THE UNIVERSITY OF CHICAGO

MASTERS IN COMPUTATIONAL SOCIAL SCIENCE
THE UNIVERSITY OF CHICAGO

MACS 30111

Stacks and queues

Misc

- SE 3
- Grading ~1 week
- MIDTERM!!!
- ED: excellent posting!

Topics:

- ❑ Data types and data structures review
- ❑ Interfaces and APIs
- ❑ Stacks
- ❑ Queues
- ❑ Working with Files

Data types and data structures review

- Data types: integer, float, string, Boolean
- Data structures: list, dictionary
- Custom data structures

Interface with a Python data structure

We interact with a Python data structure through its ***interface*** without worry about internal implementation details.

The dictionary **interface**:

```
In [1]: d = {}

In [2]: d["A"] = 4.0

In [3]: "A" in d
Out[3]: True
```

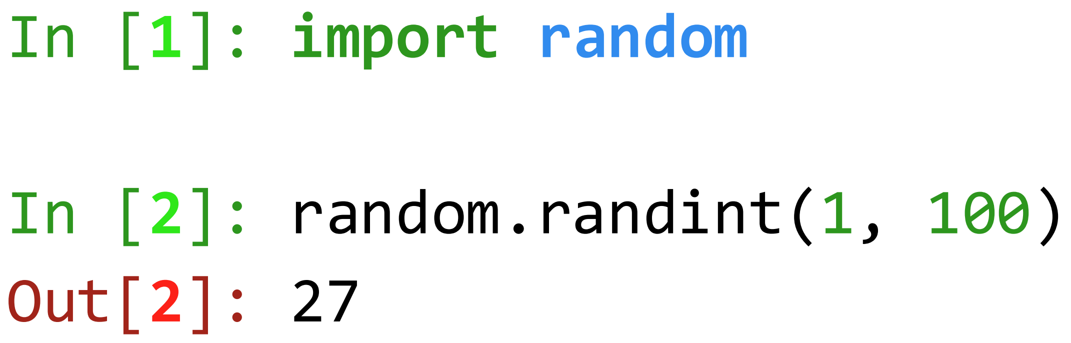
Internal implementation:

- Hash table
- Multiple steps:
  - What if a key already exists? What if it doesn’t?
  - What if the hash table doesn’t have enough memory allocated to add more keys?
- Abstract:
  - Interact with the interface
  - Don’t need to think how to manipulate the internal hash table

Interface with a Python module

An API (***Application Programming Interface***) is a collection of functions, protocols, and tools that defines how to interact with a data structure, software library, or system, while abstracting away of the internal details.

E.g., we use the random module API to interact with *random*.



```
In [1]: import random

In [2]: random.randint(1, 100)
Out[2]: 27
```

X (twitter) API

Topics:

- Data types and data structures review
- Interfaces and APIs
- **Stacks**
- Queues
- Working with Files

Stack data structure

A ***stack*** is a collection of elements with a limited set of operations.

A stack supports the following **operations**:

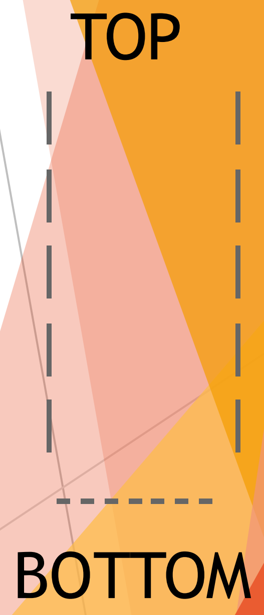
- **Create** an empty stack `stack = []`
- ***Push*** a value onto the stack `stack.append(value)`
- ***Pop*** a value from the stack `stack.pop()`
- ***Peek*** at the top of the stack `stack[-1]`
- **Check** whether the stack is **empty** `len(stack) == 0`

Example stack

```
  TOP
|  10  |
|  56  |
| 105  |
|  42  |
|   5  |
 ------
BOTTOM
```

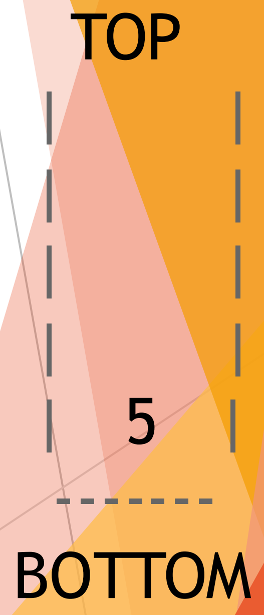
Example

1. Create an empty stack



Example

1. Create an empty stack
2. Push the value 5 to the stack



TOP

5

BOTTOM

Example

1. Create an empty stack
2. Push the value 5 to the stack
3. Push the values 42, 105, and 56 to the stack

```
   TOP
|       |
|  56   |
| 105   |
|  42   |
|   5   |
 -------
 BOTTOM
```

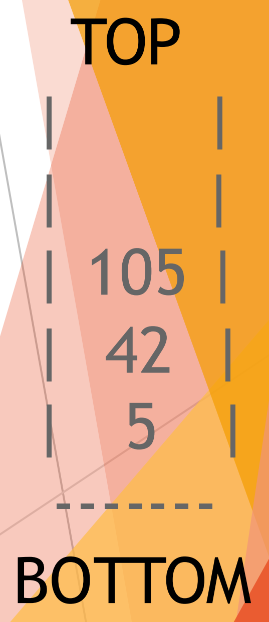
Example

1. Create an empty stack
2. Push the value 5 to the stack
3. Push the values 42, 105, and 56 to the stack
4. Pop a value from the stack

```
  TOP
|       |
|  56   |
| 105   |
|  42   |
|   5   |
 -------
 BOTTOM
```

Example

1. Create an empty stack
2. Push the value 5 to the stack
3. Push the values 42, 105, and 56 to the stack
4. Pop a value from the stack
5. Peek at the stack



