short answer,concept
input output question
programming coding: practicing problem

Lecture 3: Advanced Functions

MPCS 51042-2: Python Programming

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Local and Remote-Tracking Branches

- A branch is a pointer to a particular commit
- A local branch points to a commit on your local repo.
  - Changed by local operations like `git commit`
  - Simply named, such as “master”

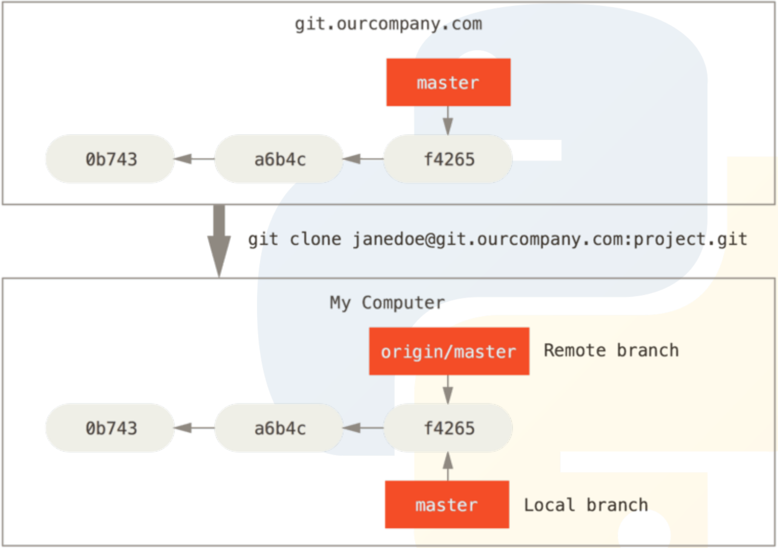
gitlab

- A remote-tracking branch points to a commit on a remote repo.
  - Named with both remote and branch name, such as “origin/master”

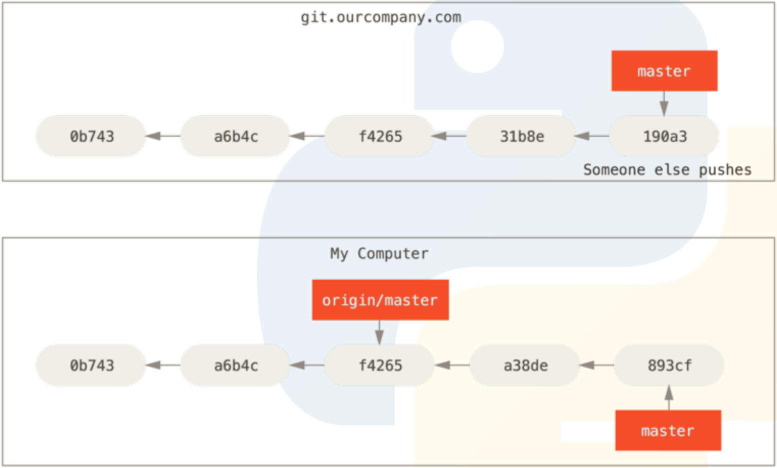
Updating Remote-Tracking Branches

- Your local repo's remote-tracking branches are not automatically updated when the remote itself changes.
- Use `git fetch` to update your remote-tracking branches:
  - `git fetch <remote_name>`: update all remote-tracking branches that point to a given remote
  - `git fetch --all`: update all remote-tracking branches from all remotes
- this does not change your local branches or your working tree.

