15-110 Principles of Computing – F19

Lecture 19:

Dictionaries 1

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Storing and Manipulating structured data

- So far we have used <u>lists</u> to store and manipulate **structured data**

- Example: data about people, including account number, sex, country of origin

```
accounts = [ ['J. Smith', [35672, 'M', 'USA']],
             ['M. Saleh', [27623, 'M', 'Jordan']],
             ['F. Dupont', [17623, 'F', 'France']] ]
```

name

n., sex, country

Data entry (**record**)

Data fields

Data fields

Storing and Manipulating structured data

- So far we have used lists to store and manipulate **structured data**

- Example: data about animals, including name, phylum, class, order

```
animals = [ ['tiger', 'vertebrate', 'mammal', 'carnivore'],
            ['orangu-tan', 'vertebrate', 'mammal', 'primate'],
            ['falcon', 'vertebrate', 'bird', 'falconiformes'] ]
```

- Example: data about countries, including name, population, GDP per capita, S&P's rating

```
countries = [ ['USA', 324459463, 59792, 'AAA'], ['Switzerland', 8476005, 80637, 'AAA'],
              ['Qatar', 2639211, 61024, 'AA-'], ['Luxembourg', 583455, 105863, 'AAA'] ]
```

Manipulating structured data

- How do we access and modify these type of data?

```
accounts = [ ['J. Smith', [35672, 'M', 'USA']],
             ['M. Saleh', [27623, 'M', 'Jordan']],
             ['F. Dupont', [17623, 'F', 'France']] ]
```

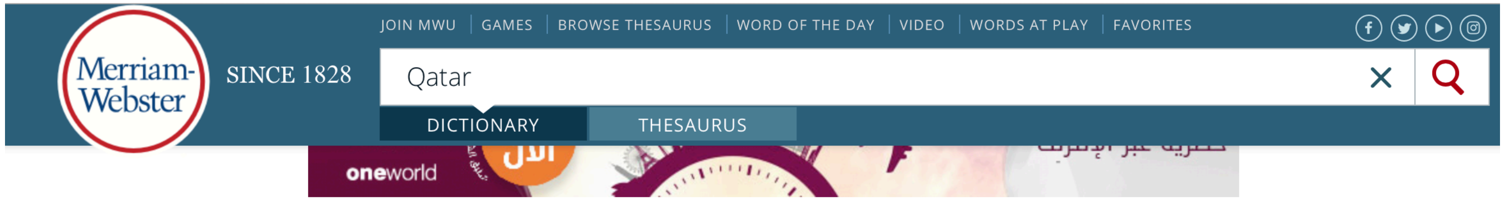
- Common queries / manipulation actions include:
  - **Get** the data of a *specific person* (e.g., Get all data about J. Smith)
  - **Modify** the data of a *specific person* (e.g., Change the account of F. Dupont)
  - **Get** the data of the citizens of a *specific country* (e.g., Get all data of USA citizens)

- No built-in method does directly the job, we need to write our own function to retrieve needed data ☹

- *Idea:* we need to provide a **search key** (e.g., 'J. Smith') and retrieve the **associate data**

Dictionary data structure

- ✓ Don't we have a more structured / <u>built-in</u> way to provide a **search key** and retrieve the **associate data?**
- ✓ Or, more in general**, to <u>label data and access / search data using labels</u>?**



Collection of *<u>data resources</u>* that can be accessed through specific <u>keyword identifiers</u> (e.g., Qatar)

Collection of *pairs* of:

<**key**>, <**data**>

Qatar geographical name

Qa·tar | \ ˈkä-tər, ˈgä-, ˈgə-; kə-ˈtär\

Definition of *Qatar*

country in eastern Arabia on a peninsula projecting into the Persian Gulf; an independent emirate; capital Doha *area* 4400 square miles (11,395 square kilometers), *population* 1,699,435

