Announcements

- Homework
  - If you haven't gotten HW4 in yet, get it finished up! I'm around all afternoon today if you have any last little questions.
  - HW5 should be posted.
- I'm trying to get some grade reports generated this week so you can know where you are sitting at in the class currently.
  - I'll send out a blast on Campuswire when that happens
- Polling: `rembold-class.ddns.net`

Review Question

What would be the final printed value of the code to the right?

A) 50
B) 12
C) 10
D) This code would error out

```
def func(a, b=5, c=True):
    if c:
        return a + b
    else:
        return a * b

b = 2
print(func(10,False))
```

Functional Communication

- We've already mentioned using comments to communicate important ideas in your code to readers
- Communication even more important with the introduction of functions
  - What does this function even do?
  - What types of values can I pass into it?
  - What types of values does it return?
  - Are there any restrictions or qualifications about what can be input or output?
- Supposedly, all of this can be gleaned from the code, but it makes far more sense to present it all upfront
  - Introducing docstrings!

What's up doc?

- A docstring (or specification) is like an elaborate comment at the start of a function
- Is surrounded in triple quotes to inform the interpreter

```
def important_function(a,b,c):
    """ This is a docstring yo! """
    <code here>
```

Tis Binding

- Contract between function writer and function users (even if they are the same person!)
  - What does the function do in broad terms?
  - Assumptions:
    - What variable types are allowed as inputs?
    - Are there any restrictions or restraints on those input parameters?
  - Guarantees:
    - What will the program return under potential conditions?
    - How accurate will answers be?

Specific Benefits

- Teamwork
  - Individual team-members can work on different functions from the same program
  - Good specifications let them know that everything will work when they bring it all together
- Testing
  - Good specifications state exactly how a function should operate
  - Makes it easy to write small tests to ensure than everything is working as intended
  - Writing a few short tests early can save lots of time later

Functional Summary

- Functions are all about providing two main things:
  - Decomposition
    - Allows us to break a program into smaller chunks
    - Makes troubleshooting more efficient
    - Can reuse chunks of code in different settings
  - Abstraction
    - Hides details that are not currently relevant to the problem at hand
    - Let's us focus only on what is important

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- Programatically: a technique of writing a function which *calls itself* within the body of the function.
  - We do NOT want infinite recursion
    - Need 1 or more base cases that we can solve without recursion

Looping vs Recursion

Example

It can be illustrative to look at a very simple example of how a looping algorithm compares to a recursive algorithm.
Take the case of multiplication, where multiplying a value A by B is the same as "adding A to itself B"

$$A \times B = A_1 + A_2 + A_3 + \cdots + A_B$$

How would we approach this using both looping and recursion?

The Looping Case

- Define a variable (often called a state variable to keep track of the current state of the multiplication and which gets updated each iteration
- Loop through the necessary number of iterations, updating the state variable each time

```
def mult_w_loop(A, B):
    total = 0
    for i in range(B):
        total += A
    return total
```

The Recursive Case

- Need a Recursive Step
  - How to reduce the problem to a simpler/smaller version of the same problem?

$$A \times B = A + \underbrace{A + A + A + \cdots + A}_{B-1}$$

$$A \times B = A + A \times (B - 1)$$

- Need a Base Case
  - When $B = 1$, $A \times B = A$

```
def mult_w_rec(A,B):
    if B == 1:
        return A
    else:
        return A + mult_w_rec(A, B-1)
```

Example!

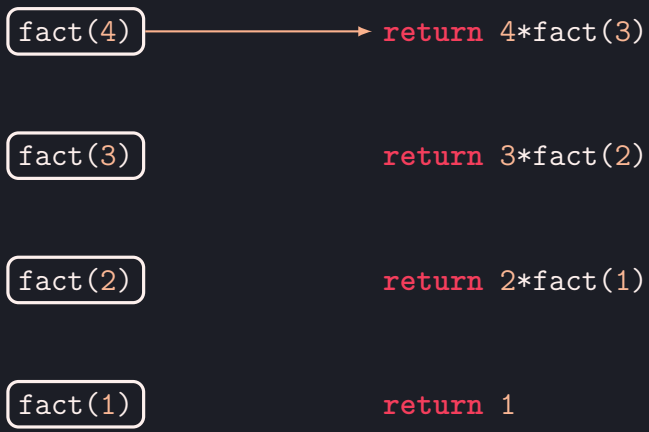
Example

The factorial of a number is defined as the product of all the positive integers equal to or smaller than that number. In variable form, this would look like:

$$n! = n \times (n-1) \times (n-2) \times \cdots \times 1$$

Write a recursive function to return the factorial of any provided positive integer.

