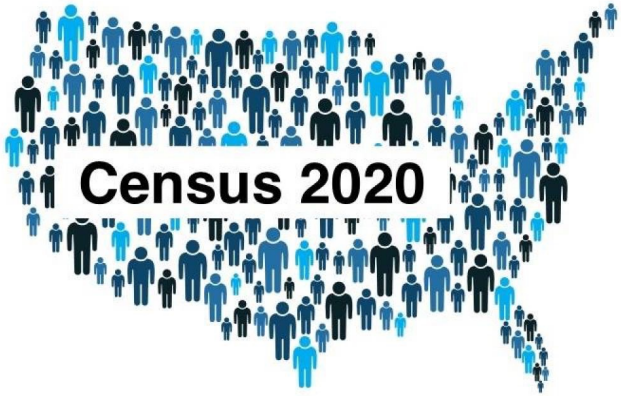
JSON & CSV Formats for Real-world Data Analysis



CS111 Computer Programming

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JSON & CSV: Popular File Formats for Real-world Data

A common way to provide input for programs is through files that store data. Thus far we have seen how to work with text file formats in which data is organized into lines, although it might also split and group lines in various ways.

Today we study two ways of formatting data in text files that are incredibly common in practice:

JSON (JavaScript Object Notation) represents arbitrarily nested lists and dictionaries in a way very similar to how we express them in Python.

CSV (Comma-Separated Values) represents tabular data found in spreadsheets and databases as lines of values separated by commas.

Why should we care about nested data structures?

Real-world data are stored as nested data structures. Most of the content on the web is transferred from a computer to another in a format known as JSON (Javascript Object Notation), which represents dicts and lists nested in each other.

Same content, but in different format.


```
{'id': 1079460557160247297,
 'source': 'Twitter for Android',
 'text': 'Looking fwd to 2019 working w @mediaaction to advance racial
justice &amp;amp; #mediajustice in a digital age! This looks like #NoDigita
lPrisons, hold FB accountable &amp;amp; ensure POC/ low-income communities
can access basic necessities like phone &amp;amp; web. Donate today! http
s://t.co/9iU1jRSLmt https://t.co/d2kb2Y9EHI',
 'public_metrics': {'retweet_count': 3,
  'reply_count': 0,
  'like_count': 5,
  'quote_count': 0},
 'entities': {'urls': [{'start': 268,
    'end': 291,
    'url': 'https://t.co/9iU1jRSLmt',
    'expanded_url': 'https://www.classy.org/fundraiser/1809542',
    'display_url': 'classy.org/fundraiser/180…',
    'status': 200,
    'unwound_url': 'https://support.mediajustice.org/fundraiser/1809542
'},
   {'start': 292,
    'end': 315,
    'url': 'https://t.co/d2kb2Y9EHI',
    'expanded_url': 'https://twitter.com/mediajustice/status/1079436958
667919361',
    'display_url': 'twitter.com/mediajustice/s…'}],
  'mentions': [{'start': 30,
    'end': 42,
    'username': 'mediaaction',
    'id': '14881478'}],
  'hashtags': [{'start': 75, 'end': 88, 'tag': 'mediajustice'},
   {'start': 123, 'end': 140, 'tag': 'NoDigitalPrisons'}],
  'annotations': [{'start': 143,
    'end': 144,
    'probability': 0.66,
    'type': 'Organization',
    'normalized_text': 'FB'}]},
 'author_id': 80507653,
```

The Nested Data Sharing Problem

How to save the `authorsDict` dictionary to a file to share it with others?

```
authorsDict = {
  "Jane Austen": [
    {"book": "Persuasion", "year": 1818},
    {"book": "Emma", "year": 1815},
    {"book": "Pride and Prejudice", "year": 1813},
    {"book": "Sense and Sensibility", "year": 1811},
    {"book": "Northanger Abbey", "year": 1818},
    {"book": "Mansfield Park", "year": 1814}
  ],
  "Virginia Woolf": [
    {"book": "The Voyage Out", "year": 1915},
    {"book": "Mrs Dalloway", "year": 1925},
    {"book": "Orlando", "year": 1928},
    {"book": "Night and Day", "year": 1919},
    {"book": "To the Lighthouse", "year": 1927},
    {"book": "The Waves", "year": 1931}
   ]
}
```

