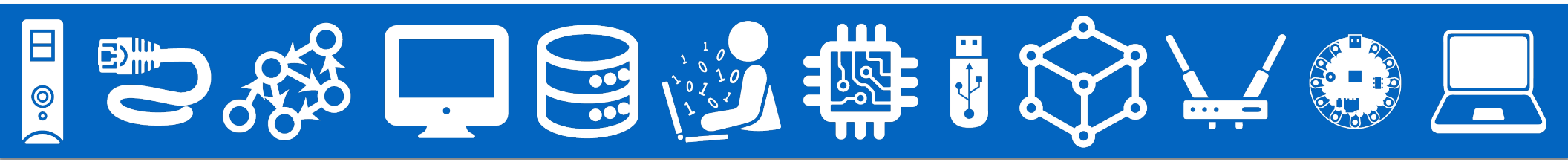
CS134:
Dictionaries & Comparison to Lists



Announcements & Logistics

- **Practice midterm** on Glow
  - Midterm from F18 with slight modifications to fit our syllabus
- **Lab 5** is a short debugging lab, due Friday at noon for everyone
  - Expect most people to finish it during scheduled lab period
- **Midterm**: Thu Oct 20 6 - 7:30pm, 8 - 9:30pm in TCL 123 (Wege)
    - TCL 206 reserved for reduced distractions/extra time (pick up exam in TCL 123)
- **Midterm review**: Tue Oct 18 8-9:30pm in TCL 123
    - Try to review practice midterm before then!
- **No class** Fri Oct 21st

Do You Have Any Questions?

Midterm Material

- Labs 1-4
  - Lab 1: Intro to Python
  - Lab 2: Day of the week (if else statements)
  - Lab 3: Word puzzles (strings and loops)
  - Lab 4: Every vote counts (lists, strings, lists of lists, loops)
- Homeworks 2-5
- Lectures 1-15 (up to dictionaries) + Jupyter notebooks
- Book: parts of Ch 1, 2, 3, 5, 8, 9 10, 12 (we won't ask questions directly from the book)

Midterm Topics

- Variables, Types & Arithmetic Operators (%, //, /, etc)
- Functions, Booleans and Conditionals (if elif else)
- Iteration: for loops, while loops, nested loops, list comprehensions
- Sequences:
  - Strings: string methods, iteration, etc
  - Lists: list methods (append, extend), iteration, lists of lists, etc
  - Ranges and tuples
  - Operators: +, [ ], [:], * , in/not in, etc
- File reading: with open(…) as
- Mutability and aliasing implications for lists
- Misc: doctests, simplification of verbose code

Last Time

- Discussed stable sorting and ways to override it using key function
- Introduced a new data structure: **dictionary**
  - Unordered, ***mutable*** key, value pairs
  - Keys must be **immutable** and **unique**, while values need not be
  - E.g., a dictionary storing key-value pairs of names and ages:
    ```
    {"Charlie": 8, "Linus": 5, "Snoopy": 72}
    ```
- (No dictionaries on the midterm)

Today's Plan

- Discuss dictionaries in more detail with examples
- Learn about dictionary methods such as `.get()`
- Use dictionaries to find the most frequent words from a wordList
- Examine differences between storing data as lists/nested lists vs. dictionaries

Recap: Dictionaries

- A **dictionary** is a **mutable** collection that maps **keys** to **values**
  - Enclosed with curly brackets, and contains comma-separated items
- An item in the dictionary pair is a ***colon-separated key, value pair***.
  - There is no ordering between the keys of a dictionary!

```
# sample dictionary
zipCodes = {'01267': 'Williamstown', '60606': 'Chicago',
            '48202': 'Detroit', '97210': 'Portland'}
```

key

value

- **Keys** must be **immutable** and **unique**
- **Values** can any Python object (numbers, strings, lists, tuples, etc.)