TOP

105

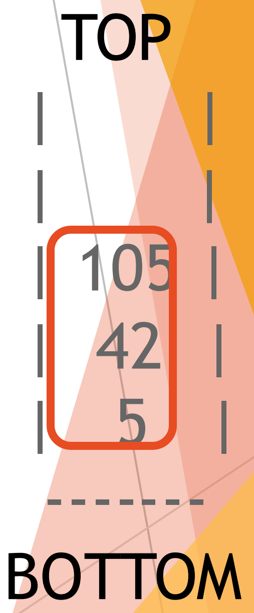
42

5

BOTTOM

Example

1. Create an empty stack
2. Push the value 5 to the stack
3. Push the values 42, 105, and 56 to the stack
4. Pop a value from the stack
5. Peek at the stack
6. Check whether the stack is empty



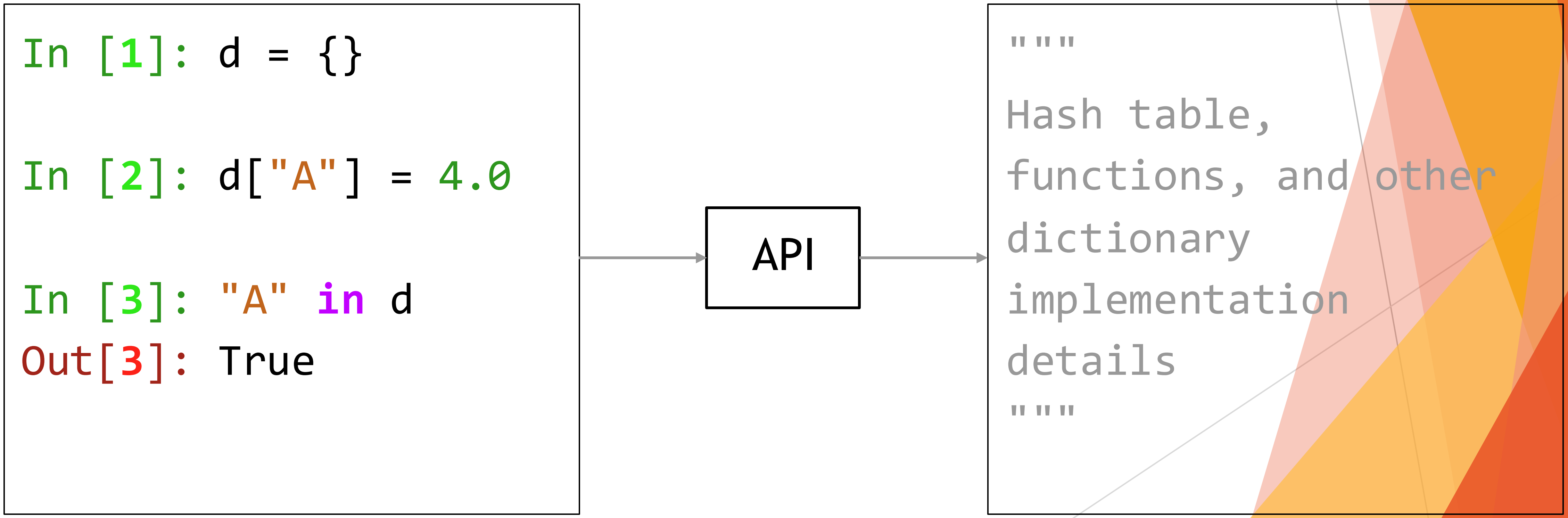
```
  TOP
|     |
|     |
| 105 |
| 42  |
|  5  |
-------
BOTTOM
```

API revisited

Recall that we interact with a data type in Python through its API.

User interface:

Developer implementation details:



```
In [1]: d = {}

In [2]: d["A"] = 4.0

In [3]: "A" in d
Out[3]: True
```

```
"""
Hash table,
functions, and other
dictionary
implementation
details
"""
```

Stack implementation

Implement a function-based interface for a stack.

```
def stack_create():
    return []
```

Stack implementation

Implement a function-based interface for a stack.

```
def stack_create():
    return []

def stack_push(stack, value):
    stack.append(value)

def stack_pop(stack):
    return stack.pop()

def stack_top(stack):
    return stack[-1]

def stack_is_empty(stack):
    return len(stack) == 0
```

```
  TOP
|     |
| 56  |
| 105 |
| 42  |
|  5  |
 -------
 BOTTOM
```

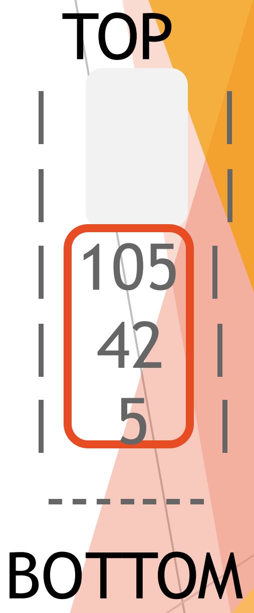
String representation

It’s often a good idea to add a function to visualize a data structure.

```
def stack_to_string(stack):
    s  = " TOP OF THE STACK\n"
    s += "-------------------\n"

    for v in reversed(stack):
        s += str(v).center(20) + "\n"

    s += "-------------------\n"
    s += "BOTTOM OF THE STACK\n"
    return s
```

Example

1. Create an empty stack
2. Push the value 5 to the stack
3. Push the values 42, 105, and 56 to the stack
4. Pop a value from the stack
5. Peek at the stack
6. Check whether the stack is empty



First In Last Out

Coding practice: 2.3.2

YOUR TURN!!

