

# Dictionaries and Sets

- dict
- set
- frozenset
- set/dict comprehensions

# Dictionaries (type dict)

$\{ key_1: value_1, \dots, key_k: value_k \}$

- Stores a mutable set of (key, value) pairs, denoted *items*, with distinct keys, i.e. *maps* keys to values
- Constructing empty dictionary: `dict()` or `{}`
- `dict[key]` lookup for key in dictionary, and returns associated value. Key must be present, otherwise a `KeyError` is raised
- `dict[key] = value` assigns value to *key*, overriding existing value if present

key	value
'a'	7
'foo'	'42nd'
5	29
'5'	44
5.5	False
False	True
(3, 4)	'abc'



distinct keys,  
i.e. not "=="

# Dictionaries (type dict)

## Python shell

```
> d = {'a': 42, 'b': 57}
> d
| {'a': 42, 'b': 57}

> d.keys()
| dict_keys(['a', 'b'])

> list(d.keys())
| ['a', 'b']

> d.items()
| dict_items([('a', 42), ('b', 57)])

> list(d.items())
| [('a', 42), ('b', 57)]
```

```
> for key in d:
    print(key)
| a
| b

> for key, val in d.items():
    print('Key', key, 'has value', val)
| Key a has value 42
| Key b has value 57

> {5: 'a', 5.0: 'b'}
| {5: 'b'}
```



## Python shell

```
> surname = dict(zip(['Donald', 'Mickey', 'Scrooge'], ['Duck', 'Mouse', 'McDuck']))
> surname['Mickey']
| 'Mouse'
```

# Dictionaries (type dict)

## Python shell

```
> gradings = [('A', 7), ('B', 4), ('A', 12), ('C', 10), ('A', 7)]
> grades = {} # empty dictionary
> for student, grade in gradings:
    if student not in grades: # is key in dictionary
        grades[student] = []
    grades[student].append(grade)
> grades
| {'A': [7, 12, 7], 'B': [4], 'C': [10]}
> print(grades['A'])
| [7, 12, 7]
> print(grades['E']) # can only lookup keys in dictionary
| KeyError: 'E'
> print(grades.get('E')) # .get returns None if key not in dictionary
| None
> print(grades.get('E', [])) # change default return value
| []
> print(grades.get('A', []))
| [7, 12, 7]
```

# Dictionary initialization

## Python shell

```
> d1 = {'A': 7, 'B': 42}
> d2 = dict([('A', 7), ('B', 42)]) # list of (key, value) pairs
> d3 = dict(A=7, B=42)             # keyword arguments to constructor
> d1 == d2 == d3
| True
```

- **Note:** *keyword initialization* only works if keys are strings which are valid keyword arguments to a function – but saves writing a lot of quotes

## Python shell

```
> d1 = dict(A=1, B=2)
> d2 = dict(B=3, C=4)
> d1 | d2                               # merge dictionaries
| {'A': 1, 'B': 3, 'C': 4}             # rightmost value for 'B' wins
> {**d1, **d2, 'D': 5}                  # ** inserts dictionary content
| {'A': 1, 'B': 3, 'C': 4, 'D': 5}     # rightmost value for 'B' wins
> d1 |= d2                             # same as d1.update(d2)
> d1
| {'A': 1, 'B': 3, 'C': 4}
```



| and |=

new in  
Python 3.9  
PEP 584

Dictionary operation	Description
<code>len(d)</code>	Items in dictionary
<code>d[key]</code>	Lookup key
<code>d[key] = value</code>	Update value of key
<code>del d[key]</code>	Delete an existing key
<code>key in d</code>	Key membership
<code>key not in d</code>	Key non-membership
<code>clear()</code>	Remove all items
<code>copy()</code>	Shallow copy
<code>get(key), get(key, default)</code>	<code>d[key]</code> if key in dictionary, otherwise <code>None</code> or default
<code>items()</code>	<i>View</i> of the dictionaries items
<code>keys()</code>	<i>View</i> of the dictionaries keys
<code>values()</code>	<i>View</i> of the dictionaries values
<code>pop(key)</code>	Remove key and return previous value
<code>popitem()</code>	Remove and return an arbitrary item
<code>update()</code>	Update key/value pairs from another dictionary

