DM550/DM857
Introduction to Programming

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Lists vs Strings

- string = sequence of letters
- list = sequence of values

- convert a string into a list using the built-in list() function
- Example: list("Hej hop") == ["H", "e", "j", " ", "h", "o", "p"]

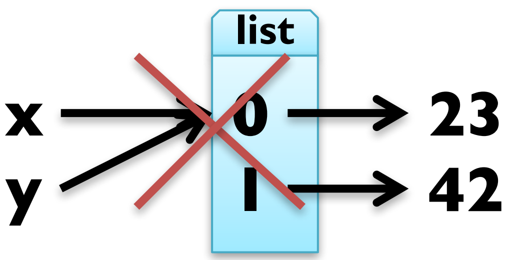
- split up a string into a list using the split(sep) method
- Example: "Slartibartfast".split("a") == ["Sl", "rtib", "rtf", "st"]

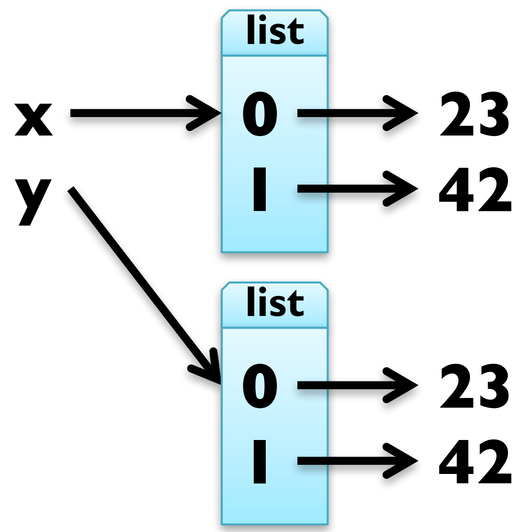
- reverse operation is the join(sequence) method
- Example: " and ".join(["A", "B", "C"]) == "A and B and C"
  "".join(["H", "e", "j", " ", "h", "o", "p"]) = "Hej Hop"

Objects and Values

- two possible stack diagrams for a = "mango"; b = "mango"

- we can check identity of objects using the is operator
- Example: a is b == True
- two possible stack diagrams for x = [23, 42]; y = [23, 42]

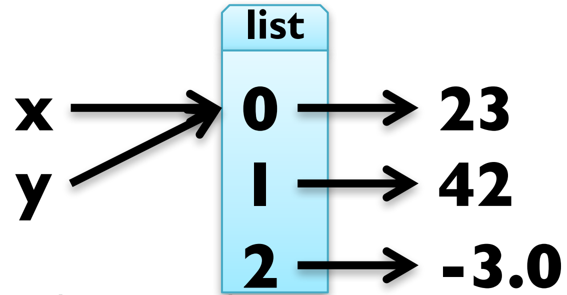




- Example: x is y == False

Aliasing

- when assigning y = x, both variables refer to same object
- Example: x = [23, 42, -3.0]
  y = x
  x is y == True



- here, there are two *references* to one (*aliased*) object

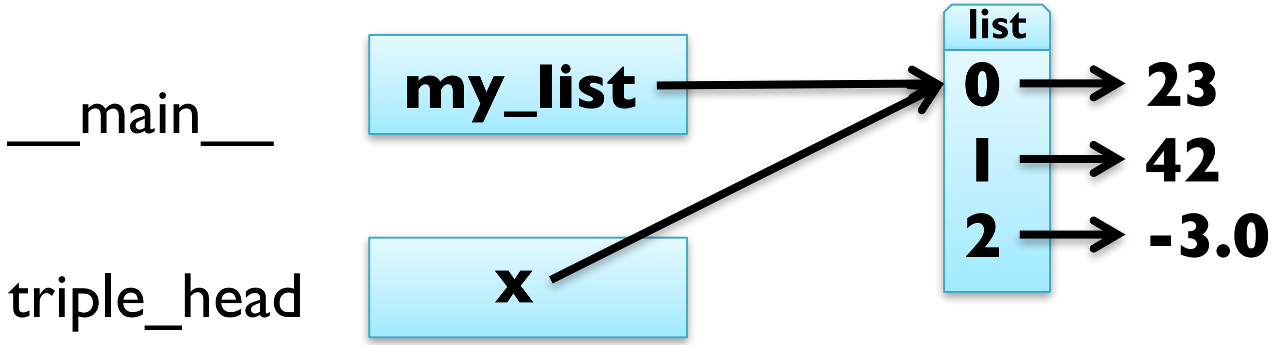
- fine for immutable objects (like strings)
- problematic for mutable objects (like lists)
- Example: y[2] = 4711
  x == [23, 42, 4711]

