Lecture 9: Abstraction, Decomposition, Functions

Comp 102 (sec: A,B)

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Recap

So far....

- We've seen **program construction** i.e **building blocks**
  - Data types, Expressions
  - Conditions, Loops

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- We've seen **program construction** i.e **building blocks**
  - Data types, Expressions
  - Conditions, Loops
- That's **ALL** you need to write **any program**
- But writing **LARGE** programs is a completely different story

Now we'll ...

- See how to **organize** and **reuse** these building blocks

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- See how to **organize** and **reuse** these building blocks
- Talk about ways of doing that using:
  - **Abstraction**
  - **Decomposition**
- Learn about Python **Functions**

Example: **The Smartphone**

A black box, and can be viewed in terms of:

- its inputs
- its outputs
- how outputs are related to inputs, without any knowledge of its internal workings
- implementation is "opaque" (or **black**)

The Smartphone Abstraction

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  - We **don't need to know how something works** in order to know how to use it
- User **does know the interface**
  - Device converts a sequence of screen touches and sounds into expected useful functionality
- Know **relationship** between input and output

Abstraction

- **Hiding** the **details** of how something works
- **Showing** only **essential** parts
- **Simplifing** the **complexity** of a system

Abstraction

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- **Showing** only **essential** parts
- **Simplifing** the **complexity** of a system

Most of the things in real life like Smartphone, Computer, Car, etc. are all examples of **Abstraction**

Abstraction enables **Decomposition**

- Breaking down a complex problem into **smaller, more manageable** parts
- Solving each part **separately**
- Combining the solutions to get the **final solution**

Big Idea

Apply **Abstraction** *(put in a black box)* and **Decomposition** *(split into self-contained parts)* to **Programming**

Abstraction

Hide Details with Abstraction

- In programming, want to think of piece of code as **black box**
  - **Hide tedious coding details** from the user
  - **Reuse** black box at different parts in the code (no copy/pasting!)

Hide Details with Abstraction

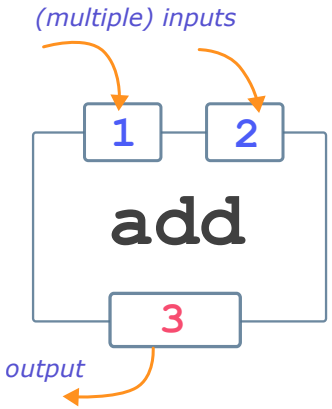
- In programming, want to think of piece of code as **black box**
  - **Hide tedious coding details** from the user
  - **Reuse** black box at different parts in the code (no copy/pasting!)
- **Coder creates details**, and designs interface
- **User does not need or want** to see details

Achieve **Abstraction** with a **Function**

Function lets us capture code in a **black box**

```
add(1,2)
len('comp 102')
max(5,1,4,3)
round(2.4)
```

Function as a Black Box



Creating Function Objects

```
1 def is_even(i):
2     """
3     input: i, a positive int
4     returns True if i is even, otherwise False
5     """
6     if i%2 == 0:
7         return True
8     else:
9         return False
```

