Part 1: Loading and inspecting the data

Before we can start answering questions about the data we need to do a little bit of exploratory analysis.The first thing we need to do when working with a new dataset is to get an idea of what the data looks like. We start by loading the data into memory. Pandas comes with a built-in `read_csv` function that we can use to read CSV files and load them directly to a pandas `DataFrame` object.

```
tx =
pd.read_csv('./mock_treatment_starts_2016.csv')
```

There are a lot of different ways to read data into a dataframe - from lists, dicts, CSVs, databases... We're just covering CSV files here.

What is a DataFrame?

A DataFrame is a 2-dimensional labeled data structure with columns of potentially different types. You can think of it like a spreadsheet or SQL table, or a dict of Series objects. It is generally the most commonly used Pandas object.

Pandas borrows the concept of DataFrame from the statistical programming language R.
Let's take a look at the data to familiarize ourselves with the format and data types.

```
# Just using the name of the dataframe will
print the entire output
# If there are too many rows, Jupyter will
print the top few and bottom few rows
# with a "..." to indicate that there are more
```

```
rows
tx
```

	PatientID	TreatmentStart	Drug	Dosage
0	PT1	1/14/16	Cisplatin	200
1	PT20	1/2/16	Cisplatin	140
2	PT2	1/10/16	Cisplatin	180
3	PT3	1/24/16	Cisplatin	140
4	PT4	2/14/16	Cisplatin	200
5	PT19	2/10/16	Cisplatin	180
6	PT5	2/6/16	Cisplatin	190
7	PT6	3/1/16	Cisplatin	180
8	PT7	3/1/16	Cisplatin	210
9	PT8	3/19/16	Cisplatin	180
10	PT9	3/27/16	Nivolumab	240
11	PT10	4/7/16	Nivolumab	240
12	PT11	4/17/16	Cisplatin	190
13	PT16	4/9/16	Cisplatin	160
14	PT12	5/15/16	Cisplatin	1800
15	PT13	5/21/16	Cisplatin	180
16	PT14	5/3/16	Nivolumab	240
17	PT15	5/7/16	Nivolumab	240
18	PT1	6/17/16	Nivolumab	240
19	PT17	6/17/16	Cisplatin	160
20	PT18	6/3/16	Nivolumab	240
21	PT19	6/2/16	Nivolumab	240
22	PT20	6/2/16	Nivolumab	240

```
# The head() function shows the first n rows in
a dataframe.
tx.head()
```

```
  PatientID TreatmentStart    Drug     Dosage
0       PT1         1/14/16  Cisplatin     200
1      PT20          1/2/16  Cisplatin     140
2       PT2         1/10/16  Cisplatin     180
3       PT3         1/24/16  Cisplatin     140
4       PT4         2/14/16  Cisplatin     200
```

```
# You can also use the sample() function to get
n random rows in the dataframe
# NOTE: sample() only works in newer versions
of pandas (0.16.1 and upwards)
tx.sample(5)
```

```
   PatientID TreatmentStart       Drug  Dosage
19      PT17         6/17/16  Cisplatin     160
14      PT12         5/15/16  Cisplatin    1800
12      PT11         4/17/16  Cisplatin     190
2        PT2         1/10/16  Cisplatin     180
18       PT1         6/17/16  Nivolumab     240
```

```
# Then len function gives us the number of rows
in the dataframe
len(tx)
```

```
23
```

```
# The dtypes property of a dataframe shows the
datatypes of every column in a dataframe.
tx.dtypes
```

```
PatientID         object
TreatmentStart    object
Drug              object
```

```
Dosage              int64
dtype: object
```

Print the first ten rows of the "tx" dataframe in the cell below

Accessing columns in a dataframe

Note: We will be applying `head()` to some results in this project to keep the output short. When working with a real dataset, keep in mind that you might be hiding some interesting records if you always use `head()` or `sample()`!