- HINT: when unsure, always copy list using y = x[:]

List Arguments

- lists passed as arguments to functions can be changed
- Example: tripling the first element

```
def triple_head(x):
    x[:1] = [x[0]]*3
my_list = [23, 42, -3.0]
triple_head(my_list)
```



List Arguments

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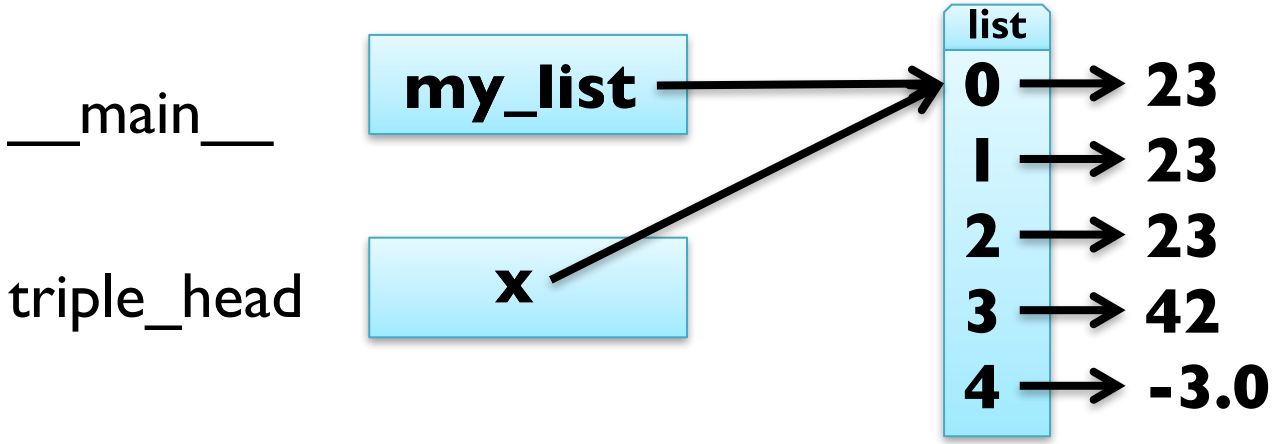
def triple_head(x):
    x[:1] = [x[0]]*3
my_list = [23, 42, -3.0]
triple_head(my_list)
my_list == [23, 23, 23, 42, -3.0]
```



List Arguments

- lists passed as arguments to functions can be changed
- some operations change object
  - assignment using indices
  - append(object) method
  - extend(iterable) method
  - sort() method
  - del statement
- some operations return a new object
  - access using slices
  - strip() method
  - "+" on strings and lists
  - "* n" on strings and lists

Debugging Lists

- working with mutable objects like lists requires attention!

1. many list methods return None and modify destructively
   - word = word.strip() makes sense
   - t = t.sort() does NOT!
2. there are many ways to do something – stick with one!
   - t.append(x) or t = t + [x]
   - use either pop, remove, del or slice assignment for deletion
3. make copies when you are unsure!
   - Example:

```
…
sorted_list = my_list[:]
sorted_list.sort()
…
```

DICTIONARIES

Generalized Mappings

- list = mapping from integer indices to values
- dictionary = mapping from (almost) any type to values
- indices are called *keys* and pairs of keys and values *items*

- empty dictionaries created using curly braces “{}”
- Example: `en2da = {}`

- keys are assigned to values using same syntax as for sequences
- Example:
```
en2da["queen"] = "dronning"
print(en2da)
```

- curly braces “{” and “}” can be used to create dictionary
- Example: `en2da = {"queen" : "dronning", "king" : "konge"}`

Dictionary Operations

- printing order can be different: print(en2da)
- access using indices: en2da["king"] == "konge"
- KeyError when key not mapped: print(en2da["prince"])
- length is number of items: len(en2da) == 2
- in operator tests if key mapped: "king" in en2da == True
  "prince" in en2da == False
- keys() metod gives list of keys:
  en2da.keys() == ["king", "queen"]
- values() method gives list of values:
  en2da.values() == ["konge", "dronning"]
- useful e.g. for test if value is used:
  "prins" in en2da.values() == False

Dictionaries as Sets

- dictionaries can be used as sets
- **Idea:** assign None to all elements of the set
- Example: representing the set of primes smaller than 20

  primes = {2: None, 3: None, 5: None, 7: None, 11: None, 13: None, 17: None, 19: None}

- then in operator can be used to see if value is in set
- Example:

  15 in primes == False

  17 in primes == True

- for lists, needs steps proportional to number of elements
- for dictionary, needs (almost) constant number of steps

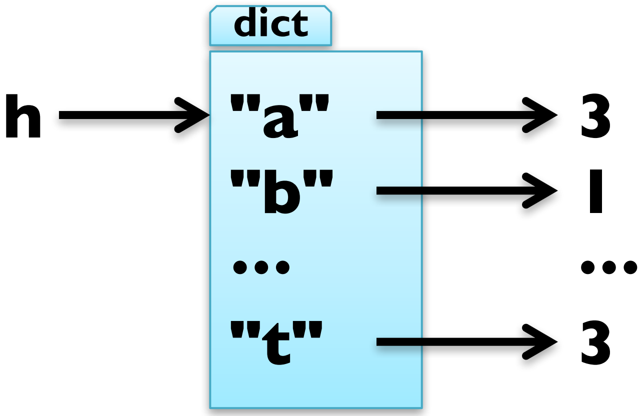
Counting Letter Frequency

- **Goal:** count frequency of letters in a string (*histogram*)
- many possible implementations, e.g.:
  - create 26(+3?) counter variables for each letterl; use chained conditionals (if … elif … elif …) to increment
  - create a list of length 26(+3?); increment the element at index n-1 if the n-th letter is encountered
  - create a dictionary with letters as keys and integers as values; increment using index access
- all these implementations work (differently)
- big differences in *runtime* and *ease of implementation*
- choice of data structure is a *design decision*

Counting with Dictionaries

- fast and counts all characters – no need to fix before!

```
def histogram(word):
    d = {}
    for char in word:
        if char not in d:
            d[char] = 1
        else:
            d[char] += 1
    return d
```



- Example: h = histogram("slartibartfast")

  h == {"a":3, "b":1, "f":1, "i":1, "l":1, "s":2, "r":2, "t":3}

Counting with Dictionaries

- fast and counts all characters – no need to fix before!

```
def histogram(word):
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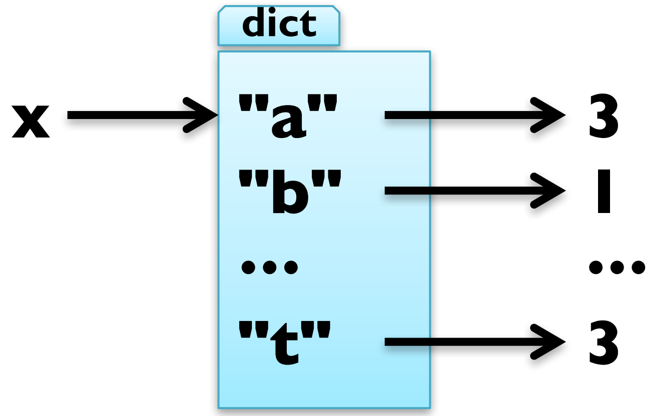

- access using the get(k, d) method:

```
h.get("t", 0) == 3
h.get("z", 0) == 0
```

