Programming Principles in Python (CSCI 503/490)

Data Visualization

Dr. David Koop

pandas DataFrame

```
df = pd.read_csv('penguins_lter.csv')
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

pandas DataFrame

Column Names

```
df = pd.read_csv('penguins_lter.csv')
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
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2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

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2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

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2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

Column: `df['Island']`

pandas DataFrame

```
df = pd.read_csv('penguins_lter.csv')
```

Column Names

Row: `df.loc[2]`

Index

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

Column: `df['Island']`

pandas DataFrame

```
df = pd.read_csv('penguins_lter.csv')
```

Column Names

Row: `df.loc[2]`

Index

Cell: `df.loc[341,'Species']`

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

Column: `df['Island']`

pandas DataFrame

```
df = pd.read_csv('penguins_lter.csv')
```

Column Names

Row: `df.loc[2]`

Index

Cell: `df.loc[341,'Species']`

Missing Data

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

Column: `df['Island']`

polars DataFrame

shape: (344, 10)

studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
str	i64	str	str	str	str	str	str	str	f64
"PAL0708"	1	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A1"	"Yes"	"11/11/07"	39.1
"PAL0708"	2	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A2"	"Yes"	"11/11/07"	39.5
"PAL0708"	3	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A1"	"Yes"	"11/16/07"	40.3
"PAL0708"	4	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A2"	"Yes"	"11/16/07"	null
"PAL0708"	5	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N3A1"	"Yes"	"11/16/07"	36.7
…	…	…	…	…	…	…	…	…	…
"PAL0910"	120	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N38A2"	"No"	"12/1/09"	null
"PAL0910"	121	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A1"	"Yes"	"11/22/09"	46.8
"PAL0910"	122	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A2"	"Yes"	"11/22/09"	50.4
"PAL0910"	123	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A1"	"Yes"	"11/22/09"	45.2
"PAL0910"	124	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A2"	"Yes"	"11/22/09"	49.9

polars DataFrame

Column Names & Types

shape: (344, 10)

studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
str	i64	str	str	str	str	str	str	str	f64
"PAL0708"	1	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A1"	"Yes"	"11/11/07"	39.1
"PAL0708"	2	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A2"	"Yes"	"11/11/07"	39.5
"PAL0708"	3	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A1"	"Yes"	"11/16/07"	40.3
"PAL0708"	4	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A2"	"Yes"	"11/16/07"	null
"PAL0708"	5	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N3A1"	"Yes"	"11/16/07"	36.7
…	…	…	…	…	…	…	…	…	…
"PAL0910"	120	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N38A2"	"No"	"12/1/09"	null
"PAL0910"	121	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A1"	"Yes"	"11/22/09"	46.8
"PAL0910"	122	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A2"	"Yes"	"11/22/09"	50.4
"PAL0910"	123	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A1"	"Yes"	"11/22/09"	45.2
"PAL0910"	124	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A2"	"Yes"	"11/22/09"	49.9

polars DataFrame

Column Names & Types

shape: (344, 10)

studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
str	i64	str	str	str	str	str	str	str	f64
"PAL0708"	1	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A1"	"Yes"	"11/11/07"	39.1
"PAL0708"	2	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A2"	"Yes"	"11/11/07"	39.5
"PAL0708"	3	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A1"	"Yes"	"11/16/07"	40.3
"PAL0708"	4	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A2"	"Yes"	"11/16/07"	null
"PAL0708"	5	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N3A1"	"Yes"	"11/16/07"	36.7
…	…	…	…	…	…	…	…	…	…
"PAL0910"	120	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N38A2"	"No"	"12/1/09"	null
"PAL0910"	121	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A1"	"Yes"	"11/22/09"	46.8
"PAL0910"	122	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A2"	"Yes"	"11/22/09"	50.4
"PAL0910"	123	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A1"	"Yes"	"11/22/09"	45.2
"PAL0910"	124	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A2"	"Yes"	"11/22/09"	49.9

Column: `df['Island']`

polars DataFrame

Column Names & Types

Row: `df[2]`

shape: (344, 10)

studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
str	i64	str	str	str	str	str	str	str	f64
"PAL0708"	1	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A1"	"Yes"	"11/11/07"	39.1
"PAL0708"	2	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A2"	"Yes"	"11/11/07"	39.5
"PAL0708"	3	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A1"	"Yes"	"11/16/07"	40.3
"PAL0708"	4	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A2"	"Yes"	"11/16/07"	null
"PAL0708"	5	"Adelie Penguin (Pygoscelis ade…	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N3A1"	"Yes"	"11/16/07"	36.7
…	…	…	…	…	…	…	…	…	…
"PAL0910"	120	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N38A2"	"No"	"12/1/09"	null
"PAL0910"	121	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A1"	"Yes"	"11/22/09"	46.8
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"PAL0910"	123	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A1"	"Yes"	"11/22/09"	45.2
"PAL0910"	124	"Gentoo penguin (Pygoscelis pap…	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A2"	"Yes"	"11/22/09"	49.9

Column: `df['Island']`

polars DataFrame

Column Names & Types

Row: `df[2]`

Cell: `df['Species'][341]`

Column: `df['Island']`

shape: (344, 10)

studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
str	i64	str	str	str	str	str	str	str	f64
"PAL0708"	1	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A1"	"Yes"	"11/11/07"	39.1
"PAL0708"	2	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A2"	"Yes"	"11/11/07"	39.5
"PAL0708"	3	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A1"	"Yes"	"11/16/07"	40.3
"PAL0708"	4	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A2"	"Yes"	"11/16/07"	null
"PAL0708"	5	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N3A1"	"Yes"	"11/16/07"	36.7
...	...	...	...	...	...	...	...	...	...
"PAL0910"	120	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N38A2"	"No"	"12/1/09"	null
"PAL0910"	122	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A2"	"Yes"	"11/22/09"	50.4
"PAL0910"	123	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A1"	"Yes"	"11/22/09"	45.2
"PAL0910"	124	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A2"	"Yes"	"11/22/09"	49.9

polars DataFrame

Column Names & Types

Row: `df[2]`

Cell: `df['Species'][341]`

shape: (344, 10)

studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
str	i64	str	str	str	str	str	str	str	f64
"PAL0708"	1	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A1"	"Yes"	"11/11/07"	39.1
"PAL0708"	2	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N1A2"	"Yes"	"11/11/07"	39.5
"PAL0708"	3	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A1"	"Yes"	"11/16/07"	40.3
"PAL0708"	4	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N2A2"	"Yes"	"11/16/07"	null
"PAL0708"	5	"Adelie Penguin (Pygoscelis ade...	"Anvers"	"Torgersen"	"Adult, 1 Egg Stage"	"N3A1"	"Yes"	"11/16/07"	
...	...	...	...	...	...	...	...	...	...
"PAL0910"	120	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N38A2"	"No"	"12/1/09"	null
"PAL0910"	122	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A1"	"Yes"	"11/22/09"	46.8
"PAL0910"	123	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N39A2"	"Yes"	"11/22/09"	50.4
"PAL0910"	124	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"	"Adult, 1 Egg Stage"	"N43A1"	"Yes"	"11/22/09"	45.2
"PAL0910"	124	"Gentoo penguin (Pygoscelis pap...	"Anvers"	"Biscoe"					49.9

Missing Data

Column: `df['Island']`

pandas Filtering

```
df[df['Culmen Length (mm)'] > 40]
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

pandas Filtering

```
df[df['Culmen Length (mm)'] > 40]
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

polars Filtering

```
df.filter(pl.col('Culmen Length (mm)') > 40)
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

polars Filtering

```
df.filter(pl.col('Culmen Length (mm)') > 40)
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
...	...	...	...	...	...	...	...	...	...	...
339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
341	PAL0910	122	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A2	Yes	11/22/09	50.4
342	PAL0910	123	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A1	Yes	11/22/09	45.2
343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

DataFrame Filtering

- polars:
  - `df['pop'] > 2 # boolean Series`
  - `df.filter(pl.col('pop') > 2) # subset of dataframe`
- pandas:
  - `dfa['pop'] > 2 # boolean Series`
  - `dfa[dfa['pop'] > 2] # subset of dataframe`
  - `dfa.query('pop > 2') # subset of dataframe`
- Multiple criteria, use `&`, `|`, and `~`; remember parentheses!
  - `df.filter((pl.col('year') < 2002) & (pl.col('pop') > 2))`
  - `dfa[(dfa['year'] < 2002) & (dfa['pop'] > 2)]`

Dataframe Statistics

- describe: overview (difference between numeric and non-numeric data
- unique: unique values (array in pandas!)
- value_counts: counts for each value
- min, max, median…

Assignment 8

- Out Soon…
- Last Assignment
- Data and Visualization

Schedule

- This week (April 20 and 22):
  - I am at a conference
  - Recorded lectures for **all** sections, no in-person lectures
  - No In-person Office hours: Email questions, virtual meetings by request
- April 27 and April 29: Normal lectures (in-person and online)
- May 6: Final Exam (starts at **8:00am**)

Reading and Writing Files Using polars & pandas

- polars uses `read_*/write_*`
- pandas uses `read_*/to_*`
- Many options available, format dependent!
- polars csv example:
  - `df = pl.read_csv(<fname>)`
  - `df.write_csv(<fname>)`
- pandas csv example:
  - `dfa = pd.read_csv(<fname>)`
  - `dfa.to_csv(<fname>)`
- Both pandas and polars can read/write to the cloud (e.g. S3)

Reading & Writing Data in pandas

Format Type	Data Description	Reader	Writer
text	CSV	read_csv	to_csv
text	Fixed-Width Text File	read_fwf	
text	JSON	read_json	to_json
text	HTML	read_html	to_html
text	Local clipboard	read_clipboard	to_clipboard
	MS Excel	read_excel	to_excel
binary	OpenDocument	read_excel	
binary	HDF5 Format	read_hdf	to_hdf
binary	Feather/IPC Format	read_feather	to_feather
binary	Apache Iceberg	read_iceberg	to_iceberg
binary	Parquet Format	read_parquet	to_parquet
binary	ORC Format	read_orc	
binary	Msgpack	read_msgpack	to_msgpack
binary	Stata	read_stata	to_stata
binary	SAS	read_sas	
binary	SPSS	read_spss	
binary	Python Pickle Format	read_pickle	to_pickle
SQL	SQL	read_sql	to_sql
SQL	Google BigQuery	read_gbq	to_gbq

[https://pandas.pydata.org/pandas-docs/stable/user_guide/io.html]

Reading & Writing Data in polars

Format Type	Data Description	Reader	Writer
text	CSV	read_csv	write_csv
text	JSON	read_json	write_json
	MS Excel	read_excel	write_excel
binary	OpenDocument	read_ods	
binary	IPC/Feather Format	read_ipc	write_ipc
binary	Apache Iceberg	scan_iceberg	
binary	Parquet Format	read_parquet	write_parquet
binary	AVRO Format	read_avro	write_avro
binary	Delta Lake	read_delta	write_delta
SQL	Database/SQL	read_database	write_database

- polars supports other methods via Apache Arrow (e.g. Google Big Query)
- polars also supports `scan_*` methods that work lazily for many formats and `sink_*` methods that write in a streaming manner

pandas/polars read_csv

- Convenient method to read csv files
- Lots of different options to help get data into the desired format
- Basic: `dfa = pd.read_csv(<path>), df = pl.read_csv(<path>)`
- Parameters:
  - `sep/separator`: the delimiter (`','`, `' '`, `'\t'`, `'\s+'`)
  - `header/has_header`: if `None/False`, no header
  - `index_col`: which column to use as the row index (pandas only)
  - `names/new_coumns`: list of header names (e.g. if the file has no header)
  - `skiprows/skip_rows`: number of list of lines to skip

pandas/polars to_csv/write_csv

- Basic: `dfa.to_csv(<path>), df.write_csv(<path>)`
- Parameters:
  - `sep/separator`: the delimiter (`',', ' ', '|', '\t'`)
  - `na_rep/null_value`: string to write for a missing value (e.g. `"NULL"`)
  - `index`: whether to write index labels (pandas only)
  - `header/include_header`: whether to write the column headers
- In pandas, a `Series` may also be written to csv