Creating Function Objects

keyword

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Creating Function Objects

keyword

name

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Creating Function Objects

keyword name parameters

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```

Creating Function Objects

keyword

name

parameters

doc string

```
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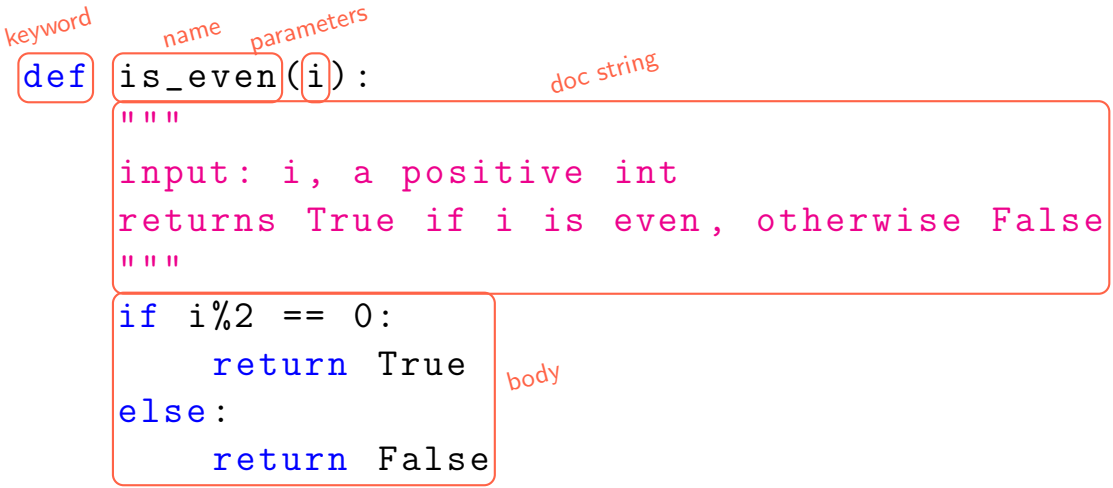
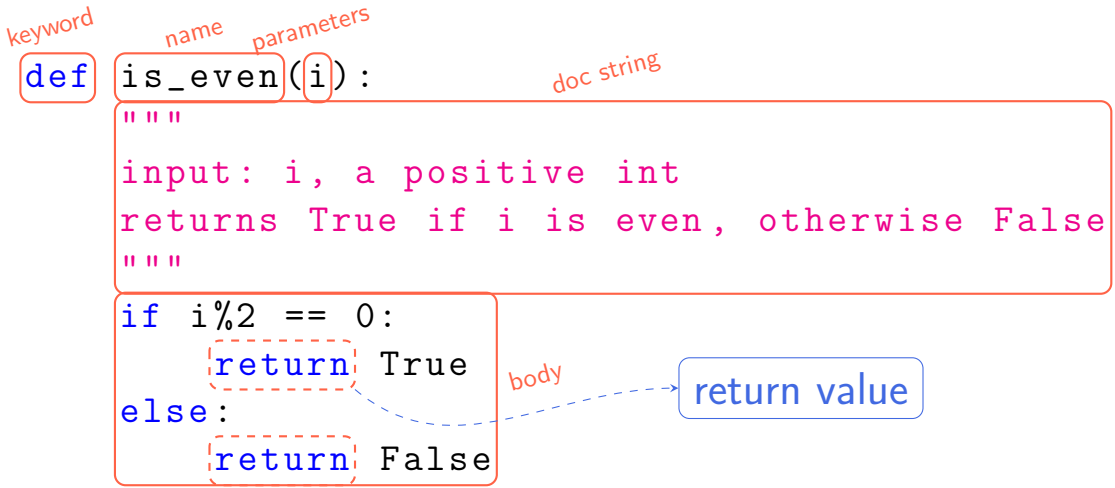
Creating Function Objects



Creating Function Objects



Creating Function Objects

- Can you make the code **cleaner**?
  - `i % 2` is a Boolean that evaluates to `True`/`False` already

```
1 def is_even( i ):
2     """
3     Input: i, a positive int
4     Returns True if i is even, otherwise False
5     """
6     return i%2 == 0
```

`print` vs `return`: They Are NOT the Same!

Version 1: `print`

```
def is_even_v1(i):
    print(i%2 == 0)
```

Prints to console, gives back `None`

Version 2: `return`

```
def is_even_v2(i):
    return i%2 == 0
```

Sends value back to caller

print vs return: They Are NOT the Same!

Version 1: `print`

```
def is_even_v1(i):
    print(i%2 == 0)
```

Prints to console, gives back `None`

Version 2: `return`

```
def is_even_v2(i):
    return i%2 == 0
```

Sends value back to caller

```
a = is_even_v1(3)    # a is None
b = is_even_v2(3)    # b is False
```

print vs return: They Are NOT the Same!

Version 1: print

```
def is_even_v1(i):
    print(i%2 == 0)
```

Prints to console, gives back None

Version 2: return

```
def is_even_v2(i):
    return i%2 == 0
```

Sends value back to caller

```
a = is_even_v1(3)    # a is None
b = is_even_v2(3)    # b is False
```

a holds None

b holds False

What Happens Without return?

