

lab_02

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1 Geographic Data Science - Lab 02

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2 Data “munging”

Real world datasets are messy. There is no way around it: datasets have “holes” (missing data), the amount of formats in which data can be stored is endless, and the best structure to share data is not always the optimum to analyze them, hence the need to [munge](#) them. As has been correctly pointed out in many outlets ([e.g.](#)), much of the time [spent](#) in what is called (Geo-)Data Science is related not only to sophisticated modeling and insight, but has to do with much more basic and less exotic tasks such as obtaining data, processing, and turning them into a shape and form that makes analysis possible.

For how labor intensive and relevant this aspect is, there is surprisingly very little published on patterns, techniques, and best practices for quick and efficient data cleaning, manipulation, and transformation. In this session, you will use a few real world datasets and learn how to process them into Python so they can be transformed and manipulated, if necessary, and analyzed. For this, we will introduce some of the bread and butter of data analysis and scientific computing in Python. These are fundamental tools that are constantly used in almost any task relating to data analysis.

The first part shows how to get data in and out of Python, so you can work on it and export it when ready; then the main part of the session discusses several patterns to clean and structure data properly, including tidying, subsetting, and aggregating; and we finish with some basic visualization.

Before we get our hands data-dirty, let us import all the additional libraries we will need, so we can get that out of the way and focus on the task at hand:

```
In [1]: # This ensures visualizations are plotted inside the notebook
        %matplotlib inline

import os                # This provides several system utilities
import pandas as pd      # This is the workhorse of data munging in Python
import seaborn as sns    # This allows us to easily and beautifully plot
```

2.0.1 The Liverpool Census Data Pack

Throughout this notebook (and later on as well), we will use the [CDRC](#)’s Census Data Pack for the city of Liverpool ([link](#)) and explore some of the city’s socio-demographic characteristics. This is a large package crafted by the CDRC that brings together several Census tables in a consistent way for the city of Liverpool. We will only be able to use just a few of them but, since they are consistently organized, the procedure used should teach you how to explore other variables on your own. In particular, in this session, we will be using a table that lists **population by country of birth**.

The pack is composed of two types of data: tabular and spatial. Tabular data are numerical tables that contain information relating to many socio-economic variables for different units (areas); spatial data contains the geometries of the areas in which Liverpool is divided into. Since there are many variables contained in several tables, that can be linked to more than one geography, the pack also includes two

“compass files” that help you find what you are looking for: one table that lists and describes the different datasets available; and a much more detailed table that lists and describes each and every single variable available in the pack.

The remainder assumes you have downloaded and unpacked the data. Specify the path to the folder in the following cell, so you can correctly run the code without errors:

```
In [2]: # Important! You need to specify the path to the data in *your* machine
        # If you have placed the data folder in the same directory as this notebook,
        # you would do:
        # path = 'Liverpool/'
        path = '../..../data/Liverpool/'
```

2.0.2 Reading data (data I/O)

It is not only that data are not ready to analyze when you get a hold on them. Sometimes, there is not such thing as *the dataset* to analyze. Instead, what you have is a collection of separated files, sometimes with different structures, that you need to bring together to begin with. This is one of the areas where a bit of scripting skills can help you a long way. While in a traditional point-and-click program like Microsoft Excel or SPSS, you would have to repeat the steps every time you wanted to incorporate a new dataset, with a bit of Python ninja tricks, you can write code that will do it for you as many times as you need.

The folder contains data at different scales. We will be using the Local Super Output Area (LSOAs). The folder is structured in the following way:

```
In [3]: os.listdir(path)
```

```
Out[3]: ['readme.txt',
        'metadata.xml',
        'variables_description.csv',
        'datasets_description.csv',
        'tables',
        'shapefiles']
```

For now, we will ignore the spatial information contained in the folder **shapefiles** and focus on the **tables** one. If you have a peek at the folder, it contains many files. You can get their names into a Python list with the following command:

```
In [4]: csvs = os.listdir(path + 'tables')
```

And count them using the core function **len**, which returns the length of a list:

```
In [5]: len(csvs)
```

```
Out[5]: 303
```

That is right, 303 files! Luckily, to navigate that sea of seemingly non-sensical letters, there is a codebook that explains things a bit. You can open it with a text editor or a spreadsheet program but, since it is a **csv** file (short for “comma-separated value”), we can also ingest it with Python:

```
In [6]: codebook = pd.read_csv(path + 'datasets_description.csv', index_col=0)
```

Let us stop for a minute to learn how we have read the file. Here are the main aspects to keep in mind:

- We are using the method **read_csv** from the **pandas** library, which we have imported with the alias **pd**.
- In this simple form, all that is required is to pass the path to the file we want to read, which in this case we have created by concatenating two strings. We can see the full path we have used:

```
In [7]: # Yours might look different if 'path' is pointing somewhere else
        path + 'datasets_description.csv'
```

```
Out[7]: '../.../.../data/Liverpool/datasets_description.csv'
```

- The argument `index_col` is not strictly necessary but allows us to choose one of the columns as the index of the table. More on indices below.
- We are using `read_csv` because the file we want to read is in the `csv` format. However, `pandas` allows for many more formats to be read (and written, just replace `read` by `write`!). A full list of formats supported includes:

```
In [8]: # This bit of code includes some more advanced tricks, not required for this session :-)
        [i for i in dir(pd) if 'read_' in i]
```

```
Out[8]: ['read_clipboard',
        'read_csv',
        'read_excel',
        'read_fwf',
        'read_gbq',
        'read_hdf',
        'read_html',
        'read_json',
        'read_msgpack',
        'read_pickle',
        'read_sql',
        'read_sql_query',
        'read_sql_table',
        'read_stata',
        'read_table']
```

If you want to learn how to use any of them, remember how to use the `help` or `?` systems for inline help.

- Finally, the read file is assigned into an object we call `codebook`, so we can manipulate it later.

Now we have read the file, we can inspect it. For example, to show the first lines of the table:

```
In [9]: codebook.head()
```

```
Out[9]:
```

DatasetId	DatasetTitle
CT0010	Ethnic group write-ins
KS101EW	Usual resident population
KS102EW	Age structure
KS103EW	Marital and civil partnership status
KS104EW	Living arrangements

Before we continue with the data, let us have a look at the object `codebook`. It is a different “animal” than we have seen so far:

```
In [10]: type(codebook)
```

```
Out[10]: pandas.core.frame.DataFrame
```

It is a “pandas data frame”. Similar to R’s “`data.frame`” class, it is one of the most essential data structures in Python for data analysis, and we will use it intensively. Data frames are sophisticated constructs that can perform several advanced tasks and have many properties. We will be discovering them as we progress on the course but, for now, let us keep in mind they are tables, indexed on rows and columns that can support mixed data types and can be flexibly manipulated.

2.0.3 Data, sliced and diced

You can use the index chosen to query rows. For example, if we want to see what dataset code QS203EW corresponds to:

```
In [11]: codebook.loc['QS203EW', 'DatasetTitle']
```

```
Out[11]: 'Country of birth (detailed)'
```

Note how we use the operator `loc` (for locator) on the dataframe, followed by squared brackets and, inside it, two strings: one for the name of the row and one for the column.