# Tuples as dictionary keys

- A tuple can be used as a dictionary key, and parenthesis can be omitted

Python shell -

```
> d = {('a', 1): 7, ('b', 2): 42}
> d[('b', 2)]
| 42
> d['b', 2] # same as above, parenthesis omitted
| 42
> T = [[None, None], [42, None]] # 2D table as lists-of-lists
> T[1][0]
| 42
> T[1, 0] # wrong, T is a list (of lists)
| TypeError: list indices must be integers or slices, not tuple
> T = {(1, 0): 42} # 2D table as dictionary
> T[1, 0] # dictionary lookup with tuple (1, 0) as key
| 42
> T[1][0] # wrong, T has only one key = the tuple (1, 0)
| KeyError: 1
```

# Order returned by `list(d.keys())` ?

## The Python Standard Library Mapping Types — dict

“Dictionaries preserve insertion order. Note that updating a key does not affect the order. Keys added after deletion are inserted at the end.” (since Python 3.7)

[docs.python.org/3/library/stdtypes.html](https://docs.python.org/3/library/stdtypes.html)

### Python shell

```
> d = {'d': 1, 'c': 2, 'b': 3, 'a': 4}
> d['x'] = 5      # new key at end
> d['c'] = 6      # overwrite value
> del d['b']      # remove key 'b'
> d['b'] = 7      # reinsert key 'b' at end
> d
| {'d': 1, 'c': 6, 'a': 4, 'x': 5, 'b': 7}
```



Raymond Hettinger @ Twitter

**See also Raymond's talk @ PyCon 2017**  
Modern Python Dictionaries  
A confluence of a dozen great ideas



# Dictionary comprehension

- Similarly to creating a list using list comprehension, one can create a set of key-value pairs:

*{key : value for variable in list}*

## Python shell

```
> names = ['Mickey', 'Donald', 'Scrooge']
> list(enumerate(names, start=1))
| [(1, 'Mickey'), (2, 'Donald'), (3, 'Scrooge')]
> dict(enumerate(names, start=1))
| {1: 'Mickey', 2: 'Donald', 3: 'Scrooge'}
> {name: idx for idx, name in enumerate(names, start=1)}
| {'Mickey': 1, 'Donald': 2, 'Scrooge': 3}
```


# Sets (set and frozenset)

$\{value_1, \dots, value_k\}$

- Values of type `set` represent mutable sets, where "==" elements only appear once
- Do **not** support: indexing, slicing
- `frozenset` is an immutable version of `set`

Python shell	
> S = {2, 5, 'a', 'c'}	> S ^ T
> T = {3, 4, 5, 'c'}	{2, 3, 4, 'a'}
> S   T	> S - T
{2, 3, 4, 5, 'a', 'c'}	{2, 'a'}
> S & T	> {4, 5, 5.0, 5.1}
{5, 'c'}	{4, 5, 5.1}



Operation	Description
$S \mid T$	Set union
$S \& T$	Set intersection
$S - T$	Set difference
$S \wedge T$	Symmetric difference
<code>set()</code>	Empty set ( <code>{}</code> = empty dictionary  )
<code>set(L)</code>	Create set from sequence
<code>x in S</code>	Membership
<code>x not in S</code>	Non-membership
<code>S.isdisjoint(T)</code>	Disjoint sets
$S \leq T$	Subset
$S < T$	Proper subset
$S \geq T$	Superset
$S > T$	Proper superset
<code>len(S)</code>	Size of S
<code>S.add(x)</code>	Add x to S (not frozenset)

<https://docs.python.org/3/tutorial/datastructures.html#sets>

<https://docs.python.org/3/library/stdtypes.html#set-types-set-frozenset>

# Question – What value has the expression ?

```
sorted( { 5, 5.5, 5.0, '5' } )
```

a) { '5', 5, 5.0, 5.5 }

b) { 5, 5.5 }

c) [ '5', 5.0, 5.5 ]

d) [ '5', 5, 5.5 ]



e) TypeError

f) Don't know

# Sets of (frozen) sets

- Sets are mutable, i.e. cannot be used as dictionary keys or elements in sets
- Frozen sets can