Other Words from *Qatar*

Qatari \ kə-ˈtär-ē, gə-\ *adjective or noun*

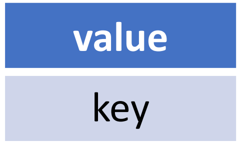
Definition of *dictionary*

1 : a reference source in print or electronic form containing words usually alphabetically arranged along with information about their forms, pronunciations, functions, etymologies, meanings, and syntactic and idiomatic uses

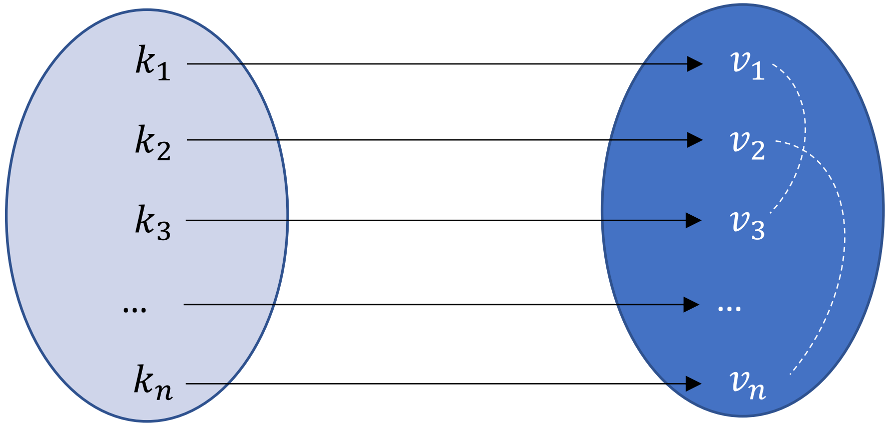
2 : a reference book listing alphabetically terms or names important to a particular subject or activity along with discussion of their meanings and applications

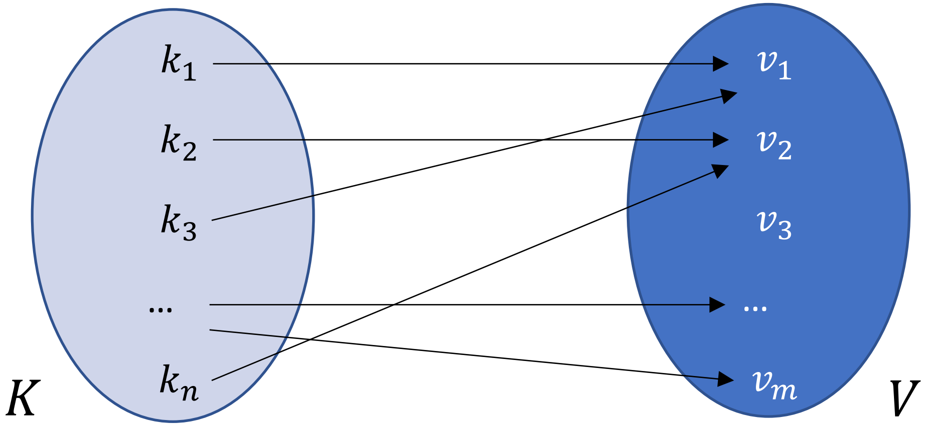
3 : a reference book listing alphabetically the words of one language and showing their meanings or translations in another language

Dictionary data structure: maps (associative, surjective)



key ↦ value





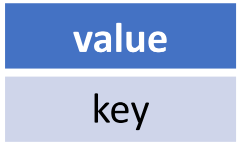
- A dictionary **maps** n keys into n values
- Keys are <u>all different / unique</u>
- Different keys might be associated to a <u>same value</u> (representing however *physically different data records*)

- In the example, the value v_1 associated to key k_1 is the same as the value v_3 associated to key k_3 (as shown by dashed lines), however they are physically different items
- E.g., k_1 = “John”, k_3= “Ann”, and they have the same age v_1 = 20, v_3 = 20

- Accounting for values that can be the same, we can represent a dictionary map as a **surjective map** in *mathematics*, where each element in the value set V (of size m) is associated to (is the co-image of) *at least* one element from the key set K (of size $n \geq m$), and all elements in K are associated to one element in V

$$dict : K \mapsto V$$

Dictionary data structure: associative maps



key ↦ value

Examples:

- SSNs ↦ Person information data
- Names ↦ phone numbers, email
- Usernames ↦ passwords, OS preferences
- ZIP codes ↦ Shipping costs and time
- Country names ↦ Capital, demographic info
- Sales items ↦ Quantity in stock, time to order
- Courses ↦ Student statistics
- Persons ↦ Friends in social network
- Animals ↦ Classification data
- Companies ↦ Rate, capital, investments
- …

- In all the examples, a **unique label** (***key***) can be associated to a (more or less complex) **piece of data** (the ***value***)
- This motivates the choice of a *dictionary data structure* to represent and manipulate these type of data

Dictionary data structure

- **Data type**: `dict`

- **Syntax:**

Separator between key-value entries

```
{ key_1: value_1,  key_2: value_2,  key_3: value_3 }
```

`dict` literal object with three elements

```
d = { key_1: value_1,  key_2: value_2,  key_3: value_3 }
```

definition of a `dict` variable `d` with three elements

```
d = { }
```

definition of an empty `dict` variable `d`

Key(word) identifier

Data value (information data) associated to the key

Delimiters for literal object definition

Separator between key and value

Dictionary data structure: unordered, associative array (map)

- **Unordered:** it's *not a sequence*, rather a collection, where items are accessed through the keys, not by their position in a sequence

```
x = [20, 22, 29, 20]
```

Value	**20**	**22**	**29**	**20**	*List*
Position index	0	1	2	3	

`x[1]` is the value of `x` at position 1, which is 22

✓ A sequence type accesses values by their position in the sequence, i.e., values are *sequentially indexed*

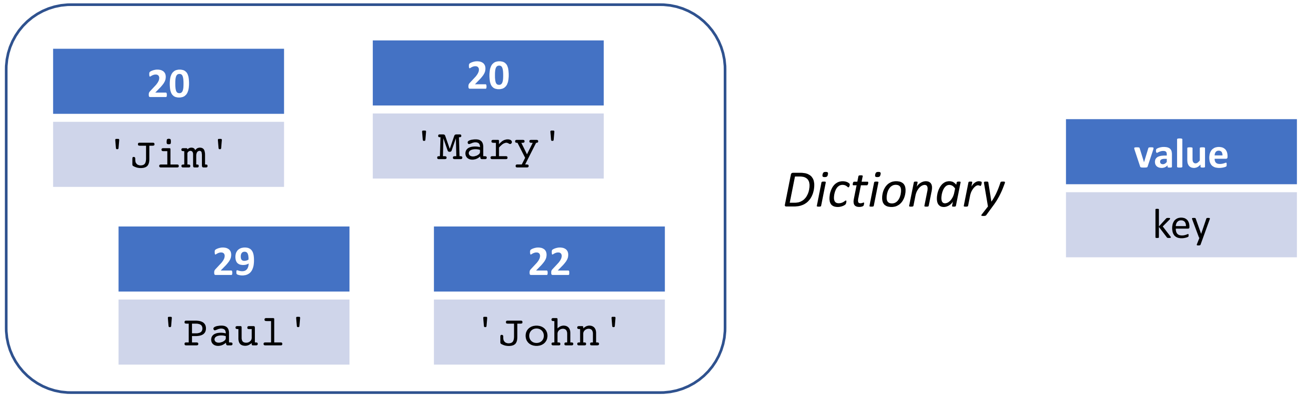
index $\mapsto$ **value**

✓ A dictionary represents data values by *using key labels*, and then accesses values by their keys, i.e., *associates* key labels to values (associative memory):

key $\mapsto$ **value**

Dictionary data structure: unordered, associative array (map)

```
d = {'John': 22, 'Jim': 20, 'Mary': 20, 'Paul': 29}
```