If we want to see what that dataset contains, there is another file in the folder called `variables_description.csv` that has further information. We can bring it in the same way we did before and, again, we will index it using the first column of the table, the ID of the dataset where the variable belongs to:

```
In [12]: variables = pd.read_csv(path+'variables_description.csv', index_col=0)
```

To have a sense of how large it is, we can call its `shape` property, which returns the number of rows and columns, respectively:

```
In [13]: variables.shape
```

```
Out[13]: (2563, 3)
```

2,563 different variables!!! Let us see what the structure of the table is:

```
In [14]: variables.head()
```

```
Out[14]:
```

DatasetId	ColumnVariableCode	ColumnVariableMeasurementUnit
CT0010	CT00100001	Count
CT0010	CT00100002	Count
CT0010	CT00100003	Count
CT0010	CT00100004	Count
CT0010	CT00100005	Count

DatasetId	ColumnVariableDescription
CT0010	All categories: Ethnic group
CT0010	English/Welsh/Scottish/Northern Irish/British
CT0010	Irish
CT0010	Gypsy or Irish Traveller
CT0010	Other White

If we are interested in exploring the country of birth (code QS203EW), we can subset the table using `loc` in a similar way as before. The only difference is that now we do not want to restrict the column to only one, so we use the colon `:` instead of a particular name, including thus *all* the columns. Let us also save the subset by assigning it to a new object, `birth_orig`:

```
In [15]: birth_orig = variables.loc['QS203EW', :]  
        birth_orig.shape
```

```
Out[15]: (78, 3)
```

To be clear, the table above contains all the variables that the dataset QS203EW is comprised of. This means that, for every row in this table, there is a column in the actual dataset which, for the LSOAs, is on the file `QS203EW_lsoa11.csv`, in the `tables` folder.

This is still a lot. Arguably, to get a first sense of the data and start exploring it, we do not need every single disaggregation available. Let us look at the names and codes of the first 25 variables to see if we can spot any pattern that helps us simplify (note how we now use `:` first to indicate we want *all* the rows):

```
In [16]: birth_orig.loc[:, ['ColumnVariableCode', 'ColumnVariableDescription']].head(25)
```

```
Out[16]:
```

DatasetId	ColumnVariableCode	ColumnVariableDescription
QS203EW	QS203EW0001	All categories: Country of birth
QS203EW	QS203EW0002	Europe: Total
QS203EW	QS203EW0003	Europe: United Kingdom: Total
QS203EW	QS203EW0004	Europe: United Kingdom: England
QS203EW	QS203EW0005	Europe: United Kingdom: Northern Ireland
QS203EW	QS203EW0006	Europe: United Kingdom: Scotland
QS203EW	QS203EW0007	Europe: United Kingdom: Wales
QS203EW	QS203EW0008	Europe: Great Britain not otherwise specified
QS203EW	QS203EW0009	Europe: United Kingdom not otherwise specified
QS203EW	QS203EW0010	Europe: Guernsey
QS203EW	QS203EW0011	Europe: Jersey
QS203EW	QS203EW0012	Europe: Channel Islands not otherwise specified
QS203EW	QS203EW0013	Europe: Isle of Man
QS203EW	QS203EW0014	Europe: Ireland
QS203EW	QS203EW0015	Europe: Other Europe: Total
QS203EW	QS203EW0016	Europe: Other Europe: EU Countries: Total
QS203EW	QS203EW0017	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0018	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0019	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0020	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0021	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0022	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0023	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0024	Europe: Other Europe: EU countries: Member cou...
QS203EW	QS203EW0025	Europe: Other Europe: EU countries: Member cou...

```

QS203EW    Europe: Other Europe: EU countries: Member cou...
QS203EW    Europe: Other Europe: EU countries: Accession ...
QS203EW    Europe: Other Europe: EU countries: Accession ...

```

Note how we have been able to pass a list of variables we wanted to select as columns, and `pandas` has returned the dataframe “sliced” with only those, cutting off the rest.

It looks like the variable name follows a hierarchical pattern that disaggregates by regions of the world. A sensible first approach might be to start considering only the largest regions. To do that, we need a list of the variable name for those aggregates since, once we have it, subsetting the dataframe will be straightforward. There are several ways we can go about it:

- Since there are not that many regions, we can hardcode them into a list:

```

In [17]: region_codes = ['QS203EW0002', 'QS203EW0032', 'QS203EW0045', \
                        'QS203EW0063', 'QS203EW0072']

```

[Advanced extension. Optional]

- However, this approach would not get us very far if the list was longer. For that, a much more useful way is to write a loop that builds the list for us. To do this, we can remember some of the tricks learnt in the previous session about writing `for` loops and `if` statements and combine them with new ones about working with strings.

```

In [18]: regions = []
         for var in birth_orig['ColumnVariableDescription']:
             # Split the name of the variable in pieces by ': '
             pieces = var.split(': ')
             # Keep the first one (top hierarchy) and append ': Total'
             name = pieces[0] + ': Total'
             # If the name create matches the variable (exists in the original list),
             # add the name to the list
             if name == var:
                 regions.append(name)
         regions

Out[18]: ['Europe: Total',
          'Africa: Total',
          'Middle East and Asia: Total',
          'The Americas and the Caribbean: Total',
          'Antarctica and Oceania: Total']

```

Let us work slowly by each step of this loop:

- We first create an empty list where we will store the names of the regions.
- We begin a loop over every single row the column containing the names (`ColumnVariableDescription`).
- For each name, which is a string, we split it in pieces using `:` as the points in the string where we want to break it, obtaining a list with the resulting pieces. For instance if we have `Europe: Total`, we essentially do:

```

In [19]: 'Europe: Total'.split(': ')

Out[19]: ['Europe', 'Total']

```

- We keep the first element, as it contains the name we want to keep.

- In order to build the actual name of the variable, we join it to ' : Total', obtaining the string we want to keep:

```
In [20]: 'Europe' + ' : Total'
```

```
Out[20]: 'Europe: Total'
```

- We then check that the string we have built is the same as the variable we began with. If so, we save it on the list we created in the beginning. This step is a bit counter-intuitive, but is done to ensure a) that the name of the variable exists, and b) that it is saved only once.

Now we have the names, we need to convert them into the codes. There are several ways to go about it, but here we will show one that relies on the indexing capabilities of `pandas`. Essentially we take `birth_orig` and index it on the names of the variables, to then subset it, keeping only those in our list (the variables we want to retain).

```
In [21]: subset = birth_orig.set_index('ColumnVariableDescription').reindex(regions)
subset
```

```
Out[21]:
```

ColumnVariableDescription	ColumnVariableCode
Europe: Total	QS203EW0002
Africa: Total	QS203EW0032
Middle East and Asia: Total	QS203EW0045
The Americas and the Caribbean: Total	QS203EW0063
Antarctica and Oceania: Total	QS203EW0072

ColumnVariableDescription	ColumnVariableMeasurementUnit
Europe: Total	Count
Africa: Total	Count
Middle East and Asia: Total	Count
The Americas and the Caribbean: Total	Count
Antarctica and Oceania: Total	Count

Once this is done, all left to do is to retrieve the codes:

```
In [22]: region_codes = list(subset.ColumnVariableCode)
region_codes
```

```
Out[22]: ['QS203EW0002', 'QS203EW0032', 'QS203EW0045', 'QS203EW0063', 'QS203EW0072']
```

2.0.4 Interrogating the country of birth dataset

With the codes in hand, we can easily subset the variables and keep them into a neat, more compact table. First, we need to load up the data file, which can be found in the `tables` folder with the code of the dataset:

```
In [23]: lsoa_orig = pd.read_csv(path+'tables/QS203EW_lsoa11.csv', index_col='GeographyCode')
lsoa_orig.head()
```

```
Out[23]:
```

GeographyCode	QS203EW0001	QS203EW0002	QS203EW0003	QS203EW0004
E01006512	1880	910	766	699
E01006513	2941	2225	2033	1806
E01006514	2108	1786	1632	1503

E01006515	1208	974	910	877
E01006518	1696	1531	1468	1446

	QS203EW0005	QS203EW0006	QS203EW0007	QS203EW0008	\
GeographyCode					
E01006512	26	21	20	0	
E01006513	98	28	101	0	
E01006514	44	18	67	0	
E01006515	16	5	12	0	
E01006518	7	6	9	0	