Missing Data

- polars: shows `null`
- pandas: shows `NaN` (or `NA` or `None` depending on dtype)
- Checking if missing:
  - polars: `pl.col('pop').is_null(), .is_not_null()`
  - pandas: `dfa['pop'].isnull(), .notnull()`
- Drop missing data:
  - polars: `pl.col('pop').drop_nulls()`, pandas: `dfa['pop'].dropna()`
- Filling in missing data:
  - polars: `pl.col('pop').fill_null()`,(`forward, backward, max,…`)
  - pandas: `dfa['pop'].fillna()`, now `ffill(), bfill()`

Derived Data

- Create new columns from existing columns
- pandas
  - `dfa["CulmenRatio"] = dfa['CLength'] / dfa['CDepth'] # Mut!`
  - `dfa = dfa.assign(CulmenRatio= dfa['CLength'] / dfa['CDepth'])`
- polars
  - ```
    df.with_columns(
            (df['CLength'] / df['CDepth']).alias('CulmenRatio'))
    ```
- Note that operations are computed in a vectorized manner
- Similarities to functional paradigm (map/filter):
  - specify the operation once, on entire column/frame
  - no loops
    ```

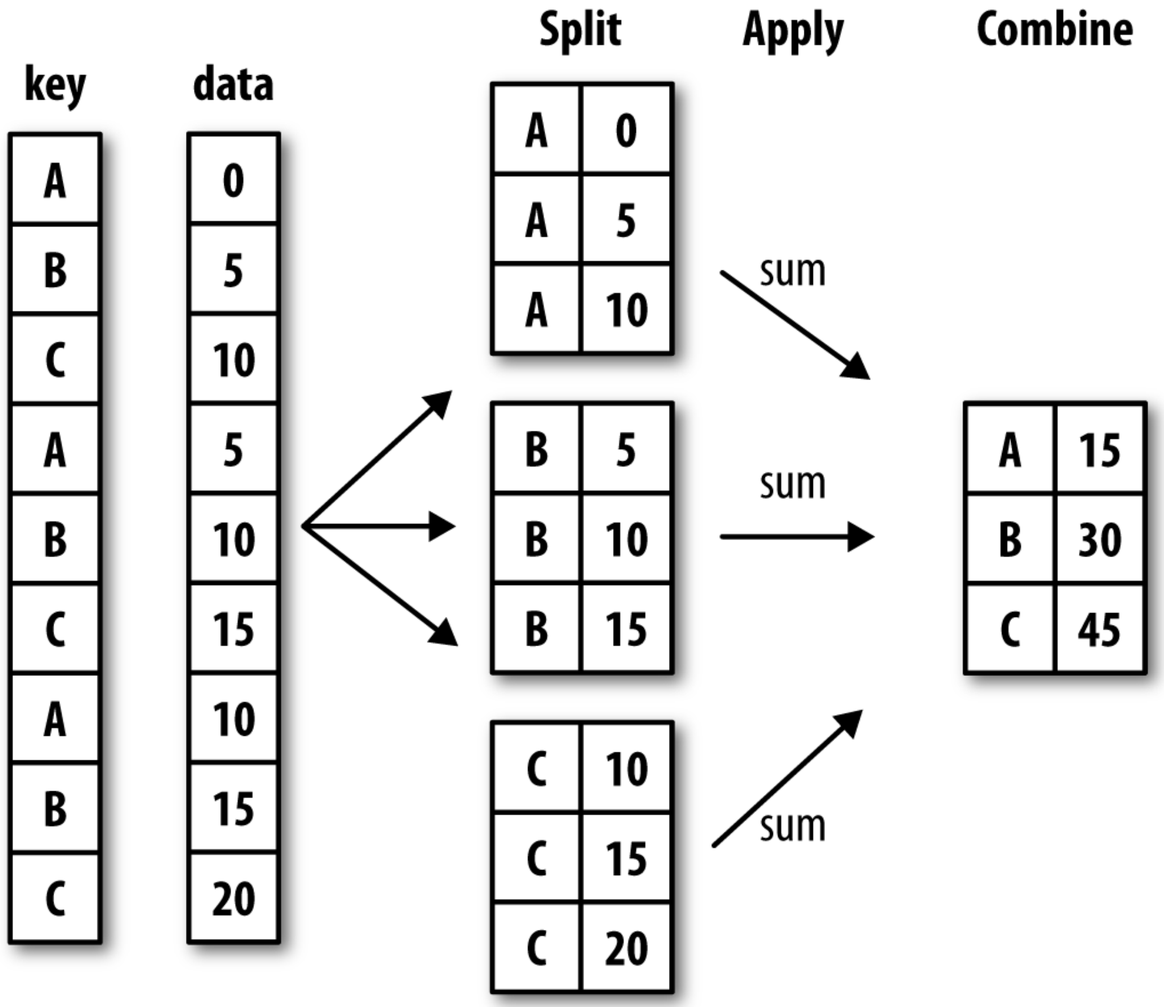
pandas inplace

- Generally, when we modify a data frame, we reassign:
  - `rdf = dfa.reset_index()`
  - This is usually very **efficient**
  - Allows for method chaining
- There are versions where you can do this "inplace" (**DO NOT USE THIS!**)
  - `dfa.reset_index(inplace=True)`
  - This means **no reassignment**, but it isn't usually any faster nor better
  - Sometimes still creates a copy
  - Will likely be deprecated

Aggregation

- Descriptive statistics
  - `df['Culmen Length (mm)'].mean()`
  - `.median()`
  - `.describe()`
  - `.count()`
  - `.min(), .max()`
- Also general methods
  - `.sum()`
  - `.product()`

Split-Apply-Combine



[W. McKinney, Python for Data Analysis]

Split-Apply-Combine

- Polars:
  - `df.group_by('Island').agg(pl.col('Length').mean())`
  - `df.group_by('Island').agg(pl.col('Length','Depth').mean())`
  - `df.group_by('Island').agg(pl.col('Length').min().alias('LMin'), pl.col('Length').max().alias('LMax'))`
- Pandas:
  - `dfa.groupby('Island')['Length (mm)'].mean()`
  - `dfa.groupby('Island')[['Length','Depth']].mean()`
  - `dfa.groupby('Island').agg({'Length': ['min','max']})`
  - `dfa.groupby('Island').agg(LMin=('Length','min') LMax=('Length','max'))`

Split-Apply-Combine

- Similar to Map (split+apply) Reduce (combine) paradigm
- The Pattern:
  1. **Split** the data by some grouping variable
  2. **Apply** some function to each group independently
  3. **Combine** the data into some output dataset
- The apply step is usually one of:
  - Aggregate
  - Transform
  - Filter

[T. Brandt]

Group By

- Polars: `group_by`, Pandas: `groupby`
- `group_by` method creates a `GroupBy` object
- `group_by` **does not compute** anything until there is an aggregate step
- Sizes of groups:
  - `df.group_by('Island').agg(pl.len()) # DataFrame`
  - `dfa.groupby('Island').size() # Series`
- Can iterate through the groups (names and dataframes):
  -
```
for name, gdf in df.group_by('Island'):
    display(name, gdf)
```

Aggregation

- Single Column:
  - `df.group_by('Island').agg(pl.col('Length (mm)').mean())`
  - `dfa.groupby('Island')['Length (mm)'].mean()`
- pandas returns a Series, polars returns a DataFrame
- List of Values:
  - `df.group_by('Island').agg(pl.col('Length (mm)'))`
  - `dfa.groupby('Island')['Length (mm)'].apply(list)`

Aggregation (Multiple Columns)

- Multiple columns in an aggregation
  - `df.group_by('Island').agg(pl.col('Length','Depth').mean())`
  - `dfa.groupby('Island')[['Length','Depth']].mean()`
- Multiple aggregations for a column
  - `df.group_by('Island').agg(pl.col('Length').min().alias('LMin'), pl.col('Length').max().alias('LMax'))`
  - `dfa.groupby('Island').agg({'Length': ['min','max']})`
  - `dfa.groupby('Island').agg(LMin=('Length','min') LMax=('Length','max'))`

Different Data Layouts

	treatmenta	treatmentb
John Smith	—	2
Jane Doe	16	11
Mary Johnson	3	1

Initial Data

	John Smith	Jane Doe	Mary Johnson
treatmenta	—	16	3
treatmentb	2	11	1

Transpose

name	trt	result
John Smith	a	—
Jane Doe	a	16
Mary Johnson	a	3
John Smith	b	2
Jane Doe	b	11
Mary Johnson	b	1

Tidy Data

[H. Wickham, 2014]

Problem: Variables stored in both rows & columns

Mexico Weather, Global Historical Climatology Network

id	year	month	element	d1	d2	d3	d4	d5	d6	d7	d8
MX17004	2010	1	tmax	—	—	—	—	—	—	—	—
MX17004	2010	1	tmin	—	—	—	—	—	—	—	—
MX17004	2010	2	tmax	—	27.3	24.1	—	—	—	—	—
MX17004	2010	2	tmin	—	14.4	14.4	—	—	—	—	—
MX17004	2010	3	tmax	—	—	—	—	32.1	—	—	—
MX17004	2010	3	tmin	—	—	—	—	14.2	—	—	—
MX17004	2010	4	tmax	—	—	—	—	—	—	—	—
MX17004	2010	4	tmin	—	—	—	—	—	—	—	—
MX17004	2010	5	tmax	—	—	—	—	—	—	—	—
MX17004	2010	5	tmin	—	—	—	—	—	—	—	—