In Pandas, you can access a specific column using the following notation which returns a **Series** (not a dataframe) - a Series is simply a vector, aka a 1-dimensional data structure similar to a list.

```
tx.PatientID.head()
```

```
0     PT1
1    PT20
2     PT2
3     PT3
4     PT4
Name: PatientID, dtype: object
```

```
# Check the type to show that this indeed
returns a Series object
type(tx.PatientID)
```

```
pandas.core.series.Series
```

```
# The alternative notation for accessing a
column in a dataframe
```

```
# Some people prefer the . notation, others the
[] notation.
tx['PatientID'].head()
```

```
0     PT1
1    PT20
2     PT2
3     PT3
4     PT4
Name: PatientID, dtype: object
```

```
# And this is how you access two columns of a
dataframe.
# Note that this will return a dataframe again,
not a series (because a series has only one
column...)
# Also note the double square brackets - you're
passing a *list* as an argument
tx[['PatientID', 'Dosage']].head()
```

```
  PatientID  Dosage
0       PT1     200
1      PT20     140
2       PT2     180
3       PT3     140
4       PT4     200
```

```
type(tx[['PatientID', 'TreatmentStart']])
```

```
pandas.core.frame.DataFrame
```

```
# This way we can now do some more data
exploration, e.g. looking at unique patients
tx['PatientID'].unique()
```

```
array(['PT1', 'PT20', 'PT2', 'PT3', 'PT4',
'PT19', 'PT5', 'PT6', 'PT7',
       'PT8', 'PT9', 'PT10', 'PT11', 'PT16',
'PT12', 'PT13', 'PT14',
       'PT15', 'PT17', 'PT18'], dtype=object)
```

Print the list of unique drugs in the dataframe in the cell below:

Accessing rows in a dataframe

In addition to slicing by column, we often want to get the record where a column has a specific value, e.g. a specific Patient_ID here. This can be done using the following syntax:

```
# Access the diagnosis record(s) for a specific patient ID
tx.loc[tx['PatientID'] == 'PT5']
```

```
  PatientID TreatmentStart       Drug  Dosage
6       PT5          2/6/16  Cisplatin     190
```

```
# This is equivalent with the following shorter notation
tx[(tx['PatientID'] == 'PT20') & (tx['Drug'] == 'Cisplatin')]
```

```
  PatientID TreatmentStart       Drug  Dosage
1      PT20          1/2/16  Cisplatin     140
```

Get all rows where Dosage is greater than 180:

There are many different ways to access rows and columns in Pandas. We're only introducing a small set here in order to keep the tutorial simple.

Sorting dataframes

Sorting a dataframe by one or multiple columns is super easy:

```
# Sort by earliest treatment start date, i.e.
in ascending order
tx.sort_values('TreatmentStart').head()

# NOTE: sort_values only works in Pandas 0.17.0
and up. This is an older version:
# tx.sort('TreatmentStart').head()
```

	PatientID	TreatmentStart	Drug	Dosage
2	PT2	1/10/16	Cisplatin	180
0	PT1	1/14/16	Cisplatin	200
1	PT20	1/2/16	Cisplatin	140
3	PT3	1/24/16	Cisplatin	140
5	PT19	2/10/16	Cisplatin	180

```
# Sort by latest treatment start, i.e. in
descending order
tx.sort_values('TreatmentStart',
ascending=False).head()

# NOTE: sort_values only works in Pandas 0.17.0
and up. This is an older version:
# tx.sort('TreatmentStart',
ascending=False).head()
```

```
   PatientID TreatmentStart       Drug  Dosage
20      PT18          6/3/16  Nivolumab     240
22      PT20          6/2/16  Nivolumab     240
21      PT19          6/2/16  Nivolumab     240
19      PT17         6/17/16  Cisplatin     160
18       PT1         6/17/16  Nivolumab     240
```

```
# Finally, you can also sort by multiple
columns:
tx.sort_values(['PatientID',
'TreatmentStart']).head()

# NOTE: sort_values only works in Pandas 0.17.0
and up. This is an older version:
# tx.sort(['PatientID',
'TreatmentStart']).head()
```

```
   PatientID TreatmentStart       Drug  Dosage
0       PT1         1/14/16  Cisplatin     200
18      PT1         6/17/16  Nivolumab     240
11     PT10          4/7/16  Nivolumab     240
12     PT11         4/17/16  Cisplatin     190
14     PT12         5/15/16  Cisplatin    1800
```

Note: Any operations on a dataframe are *not* permanent, i.e. they only modify the current output, but not the actual dataframe. If you want to preserve the sorting, for example, you have to either assign the output to a new variable, or use the `inplace=True` argument. This will not create any output but actually modify the dataframe.

```
tx
```

