# [301] Advanced Functions

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# Learning Objectives Today

Iterators

- what is an iteratable?
- how to read files, with sequences or iterators
- advantages of laziness
- writing your own generators

References to functions

- ways to get a reference
- map
- sort

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# Revisiting the For Loop

**for loops** can iterate over **sequences**

- list values
- string characters
- other sequences

```
for letter in “hello”:
    print(letter)
```

```
for num in [1,2,3]:
    print(num)
```

# Revisiting the For Loop

**for loops** can iterate over **sequences**

- list values
- string characters
- other sequences

More precisely…

```
for letter in “hello”:
    print(letter)
```

```
for num in [1,2,3]:
    print(num)
```

# Revisiting the For Loop

**for loops** can iterate over **sequences**

- list values
- string characters
- other sequences

More precisely…

**for loops** can iterate over **iterables**

- **sequences** are **iterable**
- **other things** (like dict values) are also **iterable**

# Example: Dictionary Values

```
d = {1:"one", 2:"two", 3:"three"}
d.values() # type is <class 'dict_values'>
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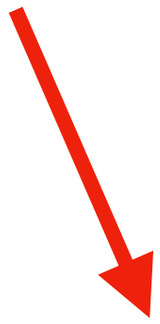

```
vals = list(d.values())
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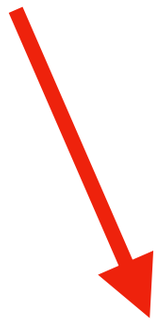


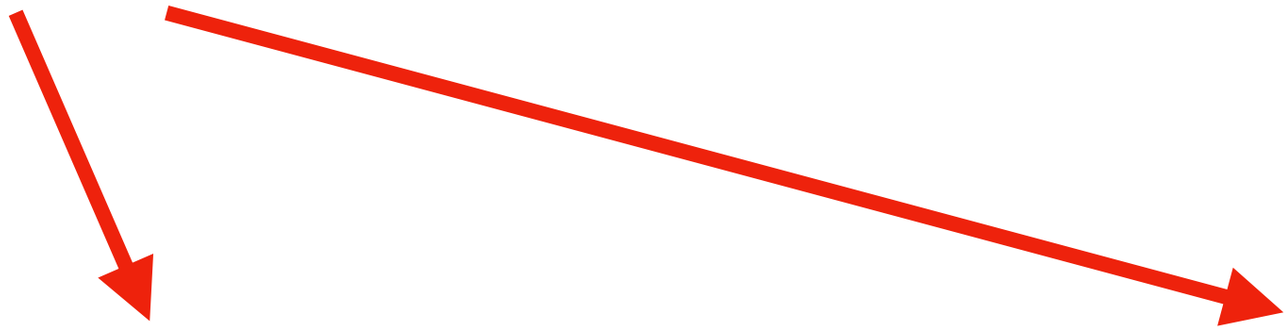
```
vals = list(d.values())

for v in vals:
    print(v)
```

**Prints (or other order):**
two
one
three

# Example: Dictionary Values

```
d = {1:"one", 2:"two", 3:"three"}
d.values() # type is <class 'dict_values'>
```



```
vals = list(d.values())
```

```
it = iter(d.values())
```

```
for v in vals:
    print(v)
```

# Example: Dictionary Values

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d = {1:"one", 2:"two", 3:"three"}
d.values() # type is <class 'dict_values'>
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vals = list(d.values())

for v in vals:
    print(v)
```

```
it = iter(d.values())
```

if you can call **iter(x)**,
then **x** is *iterable*,
by definition

# Example: Dictionary Values

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d.values() # type is <class 'dict_values'>
```

```
vals = list(d.values())

for v in vals:
    print(v)
```

```
it = iter(d.values())
```

d.values() is iterable, and **it** is an iterator

# Example: Dictionary Values

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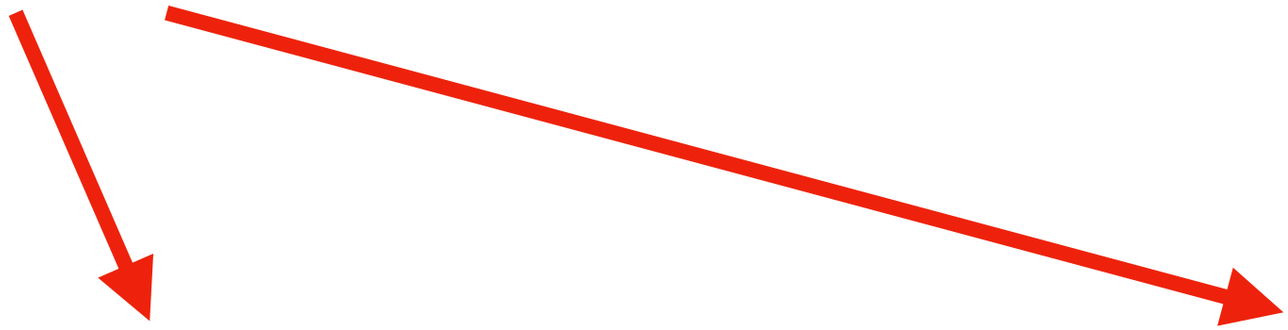

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vals = list(d.values())
for v in vals:
    print(v)
```

```
it = iter(d.values())
for v in it:
    print(v)
```

**Both print the same:**

two
one
three

# Example: Dictionary Values

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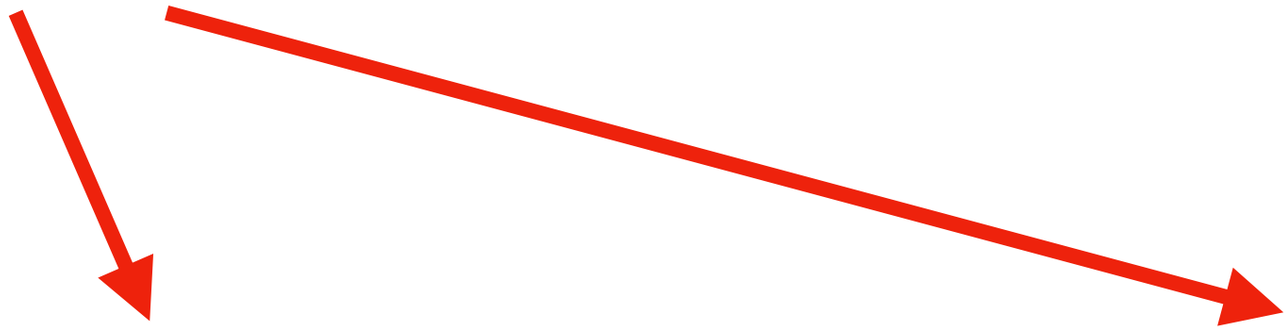

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vals = list(d.values())
for v in vals:
    print(v)
```

```
it = iter(d.values())
for v in it:
    print(v)
```

