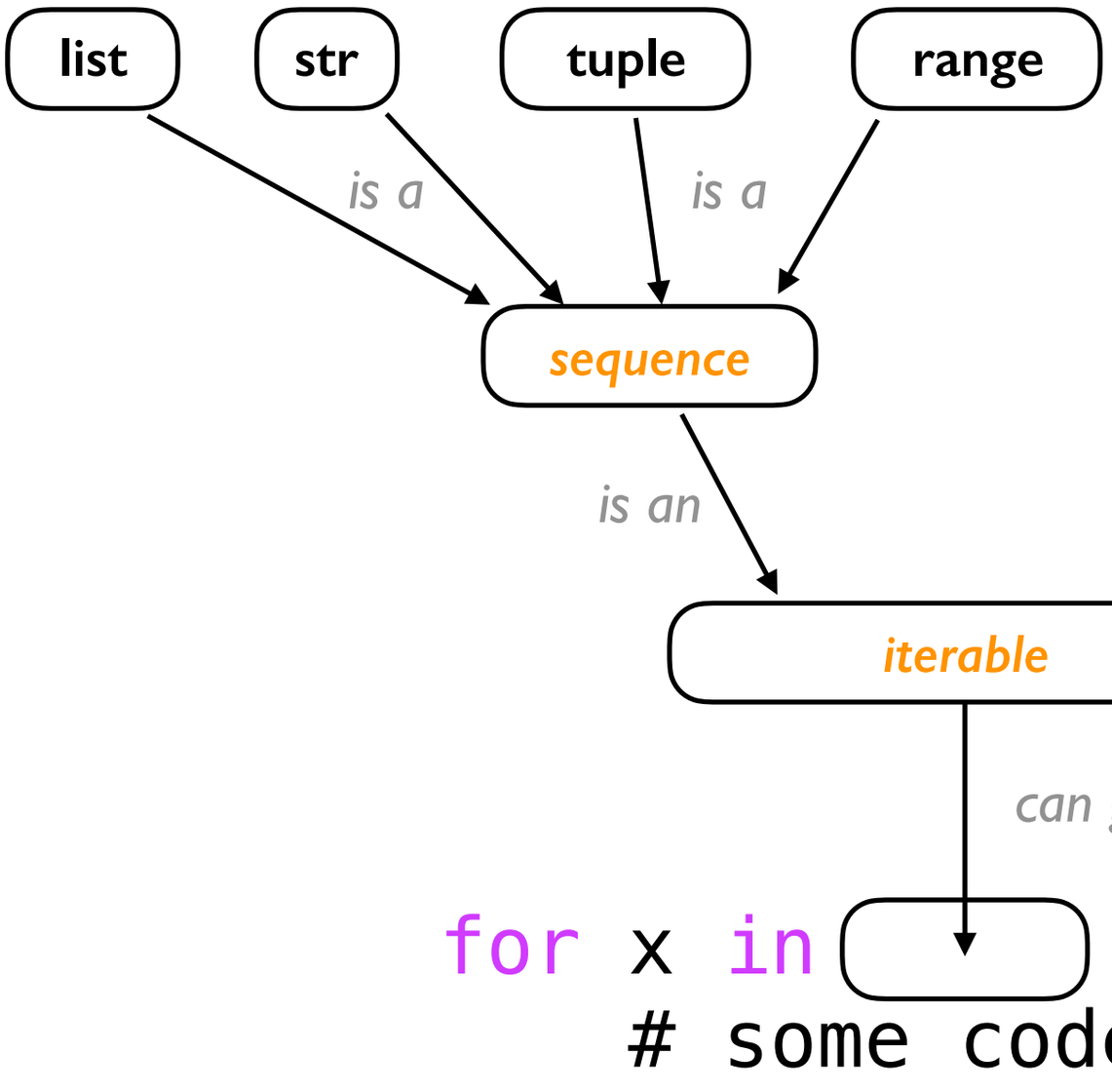

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