

# OUTLINE

- 1 CHAPTER 4: LINKED STRUCTURES AND ITERATORS
  - The Python Memory Model
  - A Linked Implementation of Lists
  - In-Class Work

# VARIABLE NAMES AND REFERENCES

## ASSIGNMENT STATEMENTS

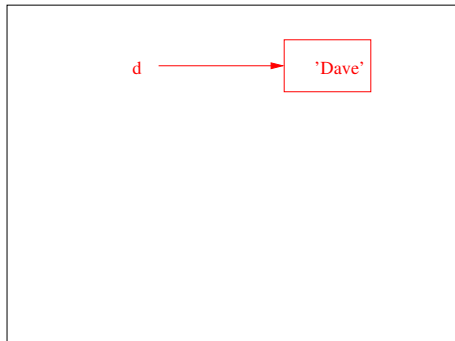
An **assignment** statement in Python associates an object with the name of a variable.

More precisely, the name is associated with a **reference** to an object of some class, or **type**.

This association remains in effect until a new object reference is associated with the variable through a new assignment statement.

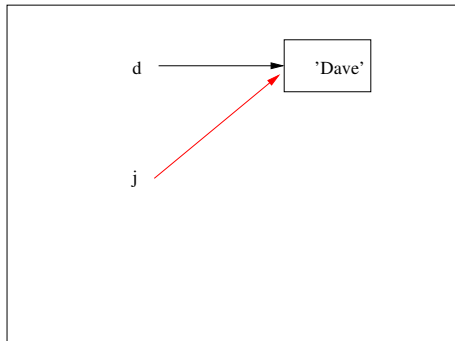
## PYTHON ASSIGNMENT EXAMPLES

```
d = 'Dave'  
j = d  
j = 'John'  
d = 'Smith'
```



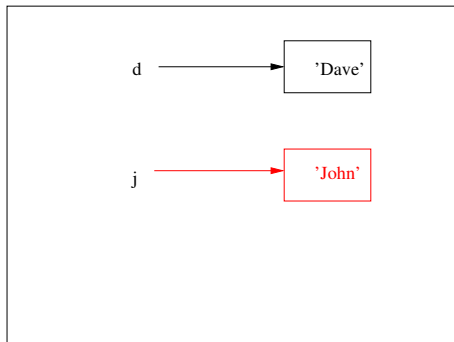
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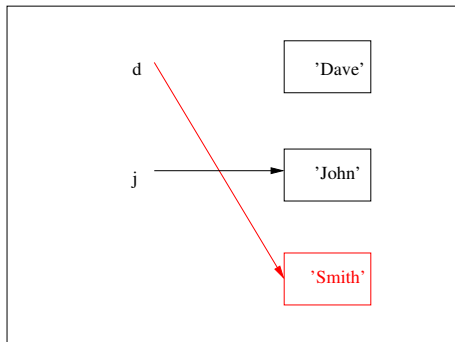
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# NAMESPACES

## THE LOCAL DICTIONARY

The values of **local** variables—those which are currently active, are kept by Python, along with function names, in a dictionary object, called a **namespace**.

This dictionary is available by calling the built-in function `locals()`.

The Python function `id` returns a unique identifier for each data object (i.e. memory address where the object is stored)

Namespace can be modified directly. For example, the command `del d` removes the name 'd' from the local namespace.

See example program [Section4\\_2.py](#).

# VARIABLE TYPES AND REFERENCES IN PYTHON

## DYNAMIC TYPING

In Python's memory model a variable just contains a reference to an object.

All variables have the same size, i.e. the standard address size of the computer, usually 4 or 8 bytes.

The data type information is stored with the object.

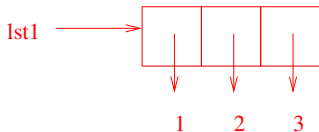
In order to avoid confusion with other languages, some people prefer to talk about **names**, rather than use traditional term **variable**.

The term **dynamic typing** in Python means that a variable/name can refer to objects of different types.