Python shell

```
> S = {'a', {'a', 'b'}, {'a', 'c'}}
| TypeError: unhashable type: 'set'
> S = {frozenset({'a'}), frozenset({'a', 'b'}), frozenset({'a', 'c'})}
> frozenset({'a', 'b'}) in S
| True
> {'a', 'b'} in S # automatically converts unhashable set to frozenset
| True
> {'a', 'b'} == frozenset(['a', 'b']) # frozenset from list
| True
> D = {frozenset({'a', 'b'}): 42} # dictionary
> frozenset({'a', 'b'}) in D
| True
> {'a', 'b'} in D # dictionaries are not that friendly as sets
| TypeError: unhashable type: 'set'
```

# Set comprehension

- Similarly to creating a list using list comprehension, one can create a set of values (also using nested for- and if-statements):

*{value for variable in list}*

- A value occurring multiple times as *value* will only be included once

## primes\_set.py

```
n = 101
not_primes = {m for f in range(2, n) for m in range(2 * f, n, f)}
primes = set(range(2, n)) - not_primes
```

## Python shell

```
> L = ['a', 'b', 'c']
> {(x,(y,z)) for x in L for y in L for z in L if x != y and y != z and z != x}
| {('a',('b','c')),('a',('c','b')),('b',('a','c')),...,(('c',('b','a')))}
> L = {'a', 'b', 'c'}
> {(x,(y,z)) for x in L for y in L - {x} for z in L - {x, y}}
| {('c',('b','a')),('c',('a','b')),('a',('c','b')),...,(('b',('a','c')))}
```