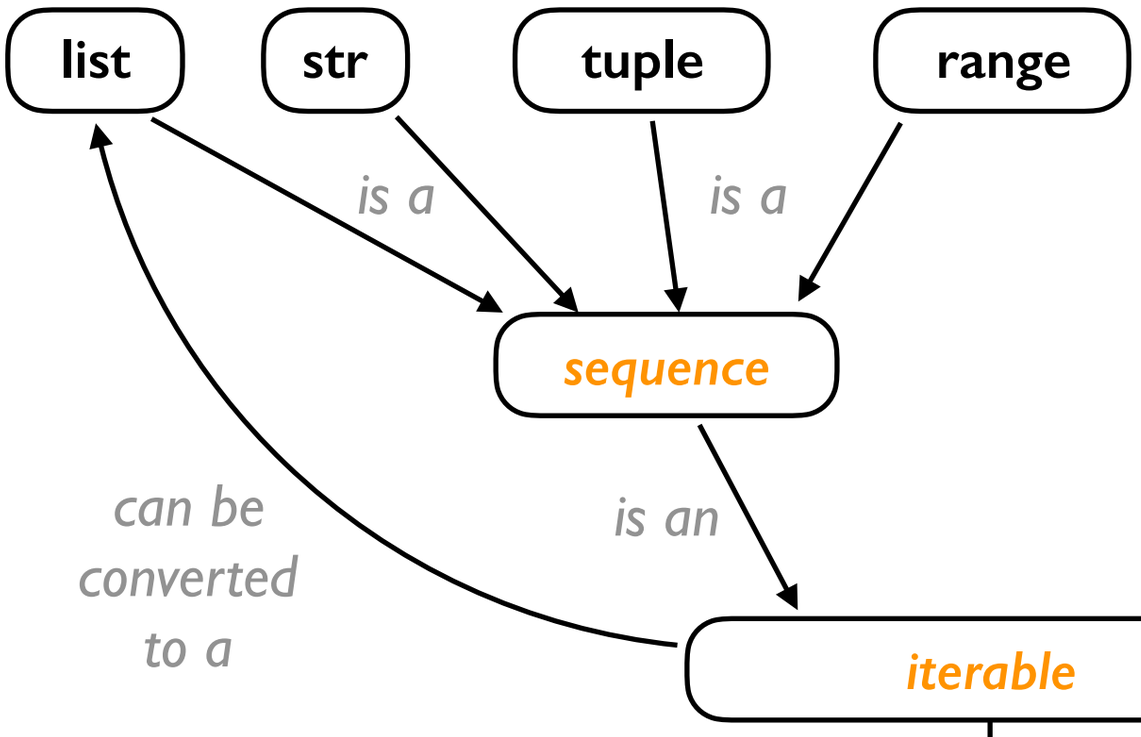
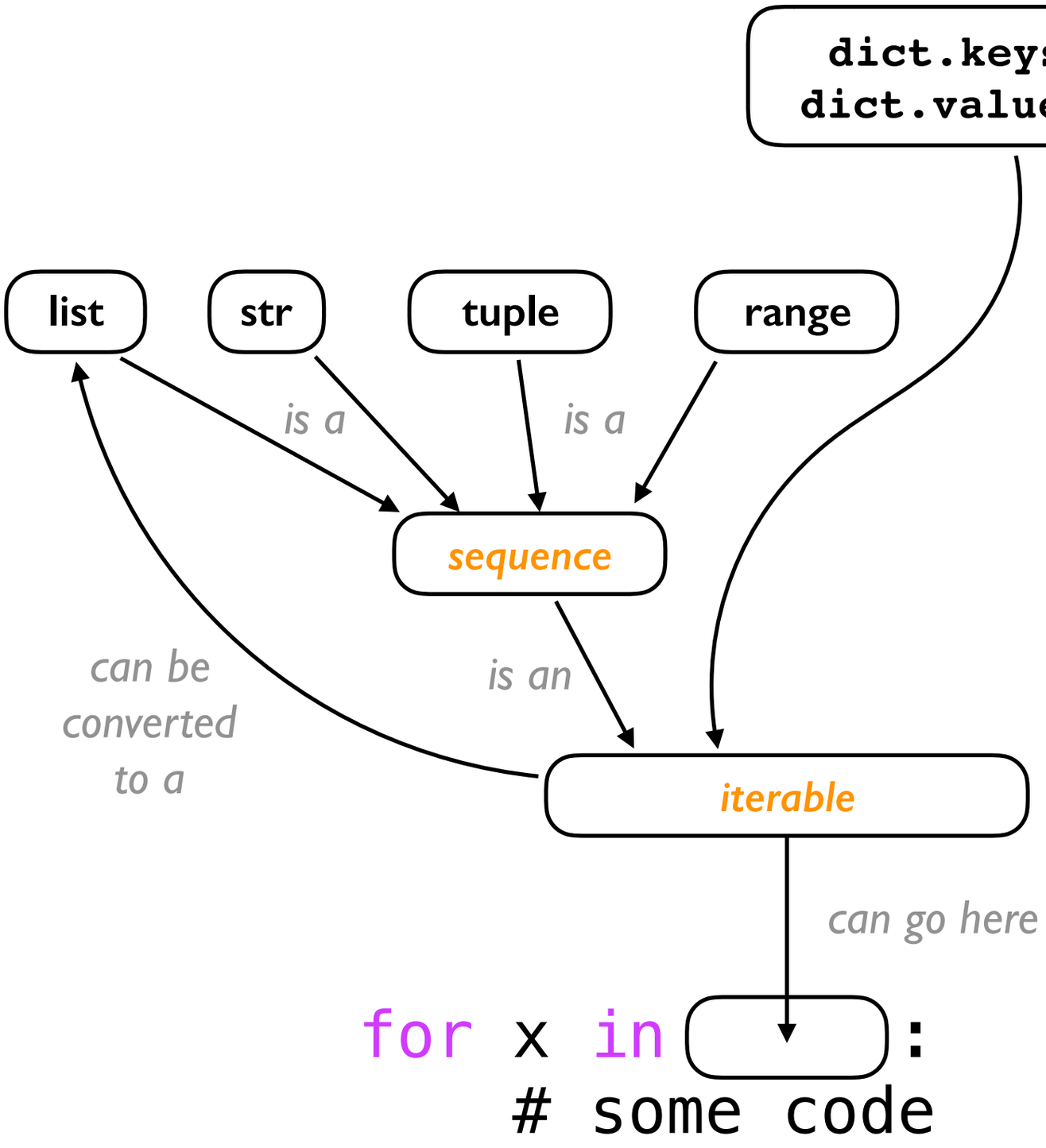