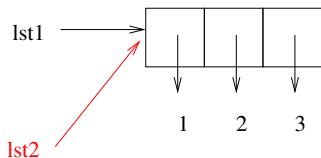
## ALIASING

```
lst1 = [1, 2, 3]  
lst2 = lst1  
lst2.append(4)  
lst1
```



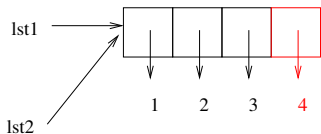
## ALIASING

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lst2.append(4)  
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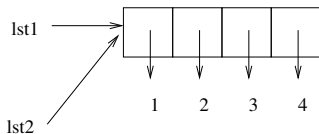
## ALIASING

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```



## ALIASING

```
lst1 = [1, 2, 3]  
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lst2.append(4)  
lst1  
[1, 2, 3, 4]
```



# COPYING VARIABLE VALUES IN PYTHON

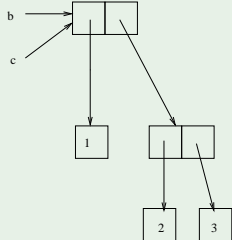
## DEEP AND SHALLOW COPY

To avoid the problem of aliasing, we can, by using the `copy` function, force a new copy of a value to be created, so when it gets changed, the original variable, which refers to the original object, will keep its original value.

## COPYING VARIABLE VALUES IN PYTHON

## DEEP AND SHALLOW COPY

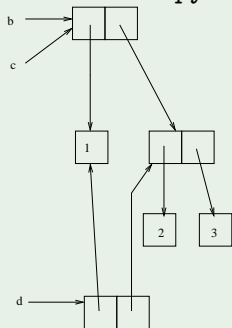
```
>>>from copy import *  
>>> b = [1, [2, 3]]  
>>> c = b
```



## COPYING VARIABLE VALUES IN PYTHON

## SHALLOW COPY

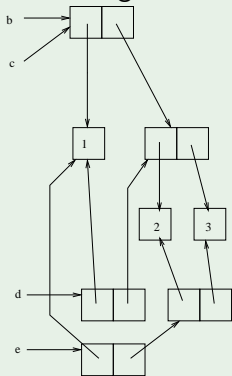
```
>>> d = copy(b)
```



## COPYING VARIABLE VALUES IN PYTHON

## DEEP COPY

If a container object refers to other objects, these can be copied as well, using the `deepcopy` function. `>>> e = deepcopy(b)`





# PASSING PARAMETERS IN FUNCTION CALLS

## FORMAL VS. ACTUAL PARAMETERS

**Formal** parameters are the variable names used in implementing the function. They are listed in parentheses after the function name in the function definition, then used to express the Python commands needed to perform the algorithm of the function.

**Actual** parameters are the variable names used by the program where the function is called with specific values. When it is called, the function cannot change the value of an actual parameter, but it **can** change an object to which the actual parameter **refers**.

## PASSING PARAMETERS IN FUNCTION CALLS

## EXAMPLE

**Example:**

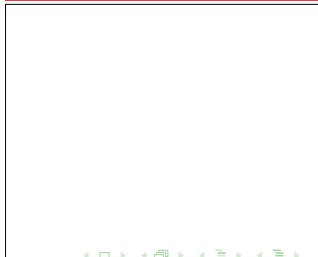
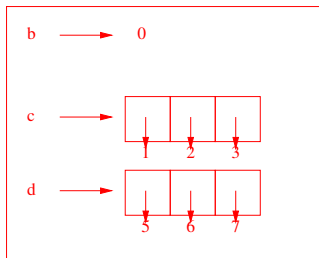
```
def f1(a,b):          a and b are formal parameters
    """ pre:  a and b are integers
        post: returns sum and product of a and b"""
    return a+b, a*b
```

```
c,d = 1,-9
```

```
sum,prod = f1(c,d)    c and d are actual parameters
```