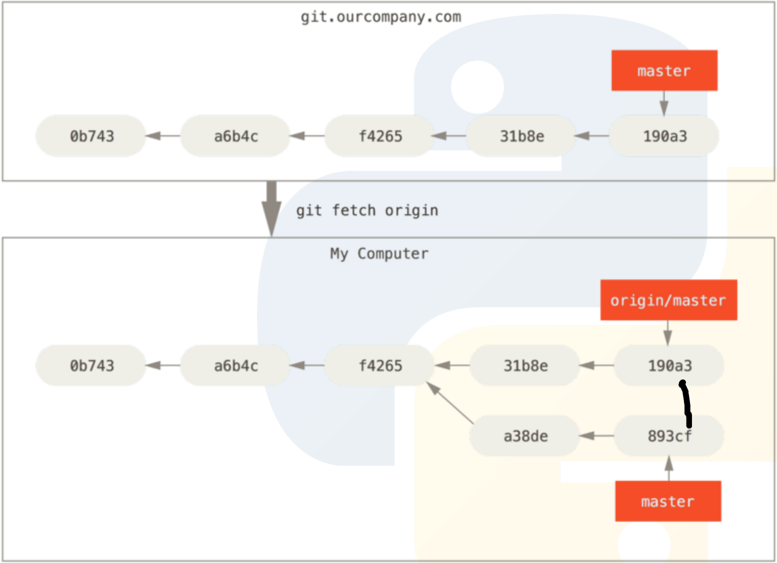
Example: A freshly-cloned repo



Example: Someone else pushes commits to remote



Example: Fetching new commits from remote



Merging Commits from Remote

Two ways to get changes from remote-tracking branch into local branch.

- Fetch and merge:

```
git fetch origin
git merge origin/master
```

- Pull:

```
git pull origin master
```

Can also name other remotes or branches:

```
git pull upstream master
```

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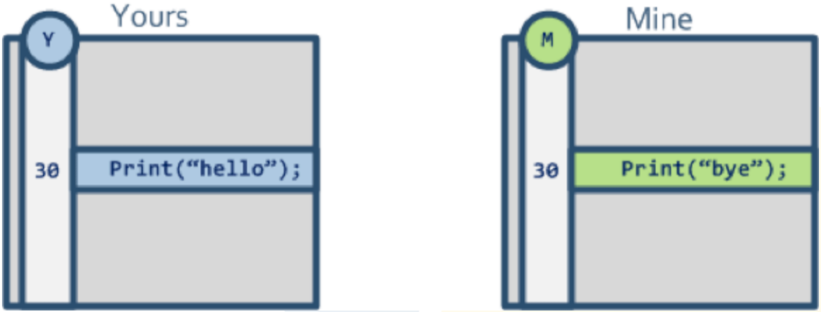
Source

- “Three-way Merging: A Look Under the Hood”: `http://blog.plasticscm.com/2016/02/three-way-merging-look-under-hood.html`

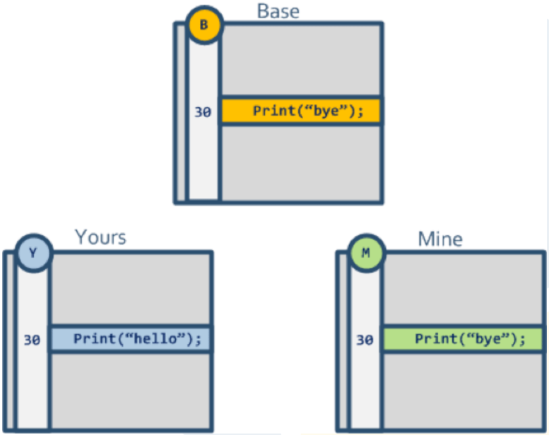
A Two-Way Merge (Hypothetical)



- You and me have different code on line 30
- Not enough info to know whose to keep

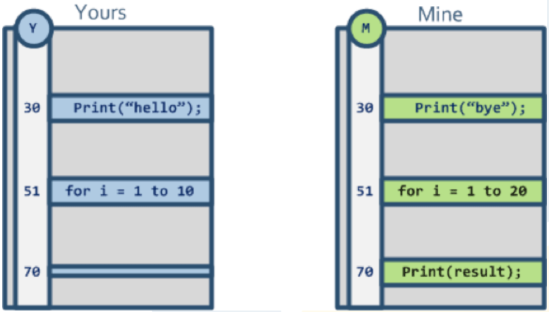
A Three-Way Merge (Actual)

