

Data Mining 2

Topic 01 : Module Introduction

Lecture 31 : Top X pandas commands

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Outline

- Reading data formats
- Computing descriptive statistics
- Processing data by filtering and grouping

Part I

Introduction

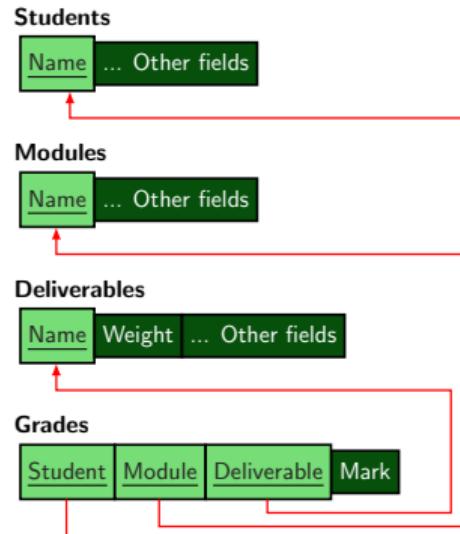
Minimal Dataset

To better understand the various pandas operations we are going to use a tiny* dataset based on (fictional) student results. (`marks.csv`)

➤ In Excel ...

Student	Module	Deliverable	Weight	Mark
1 A	Maths	Practical	40	60
3 A	Maths	Exam	60	80
4 A	Programmin	Project 1	10	50
5 A	Programmin	Project 2	30	60
6 A	Networking	Exam	100	80
7 B	Maths	Practical	40	60
8 B	Maths	Exam	60	80
9 B	Programmin	Project 1	10	50
10 B	Programmin	Project 2	30	60
11 B	Programmin	Project 3	60	75
12 B	Networking	Exam	100	80
13 C	Maths	Exam	60	80
14 C	Programmin	Project 1	10	50
15 C	Programmin	Project 2	30	60
16 C	Programmin	Project 3	60	75
17 C	Networking	Exam	100	80

... or database schema ...



- Student performance — weighted mark on each module, missing deliverables etc.
- Module performance — number of attempts and average mark.
- Deliverable performance — number of attempts and average mark, predictor of overall module grade, etc.

*Dataset is small enough that you can verify operation results by hand.

Terminology

```
df.head(1000)
```

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

- A **DataFrame** is a table of data values.
 - `df = pd.read_csv("Marks.csv")`
- A **Series** is a list of data values — typically columns in a dataframe. We can access an individual column using
 - `df.Deliverable` (dot notation)
 - `df["Deliverable"]` (dict notation)
 - `df.iloc[:,2]` (numpy, index notation)
- The **index** is a special column whose values can be used to access rows — rather using row number.
 - The default index is equal to the row number.

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10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
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Part II

Input and Output

Setup

Minimal

We begin every data mining project with importing the three core data science packages:

1.

```
import numpy as np  
import pandas as pd  
import matplotlib.pyplot as plt  
plt.style.use('seaborn-darkgrid')
```

numpy — fast array operations
pandas — data manipulation
matplotlib — visualisation

- We give modules nicknames (`np`, `pd`, ...) to simplify their later use, and we access properties/functions of a package using the dot notation (`np.max`, `pd.DataFrame`, ...).

Extra

2.

```
import seaborn as sns  
import statsmodels.api as sm  
  
pd.set_option('display.max_columns', 500)  
pd.set_option('display.width', 1000)
```

seaborn — statistical visualisation
statsmodels — statistical data exploration
pandas options to show all columns for wider datasets

Setup

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seaborn — statistical visualisation
statsmodels — statistical data exploration
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Reading data from a CSV file

Pandas supports a huge variety of input/output formats so best approach is to focus on what is needed to process the given data and verify input. Our marks dataset is in CSV format so we start with

5

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plt.style.use('seaborn-darkgrid')
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and input using

6

```
df = pd.read_csv('Marks.csv', sep=',')
print(df.shape)
df.head()
```

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(16, 5)						
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(16, 5)

Always verify input by checking dataset dimensions and looking at some rows!!!

Datatypes

Pandas data types:

- **object** — used for text or mixed numeric and non-numeric values.
- **int64** — integer values,
 - Does not support missing values, so an int column containing at least one missing value will automatically be converted to float.
- **float64** — floating point numbers.
- **bool** — **True/False** values
- **datetime64** — date and time values
- **category** — Finite (typically small) list of text values

11

df.dtypes

Student	object
Module	object
Deliverable	object
Weight	int64
Mark	int64
dtype: object	

Regularly verifying datatypes is vital[†]:

- Operations differ based on datatype, eg, '+' concatenate strings but adds numerical values.
- Datatype can change based on results, eg, int converts to float due to missing values.

[†]Google "Detecting Excel's gene auto-conversions."

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Datatypes — Converting

We will deal with modifying and creating new columns later, but while we are on datatypes, we will look at changing datatype ...