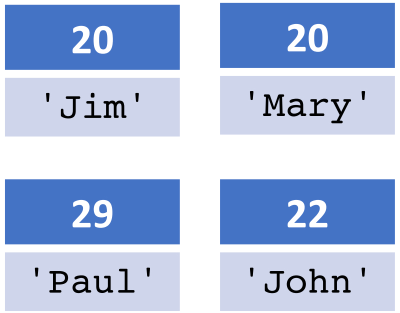


- `d['John']` is the value of **associated** to the keyword `'John'`, which is 22
- `d[1]` throws an error: there’s no a key with value 1 in the dictionary

Dictionary data structure: non-scalar, mutable

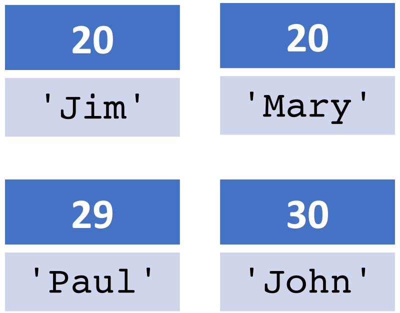
- **Non-scalar**: it’s a composite data type, it has *internal structure*
- **Mutable:** values of dictionary’s entries can be *updated* and items can be added and deleted (without changing dictionary identity), *aliases* can be created between variables

```
d = {'John': 22, 'Jim': 20, 'Mary': 20, 'Paul': 29}
```



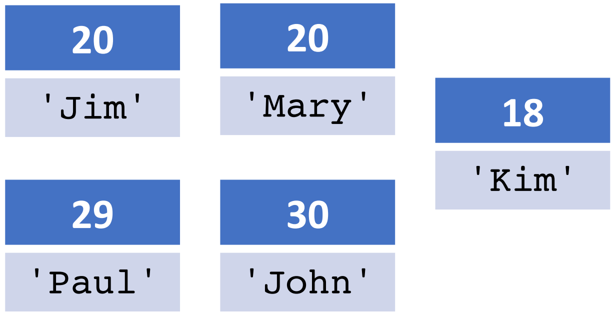
✓ Update value of existing keys

```
d['John'] = 30
```



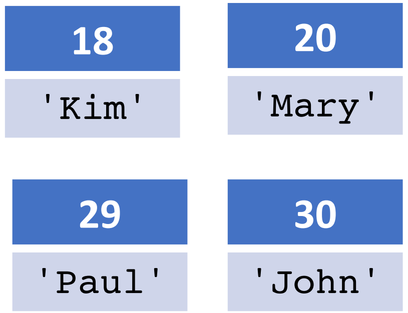
✓ Add a new key-value pair:

```
d['Kim'] = 18
```



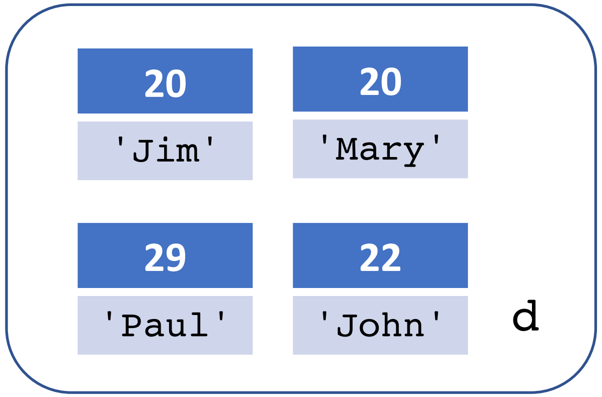
✓ Delete an existing item:

```
del d['Jim']
```