yours is
more recent,
so keep this



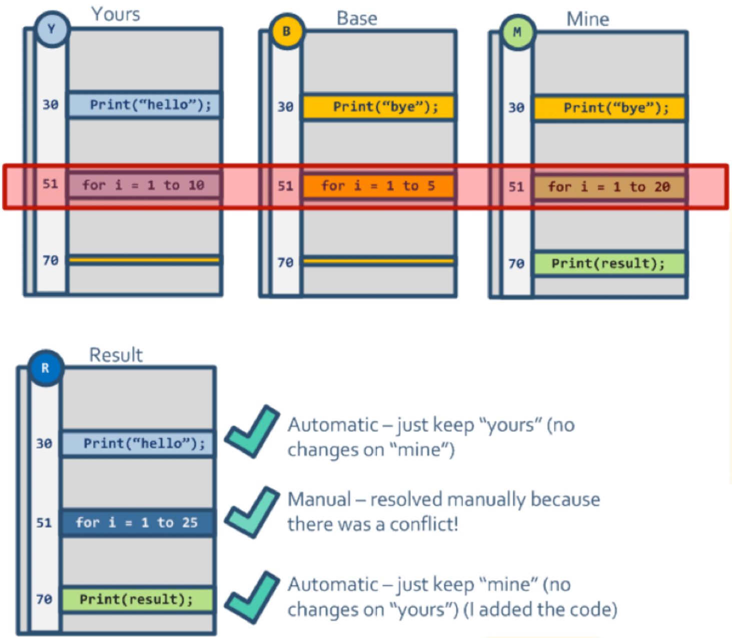
- Compares yours and mine to common ancestor
- Now it's clear that we'll keep your line 30

Multiple Lines in a Three-Way Merge



- Changes are compared and resolved on a line-by-line basis

Automatic and Manual Merging



Resolving Merge Conflicts

- Simplest way is to look in the file itself
- Lines with merge conflict will be marked like this:

```
If you have questions, please
<<<<<<< HEAD
open an issue
=======
ask your question in IRC.
>>>>>>> branch-a
```

edit manually

- For more details:
  - https://help.github.com/en/articles/resolving-a-merge-conflict-using-the-command-line
  - https://www.atlassian.com/git/tutorials/using-branches/merge-conflicts

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Pulling Upstream Changes for Homework

1. Add upstream

```
git remote add upstream git@mit.cs.uchicago.edu:mpcs51042-aut-19/mpcs51042-2-aut-19.git
```

2. Pull upstream changes

```
git pull upstream master
```

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Anonymous Functions

- A `lambda` expression creates and returns a function object.
  - A `def` statement creates a function and assigns it to a name.
  - A `lambda` expression is often not assigned to a name (for example, as an inlined argument to another function).
- A `lambda`'s body is a single expression, not a block of statements.

Example: Custom Sorting

- The `sorted()` function takes an optional argument for custom sorting.
- This argument, `key`, is a function used to obtain the comparison key for each element.

```
>>> ron = dict(skin_color='brown', hair_color='black',
...            eye_color='brown', fav_color='azure')

>>> sorted(ron.items())
[('eye_color', 'brown'), ('fav_color', 'azure'),
('hair_color', 'black'),  ('skin_color', 'brown')]

>>> sorted(ron.items(), key=lambda x: x[1])
[('fav_color', 'azure'), ('hair_color', 'black'),
('skin_color', 'brown'), ('eye_color', 'brown')]
```

sorted by keys

sorted by values

More Lambda Examples

- Sort strings using true alphabetical ordering, rather than "ASCII-betical" ordering
- Show how to make a dict-of-dict-of-lists using defaultdict

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Functional Programming

Functional programming tools apply an operation to every item in an iterable.

- Two built-in functions:
  - `map(function, iterable, ...)`: Applies a general function to every item in the passed iterable. Returns a new iterator for results.
  - `filter(function, iterable)`: Returns all elements for which function is `True`. Result is a new iterator.
- Also provided in `functools` module:
  - `functools.reduce(function, iterable[, initializer])`: Apply function cumulatively and return a single value as the result. Optionally specify the initial value.
- Others in `itertools` module: filterfalse, dropwhile, takewhile, etc.
- Standard operators are expressed as functions in the `operator` module.

Using Map

Works with built-ins:

```
>>> list(map(math.ceil, [1.1, 2.5, 3.01]))
[2, 3, 4]

>>> set(map(str.upper, {'apple', 'Banana', 'CHErry'}))
{'BANANA', 'CHERRY', 'APPLE'}
```

The operator module provides functions for built-in operators

```
>>> from operator import neg
>>> list(map(neg, [1.1, 2.5, 3.01]))
[-1.1, -2.5, -3.01]
```

Using Map, cont.