**Example:**

L = list("ABC")

```
for x in      :
    # some code
```

# The Vocabulary of Iteration

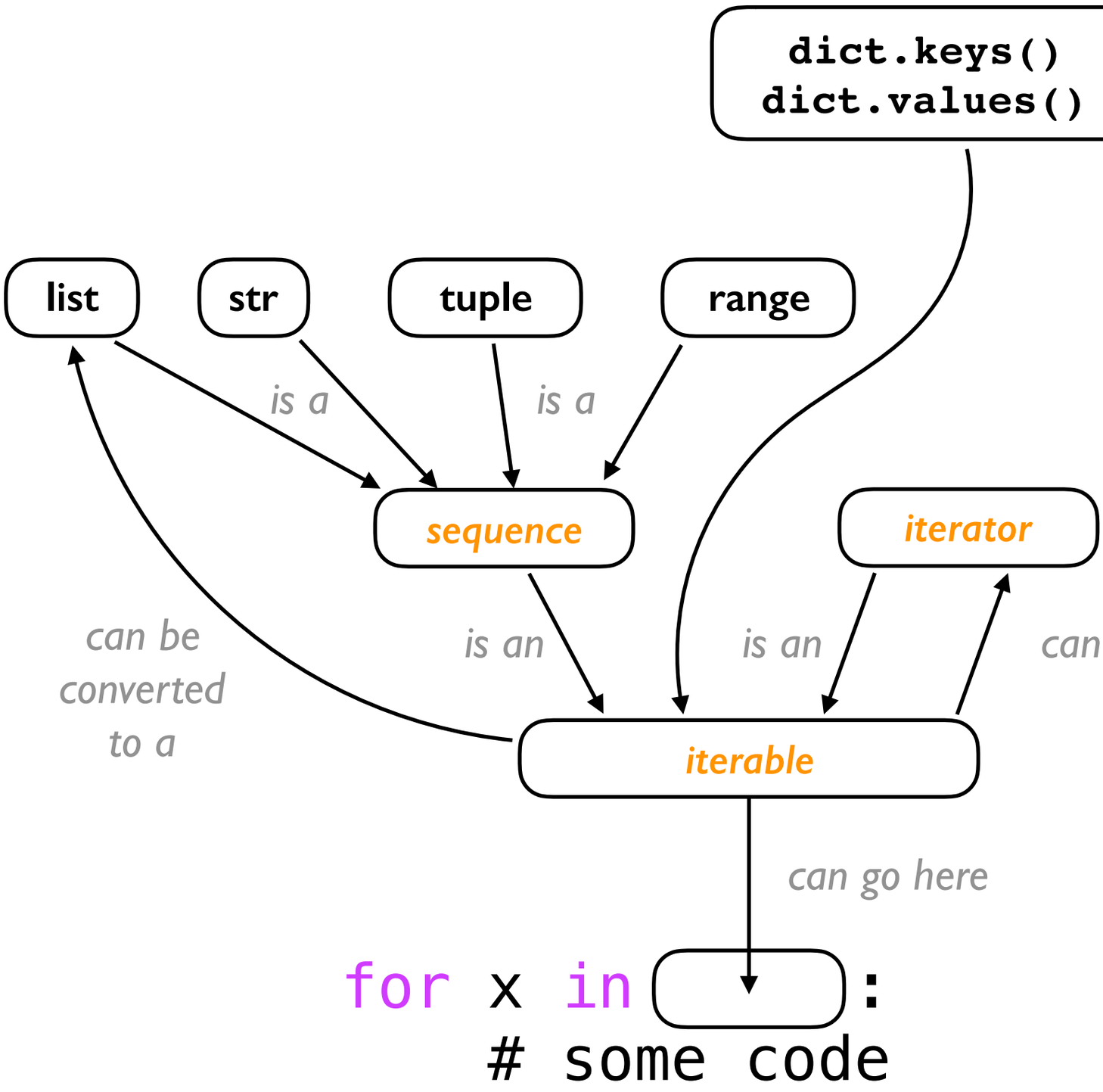



**Example:**

```
L = list(d.keys())
```