[H. Wickham, 2014]

Problem: Variables stored in both rows & columns

Mexico Weather, Global Historical Climatology Network

id	year	month	element	d1	d2	d3	d4	d5	d6	d7	d8
MX17004	2010	1	tmax	—	—	—	—	—	—	—	—
MX17004	2010	1	tmin	—	—	—	—	—	—	—	—
MX17004	2010	2	tmax	—	27.3	24.1	—	—	—	—	—
MX17004	2010	2	tmin	—	14.4	14.4	—	—	—	—	—
MX17004	2010	3	tmax	—	—	—	—	32.1	—	—	—
MX17004	2010	3	tmin	—	—	—	—	14.2	—	—	—
MX17004	2010	4	tmax	—	—	—	—	—	—	—	—
MX17004	2010	4	tmin	—	—	—	—	—	—	—	—
MX17004	2010	5	tmax	—	—	—	—	—	—	—	—
MX17004	2010	5	tmin	—	—	—	—	—	—	—	—

Variable in columns: day; Variable in rows: tmax/tmin

[H. Wickham, 2014]

Melting + Pivot

id	date	element	value
MX17004	2010-01-30	tmax	27.8
MX17004	2010-01-30	tmin	14.5
MX17004	2010-02-02	tmax	27.3
MX17004	2010-02-02	tmin	14.4
MX17004	2010-02-03	tmax	24.1
MX17004	2010-02-03	tmin	14.4
MX17004	2010-02-11	tmax	29.7
MX17004	2010-02-11	tmin	13.4
MX17004	2010-02-23	tmax	29.9
MX17004	2010-02-23	tmin	10.7

(a) Molten data

id	date	tmax	tmin
MX17004	2010-01-30	27.8	14.5
MX17004	2010-02-02	27.3	14.4
MX17004	2010-02-03	24.1	14.4
MX17004	2010-02-11	29.7	13.4
MX17004	2010-02-23	29.9	10.7
MX17004	2010-03-05	32.1	14.2
MX17004	2010-03-10	34.5	16.8
MX17004	2010-03-16	31.1	17.6
MX17004	2010-04-27	36.3	16.7
MX17004	2010-05-27	33.2	18.2

(b) Tidy data

[H. Wickham, 2014]

Unpivot/Melt

- Many columns (wider) become two columns (longer): one with column name (variable), other with value

id	year	month	element	d1	d2	d3	d4	d5	d6	d7	d8
str	i32	i32	str	f64	f64	f64	f64	f64	f64	f64	f64
"MX000017004"	1955	4	"tmax"	31.0	31.0	31.0	32.0	33.0	32.0	32.0	33.0
"MX000017004"	1955	4	"tmin"	15.0	15.0	16.0	15.0	16.0	16.0	16.0	16.0
"MX000017004"	1955	5	"tmax"	31.0	31.0	31.0	30.0	30.0	30.0	31.0	31.0
"MX000017004"	1955	5	"tmin"	20.0	16.0	16.0	15.0	15.0	15.0	16.0	16.0
"MX000017004"	1955	6	"tmax"	30.0	29.0	28.0	27.0	28.0	26.0	23.0	27.0
…	…	…	…	…	…	…	…	…	…	…	…
"MX000017004"	2011	2	"tmin"	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
"MX000017004"	2011	3	"tmax"	NaN	NaN	NaN	NaN	33.2	NaN	NaN	NaN
"MX000017004"	2011	3	"tmin"	NaN	NaN	NaN	NaN	14.8	NaN	NaN	NaN
"MX000017004"	2011	4	"tmax"	NaN	35.0	NaN	NaN	NaN	NaN	NaN	NaN
"MX000017004"	2011	4	"tmin"	NaN	16.8	NaN	NaN	NaN	NaN	NaN	NaN

id	year	month	element	variable	value
str	i32	i32	str	str	f64
"MX000017004"	1955	4	"tmax"	"d1"	31.0