Great place to use lambdas:

```
>>> tuple(map(lambda x: x+10, [1, 3, 5]))
(11, 13, 15)
```

map function generate iterable object

```
>>> f = lambda s: str.capitalize(s) + " are great!"
>>> set(map(f, {'apples', 'Bananas', 'CHErries'}))
{'Apples are great!', 'Cherries are great!',
'Bananas are great!'}
```

Using Map with Multiple Iterables

Map can use an N-argument function to handle N iterables:

- pow takes 2 arguments; map gives it 2 iterators:

```
>>> list(map(pow, [2, 4, 8], [6, 3, 2]))
[64, 64, 64]
```

- The operator module has functions for binary operators:

```
>>> from operator import mul
>>> list(map(mul, [2, 4, 8], [6, 3, 2]))
[12, 12, 16]
```

- max takes an arbitrary number of args:

```
>>> list(map(max, [1, 7, 24], [5, 1, 0], [2, -20, 100]))
[5, 7, 100]
```

Too Much Work in a Map?

Is this clearer than a for-loop or generator?

```
>>> d = {'dog': 'mammal', 'shark': 'fish',
...       'duck': 'dinosaur'}
>>> joiner = lambda x: str.join(' is a ', x)
>>> list(map(joiner, d.items()))
```

-

Filter

Filter returns all elements for which the test function is true:

```
>>> list(filter(str.isalpha, ["can't", "abc", "2nd"]))
['abc']

>>> list(filter(lambda x: x % 2 == 0, [22, 1, 0, 4.1, 15]))
[22, 0]
```

Reduce

Reduce takes a 2-argument function and applies it cumulatively to the elements in an iterable:

```
>>> from functools import reduce
>>> from operator import add, mul
>>> reduce(mul, [1, 2, 3, 4])
24
```

Takes an optional initializer:

```
>>> reduce(add, [1, 2, 3, 4], 10)
20
```

A user-defined function must take two args:

```
>>> reduce(lambda x, y: -(x+y), [1, 2, 3, 4])
-4
```

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List Comprehensions

A list comprehension will:

- Apply an arbitrary expression (not function) to an iterable.
- Create a list (not an iterator) of results.

Comprehensions can also create dictionaries and sets.

For-Loop vs. Map vs. Comprehension

All of these produce the values [0, 1, 4, 9, 16].

- All of them take the same iterable.
- Map applies a function and returns an iterator.
- Comprehension applies an expression and returns a list.

[expression
for target 1 in iterable1 if condition
for target 2 in iterable 2 if .....]

```
# For loop
L = []
for i in range(5):
    L.append(i ** 2)

# Map (an iterator, not list)
I = map(lambda i: i ** 2, range(5))

# Comprehension
L = [i ** 2 for i in range(5)]
```

Nesting and Conditionals in Comprehensions

cannot use lambda
function here

- Comprehensions can be arbitrarily nested.
  - The first for-loop is outermost.
  - Subsequent for-loops are nested inwards.

```
L = [x+" "+y for x in ('one', 'two') for y in ('fish', 'car')]
#  Returns ['one fish', 'one car', 'two fish', 'two car']
```

- Comprehensions can use conditions to “filter” the iterable:

```
L = [s.upper() for s in ('cat', 1.23, 'dOG', [])
     if isinstance(s, str)]
# Returns ['CAT', 'DOG']
```

Set and Dictionary Comprehensions

- Set comprehensions have the generator syntax:

```
{f(x) for x in iterbl if P(x)}
```

- Dictionary comprehensions have the general syntax:
  - `iterbl` should be an iterable of `(key, value)` pairs.
  - For example, `zip(keys, vals)` produces a suitable result.

```
{f(k): g(v) for (k,v) in iterbl if P(k,v)}
```

Example: Cartesian Product

Write two functions that use a for loop and a comprehension to get the Cartesian Product of two iterables:

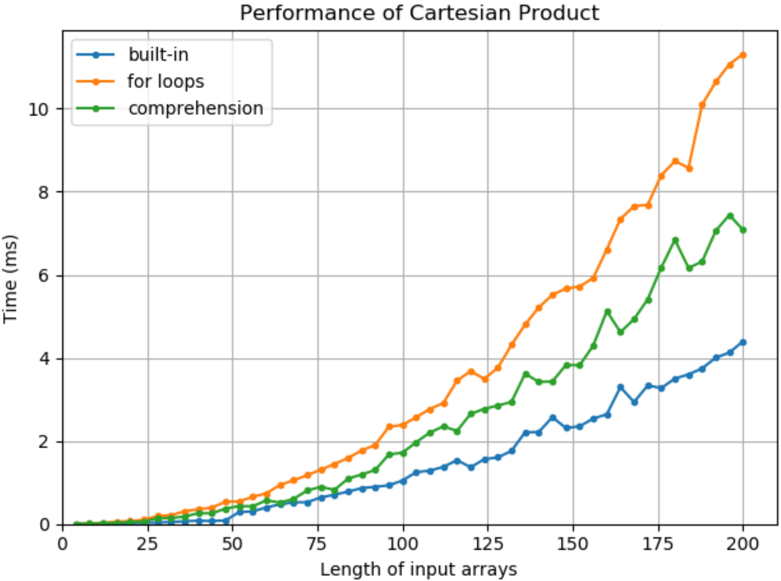
```
>>> compr_cart_product([1, 2, 3], ['A', 'B', 'C'])
[[1, 'A'], [1, 'B'], [1, 'C'], [2, 'A'], [2, 'B'], [2, 'C'],
[3, 'A'], [3, 'B'], [3, 'C']]
```

Example: Cartesian Product, cont.

```
def for_loop_cart_product(list1, list2):
    results = []
    for i in list1:
        for j in list2:
            results.append([i, j])
    return results

def compr_cart_product(list1, list2):
    return [[i, j] for i in list1 for j in list2]
```

Performance of Cartesian Products



More Comprehension Examples

- Split a string of text into a list of sentences.
- Split a string of text into a nested list of sentences and words
-

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Generator Functions

- Generator functions provide another way to retain state.
  - They suspend their state between multiple calls.
  - They are compiled into generator objects, which are a kind of iterator.
- They are written to yield a value to the caller, then resume execution.
- Returning or exiting the function terminates the execution.

Generating Fibonacci Numbers

- This yields Fibonacci numbers one at a time.
- Each iteration stops and resumes at `yield`.
- The iteration ends when the function exits.

```
def fib(end):
    last = 0
    curr = 1
    for i in range(end):
        yield curr
        nxt = curr + last
        last = curr
        curr = nxt

for i in fib(5):
    print(i, end=": ")  # prints 1: 2: 3: 5: 8:
```

Non-terminating Fibonaccis

Sometimes it is useful to make a non-terminating generator:

```
def fib():
    last = 0
    curr = 1
    while True:                          # An infinite loop
        yield curr                      stop and returns curr
        nxt = curr + last
        last = curr
        curr = nxt

f = fib()
for i in range(5):
    print(next(f), end=": ")     # Calling next() manually yields

print("\nLet's take a break...")

for i in range(5):
    print(next(f), end=": ")     # Begin yielding again
```

Other Ways to Work with Iterators

- The `itertools` module has efficient functions for iterables.
- E.g., `islice` returns selected elements from an iterable (like slicing).

```
def fib():
    last = 0
    curr = 1
    while True:
        yield curr
        nxt = curr + last
        last = curr
        curr = nxt

from itertools import islice
for i in islice(fib(), 2, 6):    # prints 2: 3: 5: 8:
    print(i, end=": ")
```

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Generator Statements

- Generator statements produce generator objects using syntax similar to comprehensions.
- Here, both `x` and `y` are generator objects that yield [-5, 10, 15, -20]
- The generator expression is more concise here. However, for more complicated cases, a generator function can retain much more state information and have more internal logic (recall earlier examples in lecture).

```python
def mygen(L):
    for i in L:
        yield i * 5

x = mygen([-1, 2, 3, -4])

y = (i * 5 for i in [-1, 2, 3, -4])
```