**Both print the same:**
two
one
three

**NOTE**: the for loop automatically calls iter if necessary, so we could have written this instead:

```
for v in d.values():
    print(v)
```

# Example: Dictionary Values

```
d = {1:"one", 2:"two", 3:"three"}
d.values() # type is <class 'dict_values'>
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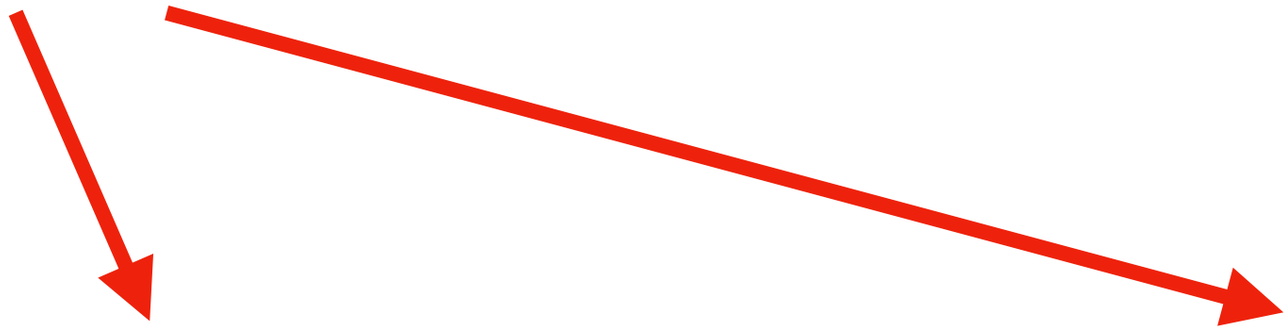

```
vals = list(d.values())
for v in vals:
    print(v)

print(vals[2])
```

```
it = iter(d.values())
for v in it:
    print(v)
```

**We can index over a sequence.**
**Example prints:**
three

# Example: Dictionary Values

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d = {1:"one", 2:"two", 3:"three"}
d.values() # type is <class 'dict_values'>
```

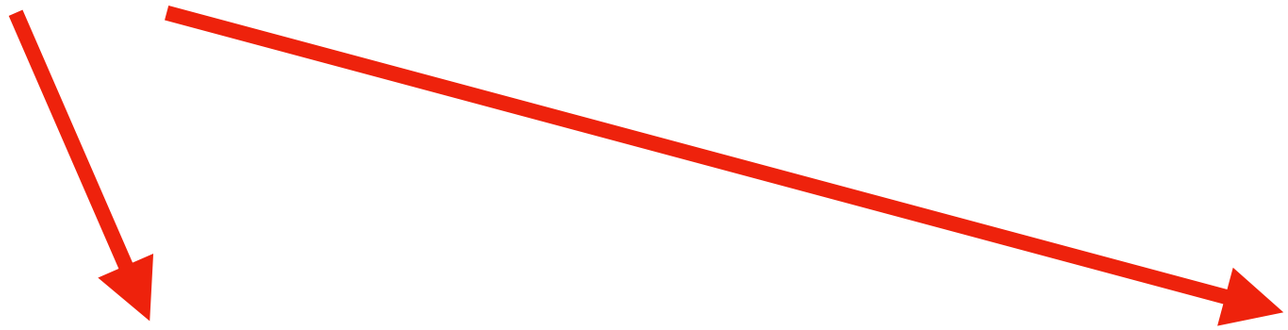

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vals = list(d.values())

for v in vals:
    print(v)

print(vals[2])
```

```
it = iter(d.values())

for v in it:
    print(v)

print(it[2]) # BAD!
```

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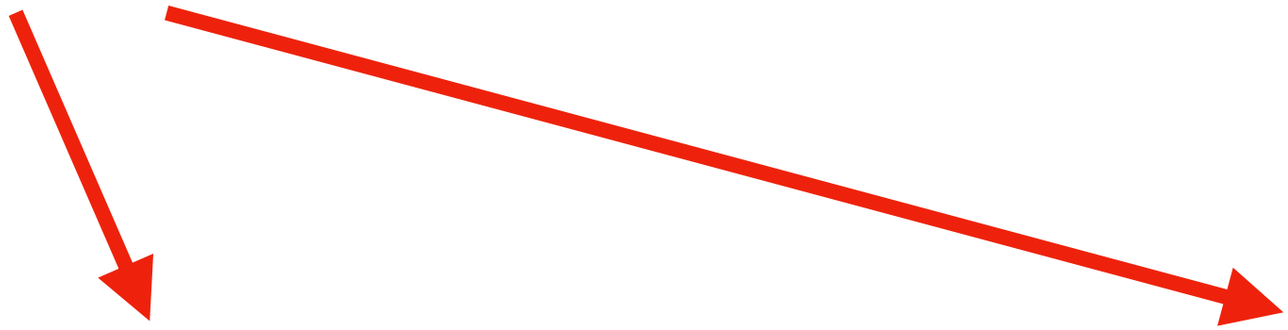

```
vals = list(d.values())

for v in vals:
    print(v)

print(vals[2])
```

```
it = iter(d.values())

for v in it:
    print(v)

print(it[2]) # BAD!
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'dict_valueiterator' object is not subscriptable
```

You can only loop over iterators, not index with them

# Comparison

| | sequence | iterator |
|---|---|---|
| can use for loop | ✓ | ✓ |
| can do indexing | ✓ | ✗ |

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**why ever use the less-capable iterator?**

# Comparison

| | sequence | iterator |
|---|---|---|
| can use for loop | ✓ | ✓ |
| can do indexing | ✓ | ✗ |

**why ever use the less-capable iterator?**

**it’s often faster (as we’ll see later)**

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- what is an iteratable?
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# Reading Files

```
path = “file.txt”
f = open(path)
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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)
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it returns a file object

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**file.txt**

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

file objects are iterable!