	PatientID	TreatmentStart	Drug	Dosage
0	PT1	1/14/16	Cisplatin	200
1	PT20	1/2/16	Cisplatin	140
2	PT2	1/10/16	Cisplatin	180
3	PT3	1/24/16	Cisplatin	140
4	PT4	2/14/16	Cisplatin	200
5	PT19	2/10/16	Cisplatin	180
6	PT5	2/6/16	Cisplatin	190
7	PT6	3/1/16	Cisplatin	180
8	PT7	3/1/16	Cisplatin	210
9	PT8	3/19/16	Cisplatin	180
10	PT9	3/27/16	Nivolumab	240
11	PT10	4/7/16	Nivolumab	240
12	PT11	4/17/16	Cisplatin	190
13	PT16	4/9/16	Cisplatin	160
14	PT12	5/15/16	Cisplatin	1800
15	PT13	5/21/16	Cisplatin	180
16	PT14	5/3/16	Nivolumab	240
17	PT15	5/7/16	Nivolumab	240
18	PT1	6/17/16	Nivolumab	240
19	PT17	6/17/16	Cisplatin	160
20	PT18	6/3/16	Nivolumab	240
21	PT19	6/2/16	Nivolumab	240
22	PT20	6/2/16	Nivolumab	240

```
tx.sort_values(['PatientID', 'TreatmentStart'],
inplace=True)
```

```
tx
```

	PatientID	TreatmentStart	Drug	Dosage
0	PT1	1/14/16	Cisplatin	200

18	PT1	6/17/16	Nivolumab	240
11	PT10	4/7/16	Nivolumab	240
12	PT11	4/17/16	Cisplatin	190
14	PT12	5/15/16	Cisplatin	1800
15	PT13	5/21/16	Cisplatin	180
16	PT14	5/3/16	Nivolumab	240
17	PT15	5/7/16	Nivolumab	240
13	PT16	4/9/16	Cisplatin	160
19	PT17	6/17/16	Cisplatin	160
20	PT18	6/3/16	Nivolumab	240
5	PT19	2/10/16	Cisplatin	180
21	PT19	6/2/16	Nivolumab	240
2	PT2	1/10/16	Cisplatin	180
1	PT20	1/2/16	Cisplatin	140
22	PT20	6/2/16	Nivolumab	240
3	PT3	1/24/16	Cisplatin	140
4	PT4	2/14/16	Cisplatin	200
6	PT5	2/6/16	Cisplatin	190
7	PT6	3/1/16	Cisplatin	180
8	PT7	3/1/16	Cisplatin	210
9	PT8	3/19/16	Cisplatin	180
10	PT9	3/27/16	Nivolumab	240

Sort the dataframe by dosage, in descending order (highest dosage first):

Part 2: Data cleaning

```
# Remember the dtypes property... the
TreatmentStart column should really be a date,
right?
tx.dtypes
```

```
PatientID          object
TreatmentStart     object
Drug               object
Dosage              int64
dtype: object
```

Date conversion

Right away we can see that the date field TreatmentDate is stored as string (object). It might be useful to convert it to **Datetime** objects so that we can perform common date arithmetic on them, like checking if a date came before or after another date, or calculating the number of days between two dates.

```
tx['TreatmentStart'] =
pd.to_datetime(tx['TreatmentStart'])
```

```
tx.dtypes
```

```
PatientID                    object
TreatmentStart    datetime64[ns]
Drug                         object
Dosage                        int64
dtype: object
```

```
# This is the alternative notation to assign a
value to a column in a dataframe
tx.TreatmentStart =
pd.to_datetime(tx.TreatmentStart)
```

Part 3: Data analysis

Let's assume we've loaded the treatment related data from a cancer clinic in order to provide them with some analytical insights around the types of drugs they use on their patient population.

Question 1: Patients treated at the practice

How many patients does the practice treat?

```
# Our data frame contains patient IDs and
treatment starts -
# let's check if some patients have multiple
treatment starts?
# The unique() function returns the number of
unique values in a dataframe column.
print('Number of treatment start records:',
len(tx))
print('Number of unique patients who start
treatment:', len(tx.PatientID.unique()))
```

```
Number of treatment start records: 23
Number of unique patients who start treatment:
20
```

So there are 20 unique patients but we have 23 treatment starts, meaning some patients start different treatments in the time that we have data for. This means that if we want to

answer the question correctly, we need to make sure to only count unique patients.