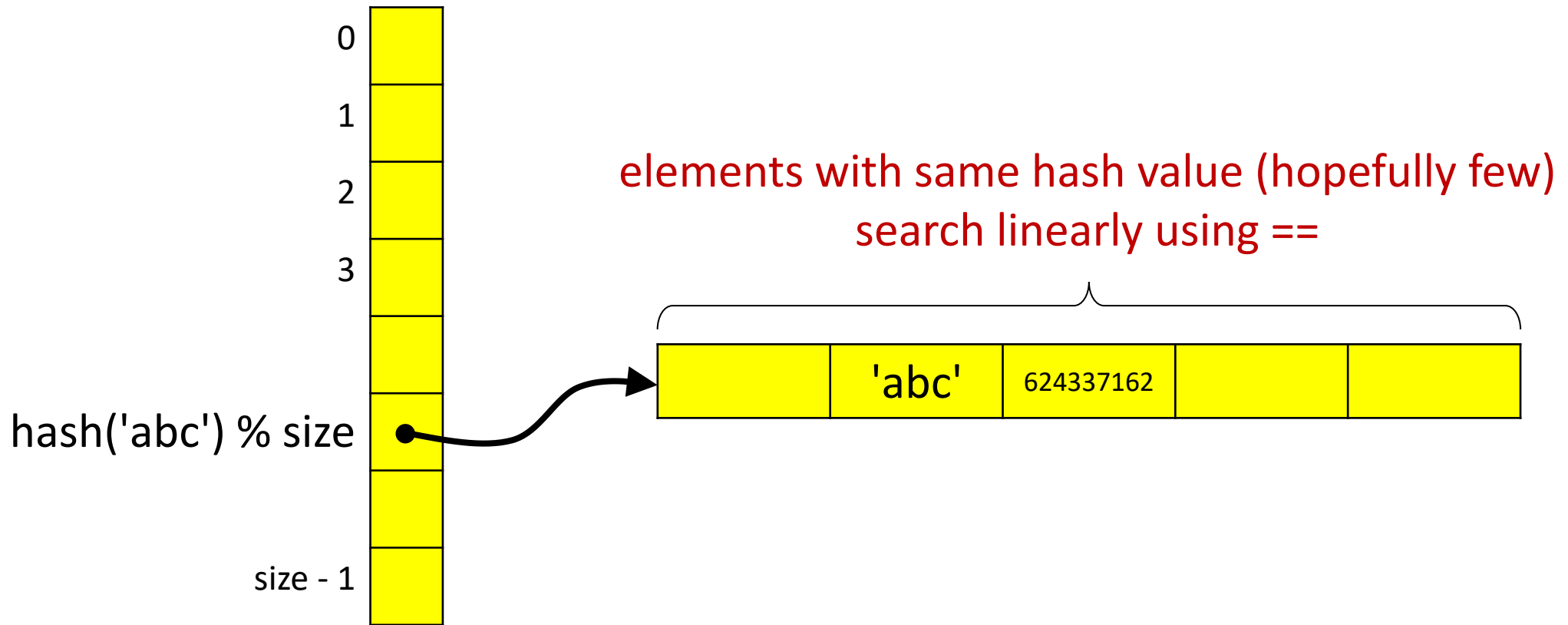
# Hash, equality, and immutability

- Keys for dictionaries and sets must be *hashable*, i.e. have a `__hash__()` method returning an integer that does not change over their lifetime and an `__eq__()` method to check for equality with “==”

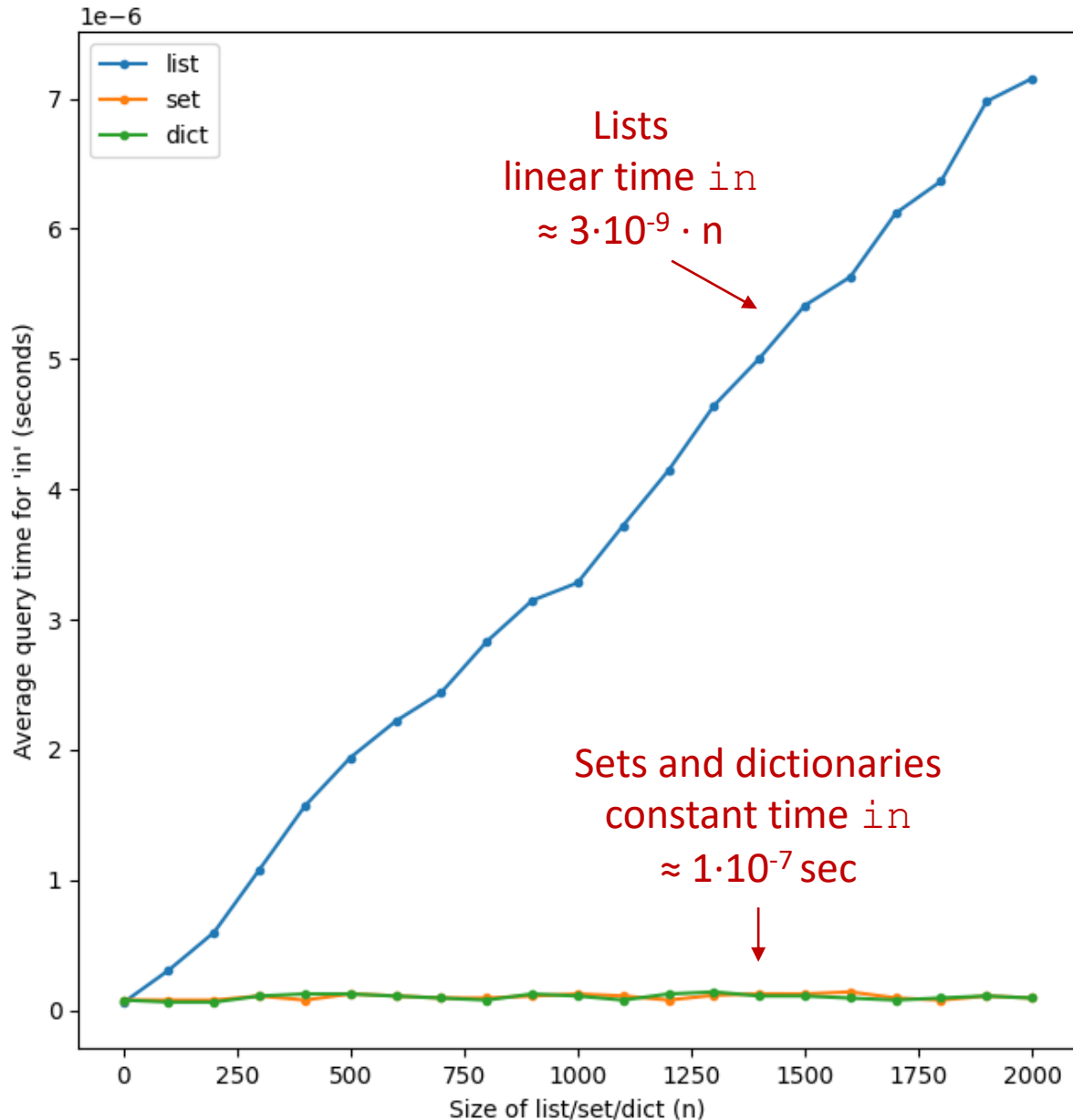
`'abc'.__hash__()` could e.g. return 624337162  
`(624337162).__hash__()` would also return 624337162