```
for x in      :
    # some code
```

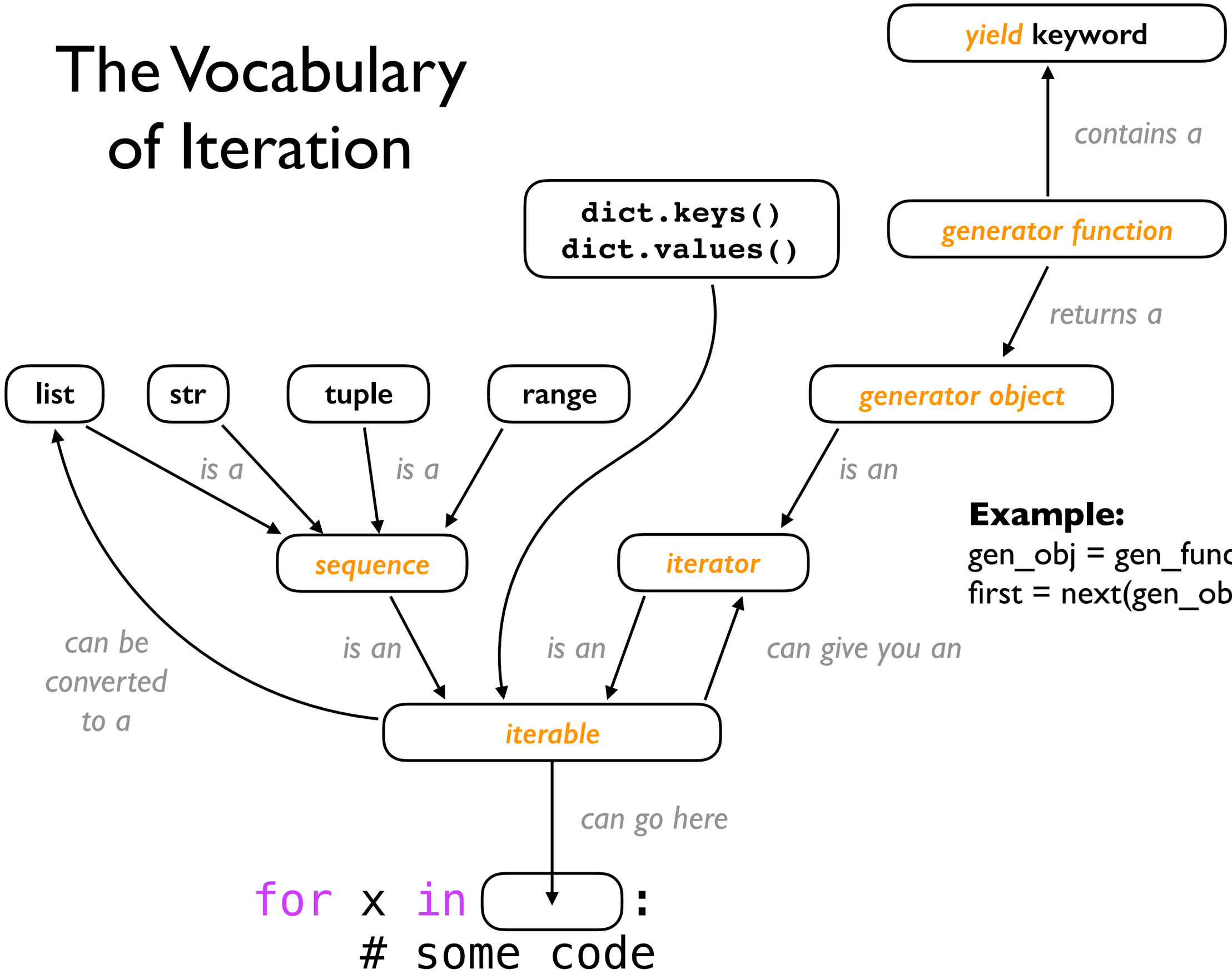
# The Vocabulary of Iteration




**Example:**

```
it = iter("ABC")
first = next(it)
```