# 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
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Go!

# Reading Files

```
path = “file.txt”
f = open(path)

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

**file.txt**

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3
2
1
Go!
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**Output**

```
This is a test!
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Go!
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# Reading Files

```
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for line in f:
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```

**file.txt**

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

**Another option:** use the iterable file object to create a list

# Reading Files

```
path = “file.txt”
f = open(path)
lines = list(f) # create list from iterable

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

**file.txt**

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

**Another option:** use the iterable file object to create a list

# Reading Files

```
path = “file.txt”
f = open(path)
lines = list(f) # create list from iterable

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

**file.txt**

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

**Another option:** use the iterable file object to create a list

lines is a list:

```
[“This is a test\n”, “3\n”, “2\n”, “1\n”, “Go!\n”]
```

# Reading Files

```
path = “file.txt”
f = open(path)
lines = list(f) # create list from iterable

for line in £ lines:
    print(line.strip())
```

**file.txt**

```
This is a test!
3
2
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**Another option:** use the iterable file object to create a list

# Reading Files

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path = “file.txt”
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    print(line.strip())
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**file.txt**

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**Another option:** use the iterable file object to create a list

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# 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
```

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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

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# Reviewing Return

```
def f():
  return “A”
  return “B”
  return “C”

print(“Got”, f())
```

**What is printed?**

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def f():
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**What is printed?**

**Got A**

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```
def f():
  return “A”
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  return “C”

print(“Got”, f())
```

**What is printed?**

**Got A**

**Let’s say we want to return 3 values**

# Reviewing Return

```
def f():
  items = []
  items.append(“A”)
  items.append(“B”)
  items.append(“C”)
  return items

for item in f():
  print(“Got”, item)
```

**What is printed?**

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```

**What is printed?**

**Got A**
**Got B**
**Got C**

# Reviewing Return

```
def f():
  items = []
  print("Produce A")
  items.append("A")
  print("Produce B")
  items.append("B")
  print("Produce C")
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for item in f():
  print("Got", item)
```

**What is printed?**

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    return items

for item in f():
    print("Got", item)
```

**What is printed?**

**Produce A**
**Produce B**
**Produce C**
**Got A**
**Got B**
**Got C**

# Reviewing Return

```
def f():
    items = []
    print("Produce A")
    items.append("A")
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    print("Produce C")
    items.append("C")
    return items

for item in f():
    print("Got", item)
```

**What is printed?**

**Produce A**
**Produce B**
**Produce C**

everything is produced…

**Got A**
**Got B**
**Got C**

# Reviewing Return

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def f():
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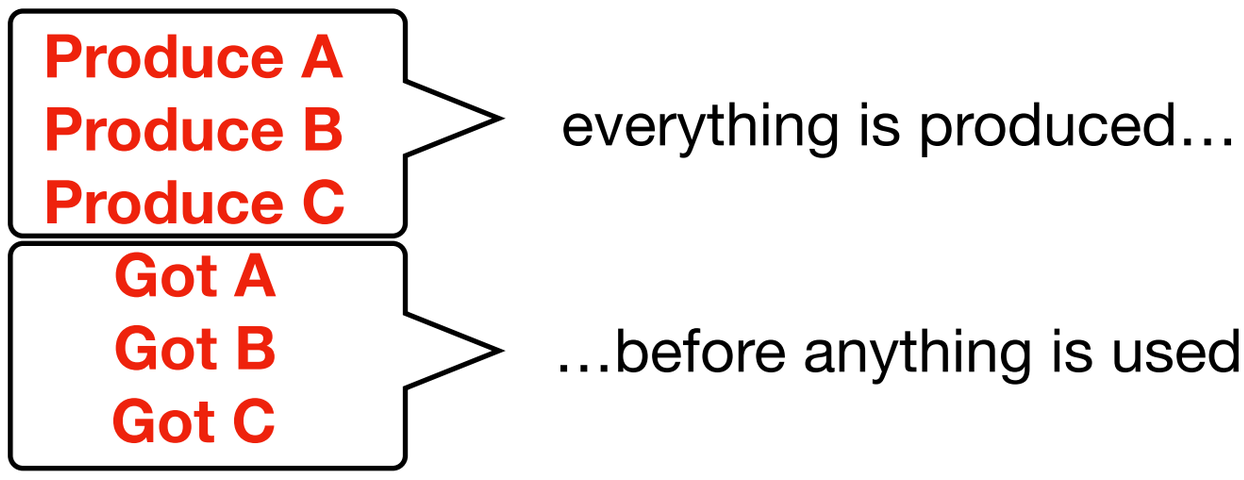
**What is printed?**



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for item in f():
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```

**What is printed?**


Sometimes we want to be "lazy" and only produce values right before they're needed

# Introducing Yield

```
def f():
  print(“Produce A”)
  yield “A”
  print(“Produce B”)
  yield “B”
  print(“Produce C”)
  yield “C”

items = f()
```

# Introducing Yield

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**what is yield?**

- produce results, like return
- can yield multiple values, unlike return

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items = f()
```

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return

**What is printed?**

*nothing*

# Introducing Yield

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def f():
  print("Produce A")
  yield "A"
  print("Produce B")
  yield "B"
  print("Produce C")
  yield "C"

items = f()
```

we never use items

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy
  (don't run until result is needed)

**What is printed?**

*nothing*

# Introducing Yield

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  yield “A”
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**what is yield?**

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- can yield multiple values, unlike return
- functions with yield are lazy
  (don’t run until result is needed)

```
items = f()
```

**What is printed?**

*nothing*

type of items is:
<class 'generator'>

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type of items is:
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weird, no?
we don’t return anything

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items = f()
```

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy
  (don’t run until result is needed)
- functions with yield automatically
  return a *generator*, a type of iterator

**What is printed?**

*nothing*

type of items is:
<class 'generator'>

weird, no?
we don’t return anything

# Introducing Yield

```
def f():
  print("Produce A")
  yield "A"
  print("Produce B")
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```

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don't run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