Traversing Dictionaries

- using a for loop, you can traverse all keys of a dictionary
- Example:

```
for key in en2da:
    print(key, en2da[key])
```

- you can also traverse all values of a dictionary
- Example:

```
for value in en2da.values():
    print(value)
```

- finally, you can traverse all items of a dictionary
- Example:

```
for item in en2da.items():
    print(item[0], item[1])        # key, value
```

Reverse Lookup

- given dict. d and key k, finding value v with v == d[k] easy
- this is called a dictionary *lookup*
- given dict. d and value v, finding key k with v == d[k] hard
- there might be more than one key mapping to v (cf. example)
- Possible implementation 1:

```
def reverse_lookup(d, v):
    result = []
    for key in d:
        if d[key] == v:
            result.append(key)
    return result
```

- returns empty list, when no key maps to value v

Reverse Lookup

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- given dict. d and value v, finding key k with v == d[k] hard
- there might be more than one key mapping to v (cf. example)
- Possible implementation 2:

```
def reverse_lookup(d, v):
    for k in d:
        if d[k] == v:
            return k
    raise ValueError
```

- gives error when no key maps to value v

Reverse Lookup

- given dict. d and key k, finding value v with v == d[k] easy
- this is called a dictionary *lookup*
- given dict. d and value v, finding key k with v == d[k] hard
- there might be more than one key mapping to v (cf. example)
- Possible implementation 2:

```
def reverse_lookup(d, v):
    for k in d:
        if d[k] == v:
            return k
    raise ValueError, "value not found in dictionary"
```

- gives error when no key maps to value v

Dictionaries and Lists

- lists cannot be keys, as they are mutable
- list can be values stored in dictionaries
- Example: inverting a dictionary

```
def invert_dict(d):
    inv = {}
    for key in d:
        val = d[key]
        if val not in inv:
            inv[val] = [key]
        else:
            inv[val].append(key)
    return inv
```