# The Vocabulary of Iteration




**Example:**

```
gen_obj = gen_function(...)
first = next(gen_obj)
```

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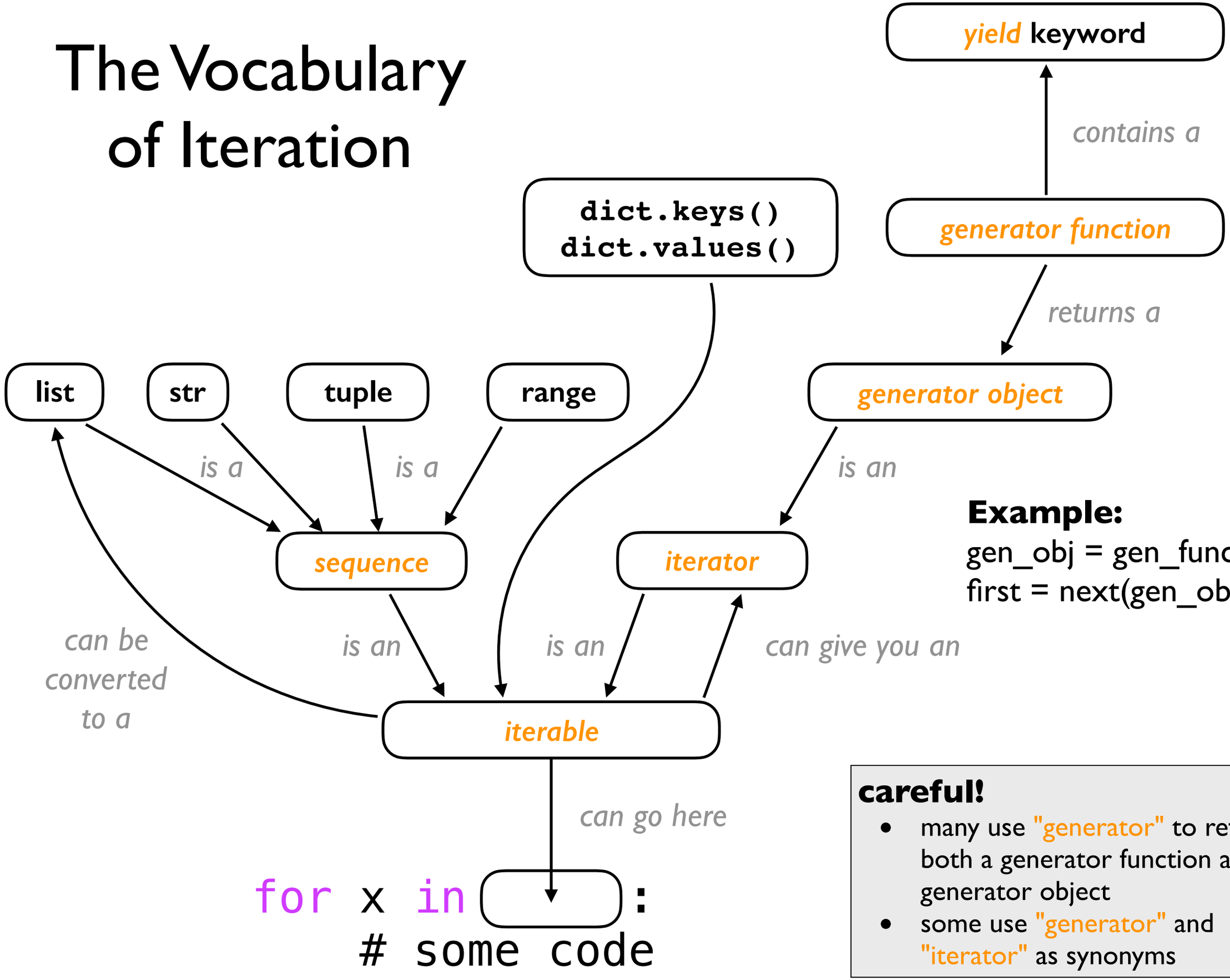