## A FUNCTION CALL EXAMPLE

```
def func(e, f, g):  
    e += 2  
    f.append(4)  
    g = [8, 9]  
    print(e, f, g)  
  
def main():  
    b = 0  
    c = [1, 2, 3]  
    d = [5, 6, 7]  
    func(b, c, d)  
    print(b, c, d)
```



## A FUNCTION CALL EXAMPLE

```
def func(e, f, g):
```

```
    e += 2
```

```
    f.append(4)
```

```
    g = [8, 9]
```

```
    print(e, f, g)
```

```
def main():
```

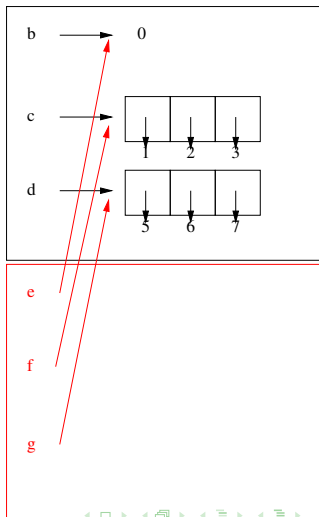
```
    b = 0
```

```
    c = [1, 2, 3]
```

```
    d = [5, 6, 7]
```

```
    func(b, c, d)
```

```
    print(b, c, d)
```



## A FUNCTION CALL EXAMPLE

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```

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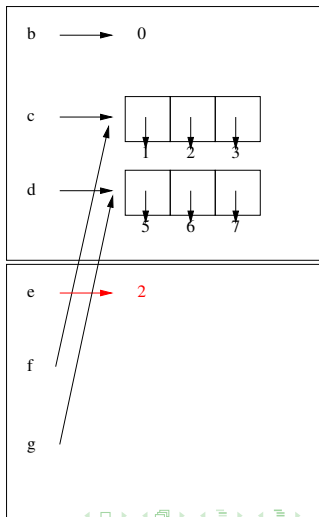
```
    b = 0
```

```
    c = [1, 2, 3]
```

```
    d = [5, 6, 7]
```

```
    func(b, c, d)
```

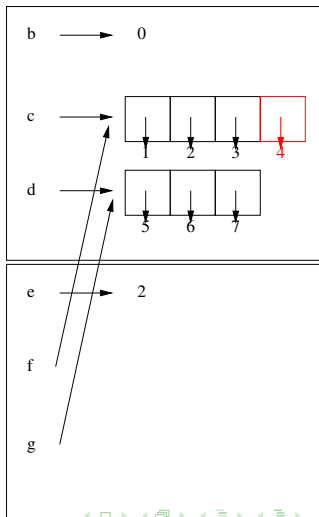
```
    print(b, c, d)
```



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    e += 2
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    print(e, f, g)

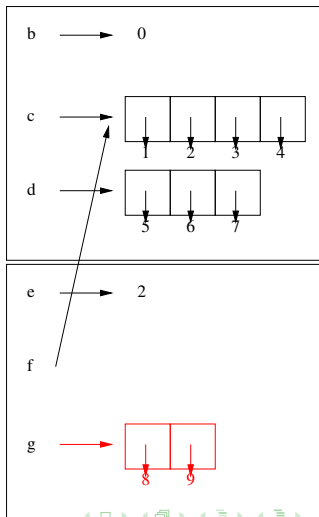
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```



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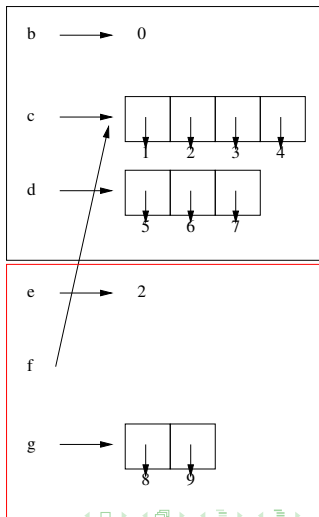
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```