Factorial in Pictures



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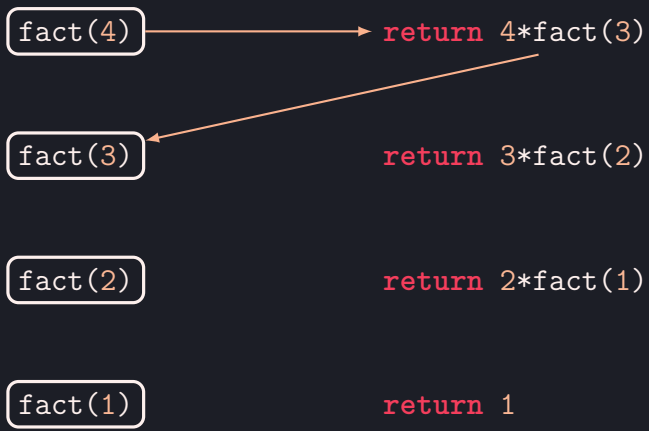
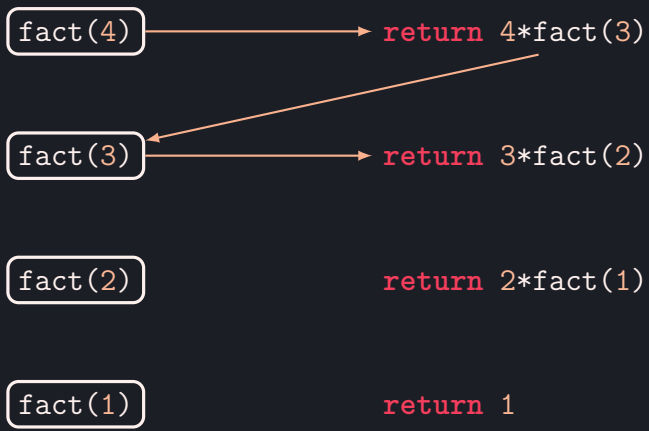


Factorial in Pictures



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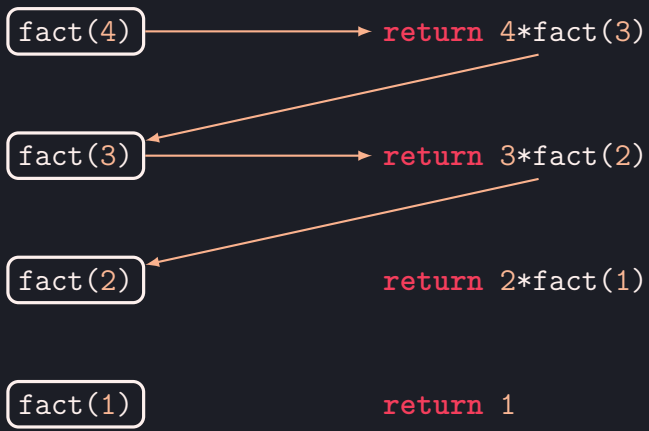

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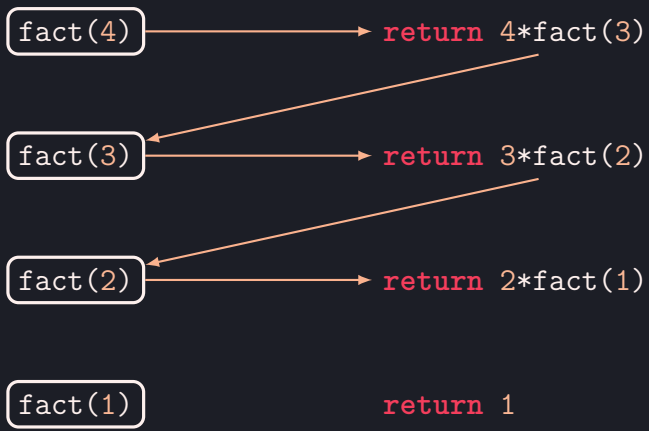

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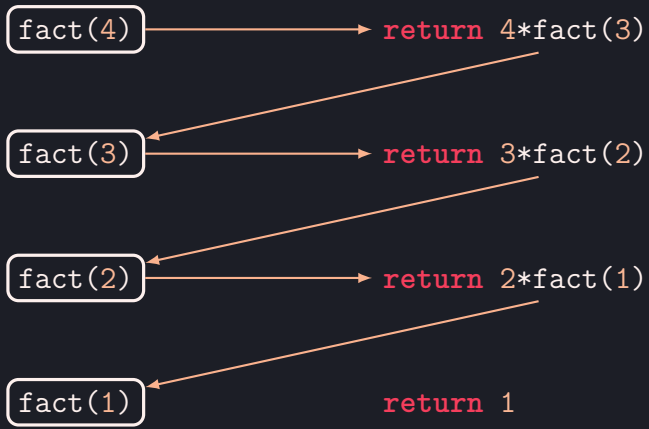