Using the Series function `astype`

14

```
df["Weight"] = df["Weight"].astype('float')  
df["Weight"].dtype
```

`dtype('float64')`

- New datatype is required argument — `'int'`, `'float'`, `'str'`, `'object'`, `'category'`, etc.
- Simple, but fragile if data conversion is possible.

or using pandas function `to_numeric`

15

```
df["Weight"] = pd.to_numeric(df["Weight"])  
df["Weight"].dtype
```

`dtype('float64')`

- More powerful, can specify what to do in cases where the conversion fails etc
- Have functions `to_numeric`, `to_datetime`, and `to_timedelta`.

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Missing Values

Identifying and dealing with missing values is critical step in data preparation. What should you do? delete rows containing missing values? or impute then?

Here we will just look at identifying missing values.

20 df.isna()

```
Student Module Deliverable Weight Mark
0  False  False    False  False  False
1  False  False    False  False  False
2  False  False    False  False  False
3  False  False    False  False  False
4  False  False    False  False  False
5  False  False    False  False  False
6  False  False    False  False  False
7  False  False    False  False  False
8  False  False    False  False  False
9  False  False    False  False  False
10 False  False    False  False  False
11 False  False    False  False  False
12 False  False    False  False  False
13 False  False    False  False  False
14 False  False    False  False  False
15 False  False    False  False  False
```

21 df.isna().sum()

```
Student      0
Module       0
Deliverable  0
Weight       0
Mark         0
dtype: int64
```

22 df.isna().sum().sum()

```
0
```

- Use dataframe function `fillna` to replace missing values.
- Recall `False` and `True` map to 0 and 1 respectively.
- Use `df.isna().sum(axis=1)` to sum along rows.

Output

Saving dataframe to CSV is straightforward (I rarely include the (default) index when saving datasets).

23.

```
df.to_csv('marks_2.csv', index=False)
```

- CSV has become the default file format in Data Mining application especially for 'informal' datasets.
 - ✓ human readable, easy to generate / parse (if correct).
 - ✗ Can be highly redundant, slow to input/output.
 - ✗ No meta information.
- Other formats are better for speed and resulting file size and for saving meta data not supported by CSV (such as columns datatypes, category information, etc).

towards
data science

: The Best Format to Save Pandas Data

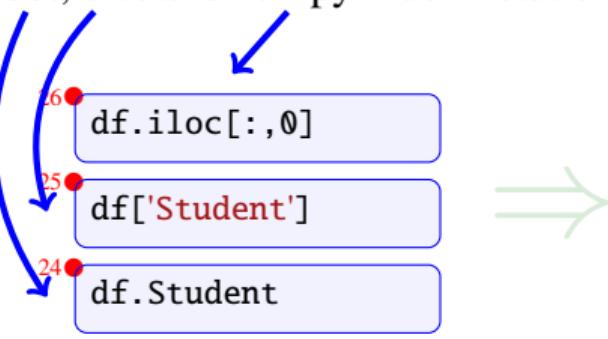
Part III

Filtering

Selecting individual rows/columns results in a series

Columns can accessed using dot, dict and numpy index notation.

df.head(1000)					
Student	Module	Deliverable	Weight	Mark	
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80



```
Student          A  
Module         Maths  
Deliverable   Practical  
Weight           40  
Mark            60  
Name: 0, dtype: object
```

0	A
1	A
2	A
3	A
4	A
5	B
6	B
7	B
8	B
9	B
10	B
11	C
12	C
13	C
14	C
15	C

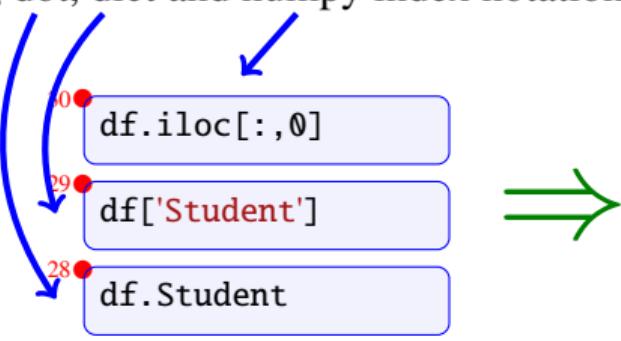
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27 `df.iloc[0]` ← Access row using numpy index

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df.head(1000)					
Student	Module	Deliverable	Weight	Mark	
0 A Maths Practical 40 60					
1 A Maths Exam 60 80					
2 A Programming Project 1 10 50					
3 A Programming Project 2 30 60					
4 A Networking Lab Work 100 80					
5 B Maths Practical 40 60					
6 B Maths Exam 60 80					
7 B Programming Project 1 10 50					
8 B Programming Project 2 30 60					
9 B Programming Project 3 60 75					
10 B Networking Project 100 80					
11 C Maths Exam 60 80					
12 C Programming Project 1 10 50					
13 C Programming Project 2 30 60					
14 C Programming Project 3 60 75					
15 C Networking Lab Work 100 80					



```
Student          A  
Module        Maths  
Deliverable  Practical  
Weight           40  
Mark            60  
Name: Student, dtype: object
```