```
1 def greet(name):
2     print("Hello", name)
3
4 x = greet("Ali")
5 print(x)
```

What Happens Without return?

```
1 def greet(name):
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4 x = greet("Ali")
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```

Console output:

```
Hello Ali
None
```

What Happens Without `return`?

```
1 def greet(name):
2     print("Hello", name)
3
4 x = greet("Ali")
5 print(x)
```

Console output:

```
Hello Ali
None
```

Every Python function returns something. If you don't write `return`, Python returns `None` automatically.

Big Idea

A function's code only runs when you call *(invoke)* the function.

Together in a File

```
1 def is_even( i ):
2     return i%2 == 0
3
4 is_even(3)
```

Together in a File

```
1 def is_even( i ):
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4 is_even(3)
```
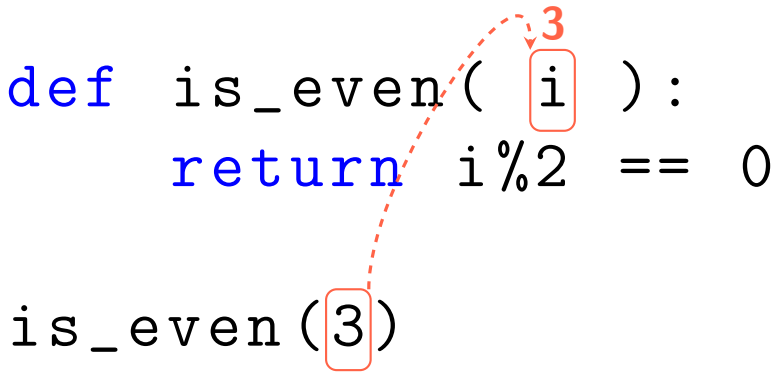
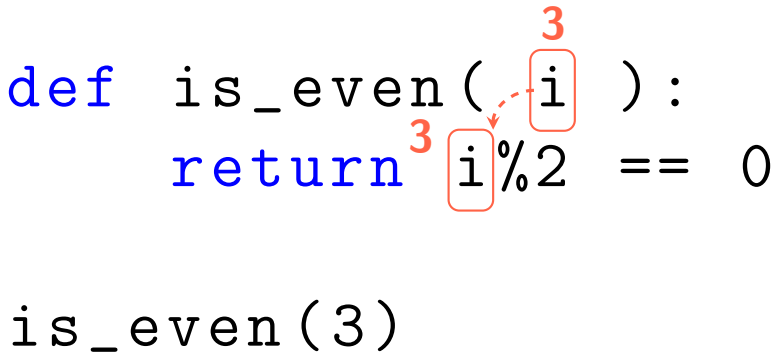

function object

call expression

Together in a File



Together in a File



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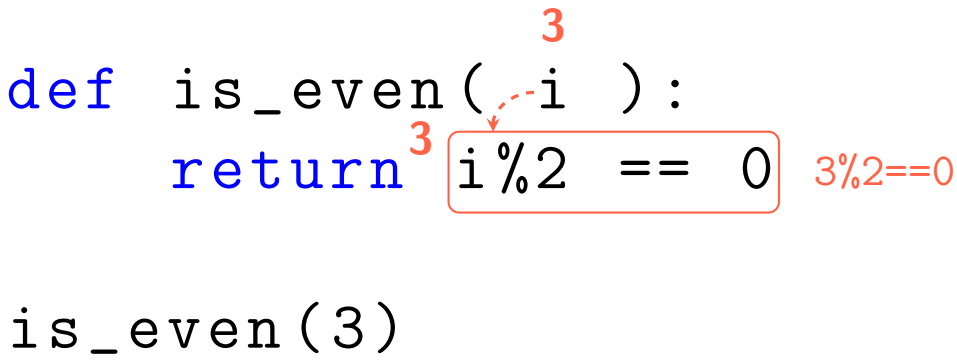


Together in a File

```
1 def is_even( i ):
2     return i%2 == 0
3
4 is_even(3)
```

3%2==0

False

Together in a File

```
1 def is_even( i ):
2     return i%2 == 0
3
4 False
```

You Try!