"MX000017004"	1955	4	"tmin"	"d1"	15.0
"MX000017004"	1955	5	"tmax"	"d1"	31.0
"MX000017004"	1955	5	"tmin"	"d1"	20.0
"MX000017004"	1955	6	"tmax"	"d1"	30.0
…	…	…	…	…	…
"MX000017004"	2011	2	"tmin"	"d31"	NaN
"MX000017004"	2011	3	"tmax"	"d31"	36.5
"MX000017004"	2011	3	"tmin"	"d31"	17.0
"MX000017004"	2011	4	"tmax"	"d31"	NaN
"MX000017004"	2011	4	"tmin"	"d31"	NaN

Unpivot/Melt

- Many columns (wider) become two columns (longer): one with column name (variable), other with value

id	year	month	element	d1	d2	d3	d4	d5	d6	d7	d8
str	i32	i32	str	f64	f64	f64	f64	f64	f64	f64	f64
"MX000017004"	1955	4	"tmax"	31.0	31.0	31.0	32.0	33.0	32.0	32.0	33.0
"MX000017004"	1955	4	"tmin"	15.0	15.0	16.0	15.0	16.0	16.0	16.0	16.0
"MX000017004"	1955	5	"tmax"	31.0	31.0	31.0	30.0	30.0	30.0	31.0	31.0
"MX000017004"	1955	5	"tmin"	20.0	16.0	16.0	15.0	15.0	15.0	16.0	16.0
"MX000017004"	1955	6	"tmax"	30.0	29.0	28.0	27.0	28.0	26.0	23.0	27.0
…	…	…	…	…	…	…	…	…	…	…	…
"MX000017004"	2011	2	"tmin"	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
"MX000017004"	2011	3	"tmax"	NaN	NaN	NaN	NaN	33.2	NaN	NaN	NaN
"MX000017004"	2011	3	"tmin"	NaN	NaN	NaN	NaN	14.8	NaN	NaN	NaN
"MX000017004"	2011	4	"tmax"	NaN	35.0	NaN	NaN	NaN	NaN	NaN	NaN
"MX000017004"	2011	4	"tmin"	NaN	16.8	NaN	NaN	NaN	NaN	NaN	NaN

id	year	month	element	variable	value
str	i32	i32	str	str	f64
"MX000017004"	1955	4	"tmax"	"d1"	31.0
"MX000017004"	1955	4	"tmin"	"d1"	15.0
"MX000017004"	1955	5	"tmax"	"d1"	31.0
"MX000017004"	1955	5	"tmin"	"d1"	20.0
"MX000017004"	1955	6	"tmax"	"d1"	30.0
…	…	…	…	…	…
"MX000017004"	2011	2	"tmin"	"d31"	NaN
"MX000017004"	2011	3	"tmax"	"d31"	36.5
"MX000017004"	2011	3	"tmin"	"d31"	17.0
"MX000017004"	2011	4	"tmax"	"d31"	NaN
"MX000017004"	2011	4	"tmin"	"d31"	NaN

Unpivot/Melt

- Two sets of columns to identify:
  - Value vars: columns to unpivot: `on` / `value_vars` (`None` → all not specified)
  - Index vars: columns to keep: `index` / `id_vars`
- Polars: unpivot
  - `wdf.unpivot(index=['id','year','month','element'])`
- Pandas: melt
  - `wdfa.melt(id_vars=['id','year','month','element'])`

Pivot

- Inverse of unpivot: two columns (longer) become many columns (wider) one column becomes column names (variable), other becomes values

id	year	month	element	variable	value
str	i32	i32	str	str	f64
"MX000017004"	1955	4	"tmax"	"d1"	31.0
"MX000017004"	1955	4	"tmin"	"d1"	15.0