```
items = f()
for item in items:
  print(item)
```

**What is printed?**

**iteration 1**

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def f():
  print(“Produce A”)
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  print(“Produce B”)
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  print(“Produce C”)
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**iteration 1**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don’t run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A

# Introducing Yield

```
def f():
  print("Produce A")
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  print("Produce B")
  yield "B"
  print("Produce C")
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items = f()
for item in items:
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```

**iteration 1**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
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- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A

# Introducing Yield

```
def f():
  print(“Produce A”)
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for item in items:
  print(item)
```

**iteration 1**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don’t run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A

A

# Introducing Yield

```
def f():
  print("Produce A")
  yield "A"
  print("Produce B")
  yield "B"
  print("Produce C")
  yield "C"
```

```
items = f()
for item in items:
  print(item)
```

**iteration 2**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don't run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A
A

# Introducing Yield

```
def f():
  print(“Produce A”)
  yield “A”
  print(“Produce B”)
  yield “B”
  print(“Produce C”)
  yield “C”

items = f()
for item in items:
  print(item)
```

resume where we left off!

**iteration 2**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don’t run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A
A
Produce B

# Introducing Yield

```
def f():
  print("Produce A")
  yield "A"
  print("Produce B")
  yield "B"
  print("Produce C")
  yield "C"

items = f()
for item in items:
  print(item)
```

**iteration 2**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don't run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A
A
Produce B

# Introducing Yield

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def f():
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for item in items:
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```

**iteration 2**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
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- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A
A
Produce B
B

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```
def f():
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  yield "B"
  print("Produce C")
  yield "C"
```

```
items = f()
for item in items:
  print(item)
```

**iteration 3**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don't run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A
A
Produce B
B

# Introducing Yield

```
def f():
  print("Produce A")
  yield "A"
  print("Produce B")
  yield "B"
  print("Produce C")
  yield "C"

items = f()
for item in items:
  print(item)
```

**iteration 3**

**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don't run until result is needed)
- functions with yield automatically return a *generator*, a type of iterator

**What is printed?**

Produce A
A
Produce B
B
Produce C

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**what is yield?**

- produce results, like return
- can yield multiple values, unlike return
- functions with yield are lazy (don't run until result is needed)
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**observations**

- we bounce in and out of a generator function
- the function starts producing values even before it finishes

**What is printed?**

Produce A
A
Produce B
B
Produce C
C

# Demo 2: Squares

Goal: generate sequence of squares

**Input**:

- none

**Output**:

- Squares

**Example**:

```
prompt> python squares.py
1
4
9
16
25
...
```

# Iterator/Generator Vocabulary Recap

**Sequence**: object we can loop over (with for) **AND** index into

**Iterator**: object we can loop over (with for)

**Iterable**: object **x** that can give us an iterator with **iter(x)**

**Generator**: iterator returned by a function that **yields**

**Generator function**: function that returns a generator

# Learning Objectives Today

Iterators

- what is an iteratable?
- how to read files, with sequences or iterators
- advantages of laziness
- writing your own generators

References to functions

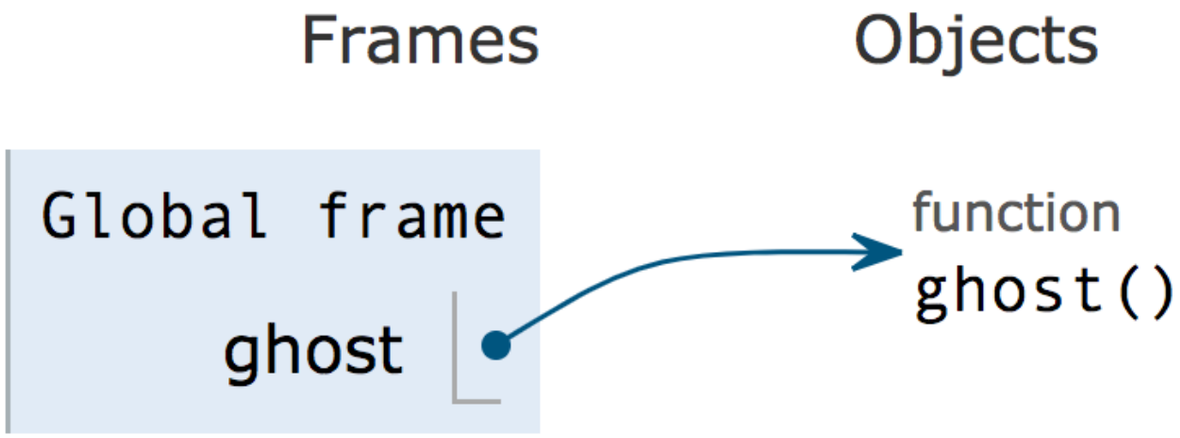
- ways to get a reference
- map
- sort

# Python Tutor

Write code in Python 3.6

(drag lower right corner to resize code editor)

```
1  def ghost():
2      print('boo')
3
4
```




why does Python Tutor visualize functions this way?

# Functions are objects

Functions are just a special type of object!

- function name is reference
- function code is the object

```
def ghost():
    print('boo')

ghost()
```

---

**State:**

*references* *objects*

# Functions are objects

Functions are just a special type of object!

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def ghost():
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```

```
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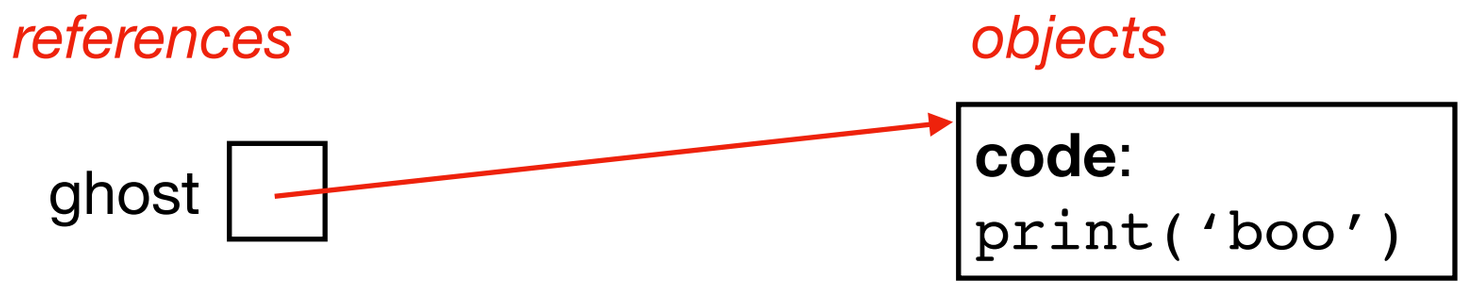

# Functions are objects

Functions are just a special type of object!