0	A
1	A
2	A
3	A
4	A
5	B
6	B
7	B
8	B
9	B
10	B
11	C
12	C
13	C
14	C
15	C

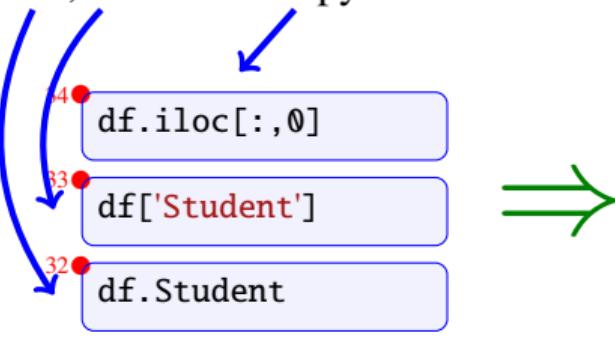
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31 df.iloc[0] ← Access row using numpy index

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0	A
1	A
2	A
3	A
4	A
5	B
6	B
7	B
8	B
9	B
10	B
11	C
12	C
13	C
14	C
15	C

Name: Student, dtype: object

35 `df.iloc[0]` ← Access row using numpy index

Head and Tail

Commands `head` and `tail` return the first and last n rows (default $n = 5$) of a dataframe/series.

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36

`df.head()`

37

`df.head(1)`

38

`df.tail()`

39

`df.tail()`

Head and Tail

Commands `head` and `tail` return the first and last n rows (default $n = 5$) of a dataframe/series.

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40
`df.head()`

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41
`df.head(1)`

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60

42
`df.tail()`

43
`df.tail()`

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Commands `head` and `tail` return the first and last n rows (default $n = 5$) of a dataframe/series.

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44

`df.head()`

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3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80

45

`df.head(1)`

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60

46

`df.tail()`

	Student	Module	Deliverable	Weight	Mark
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
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	Student	Module	Deliverable	Weight	Mark
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Query — on a single-column criteria

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48

`df.query("Student=='A'")`

49

`df.query("Mark>=70")`

Query — on a single-column criteria

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11	C	Maths	Exam	60	80	
12	C	Programming	Project 1	10	50	
13	C	Programming	Project 2	30	60	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

50

`df.query("Student=='A'")`

	Student	Module		Deliverable	Weight	Mark
0	A	Maths	Practical	40	60	
1	A	Maths	Exam	60	80	
2	A	Programming	Project 1	10	50	
3	A	Programming	Project 2	30	60	
4	A	Networking	Lab Work	100	80	
5	B	Maths	Practical	40	60	
6	B	Maths	Exam	60	80	
7	B	Programming	Project 1	10	50	
8	B	Programming	Project 2	30	60	
9	B	Programming	Project 3	60	75	
10	B	Networking	Project	100	80	
11	C	Maths	Exam	60	80	
12	C	Programming	Project 1	10	50	
13	C	Programming	Project 2	30	60	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

51

`df.query("Mark>=70")`

	Student	Module		Deliverable	Weight	Mark
0	A	Maths	Practical	40	60	
1	A	Maths	Exam	60	80	
2	A	Programming	Project 1	10	50	
3	A	Programming	Project 2	30	60	
4	A	Networking	Lab Work	100	80	
5	B	Maths	Practical	40	60	
6	B	Maths	Exam	60	80	
7	B	Programming	Project 1	10	50	
8	B	Programming	Project 2	30	60	
9	B	Programming	Project 3	60	75	
10	B	Networking	Project	100	80	
11	C	Maths	Exam	60	80	
12	C	Programming	Project 1	10	50	
13	C	Programming	Project 2	30	60	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

Query — on a single-column criteria

	Student	Module		Deliverable	Weight	Mark
0	A	Maths	Practical	40	60	
1	A	Maths	Exam	60	80	
2	A	Programming	Project 1	10	50	
3	A	Programming	Project 2	30	60	
4	A	Networking	Lab Work	100	80	
5	B	Maths	Practical	40	60	
6	B	Maths	Exam	60	80	
7	B	Programming	Project 1	10	50	
8	B	Programming	Project 2	30	60	
9	B	Programming	Project 3	60	75	
10	B	Networking	Project	100	80	
11	C	Maths	Exam	60	80	
12	C	Programming	Project 1	10	50	
13	C	Programming	Project 2	30	60	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

52

`df.query("Student=='A'")`

	Student	Module		Deliverable	Weight	Mark
0	A	Maths	Practical	40	60	
1	A	Maths	Exam	60	80	
2	A	Programming	Project 1	10	50	
3	A	Programming	Project 2	30	60	
4	A	Networking	Lab Work	100	80	
5	B	Maths	Practical	40	60	
6	B	Maths	Exam	60	80	
7	B	Programming	Project 1	10	50	
8	B	Programming	Project 2	30	60	
9	B	Programming	Project 3	60	75	
10	B	Networking	Project	100	80	
11	C	Maths	Exam	60	80	
12	C	Programming	Project 1	10	50	
13	C	Programming	Project 2	30	60	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