1. **Create** an empty stack named s111
2. **Push** the value 42 to the stack
3. **Push** the values 5, 7, and 12 to the stack
4. **Pop** a value from the stack
5. **Pop** a value from the stack
6. **Peek** at the stack
7. **Check** whether the stack is **empty**

```
def stack_create():
    return []

def stack_push(stack, value):
    stack.append(value)

def stack_pop(stack):
    return stack.pop()

def stack_top(stack):
    return stack[-1]

def stack_is_empty(stack):
    return len(stack) == 0
```

Python modules

Once we define an API for a data structure, we can put it in a **Python module** and **import** it from IPython or other Python files.

mystack.py

```
def stack_create():
    return []

def stack_push(stack, value):
    stack.append(value)

# stack operations
```

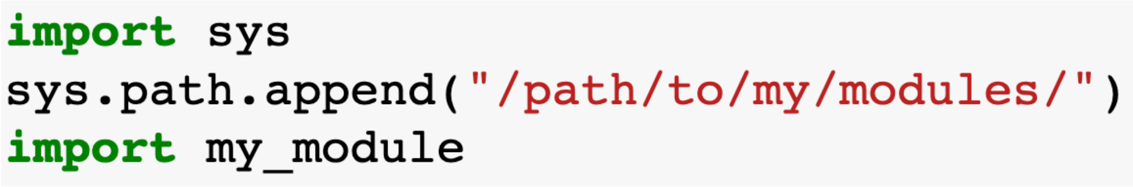
myprogram.py

```
import mystack

s = mystack.stack_create()

mystack.stack_push(s, 5)
```

IPython

```
In [1]: import mystack

In [2]: s = mystack.stack_create()

In [3]: mystack.stack_push(s, 5)
```

Import module from a different path:



```
import sys
sys.path.append("/path/to/my/modules/")
import my_module
```

Topics:

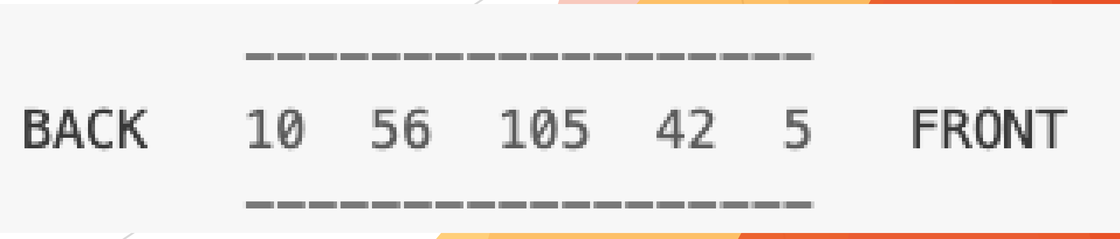
- ❑ Data types and data structures review
- ❑ Interfaces and APIs
- ❑ Stacks
- ❑ **Queues**
- ❑ Working with files

Queue data structure

A ***queue*** is a collection of elements with a limited set of operations.

Queue **operations**:

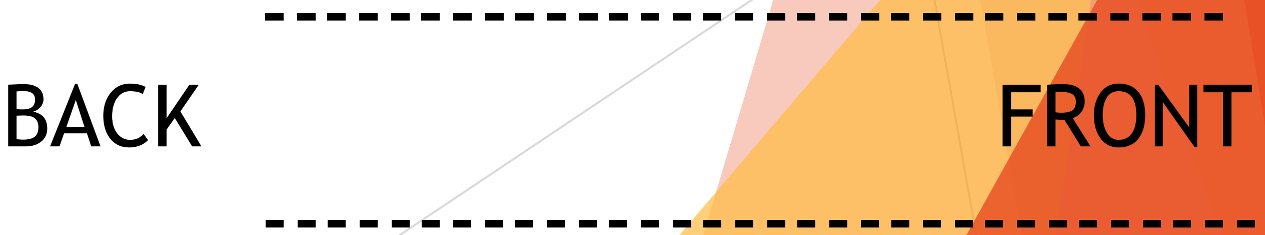
- **Create** an empty queue `queue = []`
- ***Enqueue*** a value at the back of the queue `queue.append(value)`
- ***Dequeue*** a value from the front of the queue `queue.pop(0)`
- ***Peek*** at the front of the queue `queue[0]`
- **Check** the **size** of the queue `len(queue) == 0`



```
           -------------------
BACK       10  56  105  42  5     FRONT
           -------------------
```

Example

1. Create an empty queue

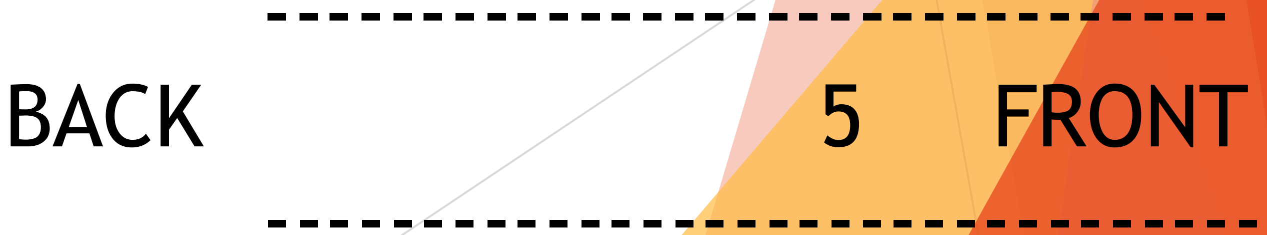


BACK

FRONT

Example

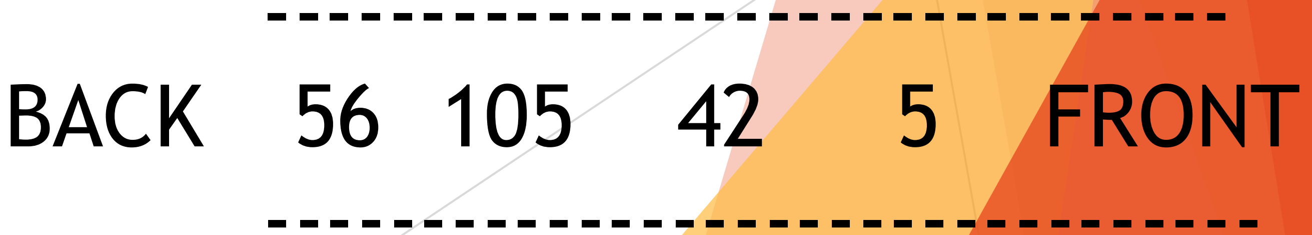
1. Create an empty queue
2. Enqueue the value 5 to the queue