Generator Statements vs. Comprehensions

- Biggest difference: generator expressions construct them one-at-a-time, but comprehensions construct results all at once.
- This often introduces space/time trade-off when consuming entire iterable:
  - Generator expressions often use less memory than the equivalent comprehension.
  - Comprehensions often run faster over all iterations.
- If the entire iterable will not be necessarily be consumed, generators can also be a better choice.

don't know how much data to use

Generator Statements vs. Map

Clarity and conciseness depends on the situation:

```
L = [-1, 2, 3, -4]

# Generator expression may be clearer.
x = map(lambda i: i*10, L)
y = (i*10 for i in L)

# Map may be clearer.
x = map(abs, L)
y = (abs(i) for i in L)
```

Generator Statements vs. Filter

- Conditionals are allowed in generator expressions (like in comprehensions)
- This allows generator expressions to emulate `filter`

```
L = ['at', 'cat', 'scat']

x = filter(lambda s: len(s) > 2, L)

y = (s for s in L if len(s) > 2)
```

Generator Statements vs. Map/Filter

Generator expressions are often more concise than combining `map` and `filter`

```
L = ['at', 'cat', 'scat']

x = map(str.upper, filter(lambda s: len(s) > 2, L))
print(list(x))

y = (s.upper() for s in L if len(s) > 2)
print(list(y))
```

generator: ()
comprehension:[]

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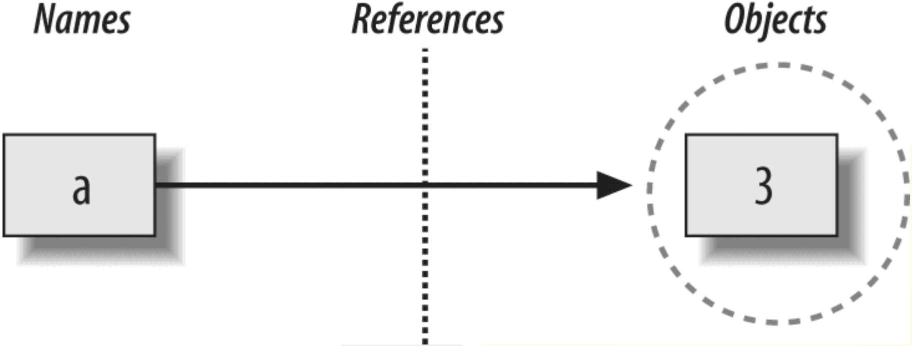
Names, References, and Objects



A name (the variable) refers to an object (the data itself).

Assignment vs. Reference

An assignment does one of the following:

- Creates a new name that refers to a new/existing object.
- Makes an existing name refer to a different object.

```
L = [1, 2, 3]     # Creates a new name, L, and new object
L = [4, 5, 6]     # L points to a different object
```

A reference looks-up a name and retrieves the object.

```
print(L[0])       # Finds the object that L[0] points to
```

Question: Is in-place modification an assignment or a reference?

```
L.append(99)
```

reference: look up
the object and
modify

The 3 Scopes: Global, Enclosing, and Local

- By default, a variable's scope is determined by where it was first assigned.
- Relative to a given function definition, there are three scopes:
  - Global variable: assigned inside the surrounding module. There are no variables that span multiple modules.
  - Nonlocal variable: assigned in a surrounding functions. This extends to arbitrarily-many nested functions.
  - Local variable: assigned inside the given function.
- Respective to `inner_func`, these `X` are all different instances:

```
X = 'global_to_inner_func'
def outer_func():
    X = 'nonlocal_to_inner_func'
    def inner_func():
        X = 'local_to_inner_func'
```

all Xs are different

Name Resolution

For variable references, Python searches in this order:

- The local scope
- The enclosing scope
- The global scope
- Built-in names

For variable assignements:

- If the variable is unqualified, a local variable is always created or changed.
- If the variable is qualified with the `global` or `nonlocal` keywords, then the global/nonlocal variable is changed.