"MX000017004"	1955	5	"tmax"	"d1"	31.0
"MX000017004"	1955	5	"tmin"	"d1"	20.0
"MX000017004"	1955	6	"tmax"	"d1"	30.0
…	…	…	…	…	…
"MX000017004"	2011	2	"tmin"	"d31"	NaN
"MX000017004"	2011	3	"tmax"	"d31"	36.5
"MX000017004"	2011	3	"tmin"	"d31"	17.0
"MX000017004"	2011	4	"tmax"	"d31"	NaN
"MX000017004"	2011	4	"tmin"	"d31"	NaN

id	year	month	variable	tmax	tmin
str	i32	i32	str	f64	f64
"MX000017004"	1955	4	"d1"	31.0	15.0
"MX000017004"	1955	5	"d1"	31.0	20.0
"MX000017004"	1955	6	"d1"	30.0	16.0
"MX000017004"	1955	7	"d1"	27.0	15.0
"MX000017004"	1955	8	"d1"	23.0	14.0
…	…	…	…	…	…
"MX000017004"	2010	12	"d31"	NaN	NaN
"MX000017004"	2011	1	"d31"	NaN	NaN
"MX000017004"	2011	2	"d31"	NaN	NaN
"MX000017004"	2011	3	"d31"	36.5	17.0
"MX000017004"	2011	4	"d31"	NaN	NaN

Pivot

- Inverse of unpivot: two columns (longer) become many columns (wider) one column becomes column names (variable), other becomes values

id	year	month	element	variable	value
str	i32	i32	str	str	f64
"MX000017004"	1955	4	"tmax"	"d1"	31.0
"MX000017004"	1955	4	"tmin"	"d1"	15.0
"MX000017004"	1955	5	"tmax"	"d1"	31.0
"MX000017004"	1955	5	"tmin"	"d1"	20.0
"MX000017004"	1955	6	"tmax"	"d1"	30.0
…	…	…	…	…	…
"MX000017004"	2011	2	"tmin"	"d31"	NaN
"MX000017004"	2011	3	"tmax"	"d31"	36.5
"MX000017004"	2011	3	"tmin"	"d31"	17.0
"MX000017004"	2011	4	"tmax"	"d31"	NaN
"MX000017004"	2011	4	"tmin"	"d31"	NaN

id	year	month	variable	tmax	tmin
str	i32	i32	str	f64	f64
"MX000017004"	1955	4	"d1"	31.0	15.0
"MX000017004"	1955	5	"d1"	31.0	20.0
"MX000017004"	1955	6	"d1"	30.0	16.0
"MX000017004"	1955	7	"d1"	27.0	15.0
"MX000017004"	1955	8	"d1"	23.0	14.0
…	…	…	…	…	…
"MX000017004"	2010	12	"d31"	NaN	NaN
"MX000017004"	2011	1	"d31"	NaN	NaN
"MX000017004"	2011	2	"d31"	NaN	NaN
"MX000017004"	2011	3	"d31"	36.5	17.0
"MX000017004"	2011	4	"d31"	NaN	NaN

Pivot

- **Three** sets of columns to identify:
  - Columns: columns to pivot: `on` / `columns`
  - Index: columns to keep: `index`
  - Values: column to fill new columns: `values`
- Polars:
  -
```
wdf_up.pivot('element',
             index=['id','year','month','variable'],
             values='value')
```
- Pandas:
  -
```
wdfa_melt.pivot(columns='element',
                index=['id','year','month','variable'],
                values='value')
```

Melting + Pivot

id	date	element	value
MX17004	2010-01-30	tmax	27.8