BACK 5 FRONT

Example

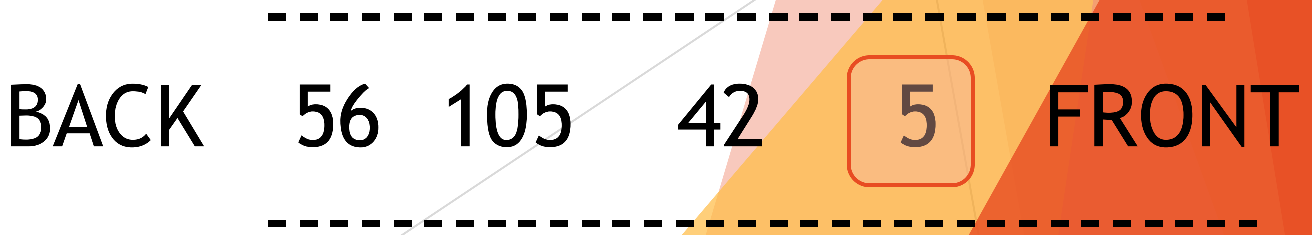
1. Create an empty queue
2. Enqueue the value 5 to the queue
3. Enqueue the values 42, 105, and 56 to the queue



BACK 56 105 42 5 FRONT

Example

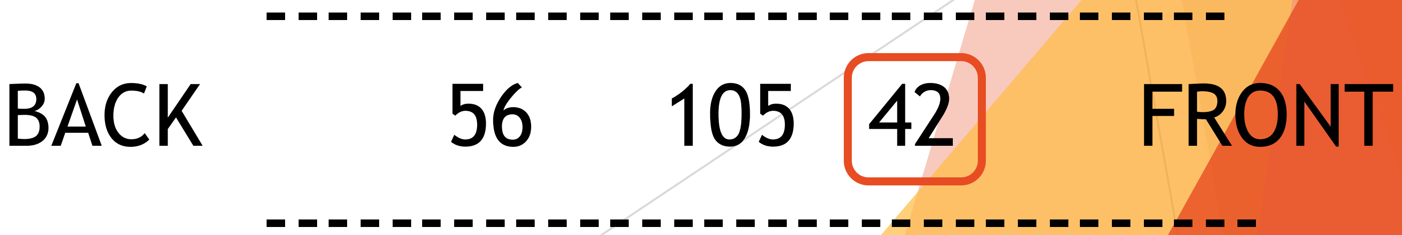
1. Create an empty queue
2. Enqueue the value 5 to the queue
3. Enqueue the values 42, 105, and 56 to the queue
4. Dequeue a value from the queue



BACK 56 105 42 5 FRONT

Example

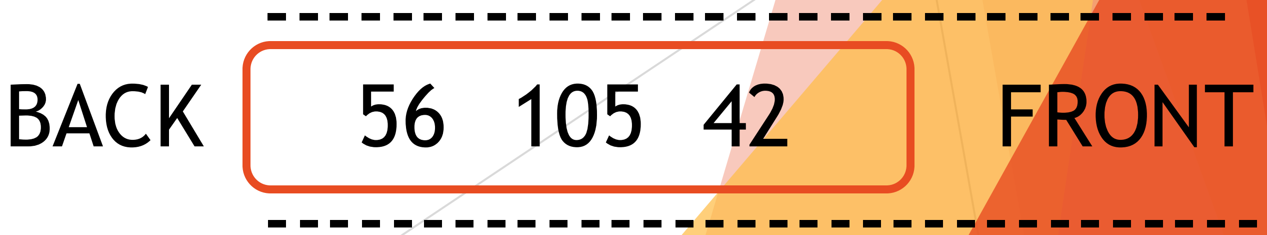
1. Create an empty queue
2. Enqueue the value 5 to the queue
3. Enqueue the values 42, 105, and 56 to the queue
4. Dequeue a value from the queue
5. Peek at the front of the queue



BACK 56 105 42 FRONT

Example

1. Create an empty queue
2. Enqueue the value 5 to the queue
3. Enqueue the values 42, 105, and 56 to the queue
4. Dequeue a value from the queue
5. Peek at the front of the queue
6. Check the size of the queue



BACK 56 105 42 FRONT

Queue implementation

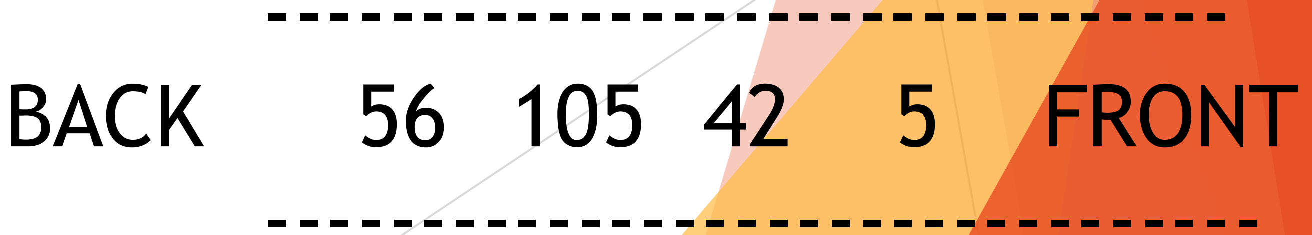
We will implement a queue as a list in Python.