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Global Reference

In `adder()`, when `x` is referenced, it is found in the global scope.

```python
x = 8                  # Creates a global variable

def adder(y):
    return x + y       # Finds x in global scope

print(adder(2))        # Prints 10
```

Question: What is the scope of `y`?

local

Local Assignment and Reference

Now there are multiple instances of `x`:

- When `x` is referenced in `adder()`, the local variable is found.
- When `x` is referenced in global scope, the global variable is found.

```python
x = 99

def adder(y):
    x = 1           # Creates local instance of x
    return x + y    # Finds x in local scope

print(adder(2))     # Prints 3
print(x)            # Prints 99, since global x is unchanged
```

Global Assignment: The global Namespace Declaration

If we want to assign a variable in the global scope, we use the `global` namespace declaration.

```
x = 99

def adder(y):
    global x
    x = 1           # Re-assigns global x
    return x + y    # Finds x in in global scope

print(adder(2))     # Prints 3
print(x)            # Prints 1, since global x was reassigned
```

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Enclosing (Nonlocal) References

When `x` is referenced inside `inner()`, it is found in the enclosing scope.

```python
x = 99              # x is global

def outer():
    x = 1           # x is local to outer()
    def inner():
        print(x)    # Gets x from enclosing scope
    inner()

outer()             # Prints "1"
```

Nonlocal Arguments in Outer Function

Arguments to the outer function are nonlocal to the inner.

```
def outer(base):
    exp = 2                      # Both base and exp are local
    def inner():
        print(base ** exp)   # Both base and exp are nonlocal
    inner()

outer(5)                         # Prints "25"
```

5 is nonlocal

Closures (or Factory Functions)

- A function object retains values in its nonlocal scope.
- You can use this to generate functions that retain state.

```
def outer(base):
    def inner(exp):
        print(base ** exp) # Base is nonlocal, exp is local
    return inner
five_pow = outer(base=5)    # base=5 is in five_pow's closure
five_pow(exp=2)             # Prints "25"
five_pow(exp=3)             # Prints "125"
```

when called outer, create new instance of inner function

then 5 here is a five_pow's closure

Independent States

Each function object gets a separate scope, even when created by the same factory.

```
def outer(base):
    def inner(exp):
        print(base ** exp)  # Base is nonlocal, exp is local
    return inner

five_pow = outer(base=5)    # base=5 is in five_pow's closure
five_pow(exp=2)             # Prints "25"

ten_pow = outer(base=10)    # base=10 is in new closure
ten_pow(exp=2)              # Prints "100"

five_pow(exp=3)             # Still has base=5 in closure
```

Nonlocal Assignments: The `nonlocal` Declaration

- Previously, we were referencing a nonlocal variable.
- To reassign a nonlocal variable, we must declare it as `nonlocal`.

```
def outer(base):
    call_count = 0
    def inner(exp):
        nonlocal call_count
        call_count += 1
        print("ans: {}, call count: {}".format(
                base**exp, call_count))
    return inner

five_pow = outer(base=5)
five_pow(exp=2)                # ans: 25, call count: 1

ten_pow = outer(base=10)
ten_pow(exp=2)                 # ans: 100, call count: 1

five_pow(exp=3)                # ans: 125, call count: 2
```

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Function Wrappers

A function wrapper takes one function and returns another:

```
def counter(func):                                  # Pass a callable
    call_count = 0
    def inner(*args, **kwargs):
        nonlocal call_count
        call_count += 1
        print("call count: {}".format(call_count))
        return func(*args, **kwargs)                # Returns result
    return inner

pow_count = counter(pow)
x = pow_count(5, 2)          # Returns 25,  prints "call count: 1"
x = pow_count(5, 3)          # Returns 125, prints "call count: 2"

min_count = counter(min)
y = min_count([3, 5, 1, 9]) # Returns 1, prints "call count: 1"
y = min_count(3, 5, 1, 9)   # Returns 1, prints "call count: 2"
```

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Function Attributes

- Function attributes are another way to maintain state.
- The attribute is nonlocal in the scope of `inner`.
- The attribute is accessible to the caller as an instance attribute.

```
def counter(func):                                  # Pass a callable
    def inner(*args, **kwargs):
        inner.call_count += 1
        print("call count: {}".format(inner.call_count))
        return func(*args, **kwargs)                # Returns result
    inner.call_count = 0
    return inner

pow_count = counter(pow)
x = pow_count(5, 2)          # Returns 25,  prints "call count: 1"
x = pow_count(5, 3)          # Returns 125, prints "call count: 2"
c = pow_count.call_count     # Accessible to caller's scope
print(c)
```