Accessing/Adding Items in a Dictionary

- We access a dictionary using its keys as the "subscript"
  - If the key exists, its value is returned. Otherwise, we get a `KeyError`

```
>>> # sample dictionary
>>> zipCodes = {"01267": "Williamstown", "60606": "Chicago",
                "48202": "Detroit", "97210": "Portland"}

>>> # what US city has this zip code?
>>> zipCodes["60606"]
'Chicago'
```

key

value

value associated with key '60606'

- To add a new key, value pair, we assign the key to the value using:
  `dictName[key] = value`
  - If the key already exists, an assignment will ***overwrite*** its value and assign it the new value to the existing key

```
>>> zipCodes["11777"] = "Port Jefferson"
```

Add a new key, value pair `'11777': 'Port Jefferson'`

Iterating Over a Dictionary

- Can **iterate over the keys** of a dictionary directly in a for loop
- Note: In Python 3.6 and beyond, the keys and values of a dictionary are **iterated over in the same order in which they were created**.

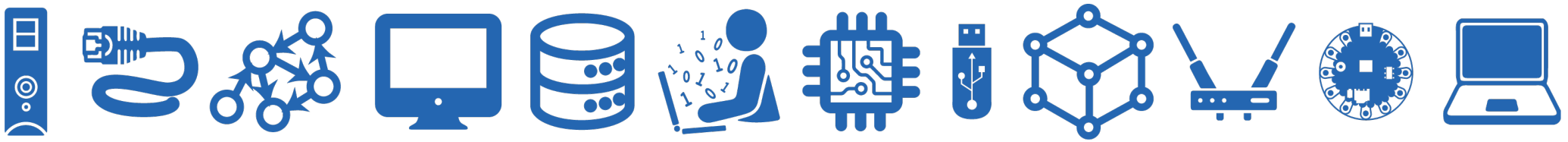
```
>>> calendar = {"Jan": 31, "Feb": 28, "Mar": 31, "Apr": 30,
                "May": 31, "Jun": 30, "Jul": 31, "Aug": 31,
                "Sep": 30, "Oct": 31, "Nov": 30, "Dec": 31}

>>> for day in calendar:
>>> ...     print(day, calendar[day], end=" ")

Jan 31 Feb 28 Mar 31 Apr 30 May 31 Jun 30
Jul 31 Aug 31 Sep 30 Oct 31 Nov 30 Dec 31
```

An aside: This changes behavior of print to use spaces instead of new lines

Computing Frequency



Computing a `frequency`

- One common use of a dictionary is to store **frequencies**.
- Let's write a function `frequency()` that takes as input a list of strings `wordList` and returns a dictionary `freqDict` with the unique strings in `wordList` as keys, and their number of occurrences (ints) in `wordList` as values
- For example if `wordList` is:

```
['hello', 'world', 'hello', 'earth', 'hello', 'earth']
```

the function should return a dictionary with the following items:

```
{'hello': 3, ‘world': 1, 'earth': 2}
```

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```
def frequencyOld(wordList):
    """Given a list of words, returns a dictionary of word frequencies"""
    freqDict = {} # initialize accumulator as empty dict
    for word in wordList:
        if word not in freqDict:
            freqDict[word] = 1 # add key with count 1
        else:
            freqDict[word] += 1 # update count
    return freqDict
```

Useful Dictionary Method: `.get()`

- The following code pattern is very common when using dictionaries:

```
if aKey not in myDict:
    myDict[aKey] = initVal + incrementVal # add key
else: # if already exists
    myDict[aKey] += incrementVal # update val
```

- Rather than writing the `if, else` block as shown above, we can use the `.get()` method for dictionaries

Useful Dictionary Method: `.get()`

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```

- Rather than writing the `if, else` block as shown above, we can use the `.get()` method for dictionaries

```
myDict[aKey] = myDict.get(aKey, initVal) + incrementVal
```

Useful Dictionary Method: `.get()`

- `.get()` method is an alternative to using [ ] to get the value associated with a key in a dictionary; eliminates the need to check for the key's existence beforehand
- `.get()` takes two arguments: a `key`, and an ***optional*** default `value` to use if the key is not in the dictionary
- It returns the `value` associated with the given `key`, and if `key` does not exist, it returns the `default value` (if given), otherwise returns **None**.
- Syntax: `value = myDict.get(aKey, defaultVal)`

key whose value we are looking for in `myDict`

if key doesn't exist, return this default value

Useful Dictionary Method: `.get()`

- `get()` method **does not modify the dictionary** it is called on