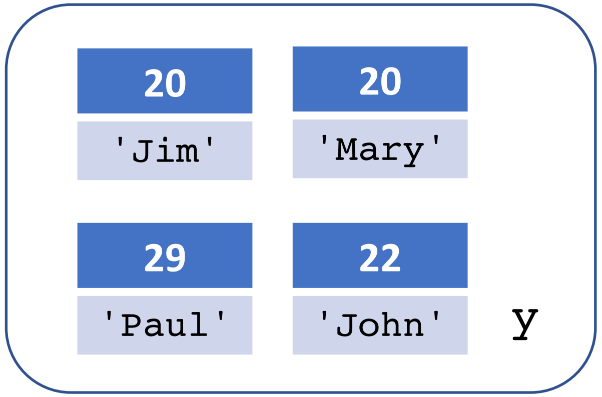
Dictionary data structure: mutable

`d = {'John': 22, 'Jim': 20, 'Mary': 20, 'Paul': 29}`



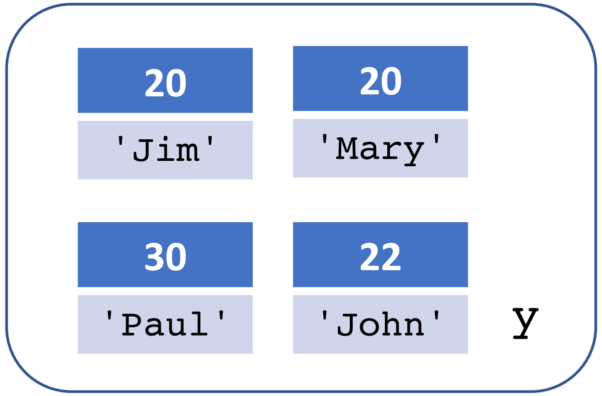
✓ Create an alias:

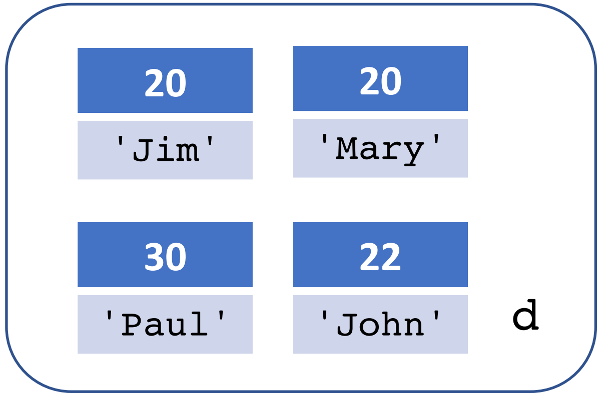
`y = d`



- Changing `y` changes `d` and vice versa:

`y['Paul'] = 30`





- The two dictionaries have the <u>same identity</u>:

`id(y)` is the same as `id(d)`

Restrictions and freedom on data types for keys and values

key ↦ **value**

- A **key** can only contain **immutable** data types: `int, float, bool, str, tuple`
- A **value** can be of **any type**
- **Keys and values** of the same dictionary can be of any (allowed) mixed type

```
d = {'John': 22, 'Jim': 20, 'Mary': 20, 'Paul': 29}
```

✓ `d[12] = 'New data value'`

✓ `d['Jim'] = True`

✓ `d['List data'] = [ [1,2,3], [4,5,6] ]`

✓ `d[(2,3)] = 7.8`

❖ `d[[2,3]] = 'Incorrect'`

❖ `d[([1,3], 2)] = 'Incorrect'`

Why do we need an associative data structure?

✓ Because by using labels we can access to values much more **efficiently** than with lists, for instance

- Dictionaries are in fact **hashed** data types, while lists (sequences) are *indexed* data types