Should the front of the queue be the end of the list?

```
q = [56, 105, 42, 5]
```

Should it be the beginning of the list?

```
q = [5, 42, 105, 56]
```



BACK 56 105 42 5 FRONT

Complexity and efficiency of list operations

Inserting or deleting **from the beginning** of a list is an **expensive** operation since all elements must be shifted.

Insert the value 3 to the beginning of the list:

```
lst = [2, 4, 8]

lst = [3, 2, 4, 8]
```

Delete the value from the beginning of the list:

```
lst = [2, 4, 8]

lst = [4, 8]
```

Time Complexity

Complexity and efficiency of list operations

Appending or deleting **from the end** of a list is a **simple** operation.

Append the value 3 to the end of the list:

```
lst = [2, 4, 8]

lst = [2, 4, 8, 3]
```

Delete a value from the end of the list:

```
lst = [2, 4, 8]

lst = [2, 4]
```

Time complexity

Queue implementation

What if we make the *beginning* of the list the *back* of the queue?

Enqueue the value 2:

back

```
[8, 9, 17]

[2, 8, 9, 17]
```

front

Dequeue a value:

```
[2, 8, 9, 17]

[2, 8, 9]
```

What if we make the *beginning* of the list the *front* of the queue?

Enqueue the value 2:

front

```
[17, 9, 8]
```

back

```
[17, 9, 8, 2]
```

Dequeue a value:

```
[17, 9, 8, 2]

[9, 8, 2]
```

Queue implementation

BACK 56 105 42 5 FRONT

Now we can implement a function-based interface for a queue.

```
def queue_create():
return []

def queue_is_empty(queue):
return len(queue) == 0

def queue_length(queue):
return len(queue)

def queue_enqueue(queue, value):
queue.append(value)

def queue_dequeue(queue):
return queue.pop(0)

def queue_front(queue):
return queue[0]
```

```
def queue_to_string(queue):

s = "FRONT OF THE QUEUE\n"

s += "------------------\n"


for v in queue:

s += str(v).center(19) + "\n"


s += "------------------\n"

s += "BACK OF THE QUEUE \n"

return s
```

YOUR TURN!!

1. **Create** an empty queue named q111
2. **Enqueue** the value 42 to the stack
3. **Enqueue** the values 5, 7, and 13 to the queue
4. **Dequeue** a value from the queue
5. **Peek** at the front of the queue
6. **Check** the **size** of the queue
7. **Check** whether the queue is **empty**

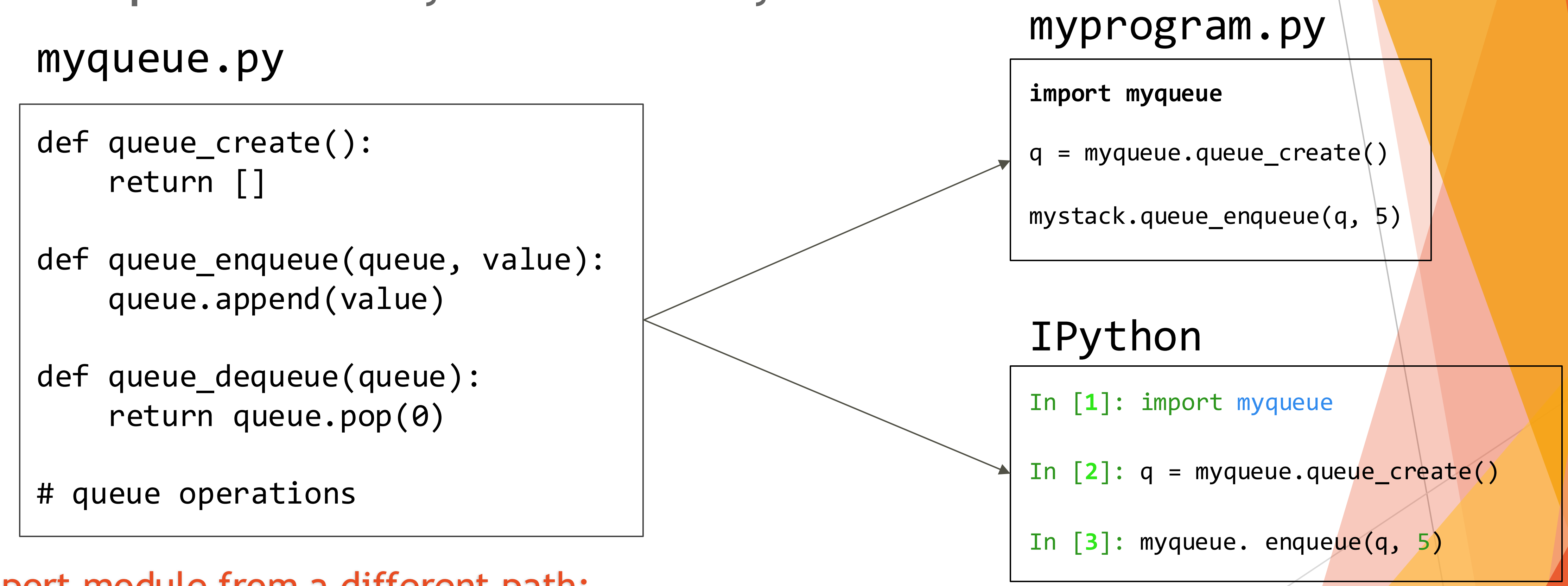
```
def queue_create():
return []

def queue_is_empty(queue):
return len(queue) == 0

def queue_length(queue):
return len(queue)

def queue_enqueue(queue, value):
queue.append(value)

def queue_dequeue(queue):
return queue.pop(0)

def queue_front(queue):
return queue[0]
```

First In First Out vs Last In First Out

Coding practice: 2.3.3

Python modules

Once we define an API for a data structure, we can put it in a **Python module** and **import** it from IPython or other Python files.



myqueue.py

```
def queue_create():
    return []

def queue_enqueue(queue, value):
    queue.append(value)

def queue_dequeue(queue):
    return queue.pop(0)

# queue operations
```

myprogram.py

```
import myqueue

q = myqueue.queue_create()

mystack.queue_enqueue(q, 5)
```