Write code that satisfies the following specs. Test your code with:

`n = 10, d = 3`

`n = 195, d = 13`

```
1  def div_by(n, d):
2      """ n and d are integers > 0
3      Returns True if d divides n evenly
4       and False otherwise """
5
```

You Try!

Write code that satisfies the following specs. Test your code with:

`n = 10, d = 3`

`n = 195, d = 13`

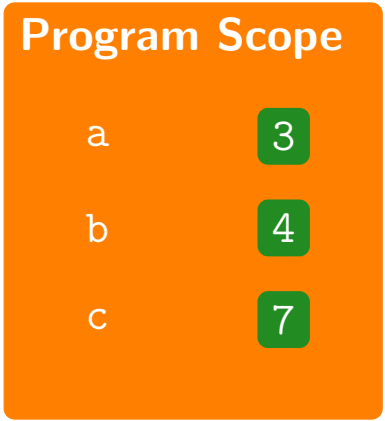
```
def div_by(n, d):
    """ n and d are integers > 0
    Returns True if d divides n evenly
     and False otherwise """

    if n % d == 0:
        return True
    else:
        return False
```

Program Scope

Program Scope

```
a = 3
b = 4
c = a+b
```



Program Scope

```
1 def is_even( i ):
2     '''my black box'''
3     print("inside is_even")
4     return i%2 == 0
5
6 a = is_even(3)
7 b = is_even(10)
8 c = is_even(123456)
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Program Scope

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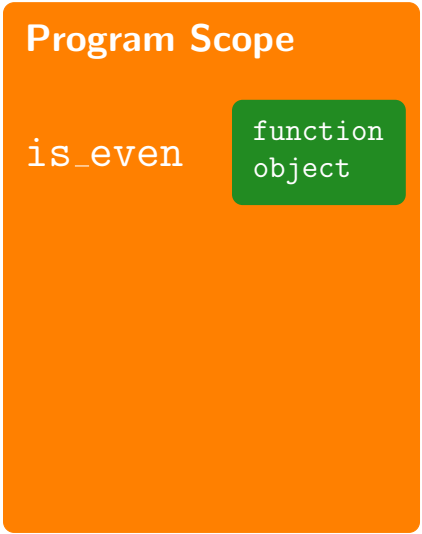

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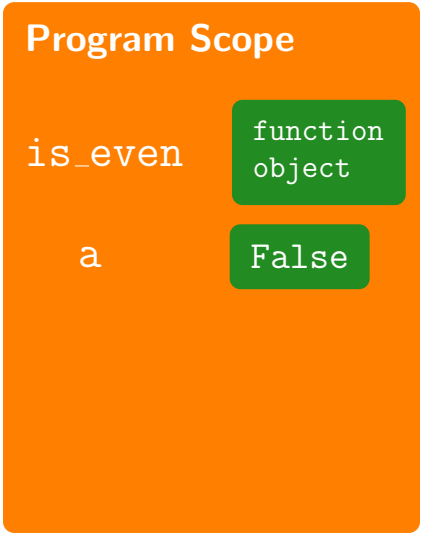

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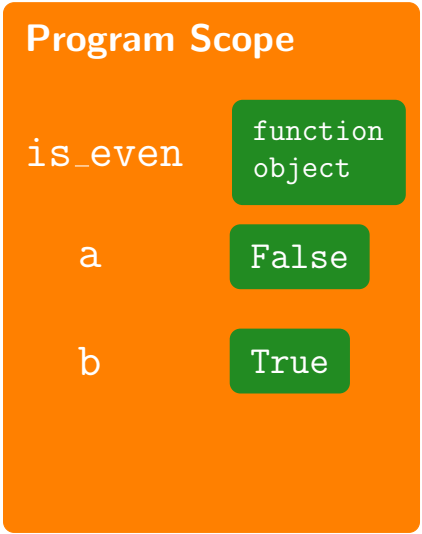

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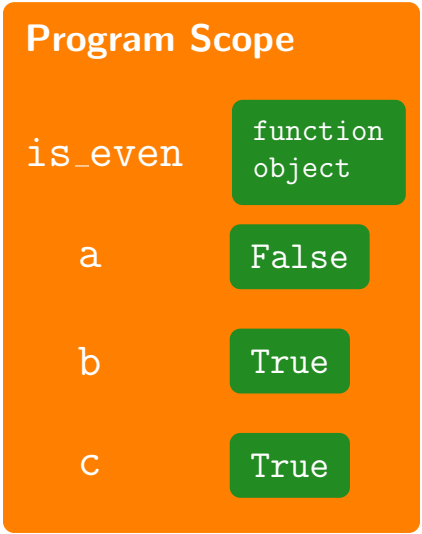
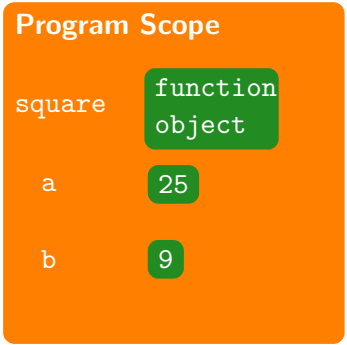


What Gets a Name in Program Scope?