- function name is reference
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```
def ghost():
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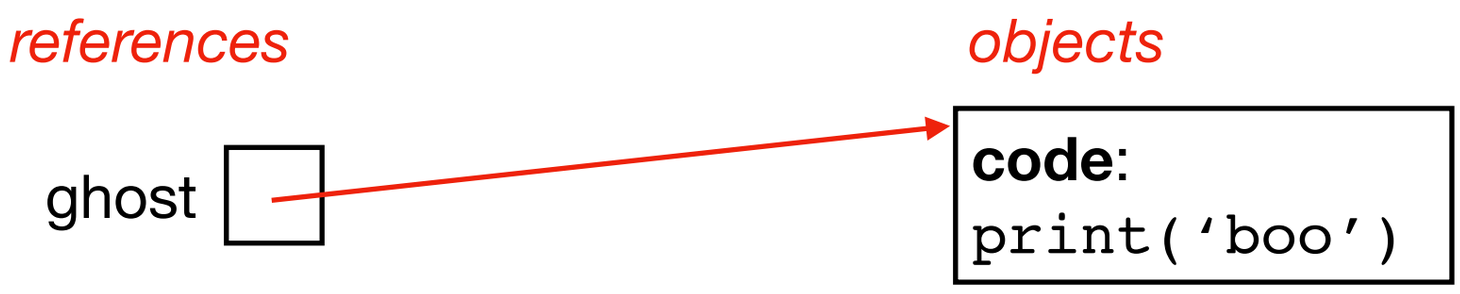
ghost()

when we say f()

- look for a variable named f
- follow the reference to some code
- run that code

---

**State:**



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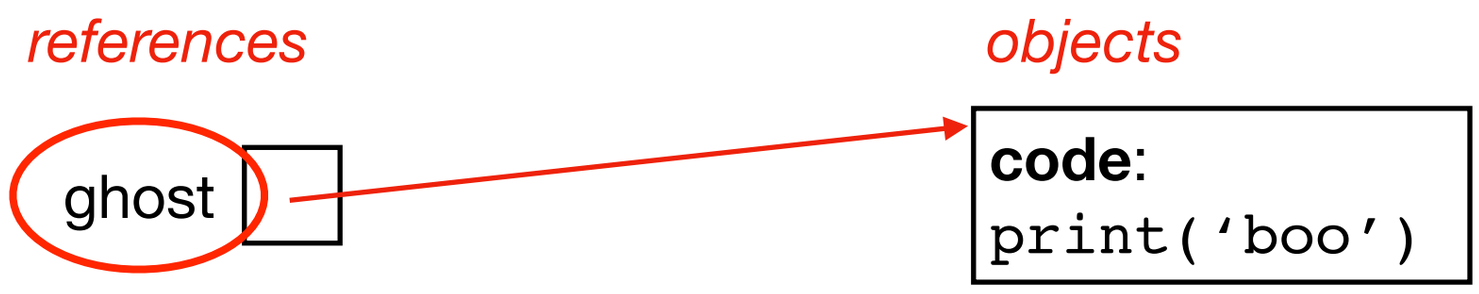

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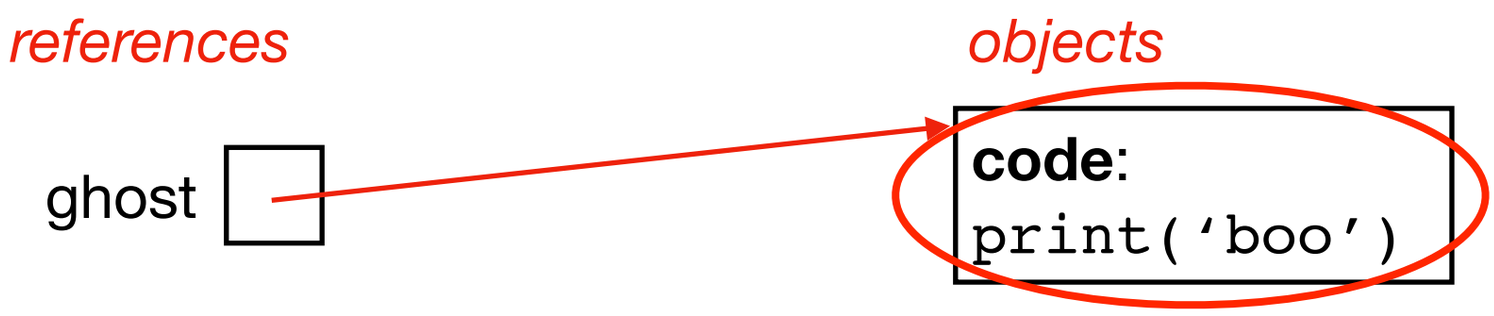

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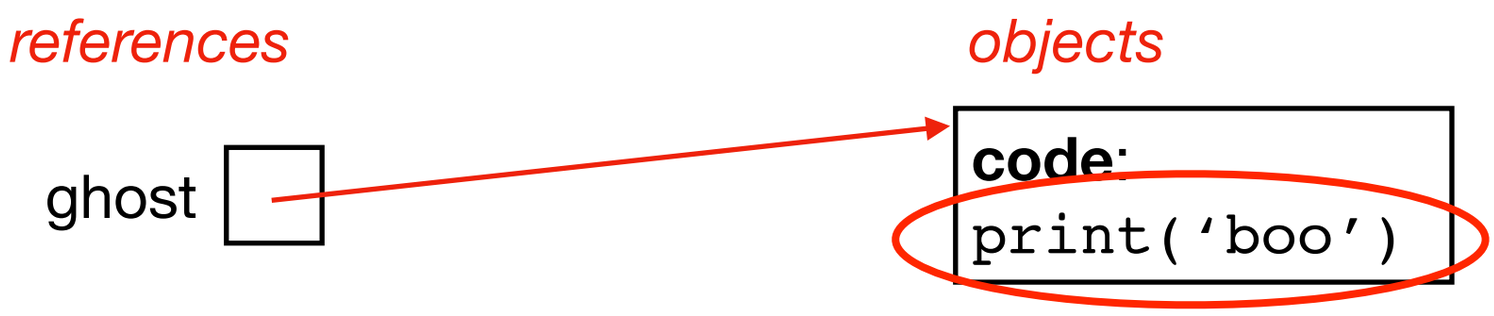