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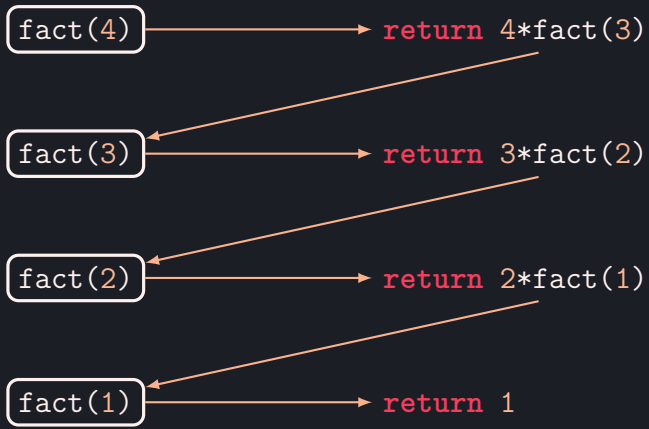

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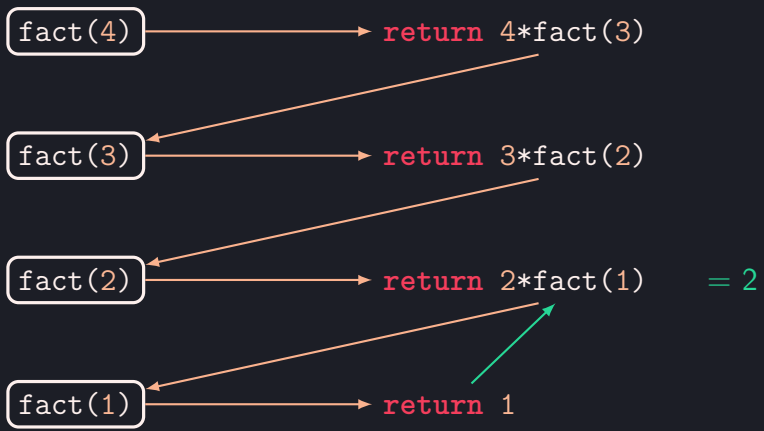

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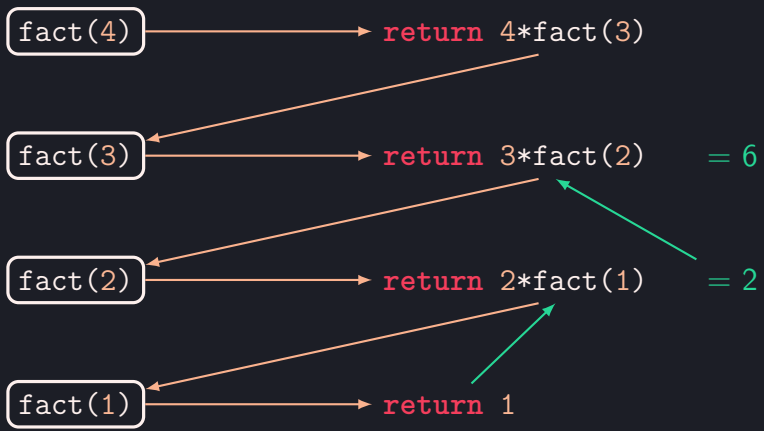

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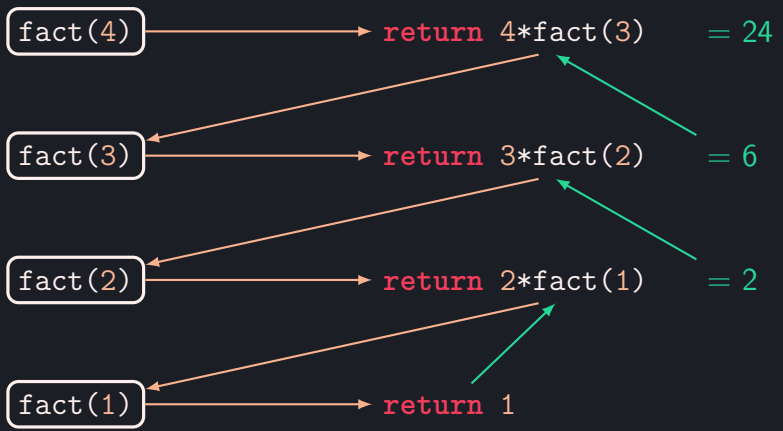

Some Observations

- Each call of the function (even the same function) *creates its own scope*.
- Variable values defined in a particular scope are not changed by further recursive calls
- Once a function returns its value, the flow of control passes back to the previous scope

Iteration vs Recursion

```
def fact_iter(n):
  prod = 1
  for i in range(1,n+1):
    prod *= i
  return prod
```

```
def fact_rec(n):
  if n == 1:
    return 1
  else:
    return n * fact_rec(n)
```

- Recursion may be simpler or more intuitive in some cases
- Recursion might be more efficient from a programmer's POV
- Recursion may not be efficient at all from a computer's POV