```
>>> ids = {"ikh1": "Iris", "jra1": "Jeannie", "lpd2": "Lida"}
>>> ids.get("jra1", "Ephelia")
'Jeannie'

>>> ids.get("xyz1", "Ephelia")
'Ephelia'

>>> ids # .get(..) does not change the dictionary!
{'ikh1': 'Iris', 'jra1': 'Jeannie', 'lpd2': 'Lida'}

>>> print(ids.get("xyz1"))
None
```

Computing `frequency` Improved

- Let's rewrite our `frequency` function using `.get()` instead of **if else**

```
def frequencyOld(wordList):
    """Given a list of words, returns a dictionary of word frequencies"""
    freqDict = {} # initialize accumulator as empty dict
    for word in wordList:
        if word not in freqDict:
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```

- What should we write instead inside the for loop?

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            freqDict[word] += 1 # update count
    return freqDict
```
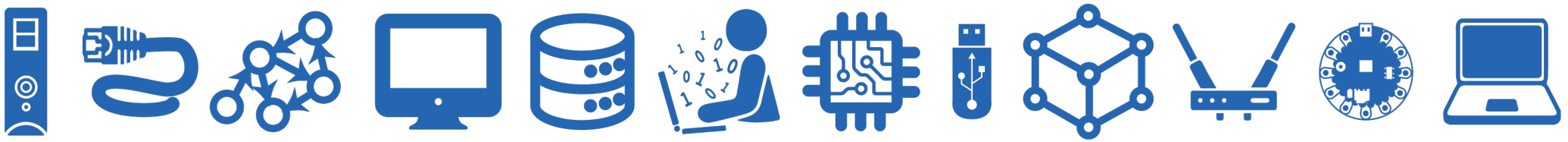

- What should we write instead inside the for loop?

```
def frequency(wordList):
    """Given a list of words, returns a dictionary of word frequencies"""
    freqDict = {} # initialize accumulator as empty dict
    for word in wordList:
        freqDict[word] = freqDict.get(word, 0) + 1
    return freqDict
```

Other Dictionary Methods



Dictionary Methods: `keys()`, `values()`, `items()`

- Dictionary methods `keys()`, `values()`, `items()`: return a (list-like) object containing only the keys, values, and items, respectively.
- Note: We don't use these very often in practice

```
calendar = {'Jan': 31, 'Feb': 28, 'Mar': 31, 'Apr': 30,
            'May': 31, 'Jun': 30, 'Jul': 31, 'Aug': 31,
            'Sep': 30, 'Oct': 31, 'Nov': 30, 'Dec': 31}
```

```
>>> calendar.keys()
dict_keys(['Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul',
'Aug', Sep', 'Oct', Nov', 'Dec'])

>>> calendar.values()
dict_values([31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31])

>>> calendar.items()
dict_items([('Jan', 31), ('Feb', 28), ('Mar', 31), ('Apr', 30),
('May', 31), ('Jun', 30), ('Jul', 31), 'Aug', 31), ('Sep', 30),
('Oct', 31), ('Nov', 30), ('Dec', 31]))
```

Summary of Dictionary Methods

Method	Result	Mutates dict?
`.keys()`	Returns all keys as a `dict_keys` object	No
`.values()`	Returns all values as a `dict_values` object	No
`.items()`	Returns all (key, value) pairs as a `dict_items` object	No
`.get(key, val)`	Returns corresponding value if `key` in dict, else returns `val`. Second argument is **optional**, defaults to `None`.	No
`.pop(key)`	Removes key:value pair with given `key` from dict and returns associated val. `KeyError` if key not in dict.	**Yes**
`.update(dict2)`	Adds new key:value pairs from `dict2` to dict, replacing any key:value pairs with existing key	**Yes**
`.clear()`	Removes all items from the dict.	**Yes**

Dictionaries and Mutability

- Dictionaries are **mutable**
  - Has implications for aliasing!