# Python Tutor: Example 1

```
x = ["A", "B", "C"]
y = x

def f(items):
    print(len(items))

f(x)
g = f
g(x)
```

# Python Tutor: Example 2

```
def call_it(my_function):
    print("calling", my_function)
    my_function()

def test():
    print("inside test function")

call_it(test)
```

# Python Tutor: Example 2

```
def call_it(my_function):
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def test():
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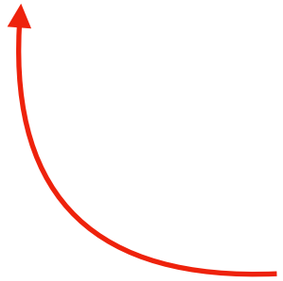
call_it(test)
```



functions like test are sometimes called “callbacks” because we’re asking somebody else’s function to call back to our own code

# Ways to get a reference

**refs to normal objects**

```
def f(z):
    # way 3: param
    print(z)

x = [1,2,3] # way 1: new object
y = x       # way 2: copy ref
f(x)
```

**refs to function objects**

```
# way 1: def
def f():
    print('hi')

def call_me(h):
    # way 3: param
    h()

g = f # way 2: copy ref
call_me(f)
```

# Ways to get a reference

**refs to normal objects**

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Iterators

- what is an iteratable?
- how to read files, with sequences or iterators
- advantages of laziness
- writing your own generators

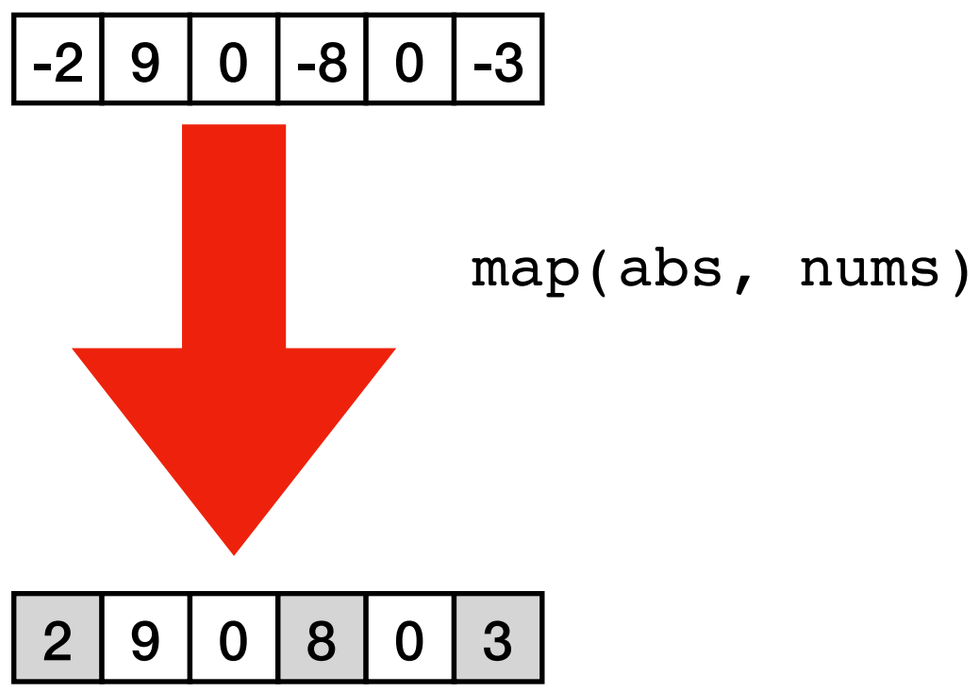
References to functions

- ways to get a reference
- map
- sort

# map function

We often will want to run a function on every item in a list

- input 1: a function
- input 2: a list
- output: list produced by running function on items in input list



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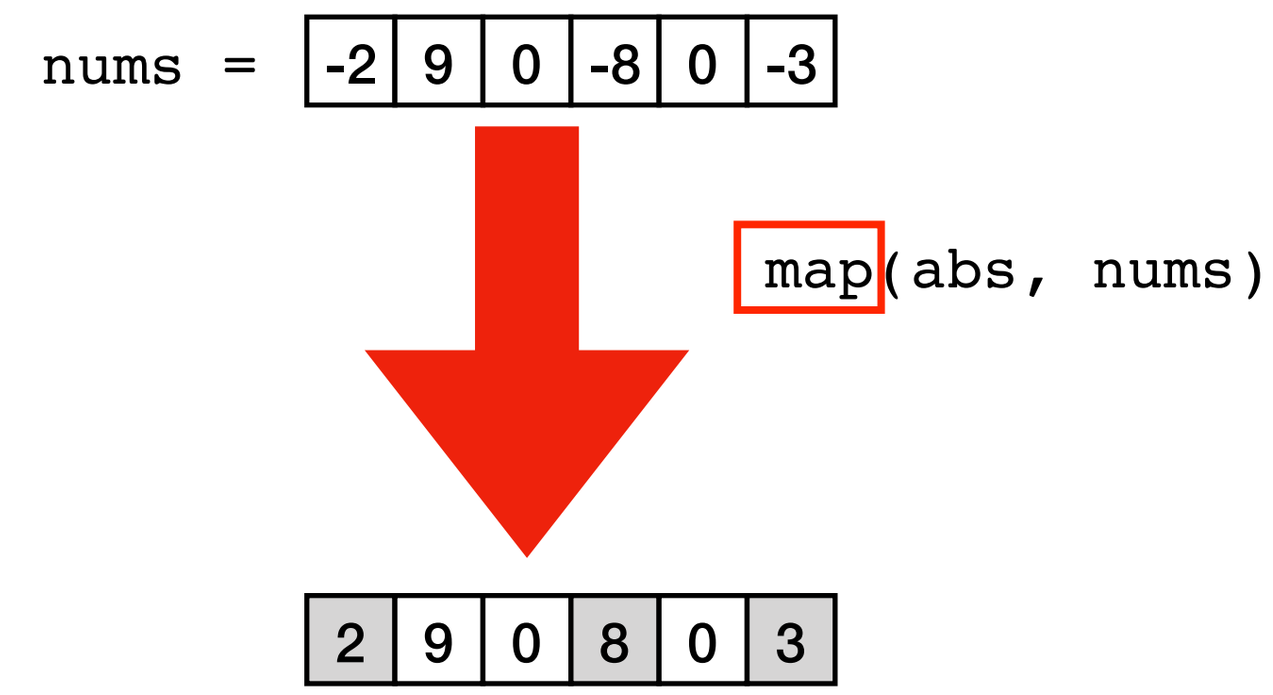