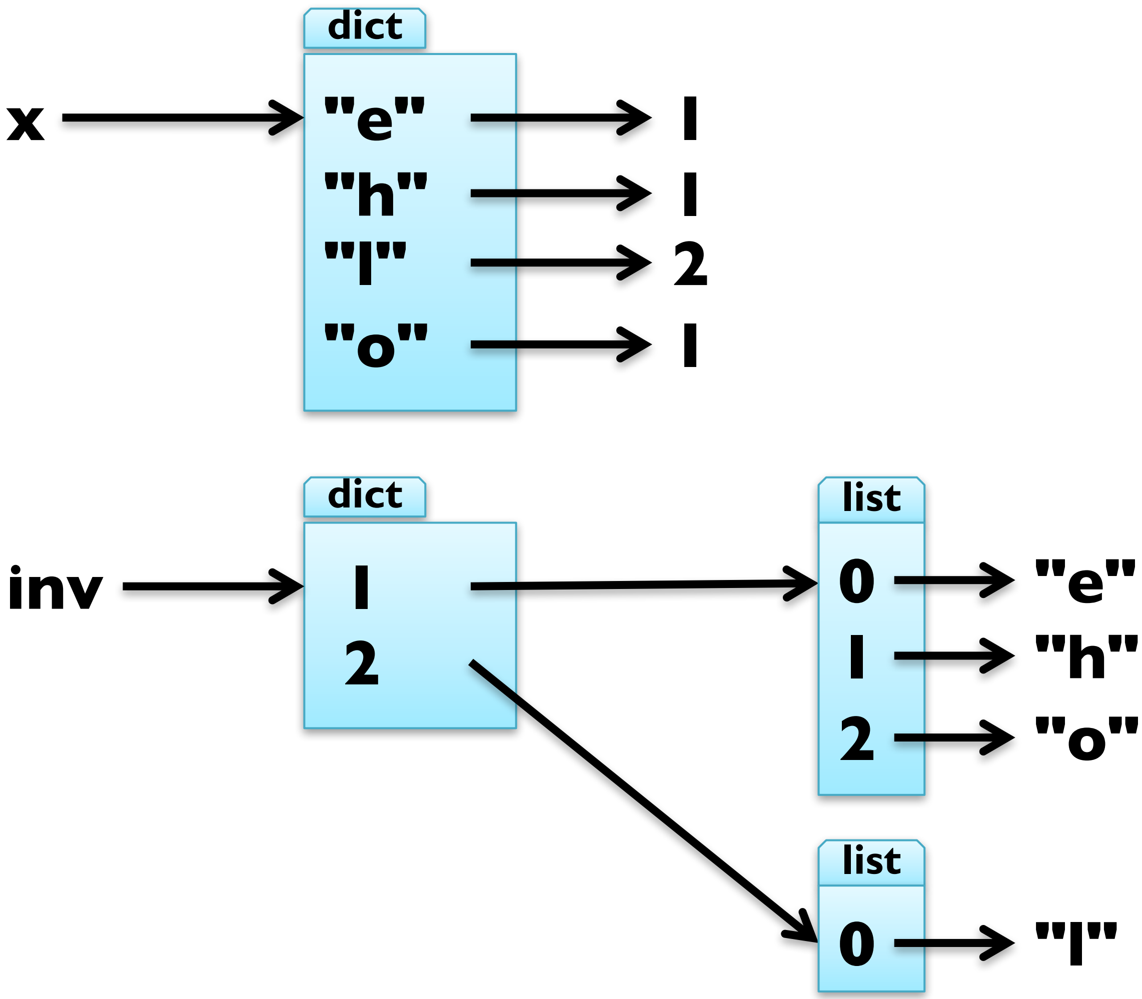
Dictionaries and Lists

- lists cannot be keys, as they are mutable
- list can be values
- Example: inverting a dictionary

```
def invert_dict(d):
    inv = {}
    for key in d:
        val = d[key]
        if val not in inv:
            inv[val] = []
        inv[val].append(key)
    return inv
```

- Example: `print invert_dict(histogram("hello"))`

Dictionaries and Lists



- Example: print invert_dict(histogram("hello"))

Memoizing

- Fibonacci numbers lead to exponentially many calls:

```
def fib(n):
    if n in [0,1]: return n
    return fib(n-1) + fib(n-2)
```

- keeping previously computed values (*memos*) helps:

```
known = {0:0, 1:1}
def fib_fast(n):
    if n in known:
        return known[n]
    res = fib_fast(n-1) + fib_fast(n-2)
    known[n] = res
    return res
```

Global Variables

- known is created outside fib_fast and belongs to __main__
- such variables are called *global*
- many uses for global variables (besides memoization)
- Example 1: flag for controlling output

```
debug = True
def pythagoras(a,b):
    if debug:     print "pythagoras with a =d", a, " and b = d", b
    result = math.sqrt(a**2 + b**2)
    if debug:     print "result of pythagoras:", result
    return result
```

Global Variables

- known is created outside fib_fast and belongs to __main__
- such variables are called *global*
- many uses for global variables (besides memoization)
- Example 2: track number of calls

```
num_calls = 0
def pythagoras(a,b):
    global num_calls
    num_calls += 1
    return math.sqrt(a**2 + b**2)
```

- gives UnboundLocalError as num_calls is local to pythagoras
- declare num_calls to be global using a global statement

Long Integers

- Python uses 32 or 64 bit for int
- this limits the numbers that can be represented:
  - 32 bit: from -2**31 to 2**31–1
  - 64 bit: from -2**63 to 2**63–1

- for larger numbers, Python automatically uses long integers
- Example:

  fib(93) == 12200160415121876738

- long integers work just like int
- Example: 2**64 + 2**64 == 2**65

  fib(100)**fib(20) # has 139016 digits :-o

Debugging Larger Datasets

- debugging larger data sets, simple printing can be too much

1. scale down the input – start with the first n lines; a good value for n is a small value that still exhibits the problem
2. scale down the output – just print a part of the output; when using strings and lists, slices are very handy
3. check summaries and types – check that type and len(…) of objects is correct by printing them instead of the object
4. write self-checks – include some *sanity checks*, i.e., test Boolean conditions that should definitely hold
5. pretty print output – even larger sets can be easier to interpret when printed in a more human-readable form