Question 2: Drugs used at the practice

What are the drugs used at the practice and how many patients receive those drugs?

```
# The groupby function works like a groupby in SQL, i.e. it groups the dataframe by the specified
# column and then lets you apply aggregate functions on the grouped values, e.g. counts, sums, means...
# The count function counts the number of rows with values in a column
# NOTE that this might include duplicates!!! (Not in this data...)
tx.groupby('Drug').count()
```

```
           PatientID  TreatmentStart  Dosage
Drug
Cisplatin         15              15      15
Nivolumab          8               8       8
```

```
# Since we are only interested in the number of patients,
# we select only the relevant column from the resulting dataframe
# Note that "PatientID" might not be the best name for this column
# - we can use a rename() function in Pandas to rename it to something like
```

```
# "PatientCount" (skipping the rename step in
this tutorial, but feel free to look it up!)
tx.groupby('Drug').count()[['PatientID']]
```

```
           PatientID
Drug
Cisplatin         15
Nivolumab          8
```

A little bit about indexes in dataframes

Notice that in the above example, the "Drug" column is printed in bold. That's because grouping by it has turned it into the **index** of the resulting dataframe.

The index in a dataframe is the "row identifier" - it is generally printed as the column on the left. For example, when we first loaded our data, the index didn't have a name and was just an incrementing integer (scroll up to check!). When you create a groupby object, the index of a resulting dataframe will be the column you group by - in this case, the Drug column became the index.
We frequently **reset** the index in a dataframe for various reasons - in this case, because the index contains data that you want to treat as a column, e.g. for plotting.

```
# Reset the index in this resulting dataframe
to see what happens:
tx.groupby('Drug').count()[['PatientID']]
```

```
           PatientID
Drug
Cisplatin         15
Nivolumab          8
```

```
x.reset_index(inplace=True)
x
```

```
        Drug  PatientID
0  Cisplatin         15
1  Nivolumab          8
```

```
# Remember that any operations on the dataframe
only modify the output?
# We didn't *really* group tx or reset the
index.
# The tx dataframe is still the same it was at
the beginning:
tx.head()
```

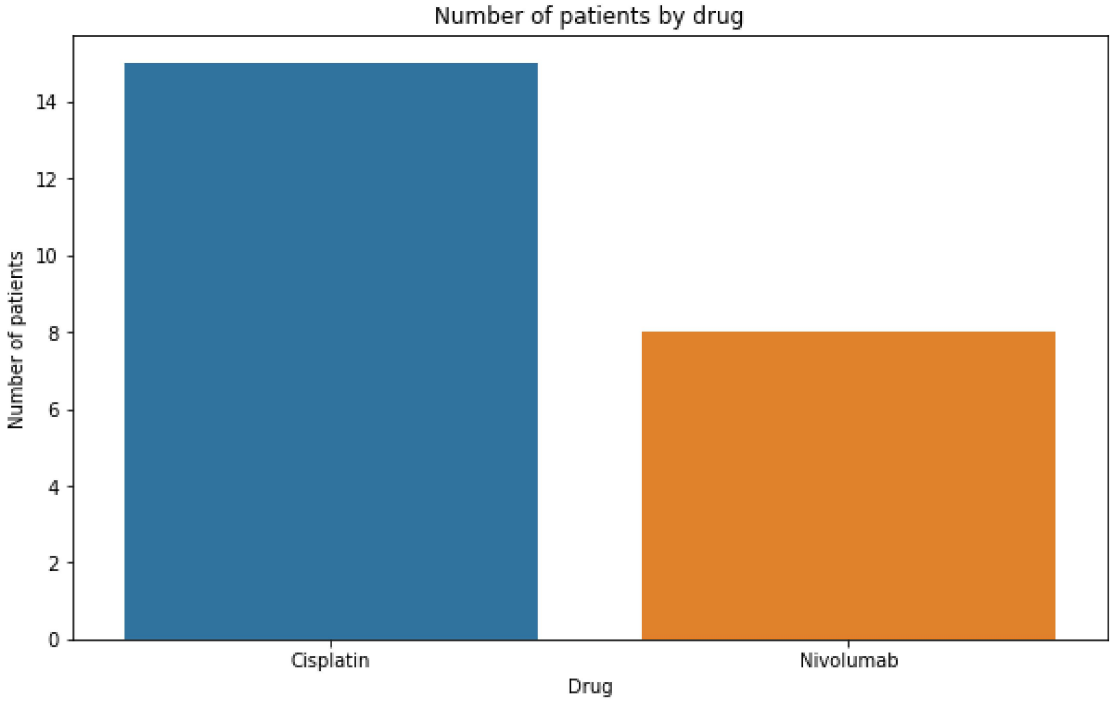
```
   PatientID TreatmentStart       Drug  Dosage
0        PT1     2016-01-14  Cisplatin     200
18       PT1     2016-06-17  Nivolumab     240
11      PT10     2016-04-07  Nivolumab     240
12      PT11     2016-04-17  Cisplatin     190
14      PT12     2016-05-15  Cisplatin    1800
```