	Student	Module		Deliverable	Weight	Mark
0	A	Maths	Practical	40	60	
1	A	Maths	Exam	60	80	
2	A	Programming	Project 1	10	50	
3	A	Programming	Project 2	30	60	
4	A	Networking	Lab Work	100	80	
5	B	Maths	Practical	40	60	
6	B	Maths	Exam	60	80	
7	B	Programming	Project 1	10	50	
8	B	Programming	Project 2	30	60	
9	B	Programming	Project 3	60	75	
10	B	Networking	Project	100	80	
11	C	Maths	Exam	60	80	
12	C	Programming	Project 1	10	50	
13	C	Programming	Project 2	30	60	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

53

`df.query("Mark>=70")`

	Student	Module		Deliverable	Weight	Mark
0	A	Maths	Practical	40	60	
1	A	Maths	Exam	60	80	
2	A	Programming	Project 1	10	50	
3	A	Programming	Project 2	30	60	
4	A	Networking	Lab Work	100	80	
5	B	Maths	Practical	40	60	
6	B	Maths	Exam	60	80	
7	B	Programming	Project 1	10	50	
8	B	Programming	Project 2	30	60	
9	B	Programming	Project 3	60	75	
10	B	Networking	Project	100	80	
11	C	Maths	Exam	60	80	
12	C	Programming	Project 1	10	50	
13	C	Programming	Project 2	30	60	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

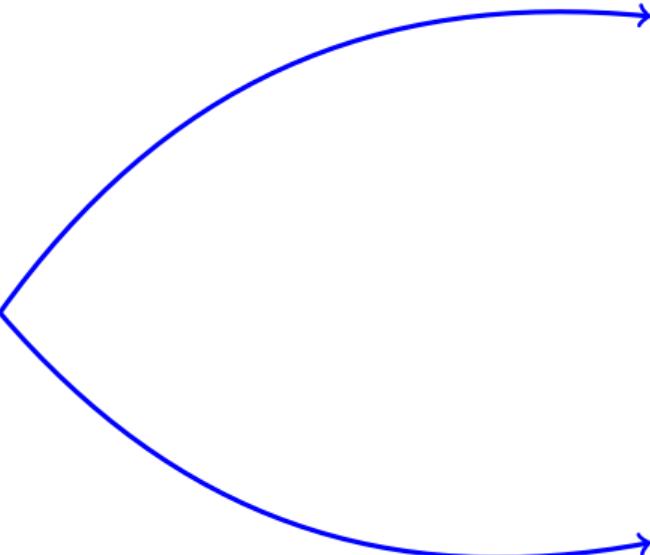
	Student	Module		Deliverable	Weight	Mark
1	A	Maths	Exam	60	80	
4	A	Networking	Lab Work	100	80	
6	B	Maths	Exam	60	80	
9	B	Programming	Project 3	60	75	
10	B	Networking	Project	100	80	
11	C	Maths	Exam	60	80	
14	C	Programming	Project 3	60	75	
15	C	Networking	Lab Work	100	80	

Query — on multiple columns (using **python logical operators**)

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

54

```
df.query("Mark<70 and Module=='Maths'")
```



55

```
df.query("Mark<70 or Module=='Maths'")
```

Query — on multiple columns (using python logical operators)

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

56

```
df.query("Mark<70 and Module=='Maths'")
```

57

```
df.query("Mark<70 or Module=='Maths'")
```

Query — on multiple columns (using python logical operators)

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

58

```
df.query("Mark<70 and Module=='Maths'")
```

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
5	B	Maths	Practical	40	60

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60

59

```
df.query("Mark<70 or Module=='Maths'")
```

Query — on multiple columns (using pandas logical operators)

Student	Module	Deliverable	Weight	Mark	
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

Student	Module	Deliverable	Weight	Mark	
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

Student	Module	Deliverable	Weight	Mark	
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

60

```
df.query("(Mark<70) & (Module=='Maths')")
```

61

```
df.query("(Mark<70) | (Module=='Maths'))
```

Student	Module	Deliverable	Weight	Mark	
0	A	Maths	Practical	40	60
5	B	Maths	Practical	40	60

Student	Module	Deliverable	Weight	Mark	
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60

Filtering using loc

Note the square (not round) brackets — think of loc as array indexing not a function call.

Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40
1	A	Maths	Exam	60
2	A	Programming	Project 1	10
3	A	Programming	Project 2	30
4	A	Networking	Lab Work	100
5	B	Maths	Practical	40
6	B	Maths	Exam	60
7	B	Programming	Project 1	10
8	B	Programming	Project 2	30
9	B	Programming	Project 3	60
10	B	Networking	Project	80
11	C	Maths	Exam	60
12	C	Programming	Project 1	10
13	C	Programming	Project 2	30
14	C	Programming	Project 3	60
15	C	Networking	Lab Work	100

`df.loc[ROW_SELECTION, COL_SELECTION]`

where row and columns selection can be

- Single values: row number or column name
- An integer list for rows or list of column names
- A boolean list for logical indexing of rows
- A colon to indicate every row/column

62

```
df.loc[df.Module=="Maths", ["Student", "Mark"]]
```

Filtering using loc

Note the square (not round) brackets — think of loc as array indexing not a function call.

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

`df.loc[ROW_SELECTION, COL_SELECTION]`

where row and columns selection can be

- Single values: row number or column name
- An integer list for rows or list of column names
- A boolean list for logical indexing of rows
- A colon to indicate every row/column

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

63

```
df.loc[df.Module=="Maths", ["Student", "Mark"]]
```

Filtering using loc

Note the square (not round) brackets — think of loc as array indexing not a function call.

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

`df.loc[ROW_SELECTION, COL_SELECTION]`

where row and columns selection can be

- Single values: row number or column name
- An integer list for rows or list of column names
- A boolean list for logical indexing of rows
- A colon to indicate every row/column

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

64

```
df.loc[df.Module=="Maths", ["Student", "Mark"]]
```

Student Mark		
0	A	60
1	A	80
5	B	60
6	B	80
11	C	80

More complicated example

I prefer to define row selection criteria, and the column list and order, separately to the `loc` statement.

Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40
1	A	Maths	Exam	80
2	A	Programming	Project 1	10
3	A	Programming	Project 2	30
4	A	Networking	Lab Work	100
5	B	Maths	Practical	40
6	B	Maths	Exam	80
7	B	Programming	Project 1	10
8	B	Programming	Project 2	30
9	B	Programming	Project 3	60

5
criteria = ((df.Mark<50) & (df.Module=='Maths')) | ((df.Mark<70) & (df.Module!='Maths'))
columns = ['Module', 'Student', 'Mark']

df.loc[criteria, columns]

More complicated example

I prefer to define row selection criteria, and the column list and order, separately to the `loc` statement.

Student Module		Deliverable Weight Mark		
0	A	Maths	Practical	40 60
1	A	Maths	Exam	60 80
2	A	Programming	Project 1	10 50
3	A	Programming	Project 2	30 60
4	A	Networking	Lab Work	100 80
5	B	Maths	Practical	40 60
6	B	Maths	Exam	60 80
7	B	Programming	Project 1	10 50
8	B	Programming	Project 2	30 60
9	B	Programming	Project 3	60 75

Student Module	Deliverable	Weight	Mark
0 A	Maths	Practical	40 60
1 A	Maths	Exam	60 80
2 A	Programming	Project 1	10 50
3 A	Programming	Project 2	30 60
4 A	Networking	Lab Work	100 80
5 B	Maths	Practical	40 60
6 B	Maths	Exam	60 80
7 B	Programming	Project 1	10 50
8 B	Programming	Project 2	30 60
9 B	Programming	Project 3	60 75
10 B	Networking	Project	100 80
11 C	Maths	Exam	60 80
12 C	Programming	Project 1	10 50
13 C	Programming	Project 2	30 60
14 C	Programming	Project 3	60 75
15 C	Networking	Lab Work	100 80

6
criteria = ((df.Mark<50) & (df.Module=='Maths')) | ((df.Mark<70) & (df.Module!='Maths'))
columns = ['Module', 'Student', 'Mark']

df.loc[criteria, columns]

More complicated example

I prefer to define row selection criteria, and the column list and order, separately to the loc statement.

Student Module		Deliverable Weight Mark		
0	A	Maths	Practical	40 60
1	A	Maths	Exam	60 80
2	A	Programming	Project 1	10 50
3	A	Programming	Project 2	30 60
4	A	Networking	Lab Work	100 80
5	B	Maths	Practical	40 60
6	B	Maths	Exam	60 80
7	B	Programming	Project 1	10 50
8	B	Programming	Project 2	30 60
9	B	Programming	Project 3	60 75
10	C	Networking	Project 1	100 80
11	C	Maths	Exam	60 80
12	C	Programming	Project 1	10 50
13	C	Programming	Project 2	30 60
14	C	Programming	Project 3	60 75
15	C	Networking	Lab Work	100 80

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	C	Networking	Project 1	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60



	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60

```
7  
criteria = ((df.Mark<50) & (df.Module=='Maths')) | ((df.Mark<70) & (df.Module!='Maths'))  
columns = ['Module', 'Student', 'Mark']
```

```
df.loc[criteria, columns]
```

Sampling

The `sample` function selects a random subset of the dataframe rows.

- Either specify the number of rows (as an integer) or fraction of the data (as a float).
- Can set the seed using `random_state` parameter for reproducible samples.