Cumbersome approach for sharing nested data

```
{
  "Jane Austen": [
    {"book": "Persuasion", "year": 1818},
    {"book": "Emma", "year": 1815},
    {"book": "Pride and Prejudice", "year": 1813},
    {"book": "Sense and Sensibility", "year": 1811},
    {"book": "Northanger Abbey", "year": 1818},
    {"book": "Mansfield Park", "year": 1814}
  ],
  "Virginia Woolf": [
    {"book": "The Voyage Out", "year": 1915},
    {"book": "Mrs Dalloway", "year": 1925},
    {"book": "Orlando", "year": 1928},
    {"book": "Night and Day", "year": 1919},
    {"book": "To the Lighthouse", "year": 1927},
    {"book": "The Waves", "year": 1931}
   ]
}
```

Alex writes a program to convert the Python dictionaries and lists into lines that express the same content in a different format, and write these lines to a file to share with Bailey

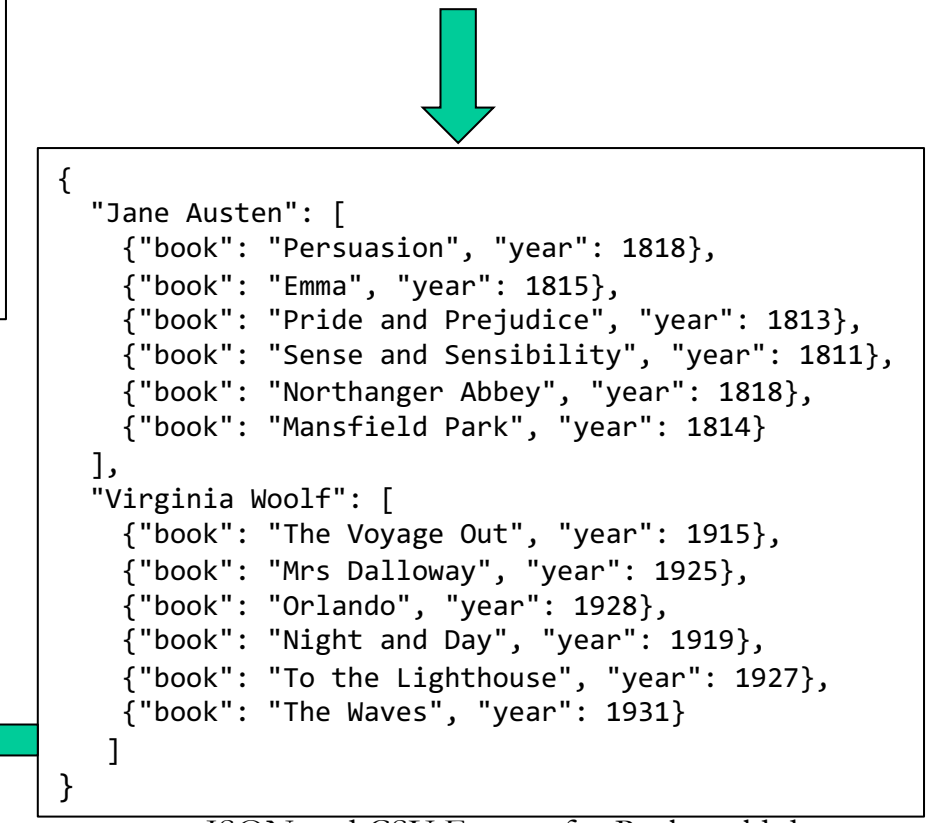
```
Jane Austen: Sense and Sensibility, 1811
Jane Austen: Pride and Prejudice, 1813
Jane Austen: Mansfield Park, 1814
Jane Austen: Emma, 1815
Jane Austen: Persuasion, 1818
Jane Austen: Northanger Abbey, 1818
Virginia Woolf: The Voyage Out, 1915
Virginia Woolf: Night and Day, 1919
Virginia Woolf: Mrs Dalloway, 1925
Virginia Woolf: To the Lighthouse, 1927
Virginia Woolf: Orlando, 1928
Virginia Woolf: The Waves, 1931
```

Baily writes a program to convert the file lines into the same dictionaries and lists that Alex had on their system.