Let's plot this! (aka our first Seaborn plot)

```
# Let's do the same groupby as above to get the
number of patient starts per drug!
# This time, we actually assign the output to a
new dataframe to make the transformation
permanent!
counts =
tx.groupby('Drug').count()[['PatientID']].reset
_index()
counts
```

```
# Let's use a simple bar chart in Seaborn to
compare counts for the two drugs
# There are several different ways to do the
plotting - this is my preferred style,
# but you might prefer different syntax

fig = sns.barplot(data=counts, x='Drug',
y='PatientID')
plt.title('Number of patients by drug')
plt.ylabel('Number of patients')
plt.xlabel('Drug')
plt.show(fig)
```



Question 3: Changes to treatment over time

Do we see any changes in treatment patterns over time?

Our data shows treatment starts by date. Let's group these starts by month to see if there are any changes of how many patients start on a given drug over time, e.g. because a new drug got approved.

Note that the data we're using here is dummy data and pretty artificial - oncology clinics see a much higher volume of patients, and drug uptake is usually slower than shown here.

```
# Let's add a new column that only has the treatment month to simplify things
# There are many different ways to do this, we picked a simple one
tx['TreatmentStartMonth'] = tx['TreatmentStart'].astype('datetime64[M]')

# NOTE .astype('datetime64[M]') only works in more recent versions of Pandas, this is an older version:
# from datetime import datetime
# tx['TreatmentStartMonth'] = tx['TreatmentStart'].apply(lambda x: x.replace(day=1))
```

```
tx.head()
```

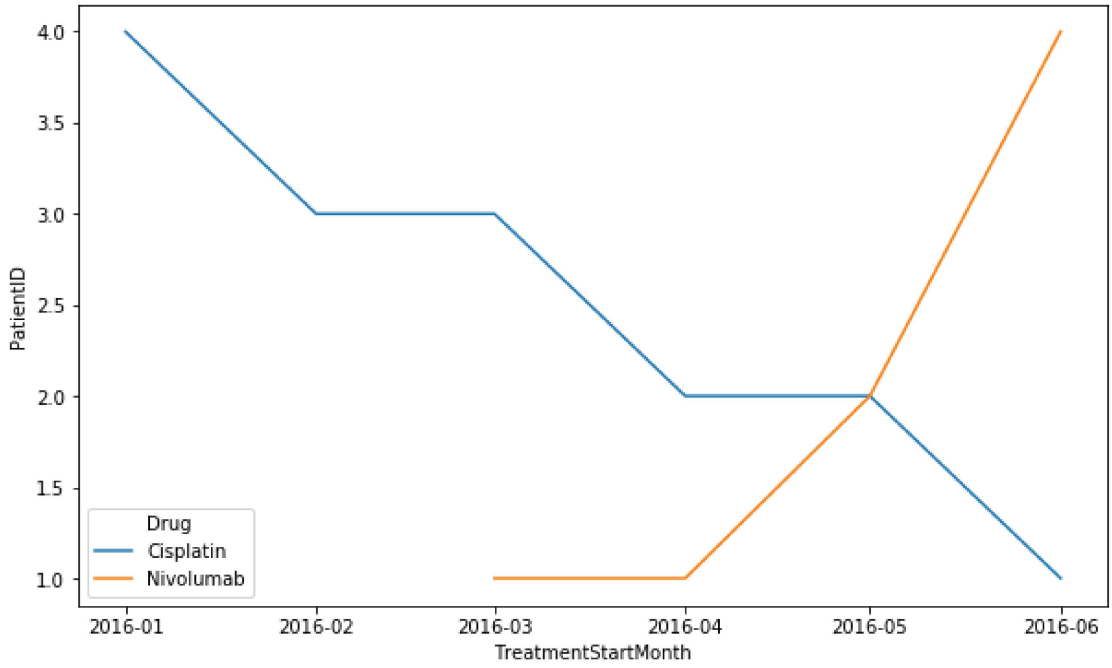
```
  PatientID TreatmentStart       Drug  Dosage
TreatmentStartMonth
0       PT1         1/14/16  Cisplatin     200
2016-01-01
1      PT20          1/2/16  Cisplatin     140
2016-01-01
2       PT2         1/10/16  Cisplatin     180
2016-01-01
3       PT3         1/24/16  Cisplatin     140
2016-01-01
4       PT4         2/14/16  Cisplatin     200
2016-02-01
```

```
# Let's count the number of starts per month
per drug to plot it later
# We only want the number of patients, so we
filter for that column at the end
drugs_by_month =
tx.groupby(['TreatmentStartMonth',
'Drug']).count()[['PatientID']]
drugs_by_month
```

```
                                  PatientID
TreatmentStartMonth Drug
2016-01-01          Cisplatin             4
2016-02-01          Cisplatin             3
2016-03-01          Cisplatin             3
                    Nivolumab             1
2016-04-01          Cisplatin             2
```

```
                    Nivolumab          1
2016-05-01          Cisplatin          2
                    Nivolumab          2
2016-06-01          Cisplatin          1
                    Nivolumab          4
```

```
# The data already looks interesting... let's
plot this
# Remember to reset_index so we can plot the
regular columns
# The "hue" keyword is generally used to
distinguish two different categorial variables
# in plots, e.g. in this case the two different
drugs
# NOTE: lineplot() only exists in Seaborn
version 0.9 and up
fig =
sns.lineplot(data=drugs_by_month.reset_index(),
                     x='TreatmentStartMonth',
                     y='PatientID',
                    hue='Drug')
```