Student	Module	Deliverable	Weight	Mark	
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
4	A	Networking	Lab Work	100	80
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60
14	C	Programming	Project 3	60	75
15	C	Networking	Lab Work	100	80

The diagram illustrates the process of sampling. A central box contains the code `df.sample(n=3)`. Three blue arrows point from this box to three separate DataFrames on the right. The top arrow points to a DataFrame with rows 11, 3, and 8. The middle arrow points to a DataFrame with rows 13, 8, and 1. The bottom arrow points to a DataFrame with rows 12, 5, and 2. A red dot labeled "68" is placed near the top arrow.

Student	Module	Deliverable	Weight	Mark	
11	C	Maths	Exam	60	80
3	A	Programming	Project 2	30	60
8	B	Programming	Project 2	30	60

Student	Module	Deliverable	Weight	Mark	
13	C	Programming	Project 2	30	60
8	B	Programming	Project 2	30	60

Student	Module	Deliverable	Weight	Mark	
12	C	Programming	Project 1	10	50
5	B	Maths	Practical	40	60

Part IV

Sorting

Sorting

A pandas dataframe has two sorting operations:

- `sort_index()` orders rows based on current index.
- `sort_values(COLUMNS)` orders rows based on single column or list of columns.

Two important modifications:

- By default, the sort order is in ascending. Set parameter `ascending=False` to reverse this.
- By default, a new dataframe is returned with desired sort order, set parameter `inplace=True` to update current dataframe instead (then no output is generated).

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	69	
4	A	Networking	Lab Work		
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60

```
df.sort_values(['Module', 'Deliverable'])
```

Sorting

A pandas dataframe has two sorting operations:

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- `sort_values(COLUMNS)` orders rows based on single column or list of columns.

Two important modifications:

- By default, the sort order is in ascending. Set parameter `ascending=False` to reverse this.
- By default, a new dataframe is returned with desired sort order, set parameter `inplace=True` to update current dataframe instead (then no output is generated).

	Student	Module	Deliverable	Weight	Mark
0	A	Maths	Practical	40	60
1	A	Maths	Exam	60	80
2	A	Programming	Project 1	10	50
3	A	Programming	Project 2	70	100
4	A	Networking	Lab Work		
5	B	Maths	Practical	40	60
6	B	Maths	Exam	60	80
7	B	Programming	Project 1	10	50
8	B	Programming	Project 2	30	60
9	B	Programming	Project 3	60	75
10	B	Networking	Project	100	80
11	C	Maths	Exam	60	80
12	C	Programming	Project 1	10	50
13	C	Programming	Project 2	30	60

`df.sort_values(['Module', 'Deliverable'])`



	Student	Module	Deliverable	Weight	Mark
1	A	Maths	Exam	60	80
6	B	Maths	Exam	60	80
11	C	Maths	Exam	60	80
A		Maths	Practical	40	60
B		Maths	Practical	40	60
4	A	Networking	Lab Work	100	80
15	C	Networking	Lab Work	100	80
10	B	Networking	Project	100	80
2	A	Programming	Project 1	10	50
7	B	Programming	Project 1	10	50
12	C	Programming	Project 1	10	50
3	A	Programming	Project 2	30	60
8	B	Programming	Project 2	30	60
13	C	Programming	Project 2	30	60

Part V

Defining New Columns

Defining new columns — row-wise operation

We want to compute the weighted mark for each module for each student. Two steps:

- Create column, `W_Mark`, to store the weighted mark for each deliverable. This is a row by row calculation — only need data in current row to compute the result.
- Create column, `M_Mark`, to store the module mark for each student. This is a group calculation — need all rows for that student and module to compute the result.

Student	Module	Deliverable	Weight	Mark
1	A	Maths	Exam	60 80
6	B	Maths	Exam	60 80
11	C	Maths	Exam	60 80
0	A	Maths	Practical	40 60
5	B	Maths	Practical	70 60
4	A	Networking	Lab Work	100 df['W_Mark'] = df.Weight * df.Mark // 100
15	C	Networking	Lab Work	100 ..
10	B	Networking	Project	100 80
2	A	Programming	Project 1	10 50
7	B	Programming	Project 1	10 50
12	C	Programming	Project 1	10 50
3	A	Programming	Project 2	30 60
8	B	Programming	Project 2	30 60
13	C	Programming	Project 2	30 60
9	B	Programming	Project 3	60 75
14	C	Programming	Project 3	60 75

```
df['W_Mark'] = df.Weight * df.Mark // 100
```

Need to use dict notation (not dot notation) when defining a new column.

Defining new columns — row-wise operation

We want to compute the weighted mark for each module for each student. Two steps:

- Create column, `W_Mark`, to store the weighted mark for each deliverable. This is a row by row calculation — only need data in current row to compute the result.
- Create column, `M_Mark`, to store the module mark for each student. This is a group calculation — need all rows for that student and module to compute the result.