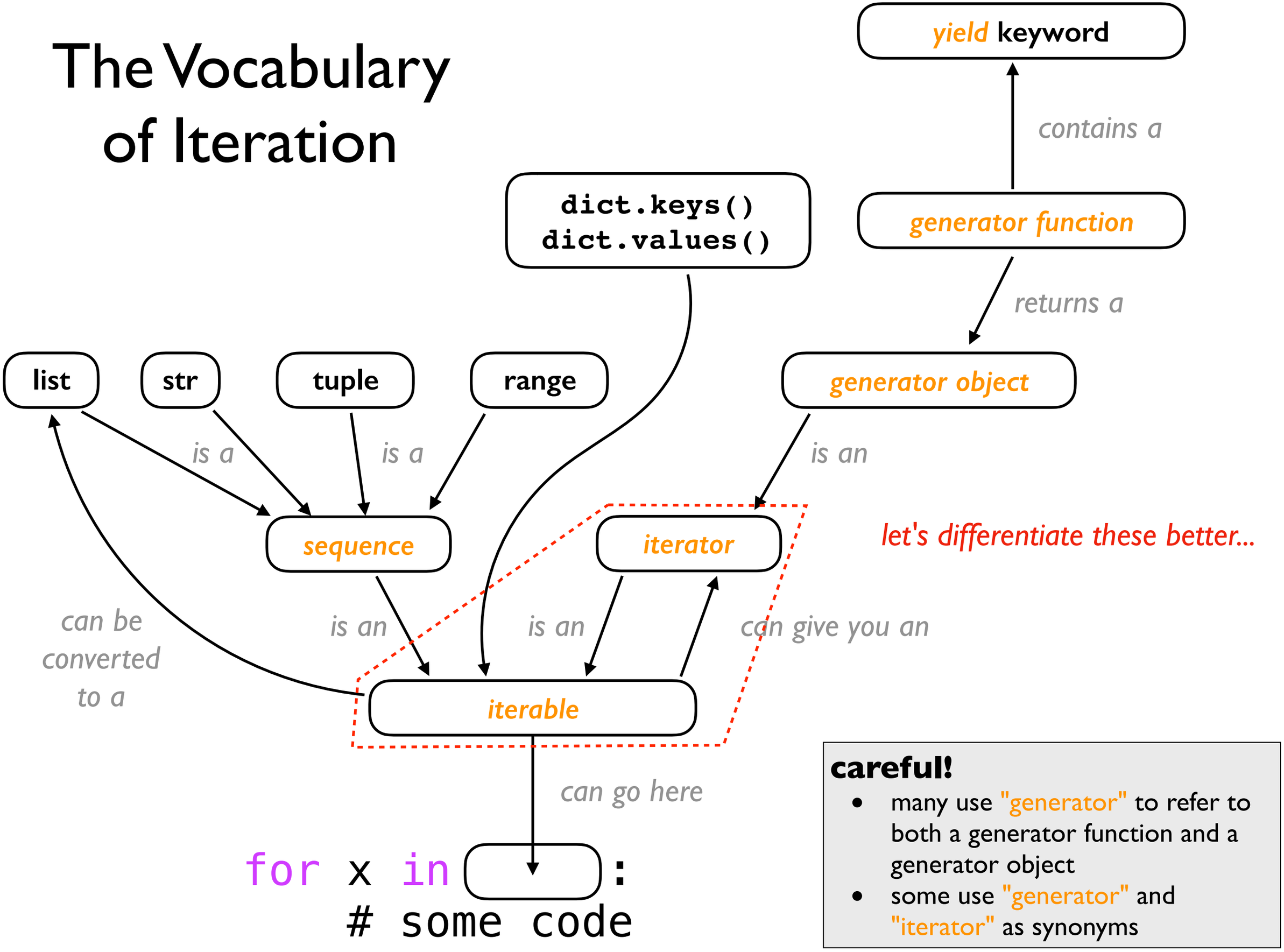

**Example:**

```
gen_obj = gen_function(...)
first = next(gen_obj)
```

**careful!**

- many use "generator" to refer to both a generator function and a generator object
- some use "generator" and "iterator" as synonyms

# The Vocabulary of Iteration




**careful!**

- many use "generator" to refer to both a generator function and a generator object
- some use "generator" and "iterator" as synonyms

## is `x` iterable?

**if this works, then yes:**

`iter(x)` **returns an iterator over x**

## is `y` an iterator?

**if this works, then yes:**

`next(y)` **returns next value from y**

## is `x` iterable?

**if this works, then yes:**

`y = iter(x)` **returns an iterator over x**

## is `y` an iterator?

**if this works, then yes:**

`next(y)` **returns next value from y**

**Can you classify x, y, and z?**

```
x = [1,2,3]
y = enumerate([1,2,3])
z = 3
```

**Things to try:**

```
iter(x)
next(x)
etc.
```

# Iterators/Generators (Part 2)

Outline

- when normal functions aren't good enough
- yield keyword by example
- the scary vocabulary of iteration
- the open function
- demos

# Reading Files

```
path = “file.txt”
f = open(path)
```

open(…) function is built in

# Reading Files

```
path = “file.txt”
f = open(path)
```

it takes a string argument,
which contains path to a file

**file.txt**

```
This is a test!
3
2
1
Go!
```