Question 4: Dosage and outliers

Question: What is the average dosage of each drug? Are there any outliers?

```
# An easy first step is to group by the respective drug and use describe()
tx.groupby(['Drug']).describe()
```

```
          Dosage
           count   mean         std    min
25%    50%    75%     max
Drug
Cisplatin   15.0  286.0  419.332803  140.0
170.0  180.0  195.0  1800.0
Nivolumab    8.0  240.0    0.000000  240.0
240.0  240.0  240.0   240.0
```

```
# This is an example of a more complex way to get aggregates in Pandas
```

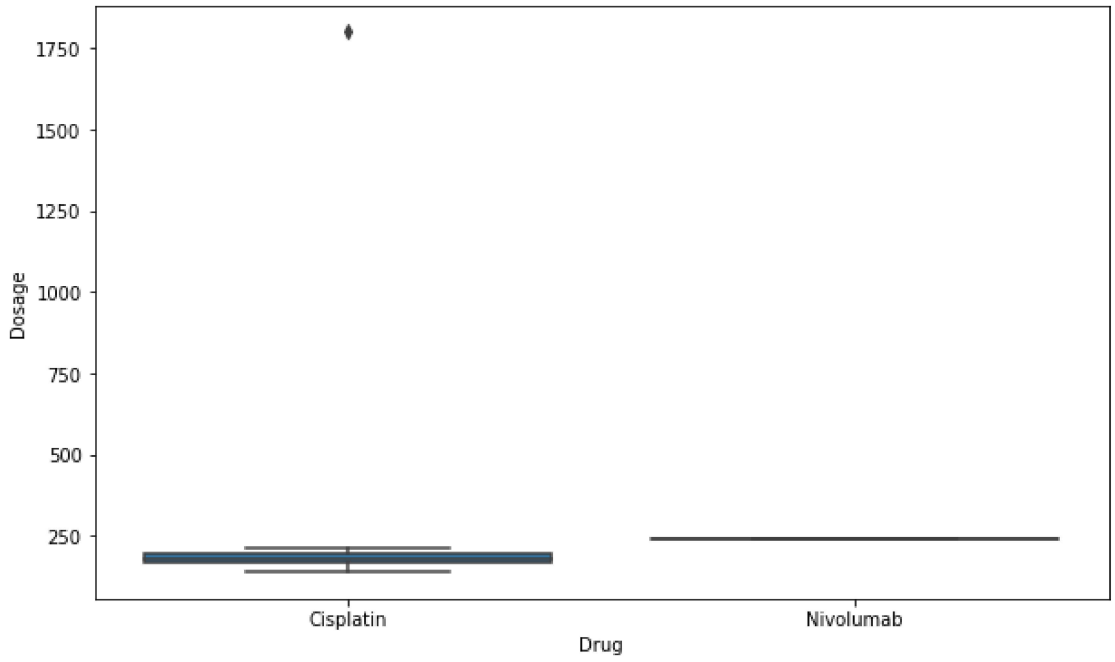
```
# The agg function takes a dictionary of
column:function pairs,
# where "function" can be a built-in function
like count, mean, min, etc,
# or a custom function like a lambda.
tx.groupby(['Drug']).agg({'Dosage': 'mean'})
```

```
           Dosage
Drug
Cisplatin     286
Nivolumab     240
```