IPython

```
In [1]: import myqueue

In [2]: q = myqueue.queue_create()

In [3]: myqueue. enqueue(q, 5)
```

Import module from a different path:

```
import sys
sys.path.append("path-to/location/”)
import myqueue
```

Examples of use

- **Stacks**: last in, first out
  - `undo’ functions (e.g. text writing, back button)
  - Check for matching (e.g. matching parentheses)
  - Function calls

- **Queues**: first in, first out
  - Scheduling
  - Breadth-first scheduling in networking
  - Event handling with GUI

- Working with files

Common Programming Pattern

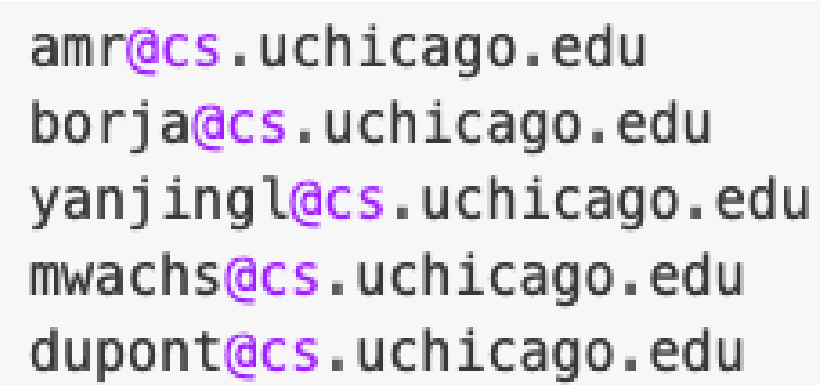
Common pattern when working with data:

1. **Read** the contents of a file (or files) from disk and **load** the data into one or more data structures
2. **Manipulate** the data in some way
3. **Print** the result or **write** the data back to disk

Sample application

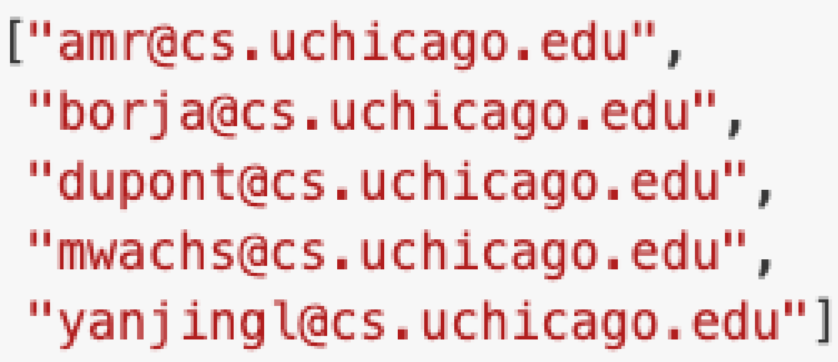
Given a file of email addresses (username@domain), construct a file with the corresponding user names.

`instructor-email.txt`



```
amr@cs.uchicago.edu
borja@cs.uchicago.edu
yanjingl@cs.uchicago.edu
mwachs@cs.uchicago.edu
dupont@cs.uchicago.edu
```

`instructor-email-sorted.txt`



```
["amr@cs.uchicago.edu",
 "borja@cs.uchicago.edu",
 "dupont@cs.uchicago.edu",
 "mwachs@cs.uchicago.edu",
 "yanjingl@cs.uchicago.edu"]
```

Coding practice: 4.1.1

Common Programming Pattern

Common pattern when working with data:

1. **Read the contents of a file (or files) from disk and load the data into one or more data structures**
2. **Manipulate** the data in some way
3. **Print** the result or **write** the data back to disk

Opening a file

Basic File I/O

To **access** the contents of a file, we first need to open it:

```
f = open("instructor-email.txt")
```

file pointer

To **read data** from a file, we use the read method:

```
addrs = f.read()
```

read the entire contents into a string

When we are done with a file, we need to close it:

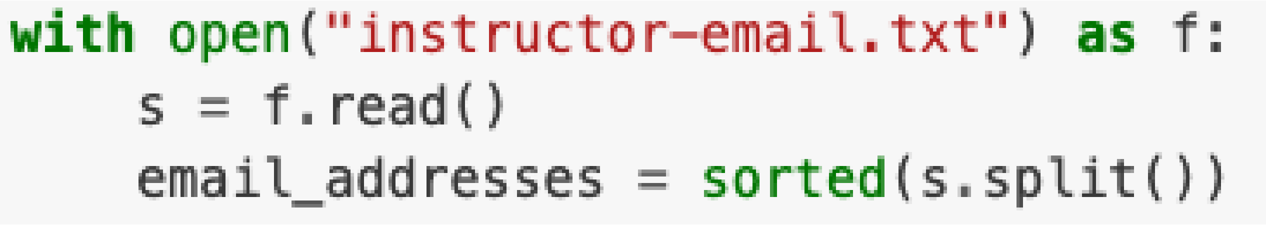
```
f.close()
```

close the file pointer

Coding practice: 4.1.1

Alternative to *close()*

The ***with*** statement to ensure that a file is closed once we're done with it:

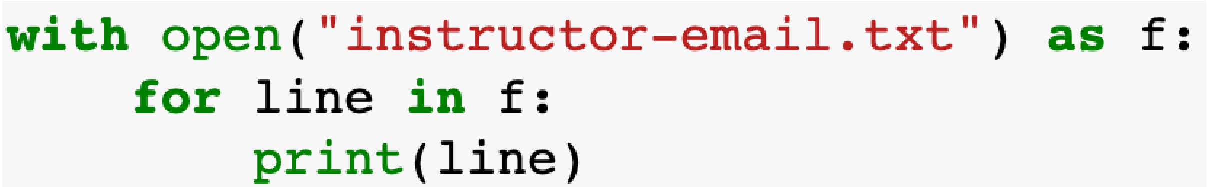


```python
with open("instructor-email.txt") as f:
    s = f.read()
    email_addresses = sorted(s.split())
```