**c:\users\tyler\my-doc.txt**

**/var/log/events.log**

**../data/input.csv**

# Reading Files

```
path = “file.txt”
f = open(path)
```

it returns a file object

**file.txt**

```
This is a test!
3
2
1
Go!
```

file objects are iterators!

# Reading Files

```
path = “file.txt”
f = open(path)

for line in f:
    print(line)
```

**Output**

This is a test!

3

2

1

Go!

**file.txt**

This is a test!
3
2
1
Go!

# Iterators/Generators (Part 2)

Outline

- when normal functions aren't good enough
- yield keyword by example
- the scary vocabulary of iteration
- the open function
- demos

# Demo 1: add numbers in a file

Goal: read all lines from a file as integers and add them

**Input**:

- file containing **50 million numbers** between 0 and 100

**Output**:

- The sum of the numbers

**Example**:

```
prompt> python sum.py
2499463617
```

**Two ways**:

- Put all lines in a list first
- Directly use iterable file

**Bonus:** create generator function that does the str => int conversion

# Demo 2: handy functions

**Learn these**:

- enumerate
- zip

**Bonus:** tuple packing/unpacking

# Demo 3: sorting files by line length

Goal: output file contents, with shortest line first

**Input**:

- a text file

**Output**:

- print lines sorted

# Demo 4: matrix load

Goal: load a matrix of integers from a file

**Input**:

- file name

**Output**:

- generator that yields lists of ints