`value in data_list ?`

Data value	20	22	29	28
Position index	0	1	2	3

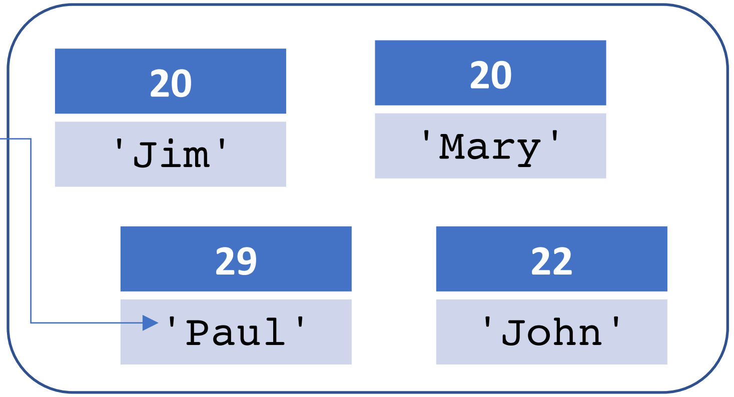
```
x = [20, 22, 29, 28]
```

Worst-case search time **linear** with the length of the list

`key in dictionary ?`

```
d = {'John': 22, 'Jim': 20, 'Mary': 20, 'Paul': 29}
```