- **All built-in immutable types are hashable.** In particular tuples of immutable values are hashable. I.e. trees represented by nested tuples like `((('a'), 'b'), ('c', ('d', 'e')))` can be used as dictionary keys or stored in a set

# Sketch of internal set implementation



# Membership queries `in`



in.py

```
from random import shuffle, choices
from time import time
import matplotlib.pyplot as plt

time_L = []
time_S = []
time_D = []

ns = [1, *range(100, 2001, 100)]

for n in ns:
    print(f'{n = }')
    L = list(range(n))
    shuffle(L)
    S = set(L)
    D = {value: 42 for value in L}

    queries = choices(L, k=1_000_000)
    for X, times in [(L, time_L), (S, time_S), (D, time_D)]:
        count = 0
        start = time()
        for q in queries:
            if q in X:
                count += 1
        end = time()
        times.append((end - start) / len(queries))

plt.plot(ns, time_L, '-.', label='list')
plt.plot(ns, time_S, '-.', label='set')
plt.plot(ns, time_D, '-.', label='dict')
plt.xlabel('Size of list/set/dict (n)')
plt.ylabel('Average query time for "in" (seconds)')
plt.legend()
plt.show()
```



Avoid using `in` repeatedly on long lists




# Module `collections` (container datatypes)

- Python builtin containers for data: `list`, `tuple`, `dict`, and `set`.
- The module `collections` provides further alternatives (but these are not part of the language like the builtin containers)

<code>deque</code>	double ended queue
<code>namedtuple</code>	tuples allowing access to fields by name
<code>Counter</code>	special dictionary to count occurrences of elements
<code>...</code>	

# deque – double ended queues

- Extends lists with efficient updates at the front
-  Inserting at the front of a standard Python list takes linear time in the size of the list – very slow for long lists

## Python shell

```
> L = list()
> L.append(1)
> L.append(2)
> L.insert(0, 0) # insert at the front
> L.insert(0, -1) # slow for long lists
> L.insert(0, -2)
> L
| [-2, -1, 0, 1, 2]
```

```
> from collections import deque
> d = deque() # create empty deque
> d.append(1)
> d.append(2)
> d.appendleft(0) # efficient
> d.appendleft(-1)
> d.appendleft(-2)
> d
| deque([2, 1, 0, -1, -2])
> for e in d: print(e, end=', ')
| -2, -1, 0, 1, 2,
```



Since  
Python 3.7  
dataclass  
better choice

# namedtuple – tuples with field names

- Compromise between `tuple` and `dict`, can increase code readability

## Python shell

```
> person = ('Donald Duck', 1934, '3 feet') # as tuple
> person[1] # not clear what is accessed
| 1934
> person = {'name': 'Donald Duck', 'appeared': 1934, 'height': '3 feet'} # as dict
> person['appeared'] # more clear what is accessed, but ['...'] overhead
| 1934
> from collections import namedtuple
> Person = namedtuple('Person', ['name', 'appeared', 'height']) # create new type
> person = Person('Donald Duck', 1934, '3 feet') # as namedtuple
> person
| Person(name='Donald Duck', appeared=1934, height='3 feet')
> person.appeared # short and clear
| 1934
> person[1] # still possible
| 1934
```