	QS203EW0009	QS203EW0010	...	QS203EW0069	\
GeographyCode			...		
E01006512	0	0	...	5	
E01006513	0	0	...	5	
E01006514	0	0	...	19	
E01006515	0	0	...	4	
E01006518	0	0	...	3	

	QS203EW0070	QS203EW0071	QS203EW0072	QS203EW0073	\
GeographyCode					
E01006512	0	5	0	0	
E01006513	1	4	7	0	
E01006514	2	17	5	0	
E01006515	2	2	2	0	
E01006518	0	3	4	0	

	QS203EW0074	QS203EW0075	QS203EW0076	QS203EW0077	QS203EW0078
GeographyCode					
E01006512	0	0	0	0	0
E01006513	7	6	1	0	0
E01006514	4	2	2	1	0
E01006515	2	2	0	0	0
E01006518	4	4	0	0	0

[5 rows x 78 columns]

In [24]: lsoa_orig.shape

Out[24]: (298, 78)

The full table, as we have seen above, contains 78 columns and 298 rows. To keep *only* the columns we are interested in, we can simply slice the table as we learnt before:

In [25]: lsoa_orig_sub = lsoa_orig.loc[:, region_codes]
lsoa_orig_sub.head()

Out[25]:

	QS203EW0002	QS203EW0032	QS203EW0045	QS203EW0063	QS203EW0072
GeographyCode					
E01006512	910	106	840	24	0
E01006513	2225	61	595	53	7
E01006514	1786	63	193	61	5
E01006515	974	29	185	18	2
E01006518	1531	69	73	19	4

We can further inspect the dataset with an additional command called `info`, that lists the names of the columns and how many non-null elements each contains:


```
In [26]: lsoa_orig_sub.info()

<class 'pandas.core.frame.DataFrame'>
Index: 298 entries, E01006512 to E01033768
Data columns (total 5 columns):
QS203EW0002    298 non-null int64
QS203EW0032    298 non-null int64
QS203EW0045    298 non-null int64
QS203EW0063    298 non-null int64
QS203EW0072    298 non-null int64
dtypes: int64(5)
memory usage: 14.0+ KB
```

[Optional extension: renaming columns]

The table we have compiled contains exactly what we wanted. However, the names of the columns are a bit unintuitive, to say the least. It would be much handier if we could rename the columns into something more human readable. The easiest way to do that in `pandas` is by creating a dictionary that maps the original name into the desired one, and then applying it to the `DataFrame` with the command `rename`. Let us walk through the steps necessary, one by one:

- Create a dictionary that maps the codes to the names. For this, we can use the list we have created before, and what we have learnt about querying tables, combined with a small `for` loop:

```
In [27]: code2name = {}
        lookup_table = variables.set_index('ColumnVariableCode') # Reindex to be able to query
        for code in region_codes:
            code2name[code] = lookup_table.loc[code, 'ColumnVariableDescription']
        code2name
```

```
Out[27]: {'QS203EW0002': 'Europe: Total',
          'QS203EW0032': 'Africa: Total',
          'QS203EW0045': 'Middle East and Asia: Total',
          'QS203EW0063': 'The Americas and the Caribbean: Total',
          'QS203EW0072': 'Antarctica and Oceania: Total'}
```

- [Optional] Because we know that each of these variables are totals for each group, we can further declutter the names by removing the piece of the string `: Total`. A simple loop can help us:

```
In [28]: for code in code2name:
        code2name[code] = code2name[code].replace(': Total', '')
        code2name
```

```
Out[28]: {'QS203EW0002': 'Europe',
          'QS203EW0032': 'Africa',
          'QS203EW0045': 'Middle East and Asia',
          'QS203EW0063': 'The Americas and the Caribbean',
          'QS203EW0072': 'Antarctica and Oceania'}
```

- With the dictionary in hand, renaming the columns is as easy as:

```
In [29]: lsoa_orig_sub = lsoa_orig_sub.rename(columns=code2name)
        lsoa_orig_sub.head()
```

```

Out [29]:
      Europe  Africa  Middle East and Asia  \
GeographyCode
E01006512      910      106                840
E01006513     2225       61                595
E01006514     1786       63                193
E01006515       974       29                185
E01006518     1531       69                73

      The Americas and the Caribbean  Antarctica and Oceania
GeographyCode
E01006512                24                0
E01006513                53                7
E01006514                61                5
E01006515                18                2
E01006518                19                4

```

[In-class exercise]

Take the subset table just created (`lsoa_orig_sub`) and write it into a `csv` file.

Now we are ready to start playing and interrogating the dataset! What we have at our fingertips is a table that summarizes, for each of the 238 LSOAs in Liverpool, how many people live in each, by the region of the world where they were born. To make what follows easier on your typing, let us rename the table to something shorter:

```
In [30]: db = lsoa_orig_sub
```

Now, let us learn a few cool tricks built into `pandas` that work out-of-the box with a table like ours.

- Inspecting what it looks like. We can check the top (bottom) `X` lines of the table by passing `X` to the method `head` (`tail`). For example, for the top/bottom five lines:

```
In [31]: db.head(5)
```

```

Out [31]:
      Europe  Africa  Middle East and Asia  \
GeographyCode
E01006512      910      106                840
E01006513     2225       61                595
E01006514     1786       63                193
E01006515       974       29                185
E01006518     1531       69                73

      The Americas and the Caribbean  Antarctica and Oceania
GeographyCode
E01006512                24                0
E01006513                53                7
E01006514                61                5
E01006515                18                2
E01006518                19                4

```

```
In [32]: db.tail(5)
```

```

Out[32]:
      Europe  Africa  Middle East and Asia \
      GeographyCode
E01033764    2106     32                   49
E01033765    1277     21                   33
E01033766    1028     12                   20
E01033767    1003     29                   29
E01033768    1016     69                  111

      The Americas and the Caribbean  Antarctica and Oceania
      GeographyCode
E01033764                        15                        0
E01033765                        17                        3
E01033766                         8                        7
E01033767                         5                        1
E01033768                        21                        6

```

- Getting an overview of the table:

```

In [33]: db.info()

<class 'pandas.core.frame.DataFrame'>
Index: 298 entries, E01006512 to E01033768
Data columns (total 5 columns):
Europe                298 non-null int64
Africa                298 non-null int64
Middle East and Asia  298 non-null int64
The Americas and the Caribbean  298 non-null int64
Antarctica and Oceania  298 non-null int64
dtypes: int64(5)
memory usage: 14.0+ KB

```

- Getting an overview of the *values* of the table:

```

In [34]: db.describe()

Out[34]:
      Europe  Africa  Middle East and Asia \
count  298.00000  298.000000  298.000000
mean   1462.38255  29.818792   62.909396
std     248.67329  51.606065  102.519614
min     731.00000   0.000000   1.000000
25%    1331.25000   7.000000  16.000000
50%    1446.00000  14.000000  33.500000
75%    1579.75000  30.000000  62.750000
max    2551.00000  484.000000  840.000000

      The Americas and the Caribbean  Antarctica and Oceania
count                298.000000  298.000000
mean                  8.087248    1.949664
std                   9.397638    2.168216
min                   0.000000    0.000000
25%                   2.000000    0.000000
50%                   5.000000    1.000000
75%                  10.000000    3.000000
max                  61.000000   11.000000

```

Note how the output is also a `DataFrame` object, so you can do with it the same things you would with the original table (e.g. writing it to a file).