```
1 def square(x):
2     return x * x
3
4 a = square(5)
5 b = square(3)
```



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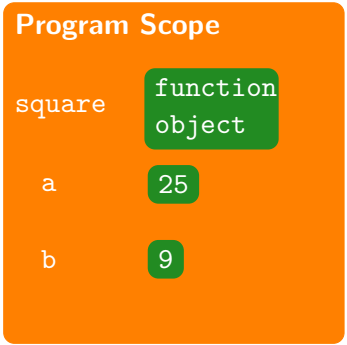

What about x? Is it in Program Scope?

What Gets a Name in Program Scope?

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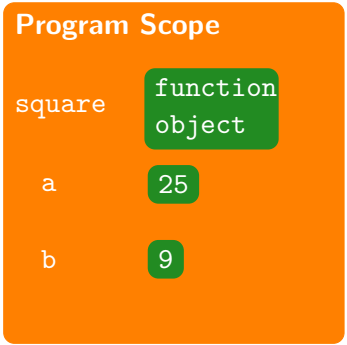


What about x? Is it in Program Scope?

No! We'll learn why next lecture.

Inserting Functions in Code

- Remember how expressions are replaced with the value?
- The **function call** is **replaced** with the **return value**!

```
1 print("Numbers between 1 and 10: even or odd")
2
3 for i in range(1,10):
4     if is_even(i):
5         print(i, "even")
6     else:
7         print(i, "odd")
```

Big Idea

Don't write code right away!

Writing Code: Paper First!

Suppose we want to add all the odd integers between (and including) **a** and **b**

Writing Code: Paper First!

Suppose we want to add all the odd integers between (and including) **a** and **b**

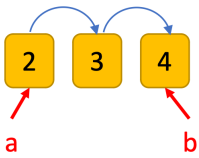
- Start with a **simple example on paper**
- Systematically solve example

```
def sum_odd(a, b):
    # your code here
    return sum_of_odds
```

Writing Code: Paper First!

Suppose we want to add all the odd integers between (and including) **a** and **b**

- Start with a **simple example on paper**
- a = 2 and b = 4
  - `sum_of_odds` should be **3**

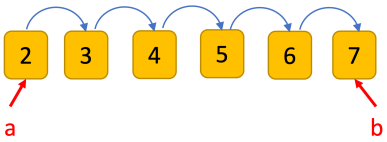



```
1  def sum_odd(a, b):
2      # your code here
3      return sum_of_odds
```

Writing Code: Paper First!

Suppose we want to add all the odd integers between (and including) **a** and **b**

- Start with a **simple example on paper**
- a = 2 and b = 7
  - `sum_of_odds` should be **15**




```
1  def sum_odd(a, b):
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```

Writing Code: Paper First!

- Add **ALL** numbers between *(and including)* a and b
  - It's a Loop

```
1 def sum_odd(a, b):
2     # your code here
3     return sum_of_odds
```

Writing Code: Paper First!