# Counter – dictionaries for counting

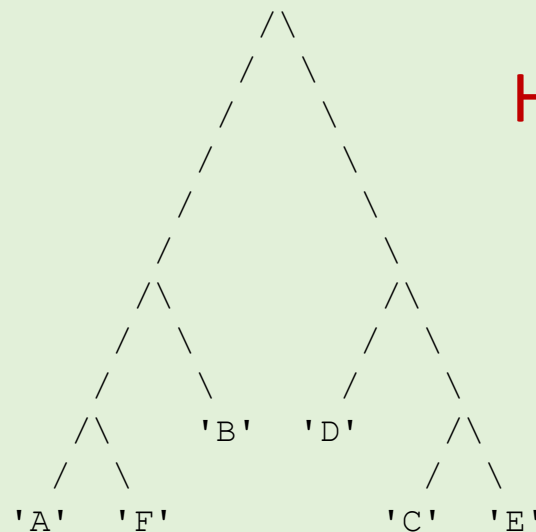
## Python shell

```
> from collections import Counter
> fq = Counter('abracadabra') # create new counter from a sequence
> fq
Counter({'a': 5, 'b': 2, 'r': 2, 'c': 1, 'd': 1}) # frequencies of the letters
> fq['a']
5
> fq.most_common(3)
[('a', 5), ('b', 2), ('r', 2)]
> fq['x'] += 5 # increase count of 'x', also valid if 'x' not in Counter yet
> Counter('aaabbbcc') - Counter('aabdd') # counters can be subtracted
Counter({'b': 2, 'c': 2, 'a': 1})
> Counter([1, 2, 1, 3, 4, 5]) + Counter([3, 3, 3]) # counters can be added
Counter({3: 4, 1: 2, 2: 1, 4: 1, 5: 1})
> T = 'AfD adsf dsa f dsaf daf dsaf DSA fda f SA dsa f dsa fdsa f dsAf sAf f dsaf'
> Counter(T.lower().split()).most_common(3)
[('f', 5), ('dsa', 4), ('dsaf', 4)]
```

# Handin 3 & 4 – Triplet distance (Dobson, 1975)

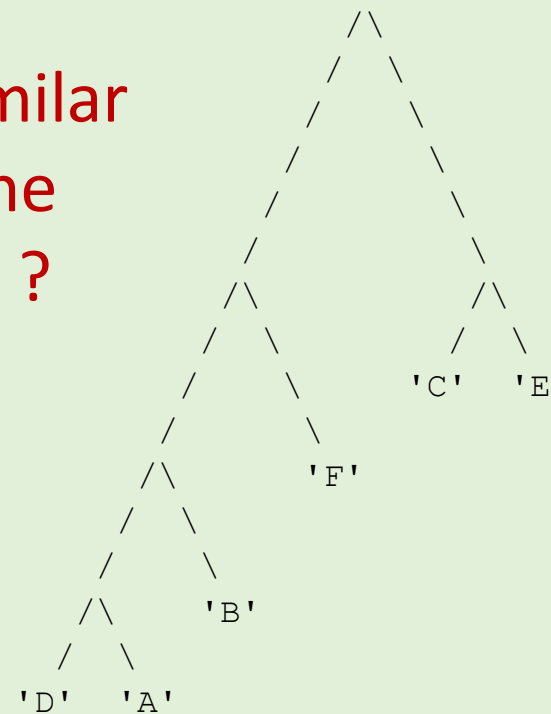
((('A', 'F'), 'B'), ('D', ('C', 'E'))))    (((('D', 'A'), 'B'), 'F'), ('C', 'E')))

(a)



How similar  
are the  
trees ?

(b)



# Handin 3 & 4 – Triplet distance (Dobson, 1975)

Consider all  $\binom{n}{3}$  subsets of size three, and count how many do not have identical substructure (topology) in the two trees.