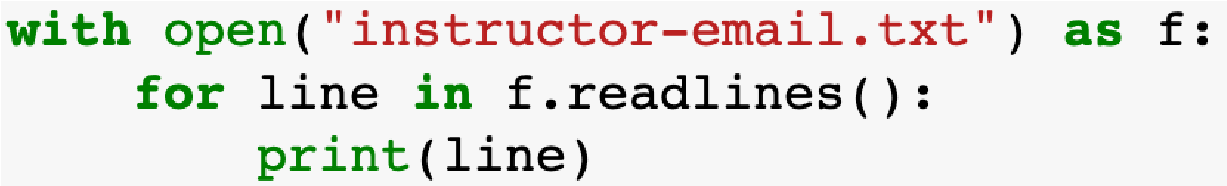
Coding practice: 4.1.1

Read the file one line at a time

Use a *for* loop to iterate over a text file line by line:



```
with open("instructor-email.txt") as f:
    for line in f:
        print(line)
```



```
with open("instructor-email.txt") as f:
    for line in f.readlines():
        print(line)
```

extra empty line

line.strip()

Coding practice: 4.1.1

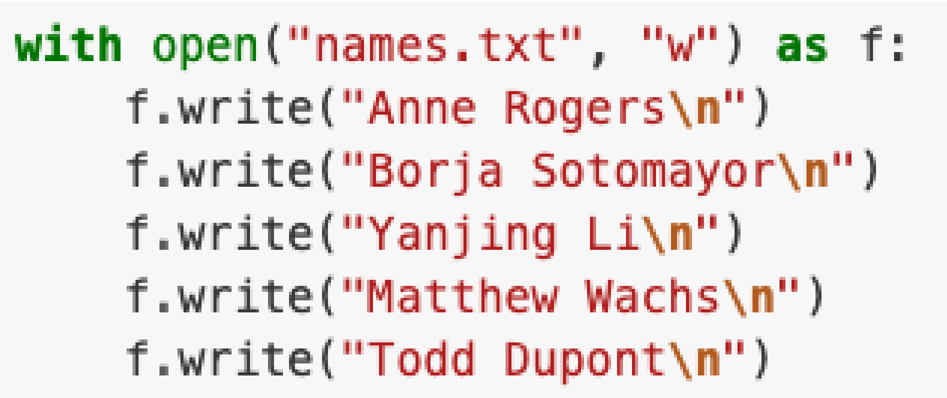
Common Programming Pattern

Common pattern when working with data:

1. **Read** the contents of a file (or files) from disk and **load** the data into one or more data structures
2. **Manipulate** the data in some way
3. **Print the result or write the data back to disk**

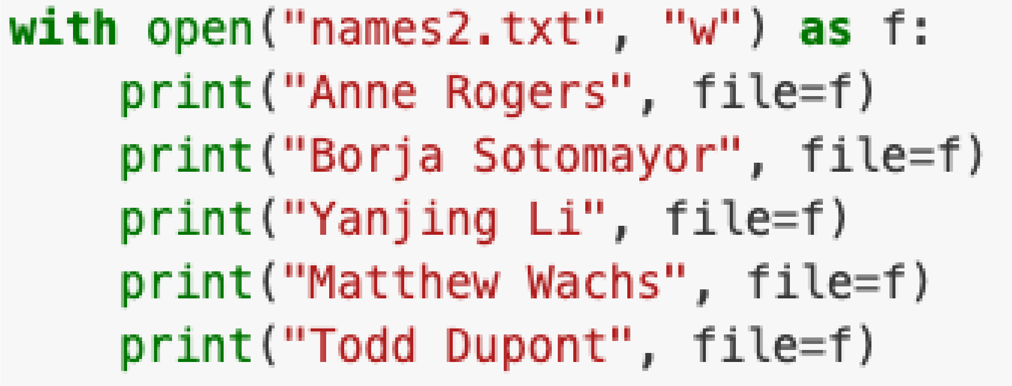
Write data to a file

To write to a file, we must open the file in **write mode**.



```
with open("names.txt", "w") as f:
    f.write("Anne Rogers\n")
    f.write("Borja Sotomayor\n")
    f.write("Yanjing Li\n")
    f.write("Matthew Wachs\n")
    f.write("Todd Dupont\n")
```

We can also use ***print*** to avoid having to worry about the newline.



```
with open("names2.txt", "w") as f:
    print("Anne Rogers", file=f)
    print("Borja Sotomayor", file=f)
    print("Yanjing Li", file=f)
    print("Matthew Wachs", file=f)
    print("Todd Dupont", file=f)
```

Very important:

- Opening an existing file in write mode will **wipe all its contents!**
- Opening a file that does not exist in write mode will **create** the file.

Coding practice: 4.1.2

Summary

The common programming pattern:

1. Load the data from disk:
   a. **Open** a file to **read**
   b. Read the contents of the file from disk
   c. Load the data into a data structure
2. Manipulate the data in some way
3. Print the result or write the data back to disk
   a. **Write** the data
   b. **Close** the file (or use a with statement when you open it)