JSON: simple but brilliant sharing of nested data

```
{
  "Jane Austen": [
    {"book": "Persuasion", "year": 1818},
    {"book": "Emma", "year": 1815},
    {"book": "Pride and Prejudice", "year": 1813},
    {"book": "Sense and Sensibility", "year": 1811},
    {"book": "Northanger Abbey", "year": 1818},
    {"book": "Mansfield Park", "year": 1814}
  ],
  "Virginia Woolf": [
    {"book": "The Voyage Out", "year": 1915},
    {"book": "Mrs Dalloway", "year": 1925},
    {"book": "Orlando", "year": 1928},
    {"book": "Night and Day", "year": 1919},
    {"book": "To the Lighthouse", "year": 1927},
    {"book": "The Waves", "year": 1931}
   ]
}
```

Alex uses `json.dump` to write the characters Python uses to represent the dictionary (modulo whitespace) into a file. This works for (most) Python values without any special processing.



Bailey uses `json.load`, which builds the lists and dictionaries from the characters in the file, to create Alex's data. No special processing needed!

Upsides of JSON

- In practice, using JSON works for most Python values with list and dictionaries without any need for special processing to write them to or read them from a file.
- Although sharing could also be accomplished by just sharing a Python .py file with the data, JSON format can be written and read in **any** programming language, which makes it a universal standard for representing data with values like lists and dictionaries.

These upsides make JSON the most popular file format for representing complex data.

Downsides of JSON

JSON only supports a subset of of the notations used in Python, so values not handled still require special processing:

- In JSON objects (dictionaries), keys **must** be strings; no other key type is allowed.
- JSON does not have tuples. `json.dump` will convert all tuples to lists.
- Python values like ranges, dictionary views, functions, etc. cannot be represented in JSON without special-case processing.

Also, some notations are different in JSON and Python:

- Python's capital `True` must be written as lowercase `true` in JSON
- Python's capital `False` must be written as lowercase `false` in JSON
- Python's `None` must be written as `null` in JSON
- In JSON, strings **must** be delimited by double quotes. Single-quoted strings and strings with triple single quotes and triple double quotes are not allowed.
- Python allows trailing comma in lists & dictionaries, but JSON does not.

Challenge Problem: Manipulate JSONs

You are given a JSON file with tweets (their text and id):

```
[{'id': 1072284009122586625, 'text': 'The case of Jacob Walter Anderson from
@Baylor is the perfect amalgamation between the #MeToo and #BlackLivesMatter
movements. #ThisIsWhyWeAreAngry'},
{'id': 1071990529448075264, 'text': 'Now, that you all have some background
information to this short story, please go read it at 👉👉👉
https://t.co/KRGkjbNJbY 👈👈👈 #NoJusticeNoPeace #BlackLivesMatter
#MissionFree #DefendOurFreedom 😎'}]
```

We want to answer the following question:

- *Which are the most frequently mentioned hashtags?*

We can answer this question via Python code that makes use of the accumulation pattern with dictionaries.

Use the notebook to answer this question (in a guided way).

File Formats so far

One way to provide input for our programs is through files that store data.
So far we have seen how to work with two file formats: TXT files and JSON files.
In both cases, we have to create first a fileObject that refers to a file that is open for either reading or writing (e.g., `fileObjR` and `fileObjW`).

```
with open(filePath, 'r') as fileObjR:
    # do reading/loading operation

with open(filePath, 'w') as fileObjW:
    # do writing/dumping operation
```

Operation	Python syntax

Reading text from a file	`fileObjR.read()`
	`fileObjR.readline()`
	`fileObjR.readlines()`

Writing text into a file	`fileObjW.write(aStr)`

Operations for working with **TXT** files

Operation	Python syntax
Loading a JSON object from a file	`json.load(fileObjR)`
Dumping a JSON object into a file	`json.dump(obj, fileObjW)`

Operations for working with **JSON** files

The CSV Format

(CSV = Comma Separated Values)

Concepts in this slide: Introducing a new file format for tabular data.

```
State,StatePop,Abbrev.,Capital,CapitalPop
Alabama,4921532,AL,Montgomery,198525
Alaska,731158,AK,Juneau,32113
Arizona,7421401,AZ,Phoenix,1680992
Arkansas,3030522,AR,Little Rock,197312
California,39368078,CA,Sacramento,513624
Colorado,5807719,CO,Denver,727211
```

Partial screenshot of the `us-states-more.csv` file, viewed with a text editor.