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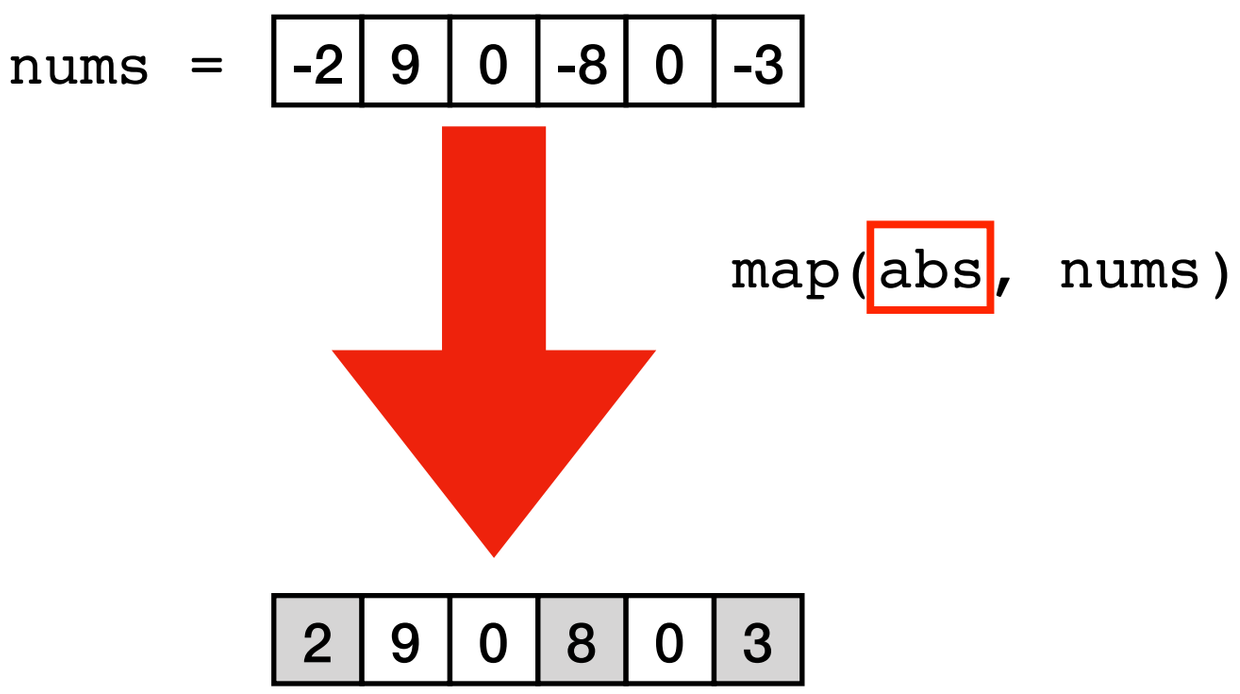

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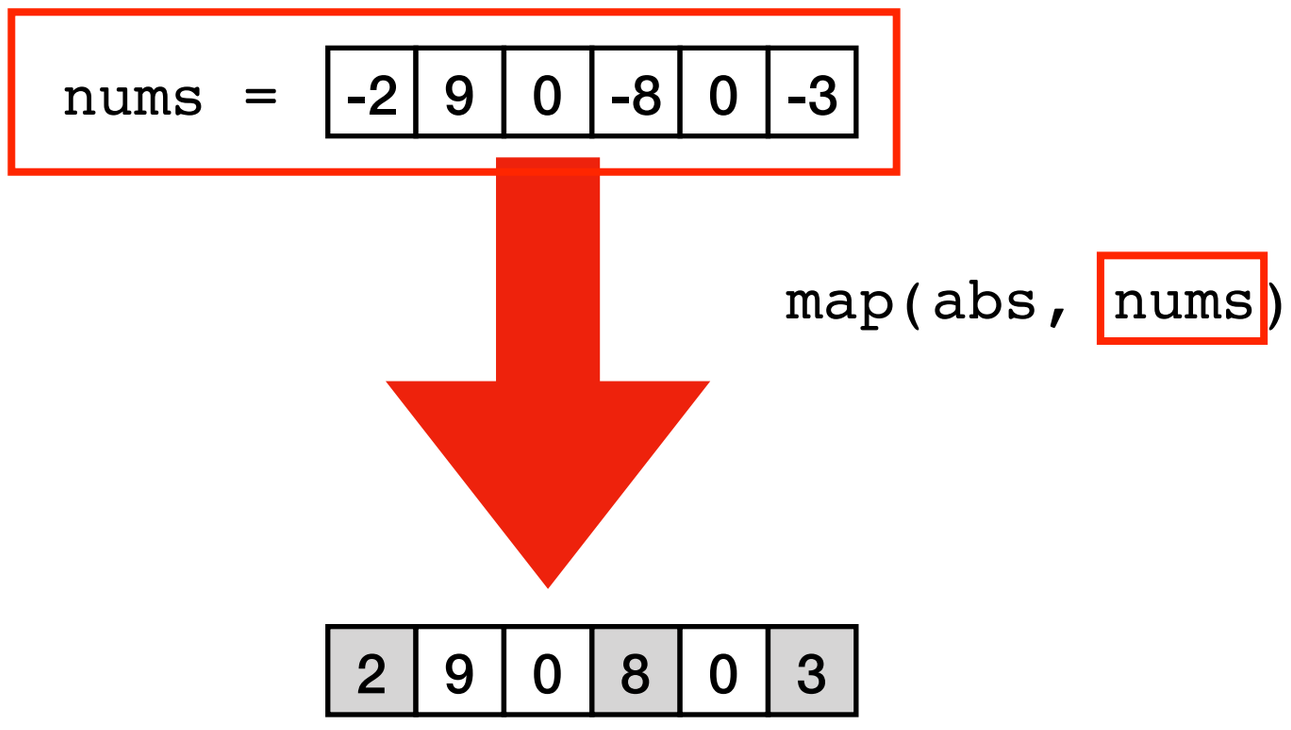