Coding practice: 4.1.2

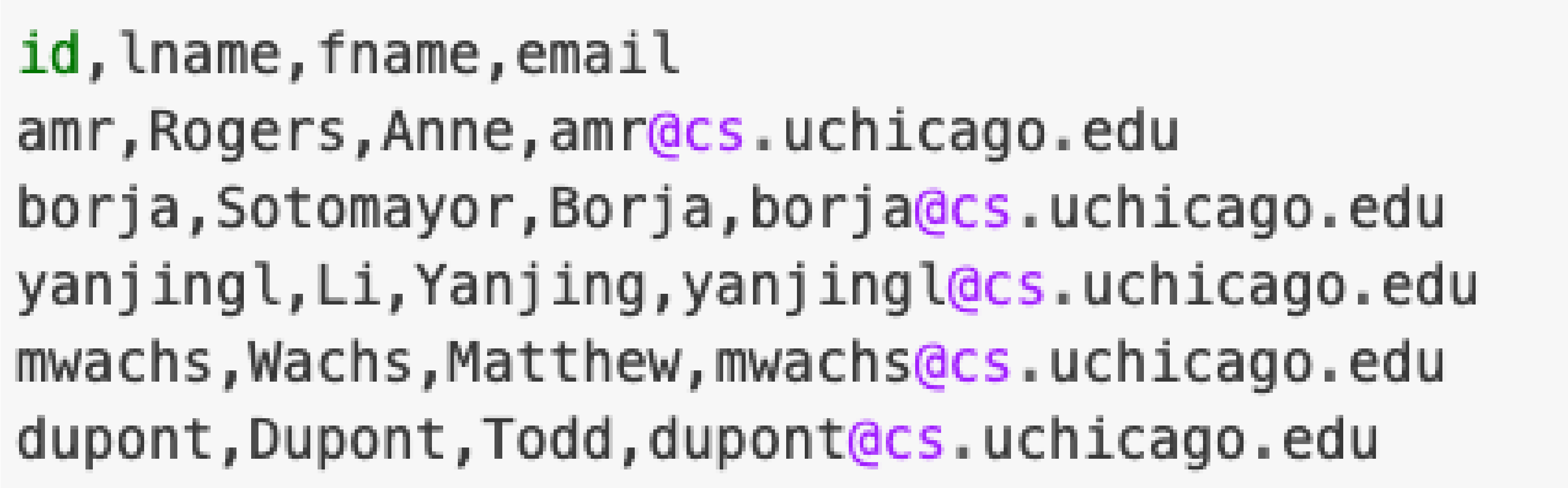
Topics:

- Basic file I/O
  - Open: load the data from disk
  - Read: manipulate the data
  - Close: print the results or write the data back to disk
- **Working with tabular data using CSV files**
- Working with JSON files
- Other file formats

CSV (Comma Separated Values) format

CSV files are useful for storing **tabular data**: any data that can be organized into rows, each with the same columns (or "fields")

`instructors.csv`



```
id,lname,fname,email
amr,Rogers,Anne,amr@cs.uchicago.edu
borja,Sotomayor,Borja,borja@cs.uchicago.edu
yanjingl,Li,Yanjing,yanjingl@cs.uchicago.edu
mwachs,Wachs,Matthew,mwachs@cs.uchicago.edu
dupont,Dupont,Todd,dupont@cs.uchicago.edu
```

header

Exercise

- You are working on a project creating a directory of buildings based on where MACSS classes typically meet.
- Use text file: https://uchicago.box.com/s/kp207rd2vita1a4zz6749oe8jkvk85l6

- How would you load your data?
- Next, you want to select the following buildings: `sched = ["1155", "SS", "TTI", "K"]` and output the new list into a separate file
- How would you summarize or use the data?

What if you want to skip lines?

- Multiple ways to approach:

```
new_lst = []
with open('names.txt') as names:
    next(names)
    next(names)
    next(names)
    new_lst = names.readlines()
```

```
new_list = []
with open('names.txt') as names:
    for i, line in enumerate(names):
        if i > 3 and  i < 149:
        new_list.append(line)
```

Read file using *csv* module

- *csv.DictReader* - read rows from a CSV file into dictionaries
- *csv.DictWriter* - write dictionaries into rows of a CSV file

Alternatively, we could also use:

- *csv.reader* - read rows from a CSV file into a list of lists
- *csv.writer* - write lists into rows of a CSV file

Different ‘modes’

- You can open files in different ‘modes’
  - r: ‘read’ mode (default)
  - w: ‘write’ mode (needs specified)
  - a: append

If you’re just reading a file, you can operate as normal. If you’re wanting to write a new file, *then* you will use “w”.

DANGER ALERT!!! In “w” mode, you will OVERWRITE THE PREEXISTING FILE!!

Writing files

“w” for “write mode”

```
with open("names_cleaned.txt", "w") as f:
    for build in new_list:
        print(build, file=f)
```

Bringing the exercise together:

```
# making it pretty:

def get_buildings(input_filename, output_filename, sched):
'''

extract relevant buildings from campus list

Inputs:
input_filename: (string) name of a file with buildings
output_filename: (string) name for the output file.
'''
```

```
# Load data into a data structure (a list of strings)
buildings = []
with open(“input_filename.txt”) as f:
        for line in f:
                builds = line.strip().split("\t", 1)
                buildings.append(builds)

# Transform the data
buildings_select = []
for line in buildings:
        if line[0] in sched:
                buildings_select.append(line)

# Write the data
with open(“output_filename.txt”, "w") as f:
        for build in buildings_select:
                print(build, file=f)
```

Exam prep!

\

Exam prep: spot 3 errors and rewrite code

```
# making it pretty:

def get_buildings(input_filename, output_filename, sched):
'''

extract relevant buildings from campus list

Inputs:
input_filename: (string) name of a file with buildings
output_filename: (string) name for the output file.
'''
```

```
# Load data into a data structure (a list of strings)
sched = ["1155", "SS", "TTI", "K"]
buildings = []
with open(input_filename) as f:
        for line in f:
                builds = line.strip().split("\t", 1)
                buildings.append(builds)

# Transform the data
buildings_select = []
for line[0] in buildings:
        if line in sched:
                buildings_select.append(line)

# Write the data
with open(output_filename) as f:
        for build in buildings:
                print(build, file=f)
```

Recap:

- Data structures:
  - **Stacks**: when you need last in, first out. Specific methods to add to/from the TOP
  - **Queues**: when you need first in, first out. Specific methods to add to the BACK of the queue
- Working with files!