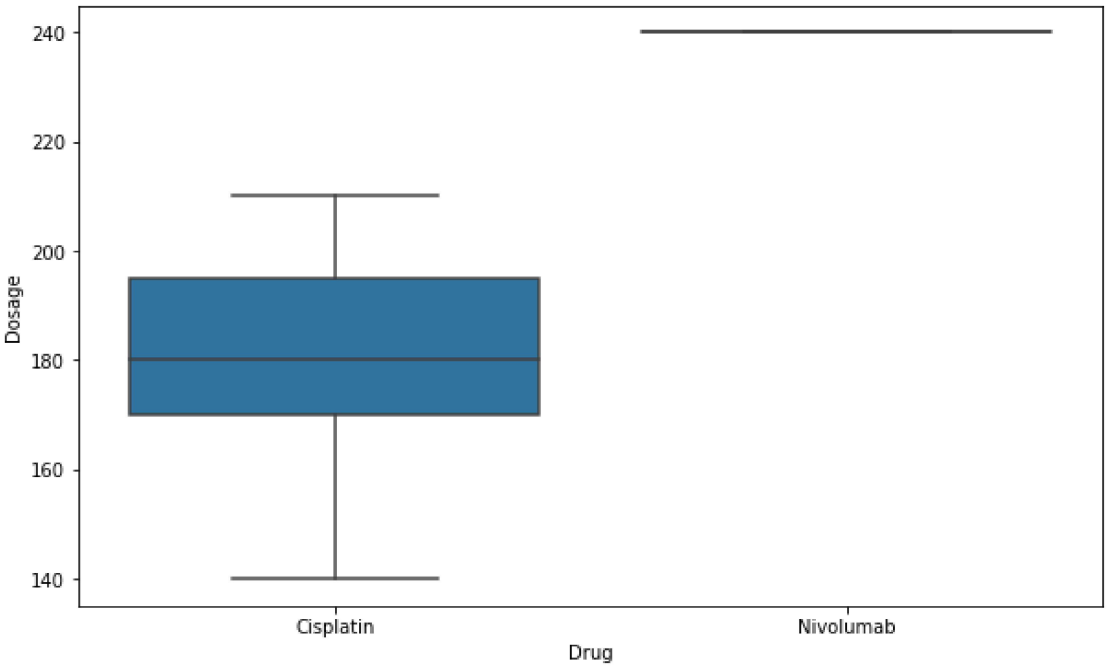
```
# We can also pass a list of functions to a
column to get multiple outputs!
tx.groupby(['Drug']).agg({'Dosage': ['count',
'mean', 'std', 'min', 'max']})
```

```
          Dosage
           count mean         std  min   max
Drug
Cisplatin     15  286  419.332803  140  1800
Nivolumab      8  240    0.000000  240   240
```

```
# We can plot this easily in Seaborn - but the
outlier squashes our display
fig = sns.boxplot(data=tx, x='Drug',
y='Dosage')
plt.show(fig)
```




```
# Use showfliers=False in a boxplot to suppress outliers
fig = sns.boxplot(data=tx, x='Drug', y='Dosage', showfliers=False)
plt.show(fig)
```


240
220
200
180
160
140
Dosage
Cisplatin
Nivolumab
Drug

Conclusion:

I've only touched on some of the basic concepts of pandas, but this will give the foundations to keep exploring the data:

- Data frames and series in pandas
- Basic data inspection (head, describe, dtypes, accessing columns and rows, sorting)
- Grouping and aggregating (count, nunique)
- Indexing in dataframes and reset_index
- Plotting (bar plots, line plots)

Reference:

- **Youtube.com**
- **Google.com**
- **Github.com**