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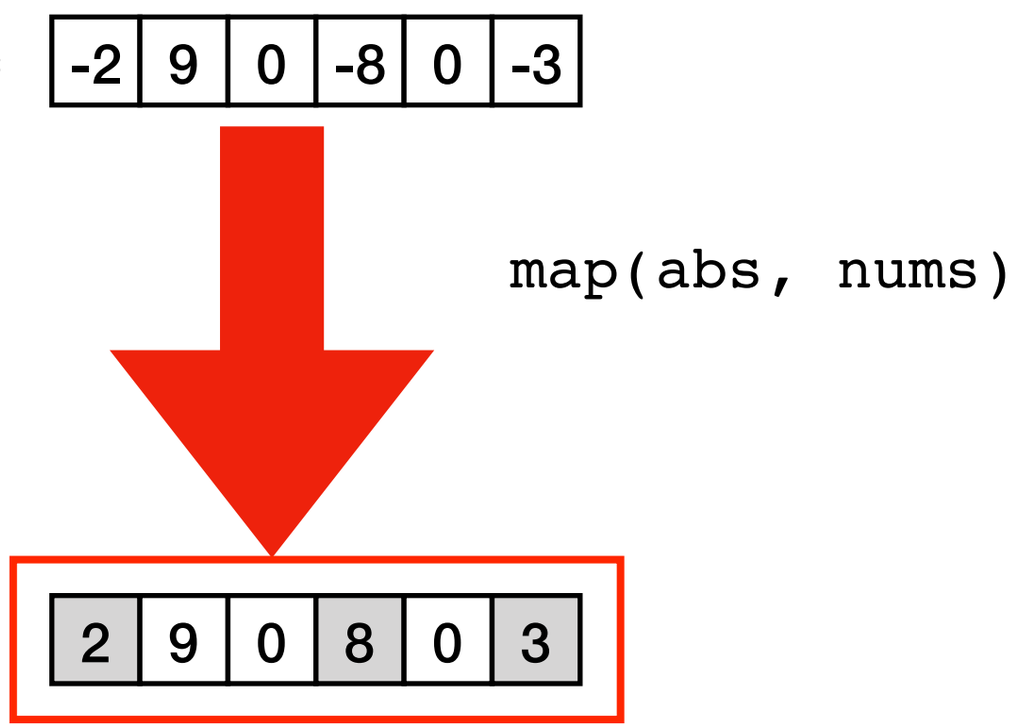

# map code

```
def map(f, items):
    result = []
    for item in items:
        new_item = f(item)
        result.append(new_item)
    return result
```

# map code

```
def map(f, items):
    result = []
    for item in items:
        new_item = f(item)
        result.append(new_item)
    return result
```

```
>>> map(abs, [1, -1])
[1, 1]
>>> map(abs, [0, 8, -9, -5, 10])
[0, 8, 9, 5, 10]
```

**Note:** Python has a built-in map function.
Like this, but returns a generator instead of list.

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# Learning Objectives Today

List of tuples:

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

| | |
|---|---|
| Cindy | Baker |
| Bob | Adams |
| Alice | Clark |

# Learning Objectives Today

List of tuples:

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

| Cindy | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
names.sort()
```

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

| Alice | Clark |
|---|---|
| Bob | Adams |
| Cindy | Baker |

# Learning Objectives Today

List of tuples:

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

| Cindy | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
names.sort()
```

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

| Alice | Clark |
|---|---|
| Bob | Adams |
| Cindy | Baker |

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List of tuples:

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

| Cindy | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

```
names.sort()
```

| Alice | Clark |
|---|---|
| Bob | Adams |
| Cindy | Baker |

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

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

**or by something else?**

# Learning Objectives Today

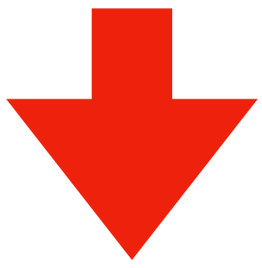
List of tuples:

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

| Cindy | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

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

list(map(extract, names))
```



```
[“Baker”, “Clark”, “Adams”]
```

# Learning Objectives Today

List of tuples:

this is what we want to sort on

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

| | |
|---|---|
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| Bob | Adams |
| Alice | Clark |

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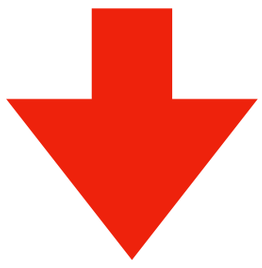

```
[“Baker”, “Clark”, “Adams”]
```

# Learning Objectives Today

List of tuples:

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     (“Alice”, “Clark”),
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]
```

| Cindy | Baker |
|---|---|
| Bob | Adams |
| Alice | Clark |

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

names.sort(key=extract)
```

| Bob | Adams |
|---|---|
| Cindy | Baker |
| Alice | Clark |

# Conclusion

Iterators

- like sequences, with for loops, but without indexing
- a function with yields automatically returns a generator
- a generator is a kind of iterator

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- like sequences, with for loops, but without indexing
- a function with yields automatically returns a generator
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Function references

- three ways to get them: (1) def, (2) assignment, (3) arg passing
- passing a function to a function: callback
- useful for map and sort