## A FUNCTION CALL EXAMPLE

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2 [1, 2, 3, 4] [8, 9]
```

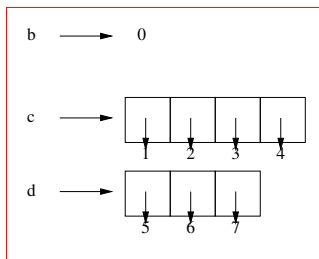




## A FUNCTION CALL EXAMPLE

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    d = [5, 6, 7]
    func(b, c, d)
    print(b, c, d)
2 [1, 2, 3, 4] [8, 9]
0 [1, 2, 3, 4] [5, 6, 7]
```



# A FUNCTION CALL EXAMPLE

## KEEP IN MIND

- a function can change the state of an object that actual parameter refers to.
- a function cannot change which object the actual parameter refers to.
- assigning a new object to a formal parameter inside a function or method will never change the actual parameter in any way, regardless of whether the actual parameter is mutable or not.

## A WEAKNESS OF USING ARRAYS TO IMPLEMENT A LIST ADT

## PROBLEM

from previous class: Python uses arrays of references to implement the list ADT

*(arrays can easily be traversed by proceeding along a series of contiguous memory locations; arrays allow random access: jumping quickly to any index location in the array, according to a formula for the address which is easy to calculate.)*

**insert** and **delete** operations for lists were both  $\Theta(n)$

*(they both require copying much of the list to keep its sequential order)*

For long lists, this is a problem.

Another design for sequential lists: it is possible to get faster insert and delete operations at the cost of slower random access.

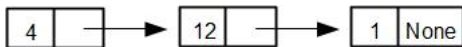
# LINKED LISTS

## DATA ITEMS AS NODES

Using the idea of a reference (pointer), ordering items into a list can be accomplished by having each item have its own reference to the next item.

The list can be traversed sequentially by hopping from each item to the one it refers to.

The value of each item is kept together with the reference/pointer to the next item in an object called a **node**.



# LINKED LISTS

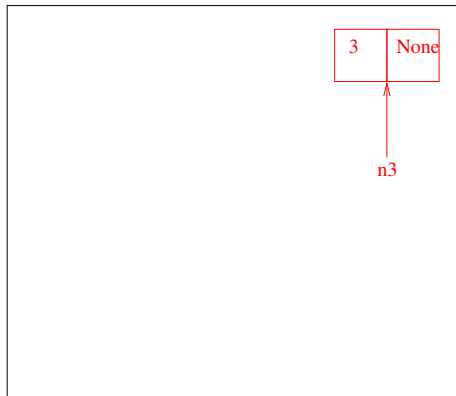
## THE LISTNODE CLASS

We can define a class to support this structure, with attributes `item` (for the data value) and `link` (for the reference to the next item):

```
class ListNode(object):
    def __init__(self, item = None, link = None):
        """
        post:  creates a ListNode with the
               specified data value and link
        """
        self.item = item
        self.link = link
```

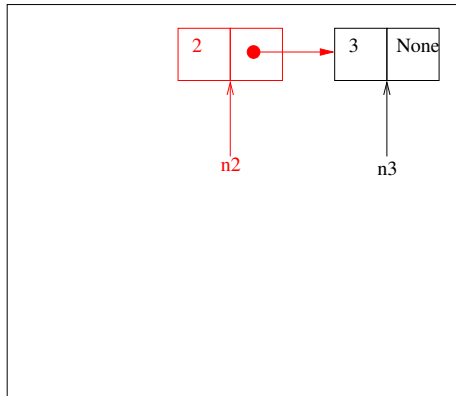
## BUILDING A LINKED LIST

```
n3 = ListNode(3)
```