Student	Module	Deliverable	Weight	Mark
1	A	Maths	Exam	60
6	B	Maths	Exam	60
11	C	Maths	Exam	60
0	A	Maths	Practical	40
5	B	Maths	Practical	70
4	A	Networking	Lab Work	100
15	C	Networking	Lab Work	100
10	B	Networking	Project	100
2	A	Programming	Project 1	10
7	B	Programming	Project 1	10
12	C	Programming	Project 1	10
3	A	Programming	Project 2	30
8	B	Programming	Project 2	30
13	C	Programming	Project 2	30
9	B	Programming	Project 3	60
14	C	Programming	Project 3	60

```
df['W_Mark'] = df.Weight * df.Mark // 100
```

Need to use dict notation (not dot notation) when defining a new column.

Student	Module	Deliverable	Weight	Mark	W_Mark
1	A	Maths	Exam	60	48
6	B	Maths	Exam	60	48
11	C	Maths	Exam	60	48
0	A	Maths	Practical	40	24
5	B	Maths	Practical	60	24
4	A	Networking	Lab Work	100	80
15	C	Networking	Lab Work	100	80
10	B	Networking	Project	100	80
2	A	Programming	Project 1	10	5
7	B	Programming	Project 1	10	5
12	C	Programming	Project 1	10	5
3	A	Programming	Project 2	30	18
8	B	Programming	Project 2	30	18
13	C	Programming	Project 2	30	18
9	B	Programming	Project 3	60	45
14	C	Programming	Project 3	60	45

Defining new columns — group aggregate result

- Create column, W_Mark, to store the weighted mark for each deliverable. This is a row by row calculation — only need data in current row to compute the result.
- Create column, M_Mark, to store the module mark for each student. This is a group calculation — need all rows for that student and module to compute the result.

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 df.groupby(['Student', 'Module'])['W_Mark'].sum()

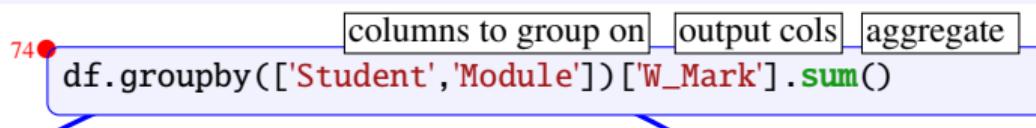
columns to group on	output cols	aggregate
---------------------	-------------	-----------

	Student	Module	Deliverable	Weight	Mark	W_Mark
1	A	Maths	Exam	60	80	48
6	B	Maths	Exam	60	80	48
11	C	Maths	Exam	60	80	48
0	A	Maths	Practical	40	60	24
5	B	Maths	Practical	40	60	24
4	A	Networking	Lab Work	100	80	80
15	C	Networking	Lab Work	100	80	80
10	B	Networking	Project	100	80	80
2	A	Programming	Project 1	10	50	5
7	B	Programming	Project 1	10	50	5
12	C	Programming	Project 1	10	50	5
3	A	Programming	Project 2	30	60	18
8	B	Programming	Project 2	30	60	18
13	C	Programming	Project 2	30	60	18
9	B	Programming	Project 3	60	75	45
14	C	Programming	Project 3	60	75	45

Result has multi-level index, need to use `reset_index` to revert to default index

Defining new columns — group aggregate result

- Create column, W_Mark, to store the weighted mark for each deliverable. This is a row by row calculation — only need data in current row to compute the result.
- Create column, M_Mark, to store the module mark for each student. This is a group calculation — need all rows for that student and module to compute the result.

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```
df.groupby(['Student', 'Module'])['W_Mark'].sum()
```

columns to group on	output cols	aggregate
['Student', 'Module']		.sum()

	Student	Module	Deliverable	Weight	Mark	W_Mark
1	A	Maths	Exam	60	80	48
6	B	Maths	Exam	60	80	48
11	C	Maths	Exam	60	80	48
0	A	Maths	Practical	40	60	24
5	B	Maths	Practical	40	60	24
4	A	Networking	Lab Work	100	80	80
15	C	Networking	Lab Work	100	80	80
10	B	Networking	Project	100	80	80
2	A	Programming	Project 1	10	50	5
7	B	Programming	Project 1	10	50	5
12	C	Programming	Project 1	10	50	5
3	A	Programming	Project 2	30	60	18
8	B	Programming	Project 2	30	60	18
13	C	Programming	Project 2	30	60	18
9	B	Programming	Project 3	60	75	45
14	C	Programming	Project 3	60	75	45

Result has multi-level index, need to use `reset_index` to revert to default index

		W_Mark
A	Maths	72
	Networking	80
	Programming	23
B	Maths	72
	Networking	80
	Programming	68
C	Maths	48
	Networking	80
	Programming	68

Defining new columns — group aggregate result

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columns to group on output cols aggregate