	A	B	C	D	E
1	**State**	**StatePop**	**Abbrev.**	**Capital**	**CapitalPop**
2	Alabama	4921532	AL	Montgomery	198525
3	Alaska	731158	AK	Juneau	32113
4	Arizona	7421401	AZ	Phoenix	1680992
5	Arkansas	3030522	AR	Little Rock	197312
6	California	39368078	CA	Sacramento	513624
7	Colorado	5807719	CO	Denver	727211

Partial screenshot of the `us-states-more.csv` file, viewed with the Google Spreadsheet editor.

CSV files are one of the most common formats to share data, since they can be displayed as a table in spreadsheet applications (Microsoft Excel, Google Spreadsheet, etc.).

Reading tuples from CSV files

For simple CSV files, we can write our own function to read its content.

```
def tuplesFromFile(filename):
    '''Read each line from opened file,
       strip newlines,
       split at commas,
       convert as tuple and
       return a list of tuples.
    '''
    with open(filename, 'r') as inputFile:
        theTuples = [tuple(line.strip('\n').split(','))
                                    for line in inputFile]
    return theTuples
```

To notice:

We are using a list comprehension to read the content of the files into a list of tuples. This statement replaces this code:

```
theTuples = []
for line in inputFile:
    theTuples.append(tuple(line.strip('\n').split(',')))
```

What happens when our data has commas?

	A	B	C	D	E
1	**State**	**StatePop**	**Abbrev.**	**Capital**	**CapitalPop**
2	Alabama	4921532	AL	Montgomery	198525
3	Alaska	731158	AK	Juneau	32113
4	Arizona	7421401	AZ	Phoenix	1680992
5	Arkansas	3030522	AR	Little Rock	197312
6	California	39368078	CA	Sacramento	513624
7	Colorado	5807719	CO	Denver	727211

Partial screenshot of the `us-states-more.csv` file, viewed with the Google Spreadsheet editor.

	A	B
1	Montgomery, AL	198525
2	Juneau, AK	32113
3	Phoenix, AZ	1680992
4	Little Rock, AR	197312
5	Sacramento, CA	513624
6	Denver, CO	727211
7	Hartford, CT	122105

Partial screenshot of the `capitals-only.csv` file, viewed with the Google Spreadsheet editor.

```
with open("capitals-only.csv", "w") as outF:
    for item in capitals:
        row = f"{item[0]},{item[1]}\n"
        outF.write(row)
```

```
capitals2 = tuplesFromFile("capitals-only.csv")
capitals == capitals2
```

```
False
```

Check the Notebook

It's easy to create the file about capitals from the state data, but when we read it back using the function **`tuplesFromFile`**, the result has tuples of three values, not two, as we desire.

The `csv` module

The `csv` module has four functions that create special objects to read/write CSV files.

A key benefit of using this modules is that it correctly handles many special cases, especially table values that contain commas.

`csv.reader`	creates an object that reads the content of CSV file as a list of lists
`csv.writer`	creates an object that writes a list of lists into a CSV file
`csv.DictReader`	**creates an object that reads the content of CSV file as a list of dictionaries**
`csv.DictWriter`	**creates an object that writes a list of dictionaries into a CSV file**

Important Note

In CS111, we will only be covering DictReader and DictWriter, since they help us work with dictionaries.

csv.DictReader [1]

Differently from reading/loading TXT and JSON files, reading a CSV file as a dictionary is a two step process:

1. Create a DictReader object that is tied to the file object open for reading
2. Read and convert each line from the text file as a dict object

```
with open('countries.csv', 'r') as inputFile:
    dctReader = csv.DictReader(inputFile)
    dctList = [dct for dct in dctReader] # read line by line
    print(inputFile)
    print(dctReader)
    print(dctList)
```

The file object

```
<_io.TextIOWrapper name= ' countries.csv' mode='r' encoding='UTF-8'>
```

The DictReader object

```
<csv.DictReader object at 0x7f84901a4c10>
```

```
[{'country': 'Canada', 'capital': 'Ottawa'}, {'country': 'Mexico',
'capital': 'Mexico City'}, {'country': 'South Korea', 'capital': 'Seoul'},
{'country': 'Ukraine', 'capital': 'Kiev'}]
```

csv.DictReader [2]

`csv.DictReader` creates an iterator object that reads lines into dictionaries only when we "force" it to do the work through iteration.

```
dctReader = csv.DictReader(inputFile)
dctList = [dct for dct in dctReader]
```

