Functional Abstraction

Announcements

Office Hours: You Should Go!

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https://cs61a.org/office-hours/

Partial Function Application & Currying

Returning a Function to Wait for More Arguments

```
def make_adder(n):          def add(n, k):
    def adder(k):
        return n + k            return n + k
    return adder
```

Identical code gives identical behavior

make_adder(3) returns a function that bundles together two things:

- The function's behavior: `return n + k`
- The value of n: 3

add(3, 4) applies addition to the arguments 3 and 4, while
make_adder(3) *partially applies* addition, but is still waiting for k.

Function Currying

```
def make_adder(n):          def add(n, k):
    def adder(k):
        return n + k            return n + k
    return adder
```

Identical code gives identical behavior

Curry: Transform a multi-argument function into a single-argument, higher-order function with the same behavior.

```
>>> make_adder(2)(3)
5
>>> add(2, 3)
5
```

(Demo)

Lambda Function Environments

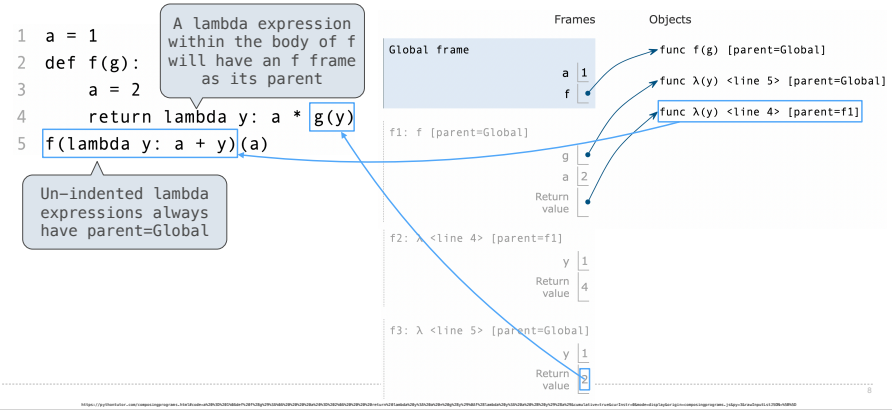
Environment Diagrams with Lambda

A lambda function's parent is the current frame in which the lambda expression is evaluated

```
1 a = 1
2 def f(g):
3     a = 2
4     return lambda y: a * g(y)
5 f(lambda y: a + y)(a)
```

A lambda expression within the body of f will have an f frame as its parent

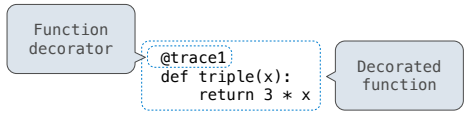
Un-indented lambda expressions always have parent=Global



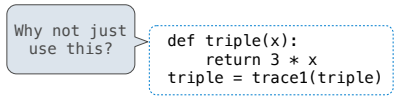
Decorators

Function Decorators

(Demo)



is identical to



Return

Return Statements

A return statement completes the evaluation of a call expression and provides its value:

f(x) for user-defined function f: switch to a new environment; execute f's body

return statement within f: switch back to the previous environment; f(x) now has a value

Only one return statement is ever executed while executing the body of a function

```
def end(n, d):
    """Print the final digits of n in reverse order until d is found.

    >>> end(34567, 5)
    7
    6
    5
    """
    while n > 0:
        last, n = n % 10, n // 10
        print(last)
        if d == last:
            return None
```

(Demo)

Designing Functions

Describing Functions

A function's *domain* is the set of all inputs it might possibly take as arguments.

A function's *range* is the set of output values it might possibly return.

A pure function's *behavior* is the relationship it creates between input and output.

```
def square(x):
    """Return X * X."""
```

x is a number

square returns a non-negative real number

square returns the square of x

Abstraction

Functional Abstractions

```
def square(x):
    return mul(x, x)
```

```
def sum_squares(x, y):
    return square(x) + square(y)
```

What does sum_squares need to know about square?

- Square takes one argument. **Yes**
- Square computes the square of a number. **Yes**
- Square computes the square by calling mul. **No**

```
def square(x):
    return pow(x, 2)
```

```
def square(x):
    return mul(x, x-1) + x
```

If the name "square" were bound to a built-in function, sum_squares would still have the same behavior.

Choosing Names

Names typically don't matter for correctness

but

they matter a lot for composition

From:	To:
true_false	rolled_a_one
d	dice
helper	take_turn
my_int	num_rolls
l, I, O	k, i, m

Names should convey the meaning or purpose of the values to which they are bound.

The type of value bound to the name is best documented in a function's docstring.

Function names typically convey their effect (**print**), their behavior (**triple**), or the value returned (**abs**).

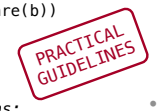
Which Values Deserve a Name

Reasons to add a new name

Repeated compound expressions:

```
if sqrt(square(a) + square(b)) > 1:
    x = x + sqrt(square(a) + square(b))
```

```
hypotenuse = sqrt(square(a) + square(b))
if hypotenuse > 1:
    x = x + hypotenuse
```



Meaningful parts of complex expressions:

```
x1 = (-b + sqrt(square(b) - 4 * a * c)) / (2 * a)
```

```
discriminant = square(b) - 4 * a * c
x1 = (-b + sqrt(discriminant)) / (2 * a)
```

More Naming Tips

- Names can be long if they help document your code:

```
average_age = average(age, students)
```

is preferable to

```
# Compute average age of students
aa = avg(a, st)
```

- Names can be short if they represent generic quantities: counts, arbitrary functions, arguments to mathematical operations, etc.

```
n, k, i - Usually integers
x, y, z - Usually real numbers
f, g, h - Usually functions
```


Errors & Tracebacks

Taxonomy of Errors

Syntax Errors	Detected by the Python interpreter (or editor) before the program executes
Runtime Errors	Detected by the Python interpreter while the program executes
Logic & Behavior Errors	Not detected by the Python interpreter; what tests are for

(Demo)