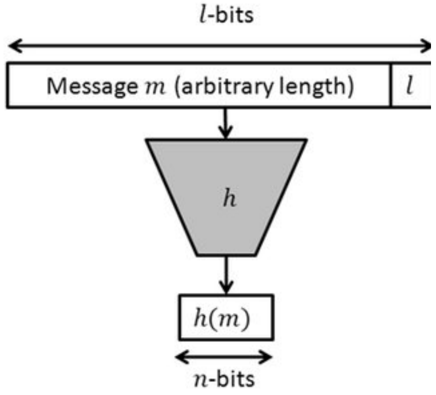
`HashFunction(key)`

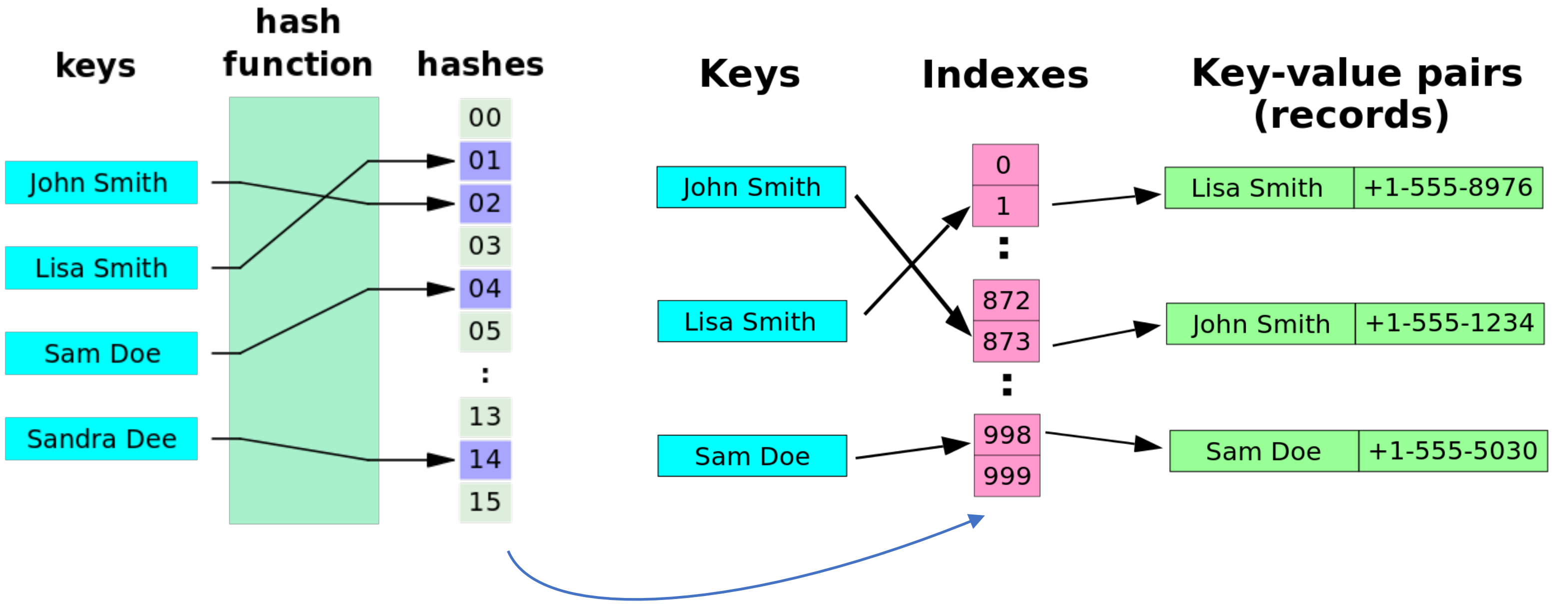


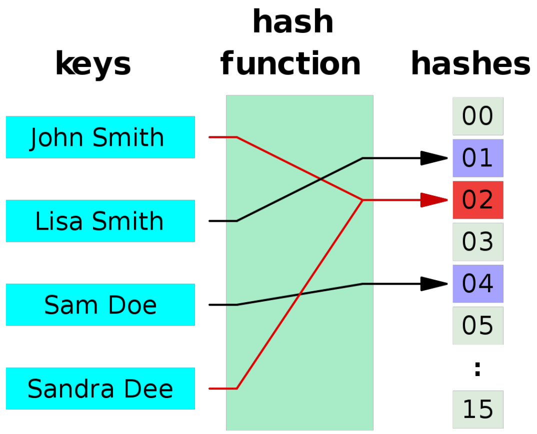
Constant search time

(independent of dictionary size)

Dictionary as hashed data type







- **Computation time:**
  Time to compute the hash
  + one direct memory access

➢ **Insert a new pair** `(key, value)` to a dictionary:
- ✓ `hash(key)` computes an *index*
- ✓ The pair `(key, value)` is stored directly at the *index* location

➢ **Access the value associated to key:**
- ✓ `hash(key)` gives the *index*
- ✓ The pair `(key, value)` at the *index* location is returned directly

Functions and operators for inspecting a dictionary

```
accounts = {'J. Smith': [35672, 'M', 'USA'], 'M. Saleh': [27623, 'M', 'Jordan'],
            'F. Dupont': [17623, 'F', 'France'] }
phone_numbers = {'Ann': 5461, 'Paul': 5472, 'Mark': 3541, 'Liz': 2451}
numbers = {1: 'r', 2: 'p', 3:'p', 4:'r', 5:'p', 6:'r'}
```

- Count all the key-value items present in the dictionary: `len(dictionary)` function

  `len(accounts)` → `3` (int type)

  `len(numbers)` → `6` (int type)

- Get the list with the keys present in the dictionary: `list(dictionary)` function

  `list(accounts)` → `['J. Smith', 'M. Saleh', 'F. Dupont']` (list type)

  `list(phone_numbers)` → `['Ann', 'Paul', 'Mark', 'Liz']` (list type)

  `list(numbers)` → `[1, 2, 3, 4, 5, 6]` (list type)

- Check whether a key exists or not in the dictionary: membership operators `in`, `not in`

  `3 in numbers` → `True` (bool type)

  `'Jim' not in phone_numbers` → `True` (bool type)

Methods for inspecting a dictionary: `keys()`

- Get a *dynamic view* on the dictionary keys: `dict.keys()` method, returns a **view object**

`numbers.keys()` → `dict_keys([1, 2, 3, 4, 5, 6])` (**view object**)

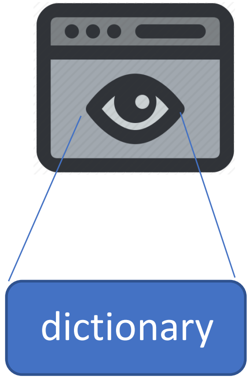
vs.