This is very similar to how the **`range`** object behaves:

```
>>> myRange = range(5, 10)
>>> myRange
range(5, 10)
>>> [num for num in myRange]
[5, 6, 7, 8, 9]
```

Rather than using a list comprehension to collect values from a **`csv.DictReader`** or **`range`** object into a list, it's easier just to use the built-in **`list`** function:

```
dctReader = csv.DictReader(inputFile)
dctList = list(dctReader)
myRangeList = list(range(5, 10))
```

csv.DictWriter

Writing a dictionary into a CSV file involves the following steps:

1. Create a DictWriter object tied to a file open for writing
2. Write the header of the file, which contains the names of the columns
3. Write all dictionaries as rows in the files

```
oscarMovies = [ {'title': 'CODA', 'year': 2022},
                {'title': 'Nomadland', 'year': 2021},
                {'title': 'Parasite', 'year': 2020}]
columns = oscarMovies[0].keys() # get the names of the keys
with open('oscarWinners.csv', 'w', newline='') as outFile:
    dctWriter = csv.DictWriter(outFile, fieldnames=columns)
    dctWriter.writeheader() # no need for argument
    dctWriter.writerows(oscarMovies)
```

Additional Parameters

Notice that we have added a third parameter to the `open` function: **`newline=''`**
This is needed to deal with the different way that Windows machines deal with newlines.

More examples

Check the notebook for examples to understand what **`writeheader`**, **`writerows`**, and one method not shown here, **`writerow`**, do.


Census 2020

Representation in Congress is based on population. More people, more seats.

STATE	APPORTIONMENT POPULATION (APRIL 1, 2020)	NUMBER OF APPORTIONED REPRESENTATIVES BASED ON 2020 CENSUS[2]	CHANGE FROM 2010 CENSUS APPORTIONMENT
Alabama	5,030,053	7	0
Alaska	736,081	1	0
Arizona	7,158,923	9	0
Arkansas	3,013,756	4	0
California	39,576,757	52	-1
Colorado	5,782,171	8	1
Connecticut	3,608,298	5	0
Delaware	990,837	1	0
Florida	21,570,527	28	1
Georgia	10,725,274	14	0
Hawaii	1,460,137	2	0
Idaho	1,841,377	2	0
Illinois	12,822,739	17	-1
Indiana	6,790,280	9	0
Iowa	3,192,406	4	0
Kansas	2,940,865	4	0
Kentucky	4,509,342	6	0
Louisiana	4,661,468	6	0
Maine	1,363,582	2	0
Maryland	6,185,278	8	0
Massachusetts	7,033,469	9	0
Michigan	10,084,442	13	-1

US States and Capitals: Doing more with our data

	A	B	C	D	E
1	**State**	**StatePop**	**Abbrev.**	**Capital**	**CapitalPop**
2	Alabama	4921532	AL	Montgomery	198525
3	Alaska	731158	AK	Juneau	32113
4	Arizona	7421401	AZ	Phoenix	1680992
5	Arkansas	3030522	AR	Little Rock	197312
6	California	39368078	CA	Sacramento	513624
7	Colorado	5807719	CO	Denver	727211

Partial screenshot of the `us-states-more.csv` file, viewed with the Google Spreadsheet editor.

Some questions to answer with our data:

- Which are the **most** populated US states? **Rank** the data in that order.
- Which are the **least** populated US states? **Rank** the data in that order.
- Which US state capitals are the **most** populated? **Rank** the data in that order.
- Which US state capitals are the **least** populated? **Rank** the data in that order.
- What percentage of each US state's population lives in the state capital? **Rank** the data by that percentage from the **largest** to the **smallest**.

Can dictionaries be sorted? Explain the outputs!

```
In [31]: fruitColors = {"banana": "yellow", "kiwi": "green",
"grapes": "purple", "apple": "red", "lemon": "yellow",
"pomegranate": "red"}

In [32]: sorted(fruitColors)

Out[32]: ['apple', 'banana', 'grapes', 'kiwi', 'lemon',
'pomegranate']

In [33]: sorted(fruitColors.keys())

Out[33]: ['apple', 'banana', 'grapes', 'kiwi', 'lemon',
'pomegranate']

In [34]: sorted(fruitColors.values())

Out[34]: ['green', 'purple', 'red', 'red', 'yellow', 'yellow']

In [35]: sorted(fruitColors.items())

Out[35]: [('apple', 'red'), ('banana', 'yellow'), ('grapes',
'purple'), ('kiwi', 'green'), ('lemon', 'yellow'),
('pomegranate', 'red')]
```