In this case, the summary might be better presented if the table is “transposed”:

```
In [35]: db.describe().T
```

```
Out[35]:
```

	count	mean	std	min	25%	\
Europe	298	1462.382550	248.673290	731	1331.25	
Africa	298	29.818792	51.606065	0	7.00	
Middle East and Asia	298	62.909396	102.519614	1	16.00	
The Americas and the Caribbean	298	8.087248	9.397638	0	2.00	
Antarctica and Oceania	298	1.949664	2.168216	0	0.00	

	50%	75%	max
Europe	1446.0	1579.75	2551
Africa	14.0	30.00	484
Middle East and Asia	33.5	62.75	840
The Americas and the Caribbean	5.0	10.00	61
Antarctica and Oceania	1.0	3.00	11

- Equally, common descriptive statistics are also available:

```
In [36]: db.min()
```

```
Out[36]: Europe          731
Africa                  0
Middle East and Asia    1
The Americas and the Caribbean  0
Antarctica and Oceania  0
dtype: int64
```

```
In [37]: db['Europe'].max()
```

```
Out[37]: 2551
```

Note here how we have restricted the calculation of the maximum value to one column only. Similarly, we can restrict the calculations to a single row:

```
In [38]: db.loc['E01006512', :].std()
```

```
Out[38]: 457.88426485303029
```

- Simple creation of new variables: we can generate new variables by applying operations on existing ones. For example, we can calculate the total population by area. Here is a couple of ways to do it:

```
In [39]: # Longer, hardcoded
total = db['Europe'] + db['Africa'] + db['Middle East and Asia'] + \
        db['The Americas and the Caribbean'] + db['Antarctica and Oceania']
total.head()
```

```
Out[39]: GeographyCode
E01006512    1880
E01006513    2941
E01006514    2108
E01006515    1208
E01006518    1696
dtype: int64
```

```
In [40]: # One shot
total = db.sum(axis=1)
total.head()
```

```
Out[40]: GeographyCode
E01006512    1880
E01006513    2941
E01006514    2108
E01006515    1208
E01006518    1696
dtype: int64
```

Note how we are using the command `sum`, just like we did with `max` or `min` before but, in this case, we are not applying it over columns (e.g. the max of each column), but over rows, so we get the total sum of populations by areas.

Once we have created the variable, we can make it part of the table:

```
In [41]: db['Total'] = total
db.head()
```

```
Out[41]:
```

	Europe	Africa	Middle East and Asia \
GeographyCode			
E01006512	910	106	840
E01006513	2225	61	595
E01006514	1786	63	193
E01006515	974	29	185
E01006518	1531	69	73

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01006512	24	0	1880
E01006513	53	7	2941
E01006514	61	5	2108
E01006515	18	2	1208
E01006518	19	4	1696

[In-class exercise]

Obtain the total population in Liverpool by each subgroup.

Tip: focus on the axis argument.

- Assigning new values: we can easily generate new variables with scalars, and modify those.

```
In [42]: # New variable with all ones
db['ones'] = 1
db.head()
```

```
Out[42]:
```

	Europe	Africa	Middle East and Asia \
GeographyCode			
E01006512	910	106	840
E01006513	2225	61	595
E01006514	1786	63	193
E01006515	974	29	185
E01006518	1531	69	73

	The Americas and the Caribbean	Antarctica and Oceania	Total \
GeographyCode			

E01006512	24	0	1880
E01006513	53	7	2941
E01006514	61	5	2108
E01006515	18	2	1208
E01006518	19	4	1696

	ones
GeographyCode	
E01006512	1
E01006513	1
E01006514	1
E01006515	1
E01006518	1

And we can modify specific values too:

```
In [43]: db.loc['E01006512', 'ones'] = 3
db.head()
```

```
Out[43]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01006512	910	106	840	
E01006513	2225	61	595	
E01006514	1786	63	193	
E01006515	974	29	185	
E01006518	1531	69	73	

	The Americas and the Caribbean	Antarctica and Oceania	Total	\
GeographyCode				
E01006512		24	0	1880
E01006513		53	7	2941
E01006514		61	5	2108
E01006515		18	2	1208
E01006518		19	4	1696

	ones
GeographyCode	
E01006512	3
E01006513	1
E01006514	1
E01006515	1
E01006518	1

- Deleting variables is also trivial:

```
In [44]: del db['ones']
db.head()
```

```
Out[44]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01006512	910	106	840	
E01006513	2225	61	595	
E01006514	1786	63	193	
E01006515	974	29	185	
E01006518	1531	69	73	

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01006512	24	0	1880
E01006513	53	7	2941
E01006514	61	5	2108
E01006515	18	2	1208
E01006518	19	4	1696

- Simple querying.

We have already seen how to subset parts of a `DataFrame` if we know exactly which bits we want. For example, if we want to extract the total and European population of the first four areas in the table, we use `loc` with lists:

```
In [45]: eu_tot_first4 = db.loc[['E01006512', 'E01006513', 'E01006514', 'E01006515'], \
                                ['Total', 'Europe']]
eu_tot_first4
```

```
Out[45]:
```

	Total	Europe
GeographyCode		
E01006512	1880	910
E01006513	2941	2225
E01006514	2108	1786
E01006515	1208	974

- Querying based on conditions.

However, sometimes, we do not know exactly which observations we want, but we do know what conditions they need to satisfy (e.g. areas with more than 2,000 inhabitants). For these cases, `DataFrames` support selection based on conditions. Let us see a few examples. Suppose we want to select...

... areas with more than 2,500 people in Total:

```
In [46]: m5k = db.loc[db['Total'] > 2500, :]
m5k
```

```
Out[46]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01006513	2225	61	595	
E01006747	2551	163	812	
E01006751	1843	139	568	

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01006513	53	7	2941
E01006747	24	2	3552
E01006751	21	1	2572

... areas where there are no more than 750 Europeans:

```
In [47]: nm5ke = db.loc[db['Europe'] < 750, :]
nm5ke
```

```
Out[47]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01033757	731	39	223	

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01033757	29	3	1025

... areas with exactly ten person from Antarctica and Oceania:

```
In [48]: oneOA = db.loc[db['Antarctica and Oceania'] == 10, :]  
oneOA
```

```
Out[48]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01006679	1353	484		354

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01006679	31	10	2232

Pro-tip: these queries can grow in sophistication with almost no limits. For example, here is a case where we want to find out the areas where European population is less than half the population:

```
In [49]: eu_lth = db.loc[(db['Europe'] * 100. / db['Total']) < 50, :]  
eu_lth
```

```
Out[49]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01006512	910	106		840

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01006512	24	0	1880

- Combining queries.

Now all of these queries can be combined with each other, for further flexibility. For example, imagine we want areas with more than 25 people from the Americas and Caribbean, but less than 1,500 in total:

```
In [50]: ac25_1500 = db.loc[(db['The Americas and the Caribbean'] > 25) & \  
                             (db['Total'] < 1500), :]  
ac25_1500
```

```
Out[50]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01033750	1235	53		129
E01033752	1024	19		114
E01033754	1262	37		112
E01033756	886	31		221
E01033757	731	39		223
E01033761	1138	52		138

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01033750	26	5	1448
E01033752	33	6	1196
E01033754	32	9	1452
E01033756	42	5	1185
E01033757	29	3	1025
E01033761	33	11	1372

- Sorting.

Among the many operations `DataFrame` objects support, one of the most useful ones is to sort a table based on a given column. For example, imagine we want to sort the table by total population:

```
In [51]: db_pop_sorted = db.sort('Total', ascending=False)
         db_pop_sorted.head()
```