`list(numbers)` → `[1, 2, 3, 4, 5, 6]` (**list object**)

→ The keys() method doesn't return a *physical list* with the current keys, as list() does, instead it provides a **view object,** a window view on the dictionary which is dynamically kept up-to-date

- ✓ Save memory
- ✓ If things changes in the dictionary, these can be seen through the view object

view object



Methods for inspecting a dictionary: `keys()`

```
numbers = {1: 'p', 2: 'p', 3:'p', 4:'r', 5:'p', 6:'r'}
keys_now_in_dict = list(numbers)
keys_view = numbers.keys()
numbers[13] = 'p'
print("Is 13 in dict? From static list copy:", (13 in keys_now_in_dict) )
print("Is 13 in dict? From dynamic view:", (13 in keys_view) )
```

Methods for inspecting a dictionary: `values()`, `items()`

- Get a *dynamic view* on the dictionary **values** : `dict.values()` method, returns a **view object**

```
numbers.values()   →   dict_values(['p', 'p', 'p', 'r', 'p', 'r'])
```

- Get a *dynamic view* on the **entire dictionary**: `dict.items()` method, returns a **view object**

```
numbers.items()   → dict_items([(1, 'p'), (2, 'p'), (3, 'p'),
                                (4, 'r'), (5, 'p'), (6, 'r')])
```

Methods for inspecting a dictionary: iterations

- Iterate over all dictionary elements :

```
for k in numbers:
  print('Key:', k)

for i in numbers.items():
  print('Pair (key, value):', i[0], i[1])
```

Observations:

- A dictionary is "*identified*" by its collection of keys, this is why directly iterating over the dictionary in the first example is in practice equivalent to iterate over the keys, that are the returned sequence values
- Iterations over `dict.items()` return the pairs (key, value) as tuples, where the key has index 0 and the value has index 1

Relational and arithmetic operators for dictionaries

```
accounts = {'J. Smith': [35672, 'M', 'USA'], 'M. Saleh': [27623, 'M', 'Jordan'],
            'F. Dupont': [17623, 'F', 'France'] }
numbers = {1: 'r', 2: 'p', 3:'p', 4:'r', 5:'p', 6:'r'}
```

- `==` operator: check whether two dictionary are the same, same (key , value) pairs

```
x = accounts == numbers   → False

accounts2 = accounts.copy()
x = accounts == accounts2   → True
```

- Other relational operators `>, >=, <, <=` do not apply to dictionary operands
- Arithmetic operators do not apply to dictionary operands

Practice:

Implement the function `add_pair(k, v, d)` that returns the dictionary `d` modified such that the key `k` is associated with value `v`. If the key is already in the dictionary, its value may be modified. Otherwise, a new key needs to be added to the dictionary.

```
def add_pair(k, v, d):
    d[k] = v
    return d
```

Practice:

Implement the function `is_key_in(k, d)` that returns `True` if the key `k` is in the dictionary `d`, or `False` otherwise.

```
def is_key_in(k, d):
    return k in d
```

Practice:

Implement the function `is_value_in(v, d)` that returns `True` if the value `v` is in the dictionary `d`, or `False` otherwise.

```
def is_value_in(v, d):
    for k in d:
        if d[k] == v:
            return True
    return False
```

Practice:

Implement the function `get_value(k, d)` that returns the value associated with key `k` in the dictionary `d`, if it exists. If the dictionary does not contain such key, return `None`.

```
def get_value(k, d):
    if k in d:
        return d[k]
    else:
        return None
```

Practice:

Implement the function `get_key(k, d)` that returns a key which contains value `v` in the dictionary `d`, if it exists. If the dictionary does not contain a key with this value, return `None`.

```
def get_value(k, d):
    if k in d:
        return d[k]
    else:
        return None
```

Practice:

Implement the function `count(l)` that takes a list and returns a dictionary where the keys are elements of the list and the values are the number of times that element occurred in the list.

For example, count(['a','b','b','a','c','b'])
should return the dictionary: {'a': 2, 'b': 3, 'c': 1}.

```
def count(l):
    d = {}
    for e in l:
        if e in d:
            d[e] += 1
        else:
            d[e] = 1
    return d
```

Practice:

Implement the function `get_middle(d)` that takes a dictionary and returns value of the middle key (if the dictionary was sorted).

For example, `get_middle({'b': 5, 'a': 3, 'c': 1})` should return 5.

```
def get_middle(d):
    items = d.items()
    items = sorted(items)
    middle = items[len(items)//2]
    return middle[1]
```