- Add **ALL** numbers between *(and including)* a and b
  - It's a Loop
- `while` or `for` ?

```
1 def sum_odd(a, b):
2     # your code here
3     return sum_of_odds
```

for loop

```
1  def sum_odd(a, b):
2      for i in range(a,b):
3          # do something
4      return sum_of_odds
```

while loop

```
1  def sum_odd(a, b):
2      i = a
3      while i <= b:
4          # do something
5          i += 1
6      return sum_of_odds
```

for loop

```
1  def sum_odd(a, b):
2      sum_of_odds = 0
3      for i in range(a,b):
4          sum_of_odds += i
5      return sum_of_odds
```

while loop

```
1  def sum_odd(a, b):
2      sum_of_odds = 0
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4      while i <= b:
5          sum_of_odds += i
6          i += 1
7      return sum_of_odds
```

for loop

```
def sum_odd(a, b):
    sum_of_odds = 0
    for i in range(a,b+1):
        if i%2 != 0:
            sum_of_odds += i
    return sum_of_odds
```

while loop

```
def sum_odd(a, b):
    sum_of_odds = 0
    i = a
    while i <= b:
        if i%2 != 0:
            sum_of_odds += i
        i += 1
    return sum_of_odds
```

for loop

```
def sum_odd(a, b):
    sum_of_odds = 0
    for i in range(a,b+1):
        if i%2 != 0:
            sum_of_odds += i
            # always debug
            print(i,sum_of_odds)
    return sum_of_odds
```

while loop

```
def sum_odd(a, b):
    sum_of_odds = 0
    i = a
    while i <= b:
        if i%2 != 0:
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            # always debug
            print(i,sum_of_odds)
        i += 1
    return sum_of_odds
```

Decomposition: Functions Calling Functions

Rewrite sum_odd using our is_even function:

```
1  def is_odd(i):
2      return not is_even(i)
3
4  def sum_odd(a, b):
5      total = 0
6      for i in range(a, b+1):
7          if is_odd(i):
8              total += i
9      return total
```

Decomposition: Functions Calling Functions

Rewrite sum_odd using our is_even function:

```
1  def is_odd(i):
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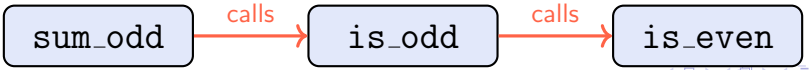


You Try!

Write code that satisfies the following specs

```
def is_divisible_by_3_and_5(n):
    """ n is a positive integer
    Returns True if n is divisible by both 3 and 5
    Hint: use your div_by function! """
```

Test your code with:

```
>>> is_divisible_by_3_and_5(15)
True
>>> is_divisible_by_3_and_5(9)
False
>>> is_divisible_by_3_and_5(30)
True
```

You Try! — Solution

```
1 def is_divisible_by_3_and_5(n):
2     """ True if both 3 and 5 divide n """
3     return div_by(n, 3) and div_by(n, 5)
```

You Try! — Solution

```
1 def is_divisible_by_3_and_5(n):
2     """ True if both 3 and 5 divide n """
3     return div_by(n, 3) and div_by(n, 5)
```

✓ `div_by` already answers "does `d` divide `n`?" — call it twice instead of writing `%` again
✓ `and` gives `True` only when *both* calls are `True`: 15 and 30 pass, 9 fails the `div_by(n, 5)` test
✓ no `if`/`else` needed — `return` the boolean expression directly

You Try!

Write code that satisfies the following specs

```
def is_palindrome(s):
    """ s is a string
    Returns True if s is a palindrome
        and False otherwise
    """
```

For example:

```
>>> is_palindrome("madam")
True
>>> is_palindrome("abc")
False
```

You Try! — Solution

```
1 def is_palindrome(s):
2     """ s is a string
3     Returns True if s is a palindrome
4         and False otherwise """
5     return s == s[::-1]
```

You Try! — Solution

```
1 def is_palindrome(s):
2     """ s is a string
3     Returns True if s is a palindrome
4         and False otherwise """
5     return s == s[::-1]
```

✓ `s[::-1]` is the slice from Lecture 3: the string **reversed**. A palindrome reads the same both ways, so it equals its own reverse

✓ `"madam"[::-1]` is `"madam"` → `True`; `"abc"[::-1]` is `"cba"` → `False`

✓ loop version: `for i in range(len(s)):` compare `s[i]` with `s[len(s) - 1 - i]`; `return False` on the first mismatch, `return True` after the loop

Default Parameters

A Simple power Function

We wrote square(x) earlier. But what if we want cubes too?