```
Out[51]:
```

	Europe	Africa	Middle East and Asia \
GeographyCode			
E01006747	2551	163	812
E01006513	2225	61	595
E01006751	1843	139	568
E01006524	2235	36	125
E01006787	2187	53	75

	The Americas and the Caribbean	Antarctica and Oceania	Total
GeographyCode			
E01006747	24	2	3552
E01006513	53	7	2941
E01006751	21	1	2572
E01006524	24	11	2431
E01006787	13	2	2330

If you inspect the help of `db.sort`, you will find that you can pass more than one column to sort the table by. This allows you to do so-called hierarchical sorting: sort first based on one column, if equal then based on another column, etc.

[In-class exercise]

- Create a new table that, instead of the total counts, has the percentages of population groups in each area. Call this `db.pct`.
 - Practice your query skills further by answering the following questions:
 - What is the most populated area?
 - What is the area with the largest variance of group sizes?
 - List the five areas with the largest proportion of people born in Antarctica and Oceania.
 - Find areas that have more than 25% of population from Europe but are still among the top-5 in terms of African population.
 - **[Bonus]** Is there any area in the top-5 of percentage of American/Caribbean *and* of Middle East/Asia population?
-

2.0.5 Visual exploration

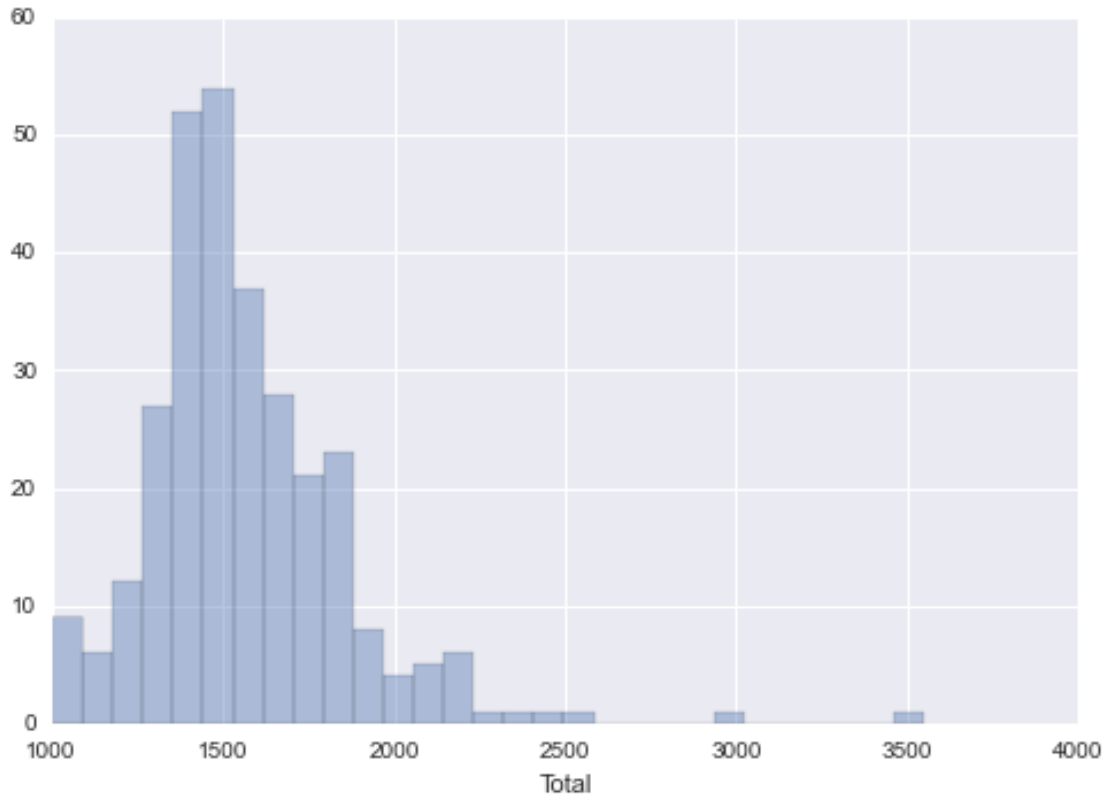
The next step to continue exploring a dataset is to get a feel for what it looks like, visually. We have already learnt how to uncover and inspect specific parts of the data, to check for particular cases we might be interested in. Now we will see how to plot the data to get a sense of the overall distribution of values. For that, we will be using the Python library [seaborn](#).

- Histograms.

One of the simplest graphical devices to display the distribution of values in a variable is a histogram. Values are assigned into groups of equal intervals, and the groups are plotted as bars rising as high as the number of values into the group.

A histogram is easily created with the following command. In this case, let us have a look at the shape of the overall population:

```
In [52]: _ = sns.distplot(db['Total'], kde=False)
```

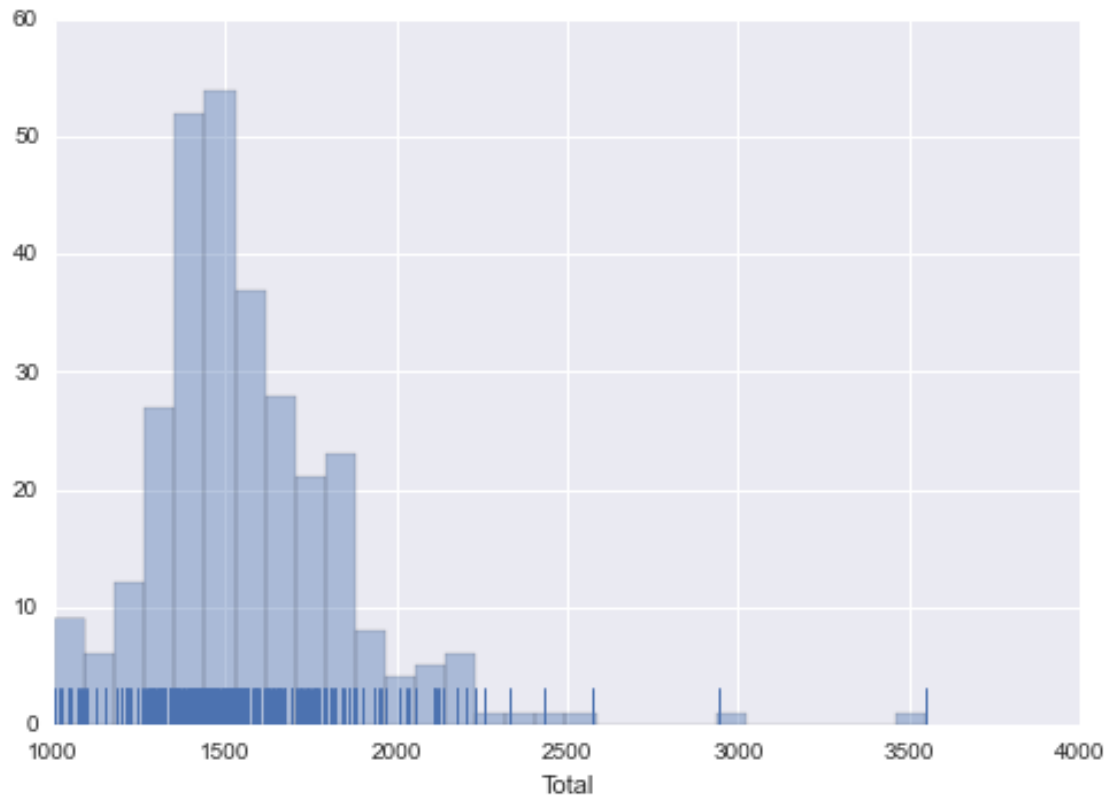


Note we are using **sns** instead of **pd**, as the function belongs to **seaborn** instead of **pandas**.

We can quickly see most of the areas contain somewhere between 1,200 and 1,700 people, approx. However, there are a few areas that have many more, even up to 3,500 people.

An additional feature to visualize the density of values is called **rug**, and adds a little tick for each value on the horizontal axis:

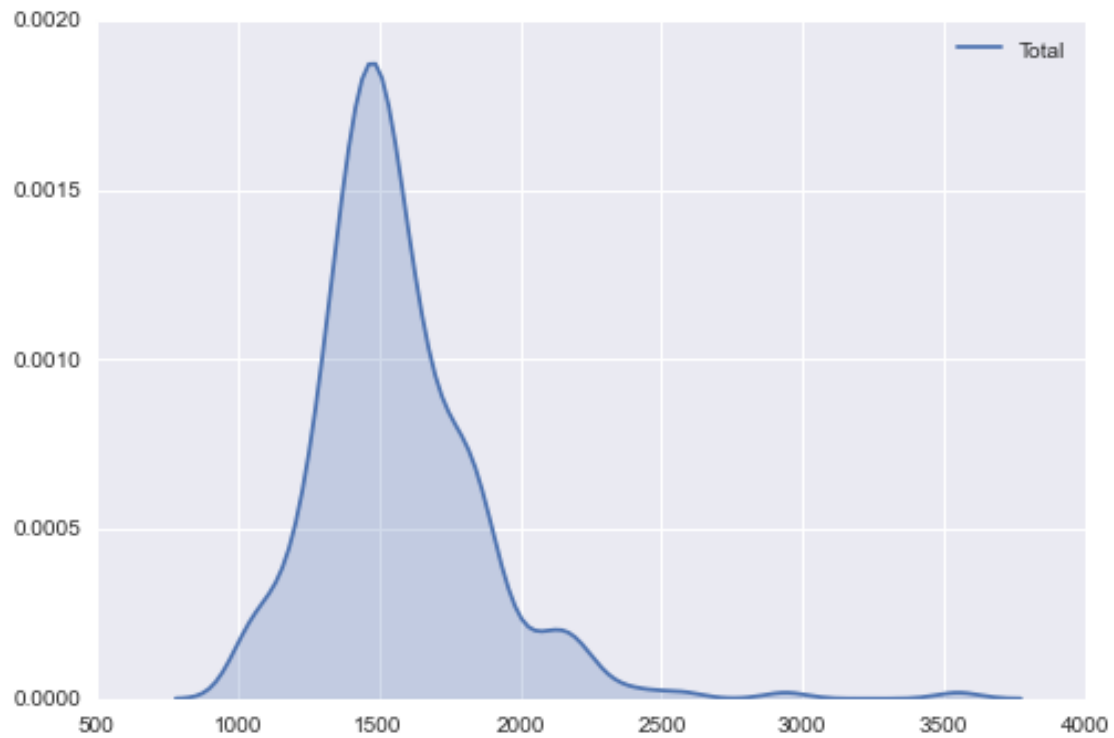
```
In [53]: _ = sns.distplot(db['Total'], kde=False, rug=True)
```



- Kernel Density Plots

Histograms are useful, but they are artificial in the sense that a continuous variable is made discrete by turning the values into discrete groups. An alternative is kernel density estimation (KDE), which produces an empirical density function:

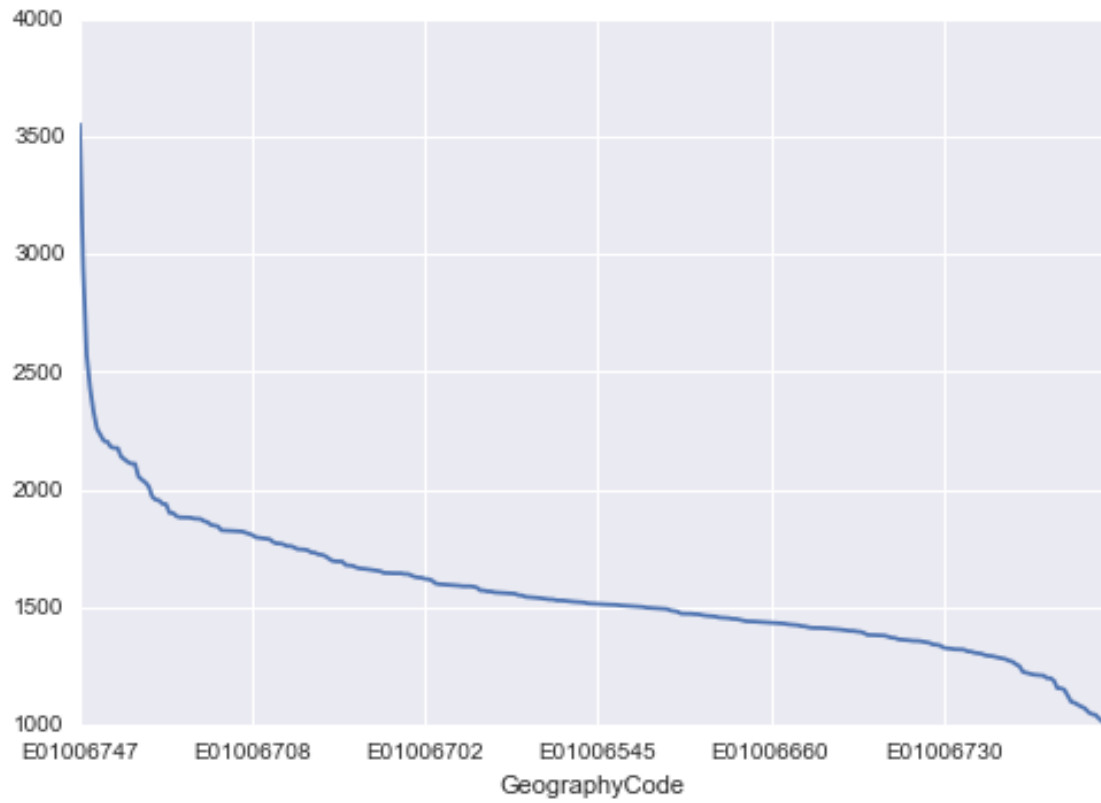
```
In [54]: _ = sns.kdeplot(db['Total'], shade=True)
```



- Line and bar plots

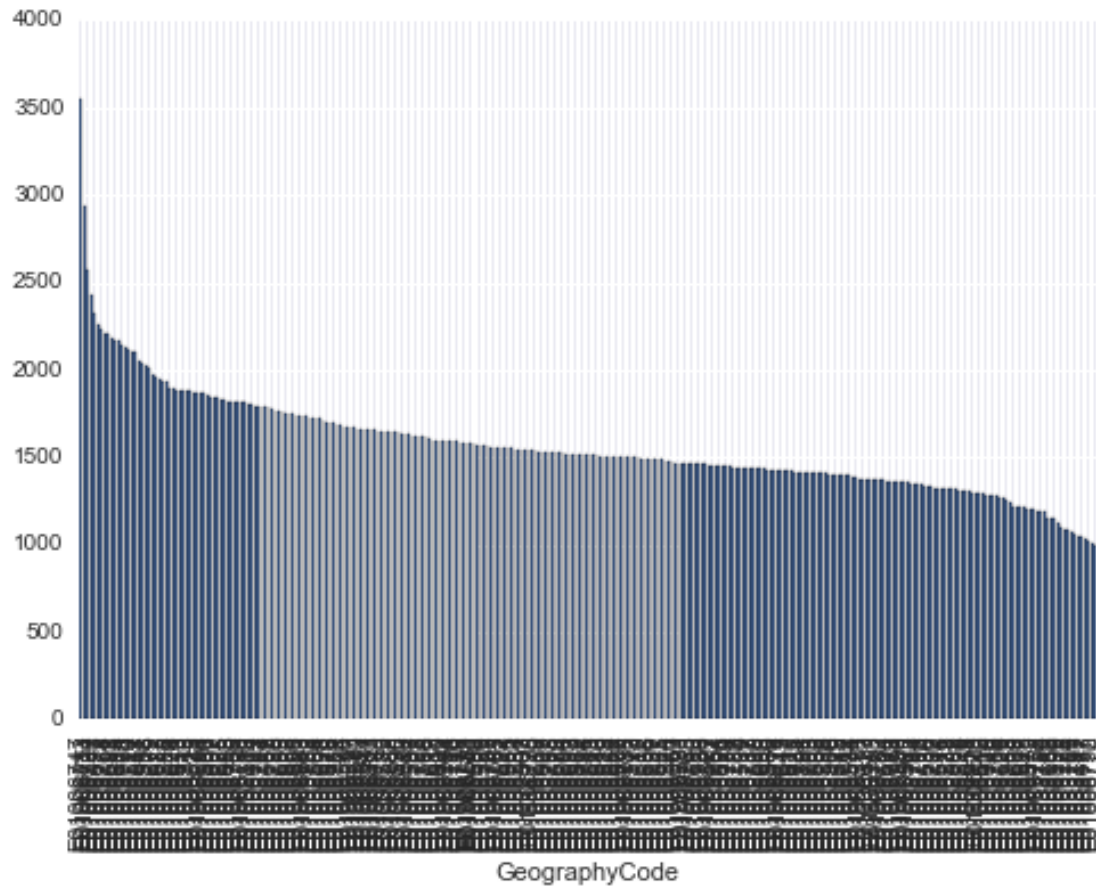
Another very common way of visually displaying a variable is with a line or a bar chart. For example, if we want to generate a line plot of the (sorted) total population by area:

```
In [55]: _ = db['Total'].order(ascending=False).plot()
```



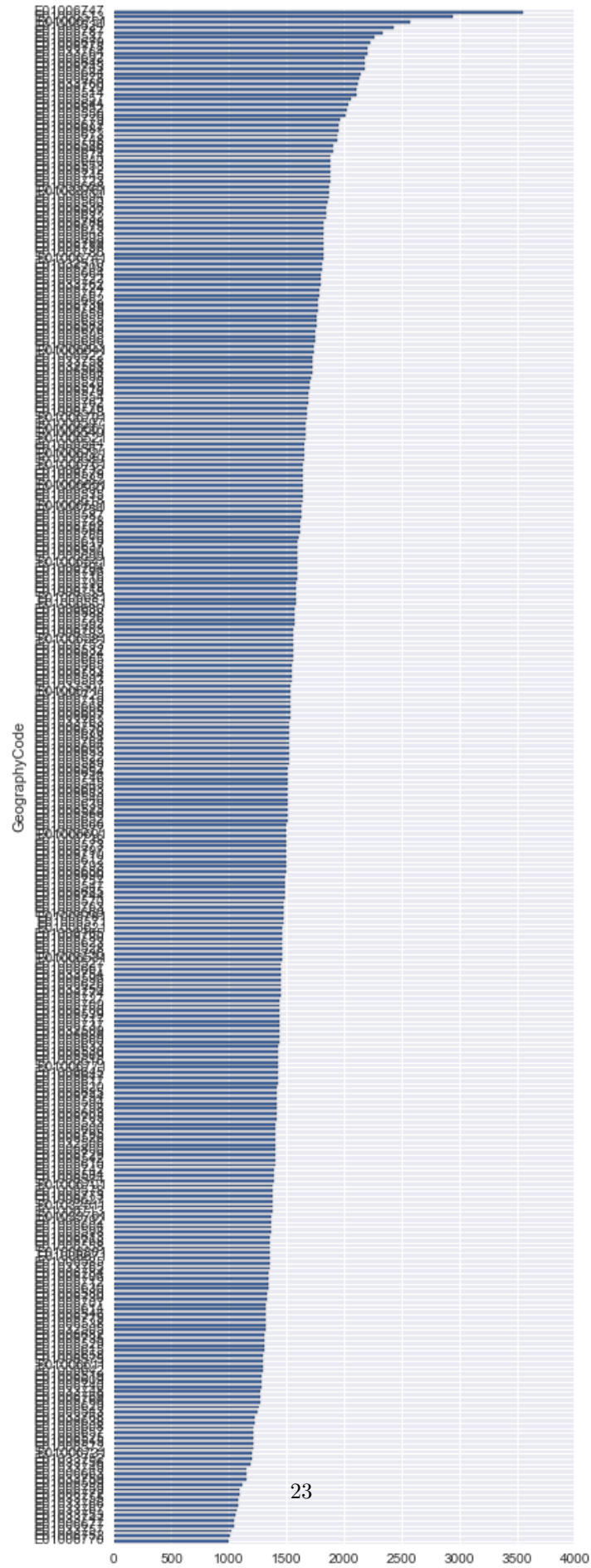
For a bar plot all we need to do is to change an argument of the call:

```
In [56]: _ = db['Total'].order(ascending=False).plot(kind='bar')
```



Note that the large number of areas makes the horizontal axis unreadable. We can try to turn the plot around by displaying the bars horizontally (see how it's just changing `bar` for `barh`). To make it readable, let us expand the plot's height:

```
In [57]: _ = db['Total'].order().plot(kind='barh', figsize=(6, 20))
```



[In-class exercise]

- Explore the help of `sns.distplot` and `sns.kdeplot` to discover additional arguments. Check also the [tutorial](#).
 - Create a figure that overlays both a histogram and a KDE plot of the total population in a single figure.
 - Create histogram and KDE plots for the other variables in the dataset.
-

2.0.6 Un/tidy data

Happy families are all alike; every unhappy family is unhappy in its own way.

Leo Tolstoy.

Once you can read your data in, explore specific cases, and have a first visual approach to the entire set, the next step can be preparing it for more sophisticated analysis. Maybe you are thinking of modeling it through regression, or on creating subgroups in the dataset with particular characteristics, or maybe you simply need to present summary measures that relate to a slightly different arrangement of the data than you have been presented with.

For all these cases, you first need what statistician, and general R wizard, Hadley Wickham calls “*tidy data*”. The general idea to “tidy” your data is to convert them from whatever structure they were handed in to you into one that allows easy and standardized manipulation, and that supports directly inputting the data into what he calls “*tidy*” analysis tools. But, at a more practical level, what is exactly “*tidy data*”? In Wickham’s own words:

Tidy data is a standard way of mapping the meaning of a dataset to its structure. A dataset is messy or tidy depending on how rows, columns and tables are matched up with observations, variables and types.

He then goes on to list the three fundamental characteristics of “*tidy data*”:

1. Each variable forms a column.
2. Each observation forms a row.
3. Each type of observational unit forms a table.

If you are further interested in the concept of “*tidy data*”, I recommend you check out the [original paper](#) (open access) and the [public repository](#) associated with it.

Let us bring in the concept of “*tidy data*” to our own Liverpool dataset. First, remember its structure:

```
In [58]: db.head()
```

```
Out[58]:
```

	Europe	Africa	Middle East and Asia	\
GeographyCode				
E01006512	910	106		840
E01006513	2225	61		595
E01006514	1786	63		193
E01006515	974	29		185
E01006518	1531	69		73

	The Americas and the Caribbean	Antarctica and Oceania	Total
--	--------------------------------	------------------------	-------

GeographyCode			
E01006512	24	0	1880
E01006513	53	7	2941
E01006514	61	5	2108
E01006515	18	2	1208
E01006518	19	4	1696

Thinking through *tidy* lenses, this is not a tidy dataset. It is not so for each of the three conditions:

- Starting by the last one (*each type of observational unit forms a table*), this dataset actually contains not one but two observational units: the different areas of Liverpool, captured by `GeographyCode`; *and* subgroups of an area. To *tidy* up this aspect, we can create two different tables:

```
In [59]: db_totals = db[['Total']]
         db_totals.head()
```

```
Out[59]:
```

	Total
GeographyCode	
E01006512	1880
E01006513	2941
E01006514	2108
E01006515	1208
E01006518	1696