```
df.groupby(['Student', 'Module'])[['W_Mark']].sum().reset_index()
```

	Student	Module	Deliverable	Weight	Mark	W_Mark
1	A	Maths	Exam	60	80	48
6	B	Maths	Exam	60	80	48
11	C	Maths	Exam	60	80	48
0	A	Maths	Practical	40	60	24
5	B	Maths	Practical	40	60	24
4	A	Networking	Lab Work	100	80	80
15	C	Networking	Lab Work	100	80	80
10	B	Networking	Project	100	80	80
2	A	Programming	Project 1	10	50	5
7	B	Programming	Project 1	10	50	5
12	C	Programming	Project 1	10	50	5
3	A	Programming	Project 2	30	60	18
8	B	Programming	Project 2	30	60	18
13	C	Programming	Project 2	30	60	18
9	B	Programming	Project 3	60	75	45
14	C	Programming	Project 3	60	75	45

Defining new columns — group aggregate result

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```
columns to group on    output cols    aggregate
df.groupby(['Student', 'Module'])[['W_Mark']].sum().reset_index()
```

	Student	Module	Deliverable	Weight	Mark	W_Mark
1	A	Maths	Exam	60	80	48
6	B	Maths	Exam	60	80	48
11	C	Maths	Exam	60	80	48
0	A	Maths	Practical	40	60	24
5	B	Maths	Practical	40	60	24
4	A	Networking	Lab Work	100	80	80
15	C	Networking	Lab Work	100	80	80
10	B	Networking	Project	100	80	80
2	A	Programming	Project 1	10	50	5
7	B	Programming	Project 1	10	50	5
12	C	Programming	Project 1	10	50	5
3	A	Programming	Project 2	30	60	18
8	B	Programming	Project 2	30	60	18
13	C	Programming	Project 2	30	60	18
9	B	Programming	Project 3	60	75	45
14	C	Programming	Project 3	60	75	45

This is the required result and we can save this to a new dataframe. However, we often want to put this into our original dataframe as an extra column. Only problem we have different rows so can't just assign to a new column — need to use `transform` function.

	Student	Module	W_Mark
0	A	Maths	72
1	A	Networking	80
2	A	Programming	23
3	B	Maths	72
4	B	Networking	80
5	B	Programming	68
6	C	Maths	48
7	C	Networking	80
8	C	Programming	68

Defining new columns — group aggregate result

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```
df['M_Mark'] = df.groupby(['Student', 'Module'])[['W_Mark']].transform(sum)
```

columns to group on

output cols

aggregate

	Student	Module	Deliverable	Weight	Mark	W_Mark
1	A	Maths	Exam	60	80	48
6	B	Maths	Exam	60	80	48
11	C	Maths	Exam	60	80	48
0	A	Maths	Practical	40	60	24
5	B	Maths	Practical	40	60	24
4	A	Networking	Lab Work	100	80	80
15	C	Networking	Lab Work	100	80	80
10	B	Networking	Project	100	80	80
2	A	Programming	Project 1	10	50	5
7	B	Programming	Project 1	10	50	5
12	C	Programming	Project 1	10	50	5
3	A	Programming	Project 2	30	60	18
8	B	Programming	Project 2	30	60	18
13	C	Programming	Project 2	30	60	18
9	B	Programming	Project 3	60	75	45
14	C	Programming	Project 3	60	75	45

	Student	Module	W_Mark
0	A	Maths	72
1	A	Networking	80
2	A	Programming	23
3	B	Maths	72
4	B	Networking	80
5	B	Programming	68
6	C	Maths	48
7	C	Networking	80
8	C	Programming	68

	Student	Module	Deliverable	Weight	Mark	W_Mark	M_Mark
1	A	Maths	Exam	60	80	48	72
6	B	Maths	Exam	60	80	48	72
11	C	Maths	Exam	60	80	48	48
0	A	Maths	Practical	40	60	24	72
5	B	Maths	Practical	40	60	24	72
4	A	Networking	Lab Work	100	80	80	80
15	C	Networking	Lab Work	100	80	80	80
10	B	Networking	Project	100	80	80	80
2	A	Programming	Project 1	10	50	5	23
7	B	Programming	Project 1	10	50	5	68
12	C	Programming	Project 1	10	50	5	68
3	A	Programming	Project 2	30	60	18	23
8	B	Programming	Project 2	30	60	18	68
13	C	Programming	Project 2	30	60	18	68
9	B	Programming	Project 3	60	75	45	68
14	C	Programming	Project 3	60	75	45	68

The `transform` broadcasts the result for each group over every row in that group.

Part VI

Review Exercises

Review Exercises

Generate the following reports:

- ① Number of deliverables by each student. (value_counts, or groupby and count)
- ② List and rank deliverables by grade. (sort_values, rank)
- ③ Top 2 deliverables (by grade).
- ④ Top 2 module (by average grade).
- ⑤ Top 2 modules (by minimum grade).
- ⑥ Modules (by minimum grade).

Harder exercises (new functions)

- ① List which students missed which deliverables. (pivot, melt)