```
1 def power(x):
2     return x ** 2
3
4 print(power(5))    # 25
5 print(power(3))    # 9
```

A Simple power Function

We wrote `square(x)` earlier. But what if we want cubes too?

```
1 def power(x):
2     return x ** 2
3
4 print(power(5))    # 25
5 print(power(3))    # 9
```

This function **always** squares — what if we want `x**3` or `x**4`?

Adding a Parameter

- **Motivation:** want to compute **any** power, not just squares
- **Options:**
  - Change the exponent **inside function** (all calls are affected)
  - Use an exponent **outside function** (global variables are bad)
  - Add the exponent as **an argument** to the function

n as a Parameter

```
1 def power(x, n):
2     return x ** n
3
4 print(power(5, 2))     # 25
5 print(power(5, 3))     # 125
```

n as a Parameter

```
1 def power(x, n):
2     return x ** n
3
4 print(power(5, 2))     # 25
5 print(power(5, 3))     # 125
```

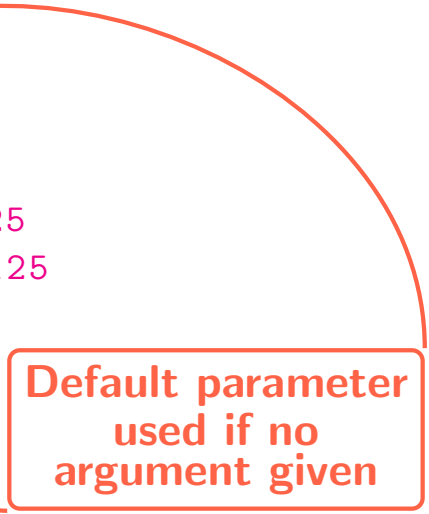
But most of the time we just want to **square** — do we **always** have to pass n?

Default Parameter

```
1 def power(x, n=2):
2     return x ** n
3
4 print(power(5))       # 25
5 print(power(5, 3))    # 125
```

Default Parameter

```
1 def power(x, n=2):
2     return x ** n
3
4 print(power(5))       # 25
5 print(power(5, 3))    # 125
```



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```

Use arg, default value not used

Default Parameters: Rules

In the **function definition**:

- Default parameters must go at the end of the parameter list

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These are **ok for calling a function**:

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2 power(5, 3)
3 power(5, n=3)
4 power(x=5, n=3)
5 power(n=3, x=5)
```

Default Parameters: Rules

In the **function definition**:

- Default parameters must go at the end of the parameter list

These are **ok for calling a function**:

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power(5)
power(5, 3)
power(5, n=3)
power(x=5, n=3)
power(n=3, x=5)
```

These are **not ok for calling a function**:

```
# error, cannot have positional after keyword:
power(n=3, 5)
power(3, 5)           # no error but wrong
```

Common Mistakes with Functions

1. Forgetting `return` — function gives `None`
   - ```
     def f(x):
         x * 2      ← missing return!
     ```
     ```

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2. Using `print` instead of `return` — can't store or reuse the result
3. Forgetting to **call** the function
   - `is_even` vs `is_even(4)`
4. Forgetting `b+1` in `range(a, b+1)` when you want to include `b`

Summary

Questions?

Exit Ticket

Today's question *(2 minutes)*

Given this function:

```
def power(x, n=2):
    return x ** n
```

(a) What does `power(3)` return?

(b) What does `power(2, 3)` return?

COMP 102 — Exit Ticket #9

Name: _____

Roll #: _____ Date: _____

Answer:

Hand it to me on your way out.
No name, no attendance.