Sort a list of dictionaries

```
In [36]: peopleDctList = [{'name':'Mary Beth Johnson', 'age': 18},
                          {'name':'Ed Smith', 'age': 17},
                          {'name':'Janet Doe', 'age': 25},
                          {'name':'Bob Miller', 'age': 31}]
In [37]: sorted(peopleDctList)
Traceback (most recent call last):
  File "<pyshell>", line 1, in <module>
TypeError: '<' not supported between instances of 'dict' and 'dict'

def byAge(personDct):
    return personDct['age']

In [38]: sorted(peopleDctList, key=byAge, reverse=True)
Out[38]: [{'name': 'Bob Miller', 'age': 31},
          {'name': 'Janet Doe', 'age': 25},
          {'name': 'Mary Beth Johnson', 'age': 18},
          {'name': 'Ed Smith', 'age': 17}]
```

Questions 1 & 2: Sort by US state population

How to implement the solution with Python code:

1. Read the content of the CSV file `us-states-more.csv` using **`csv.DictReader`**, which returns a list of dictionaries.
2. Create a helper function byStatePop, which, given a dictionary with state data (one row from our file), returns the appropriate value. Remember that all values in the dictionary are strings, because they come from the CSV file.
3. Apply the **`sorted`** function to the list of dictionaries of state data, using the **`key`** parameter with the function byStatePop.
4. Look at the results, in which way are they sorted?
5. Include the function parameter **`reverse`** to change the order of sorting.
6. Use f-string formatting to print out top six results as shown below.

```
Top six most populated US states:

CA -> 39,368,078
TX -> 29,360,759
FL -> 21,733,312
NY -> 19,336,776
PA -> 12,783,254
IL -> 12,587,530
```

```
Top six least populated US states:

WY -> 582,328
VT -> 623,347
AK -> 731,158
ND -> 765,309
SD -> 892,717
DE -> 986,809
```

Questions 3 &4: Sort by capital population

How to implement the solution with Python code:

Follow the steps from the previous slide, but create appropriate functions to use with the parameter key for sorted. Try to come as close as possible to these outputs, but don't worry if you cannot. These outputs use some special f-string features for formatting.

```
Top six most populated US state capitals:

Phoenix (AZ)        ->  1,680,992
Austin (TX)         ->    978,908
Columbus (OH)       ->    898,553
Indianapolis (IN)   ->    876,384
Denver (CO)         ->    727,211
Boston (MA)         ->    692,600
```

```
Top six least populated US state capitals:

Montpelier (VT)     ->      7,855
Pierre (SD)         ->     13,646
Augusta (ME)        ->     18,681
Frankfort (KY)      ->     27,679
Juneau (AK)         ->     32,113
Helena (MT)         ->     32,315
```

Questions 5: Sort by percentage

How to implement the solution with Python code:

This will be similar to the two previous slides, by you'll have to create a helper function, **byPercentage**, which can calculate the percentage of people living in the capital of the state. This function will be used by the **sorted** function, as well as by the f-string. Try to come close to this output, but do not worry if you cannot achieve it yet.

```
Top six US states with the largest population percentage living in the capital:

Hawaii          24.52% of population lives in the capital, Honolulu.
Arizona         22.65% of population lives in the capital, Phoenix.
Rhode Island    17.02% of population lives in the capital, Providence.
Oklahoma        16.46% of population lives in the capital, Oklahoma City.
Nebraska        14.92% of population lives in the capital, Lincoln.
Indiana         12.97% of population lives in the capital, Indianapolis.
```

Test your knowledge

1. What do the acronyms JSON and CSV stand for?
2. In what ways do these two formats differ from one another?
3. Which format allows programmers more flexibility in transferring data? Why?
4. What do the two functions `dump` and `load` of the **`json`** module do?
5. What do the two functions `csv.DictReader` and `csv.DictWriter` do?
6. What does the method `writeheader` do?
7. What do we need to do in order to sort a list of dictionaries? Why is that?
8. What are some other questions that you could answer with the Census data. Can you write the Python code to answer them? Try it out and let us know what you did. We might add that in our material for future semesters.