```
>>> myDict = {1: 'a', 2: 'b', 3: 'c'}
>>> newDict = myDict # alias!
>>> newDict[4] = 'd'
>>> myDict # changes as well
{1: 'a', 2: 'b', 3: 'c', 4: 'd'}
```

- Note: dictionary keys **must be immutable**
  - Cannot have keys of mutable types such as list
- Dictionary values can be any type (mutable values such as lists)

Dictionary Comprehensions

- Like list comprehensions, dictionary comprehensions are useful for mapping and filtering
- Remember: when iterating over a dictionary, we are iterating over its **keys** (in the order of creation)

```
calendar = {'Jan': 31, 'Feb': 28, 'Mar': 31, 'Apr': 30,
            'May': 31, 'Jun': 30, 'Jul': 31, 'Aug': 31,
            'Sep': 30, 'Oct': 31, 'Nov': 30, 'Dec': 31}
```

```
>>> days30 = {k: calendar[k] for k in calendar if calendar[k] == 30}
>>> print(days30)
{'Apr': 30, 'Jun': 30, 'Sep': 30, 'Nov': 30}
```

Advantages of Using Dictionaries

- Easy access based on **keys** rather than **indices** (or position)
- For example, recall our Scrabble score example

```
scrabbleScore = {'a':1 , 'b':3, 'c':3, 'd':2, 'e':1,
                 'f':4, 'g':2, 'h':4, 'i':1, 'j':8,
                 'k':5, 'l':1, 'm':3, 'n':1, 'o':1,
                 'p':3, 'q':10, 'r':1, 's':1, 't':1,
                 'u':1, 'v':8, 'w':4, 'x':8, 'y':4, 'z': 10}
```

- To access the Scrabble score for `'p'` using a dictionary we simply ask for `scrabbleScore['p']`
- Difficult to accomplish with lists!
  - Store letters and scores are stored as two "parallel" ordered lists? Or a list of lists/tuples?
- We have to find **where** `'p'` is located in these lists and then extract its corresponding score

Advantages of Using Dictionaries

- Side-by-side this is what that would look like

```
# dictionary access
scoreDict = scrabbleScore['p']
```

```
# list access
indexP = letters.index('p')
scoreList = scores[indexP]
```

- Though list access seems like a minor notational inconvenience, it also has **computational implications**
- Finding the position of a letter in a list requires **looping** over each letter until we find the one we're looking for (this is what `.index()` does!)
- The dictionary access on the other hand **instantly** knows what it's looking for

Advantages of Using Dictionaries

- Let's see how this difference plays out when we ask the computer to do 6 million queries (people across the world play a lot of Scrabble!)
- We'll use our old friend the `time` module for this

```
>>> # random letters to query several times
>>> randomLetter = ['a', 'l', 'q', 's', 'y', 'z']*1000000
>>> print("Number of queries", len(randomLetters))
Number of queries 6000000
```

- Ex: Jupyter notebook

Advantages of Using Dictionaries

- Even in this really simple case, dictionaries give a 4x speed-up!

```
# generate list of letters and scores
letters = list(scrabbleScore.keys())
scores = list(scrabbleScore.values())

# time using list operations to compute total score
startTime = time.time()
totalScore = 0

for query in randomLetters:
    index = letters.index(query)
    totalScore += scores[index]

endTime = time.time()
timeList = endTime - startTime
print("Time taken using a list", round(timeList, 3), "seconds")
```

```
Time taken using a list 2.219 seconds
```

```
# time using dictionaries to compute total score
startTime = time.time()
totalScore = 0

for query in randomLetters:
    totalScore += scrabbleScore[query]

endTime = time.time()
timeDict = endTime - startTime
print("Time taken using a dictionary", round(timeDict, 3), "seconds")
```

```
Time taken using a dictionary 0.589 seconds
```

Benefits of Dictionaries

- **Dictionaries** are **more efficient** than lists for **some common operations**
- When we **insert** into an ordered sequence (e.g., a list)
  - We need to "move over" all elements to make space
  - This is an expensive operation: worst case (insert at beginning of list) takes time ***proportional to number of items*** stored in list
- When we **search** for an item in an ordered sequence:
  - We might have to loop and check every item stored
- Using a **dictionary** instead of a list means:
  - Can **insert** more efficiently (without having to move any other items)
  - Can support more efficient **searching** (just look up key, no loop required)
- To learn more about about efficiency of data structures, take CS136/CS256!

The end!