```
In [60]: # Note we use 'drop' to exclude "Total", but we could also use a list with the names
         # of all the columns to keep
         db_subgroups = db.drop('Total', axis=1)
         db_subgroups.head()
```

```
Out[60]:
```

	Europe	Africa	Middle East and Asia \
GeographyCode			
E01006512	910	106	840
E01006513	2225	61	595
E01006514	1786	63	193
E01006515	974	29	185
E01006518	1531	69	73

	The Americas and the Caribbean	Antarctica and Oceania
GeographyCode		
E01006512	24	0
E01006513	53	7
E01006514	61	5
E01006515	18	2
E01006518	19	4

At this point, the table `db_totals` is tidy: every row is an observation, every table is a variable, and there is only one observational unit in the table.

The other table (`db_subgroups`), however, is not entirely tidied up yet: there is only one observational unit in the table, true; but every row is not an observation, and there are variable values as the names of columns (in other words, every column is not a variable). To obtain a fully tidy version of the table, we need to re-arrange it in a way that every row is a population subgroup in an area, and there are three variables: `GeographyCode`, population subgroup, and population count (or frequency).

Because this is actually a fairly common pattern, there is a direct way to solve it in `pandas`:

```
In [61]: tidy_subgroups = db_subgroups.stack()
         tidy_subgroups.head()
```

```
Out[61]: GeographyCode
        E01006512      Europe      910
                Africa      106
        Middle East and Asia      840
        The Americas and the Caribbean      24
        Antarctica and Oceania      0
        dtype: int64
```

The method `stack`, well, “stacks” the different columns into rows. This fixes our “tidiness” problems but the type of object that is returning is not a `DataFrame`:

```
In [62]: type(tidy_subgroups)
```

```
Out[62]: pandas.core.series.Series
```

It is a `Series`, which really is like a `DataFrame`, but with only one column. The additional information (`GeographyCode` and population group) are stored in what is called an multi-index. We will skip these for now, so we would really just want to get a `DataFrame` as we know it out of the `Series`. This is also one line of code away:

```
In [63]: tidy_subgroupsDF = tidy_subgroups.reset_index()
        tidy_subgroupsDF.head()
```

```
Out[63]:  GeographyCode      level_1      0
0      E01006512      Europe      910
1      E01006512      Africa      106
2      E01006512  Middle East and Asia      840
3      E01006512  The Americas and the Caribbean      24
4      E01006512  Antarctica and Oceania      0
```

And some basic renaming of the columns:

```
In [64]: tidy_subgroupsDF = tidy_subgroupsDF.rename(columns={'level_1': 'Subgroup', 0: 'Freq'})
        tidy_subgroupsDF.head()
```

```
Out[64]:  GeographyCode      Subgroup      Freq
0      E01006512      Europe      910
1      E01006512      Africa      106
2      E01006512  Middle East and Asia      840
3      E01006512  The Americas and the Caribbean      24
4      E01006512  Antarctica and Oceania      0
```

Now our table is fully tidied up!

2.0.7 Grouping, transforming, aggregating

One of the advantage of tidy datasets is they allow to perform advanced transformations in a more direct way. One of the most common ones is what is called “group-by” operations. Originated in the world of databases, these operations allow you to group observations in a table by one of its labels, index, or category, and apply operations on the data group by group.

For example, given our tidy table with population subgroups, we might want to compute the total sum of population by each group. This task can be split into two different ones:

- Group the table in each of the different subgroups.
- Compute the sum of `Freq` for each of them.

To do this in `pandas`, meet one of its workhorses, and also one of the reasons why the library has become so popular: the `groupby` operator.

```
In [65]: pop_grouped = tidy_subgroupsDF.groupby('Subgroup')
        pop_grouped
```

```
Out[65]: <pandas.core.groupby.DataFrameGroupBy object at 0x7fab16483b10>
```

The object `pop_grouped` still hasn't computed anything, it is only a convenient way of specifying the grouping. But this allows us then to perform a multitude of operations on it. For our example, the sum is calculated as follows:

```
In [66]: pop_grouped.sum()
```

```
Out[66]:
```

Subgroup	Freq
Africa	8886
Antarctica and Oceania	581
Europe	435790
Middle East and Asia	18747
The Americas and the Caribbean	2410

Similarly, you can also obtain a summary of each group:

```
In [67]: pop_grouped.describe()
```

```
Out[67]:
```

Subgroup		Freq
Africa	count	298.000000
	mean	29.818792
	std	51.606065
	min	0.000000
	25%	7.000000
	50%	14.000000
	75%	30.000000
	max	484.000000
Antarctica and Oceania	count	298.000000
	mean	1.949664
	std	2.168216
	min	0.000000
	25%	0.000000
	50%	1.000000
	75%	3.000000
	max	11.000000
Europe	count	298.000000
	mean	1462.382550
	std	248.673290
	min	731.000000
	25%	1331.250000
	50%	1446.000000
	75%	1579.750000
	max	2551.000000
Middle East and Asia	count	298.000000
	mean	62.909396
	std	102.519614
	min	1.000000
	25%	16.000000
	50%	33.500000
	75%	62.750000

	max	840.000000
The Americas and the Caribbean	count	298.000000
	mean	8.087248
	std	9.397638
	min	0.000000
	25%	2.000000
	50%	5.000000
	75%	10.000000
	max	61.000000

Pro-tip: since we only have one variable (`Freq`), a more compact way to display that summary can be obtained with the counterpart of `stack`, `unstack`:

```
In [68]: pop_grouped.describe().unstack()
```

```
Out[68]:
```

	Freq				
	count	mean	std	min	25%
Subgroup					
Africa	298	29.818792	51.606065	0	7.00
Antarctica and Oceania	298	1.949664	2.168216	0	0.00
Europe	298	1462.382550	248.673290	731	1331.25
Middle East and Asia	298	62.909396	102.519614	1	16.00
The Americas and the Caribbean	298	8.087248	9.397638	0	2.00

	50%	75%	max
Subgroup			
Africa	14.0	30.00	484
Antarctica and Oceania	1.0	3.00	11
Europe	1446.0	1579.75	2551
Middle East and Asia	33.5	62.75	840
The Americas and the Caribbean	5.0	10.00	61

We will not get into it today as it goes beyond the basics we want to cover, but keep in mind that `groupby` allows you to not only call generic functions (like `sum` or `describe`), but also your own functions. This opens the door for virtually any kind of transformation and aggregation possible.

[In-class exercise]

Practice your data tidying skills with a different dataset. For example, you can have a look at the Guardian's version of [Wikileaks' Afghanistan war logs](https://www.theguardian.com/world/2016/jul/14/wikileaks-afghanistan-war-logs). The table is stored on a GoogleDoc on the following address:

```
https://docs.google.com/spreadsheets/d/1EAX8\_ksSCmoWW\_SlhFyq2QrRn0FNNhcg1TtDFJzZRgc/edit?hl=en#gid=1
```

And its structure is as follows:

```
In [69]: from IPython.display import IFrame
url = 'https://docs.google.com/spreadsheets/d/1EAX8_ksSCmoWW_SlhFyq2QrRn0FNNhcg1TtDFJzZRgc/edit?hl=en#gid=1'
IFrame(url, 700, 400)
```

```
Out[69]: <IPython.lib.display.IFrame at 0x7fab1607d810>
```

Follow these steps:

- Download the table as a `csv` file (File -> Download as -> .csv, current sheet).
 - Read it into Python.
 - Explore it by creating a few plots.
 - Examine its level of tidiness and turn it into a fully tidy dataset.
 - Obtain a monthly total count of casualties and create a line or a bar plot of them.
-