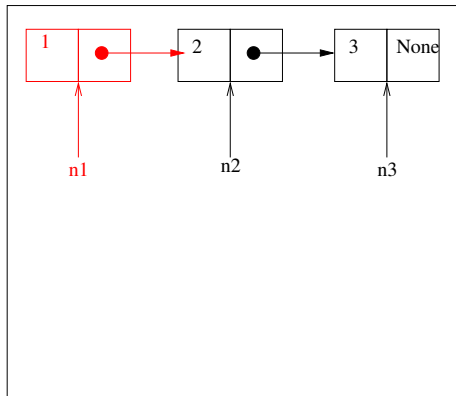
## BUILDING A LINKED LIST

```
n3 = ListNode(3)
n2 = ListNode(2, n3)
```



## BUILDING A LINKED LIST

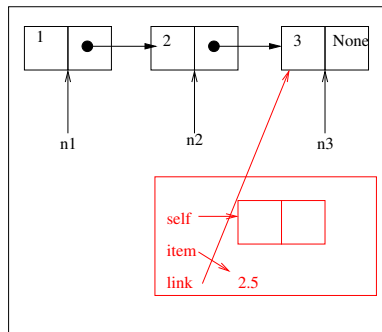
```
n3 = ListNode(3)
n2 = ListNode(2, n3)
n1 = ListNode(1, n2)
```





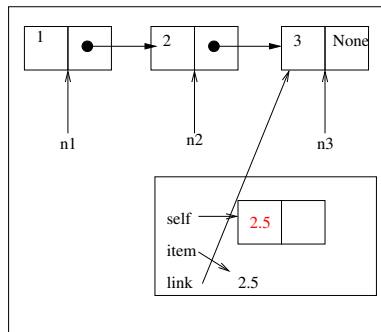
## INSERTING A NODE INTO A LINKED LIST

```
def __init__(self, item,  
link):  
    self.item = item  
    self.link = link  
n25 = ListNode(2.5, n2.link)  
n2.link = n25
```



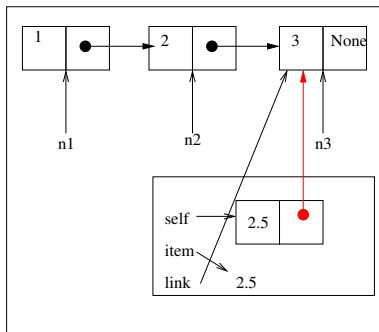
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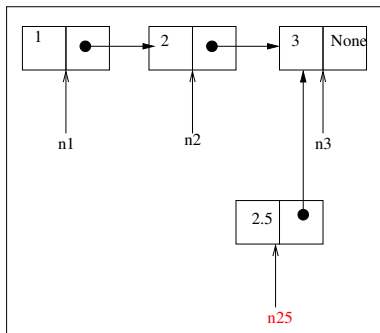
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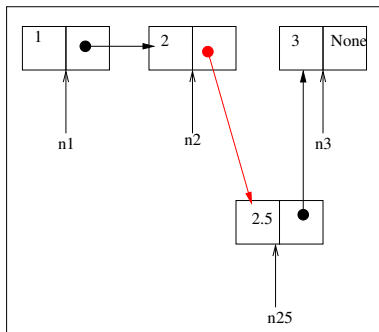
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## INSERTING A NODE INTO A LINKED LIST

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```



## IN-CLASS WORK - PART I

1. Add a method (or override `__str__`) to display the value of the node to the `ListNode` class (no need to display the reference to the next node)
2. Write a program that uses the `ListNode` class to do the following:
  - creates a linked list of the following values: 25, 7, 3, 5, and then displays it, then
  - inserts value 30 between 3 and 5 and displays the updated list, then
  - deletes 7 from the list and displays the updated list.

## IN-CLASS WORK - PART II

3. Find the asymptotic running time of the following procedure:

```
n = input("Enter an integer number greater than 5:")  
for i in range(n):  
    for j in range(n//10):  
        print("i = ", i, ", j = ", j)
```

4. Look at the code of [Sections4\\_1-4\\_3InClassWork.py](#) and draw the memory model after each line of code.
5. Look at the code of [Section4\\_2example2.py](#) and draw the memory model after each line of code.