MX17004	2010-01-30	tmin	14.5
MX17004	2010-02-02	tmax	27.3
MX17004	2010-02-02	tmin	14.4
MX17004	2010-02-03	tmax	24.1
MX17004	2010-02-03	tmin	14.4
MX17004	2010-02-11	tmax	29.7
MX17004	2010-02-11	tmin	13.4
MX17004	2010-02-23	tmax	29.9
MX17004	2010-02-23	tmin	10.7

(a) Molten data

id	date	tmax	tmin
MX17004	2010-01-30	27.8	14.5
MX17004	2010-02-02	27.3	14.4
MX17004	2010-02-03	24.1	14.4
MX17004	2010-02-11	29.7	13.4
MX17004	2010-02-23	29.9	10.7
MX17004	2010-03-05	32.1	14.2
MX17004	2010-03-10	34.5	16.8
MX17004	2010-03-16	31.1	17.6
MX17004	2010-04-27	36.3	16.7
MX17004	2010-05-27	33.2	18.2

(b) Tidy data

[H. Wickham, 2014]

String Methods

- Can do many of the same methods used for single strings on entire columns
- Requires `.str` prefix before calling the method
  - polars: `df['Species'].str.split('(')`
  - pandas: `dfa['Species'].str.split('(')`
- Also can extract from a list
  - polars: `df['Species'].str.split('(').list[0]`
  - pandas: `dfa['Species'].str.split('(').str[0]`
- Many, many more (see documentation):
  - pandas: link
  - polars: link

Datetime Support

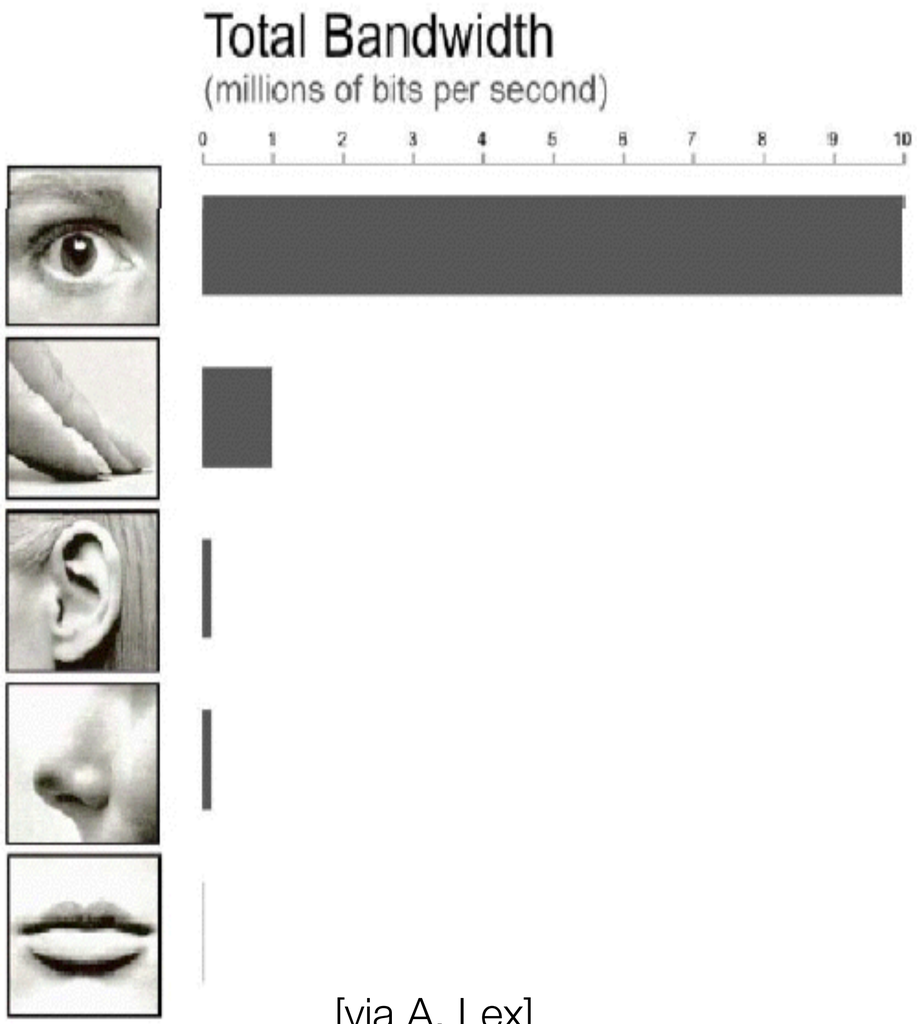
- Python has datetime library to support dates and times
- pandas has a Timestamp data type that functions somewhat similarly
- polars has a Datetime data type that functions somewhat similarly
- Can convert timestamps
  - `pl.to_datetime` and `pl.str.to_datetime`: directed, require format
  - `pd.to_datetime`: versatile, can often guess format from a string
- Like string methods, also a `.dt` accessor for datetime methods/properties
  - polars: `df['date'].dt.year()`,
  - pandas: `dfa['date'].dt.year`

Definition of Visualization

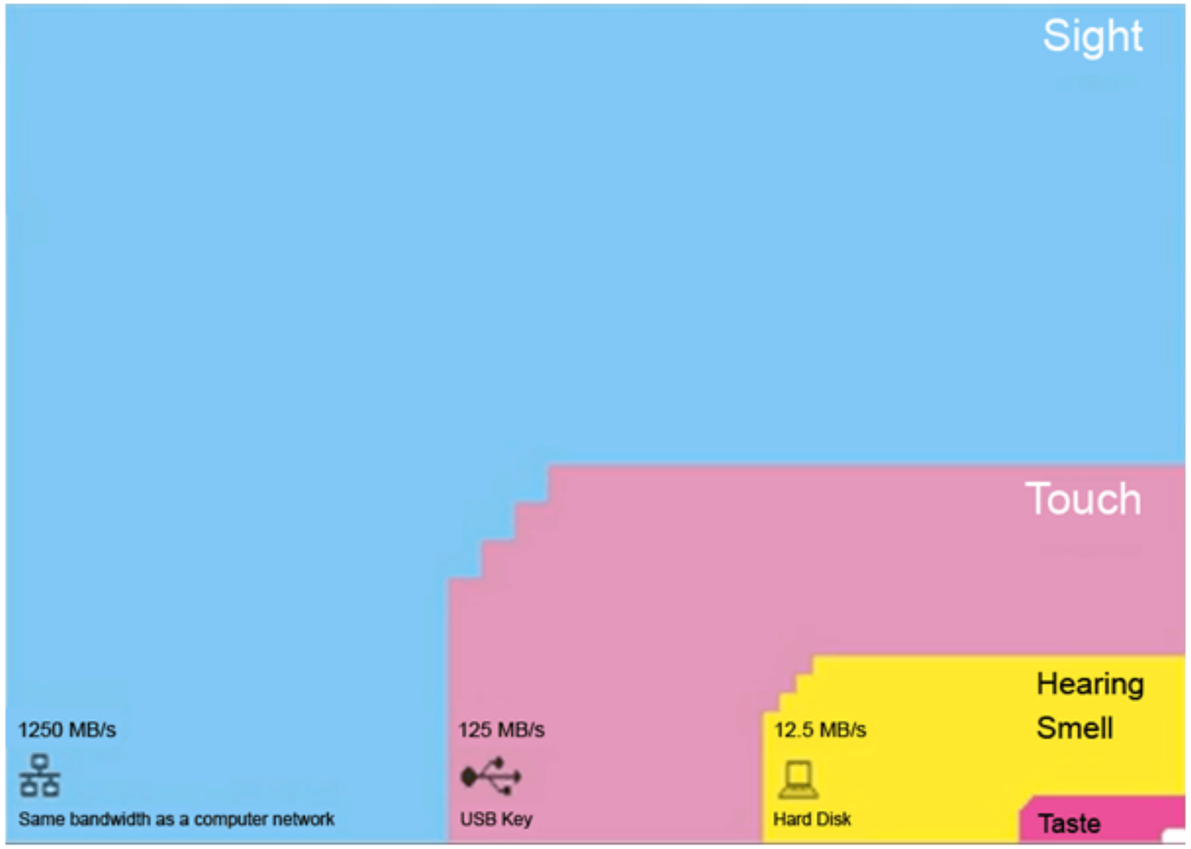
"Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively"

— T. Munzner

Why do we visualize data?



[via A. Lex]



[T. Nørretranders]

Why Visual?

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

[F. J. Anscombe]

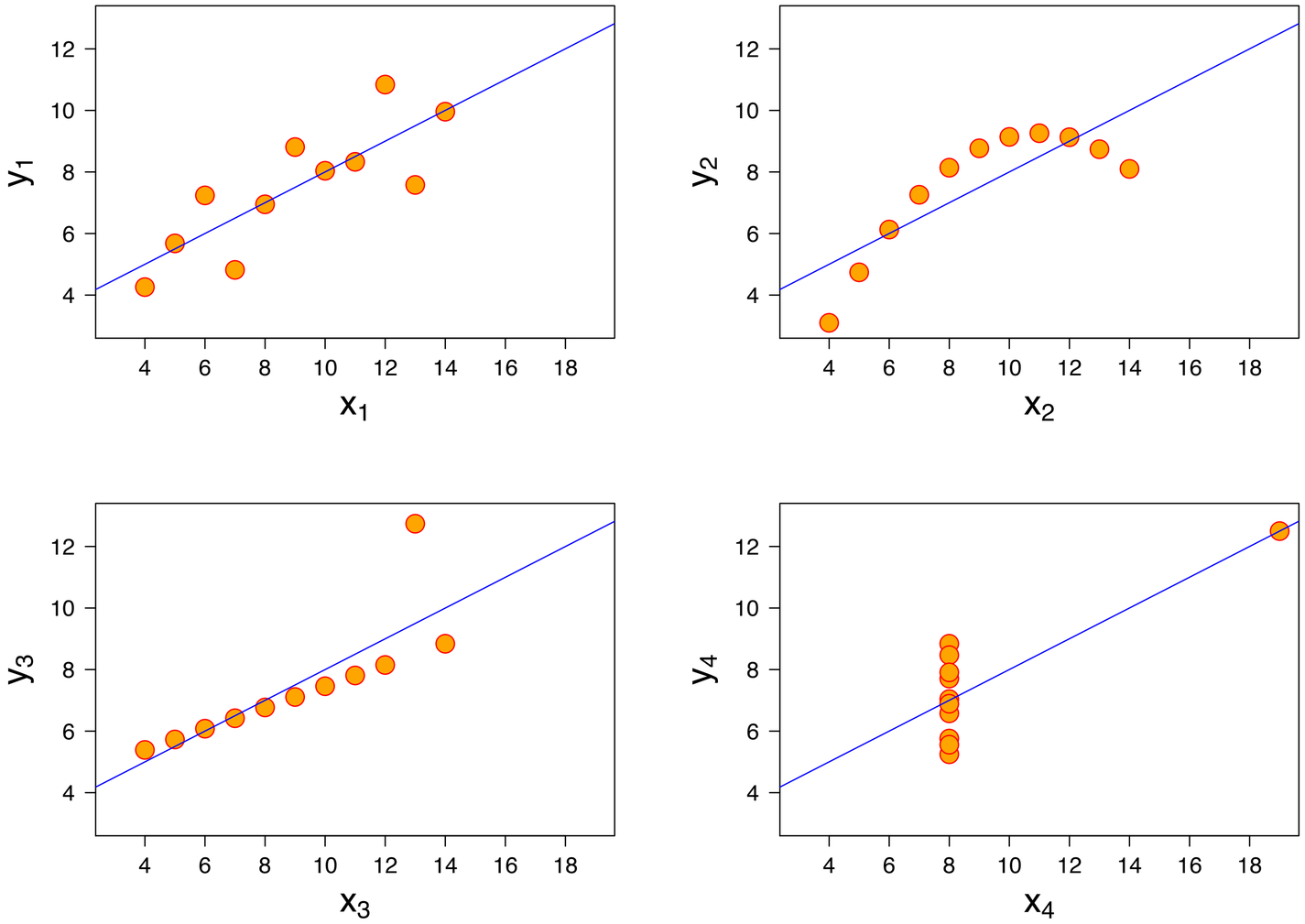
Why Visual?

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816

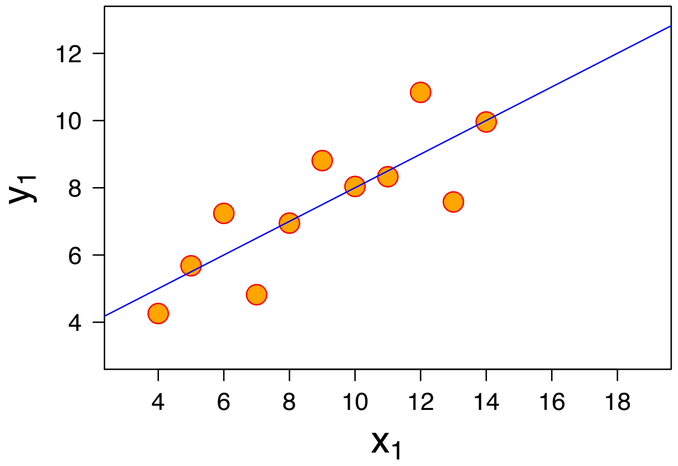
[F. J. Anscombe]

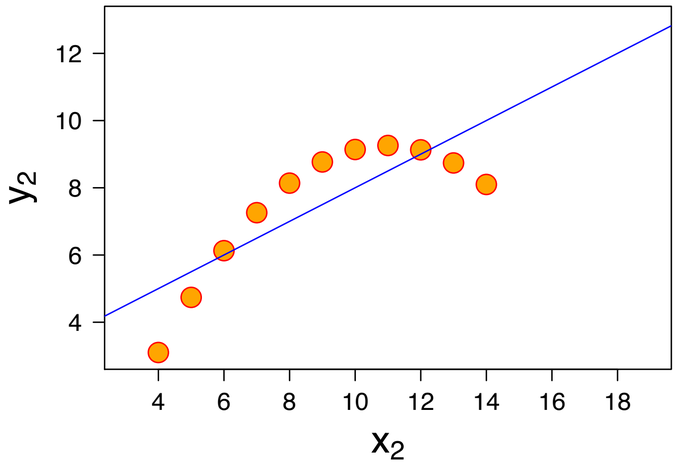
Why Visual?

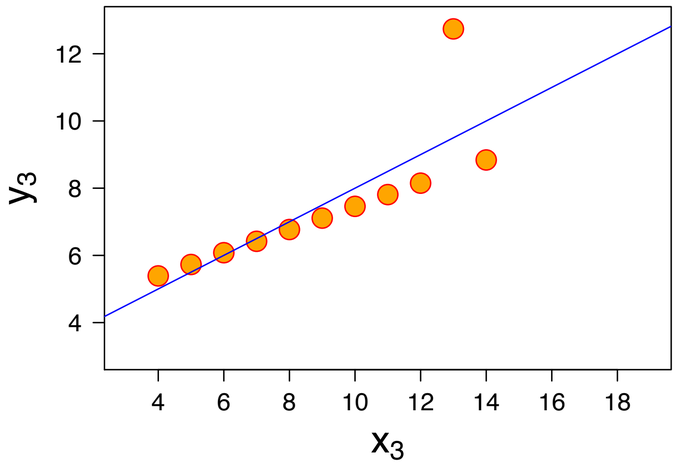


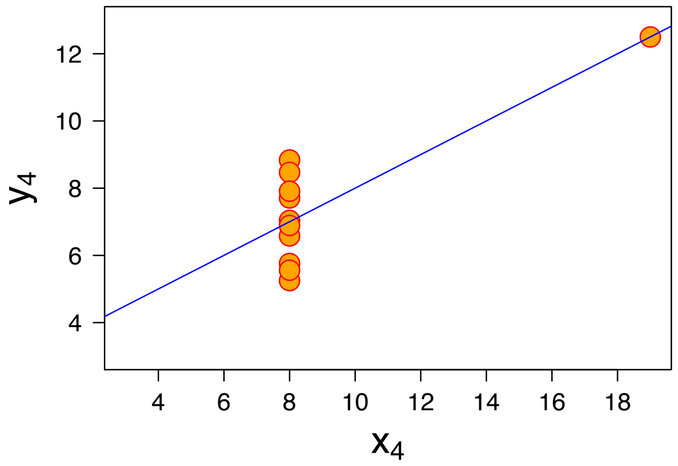
[F. J. Anscombe]

Why Visual?









Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816

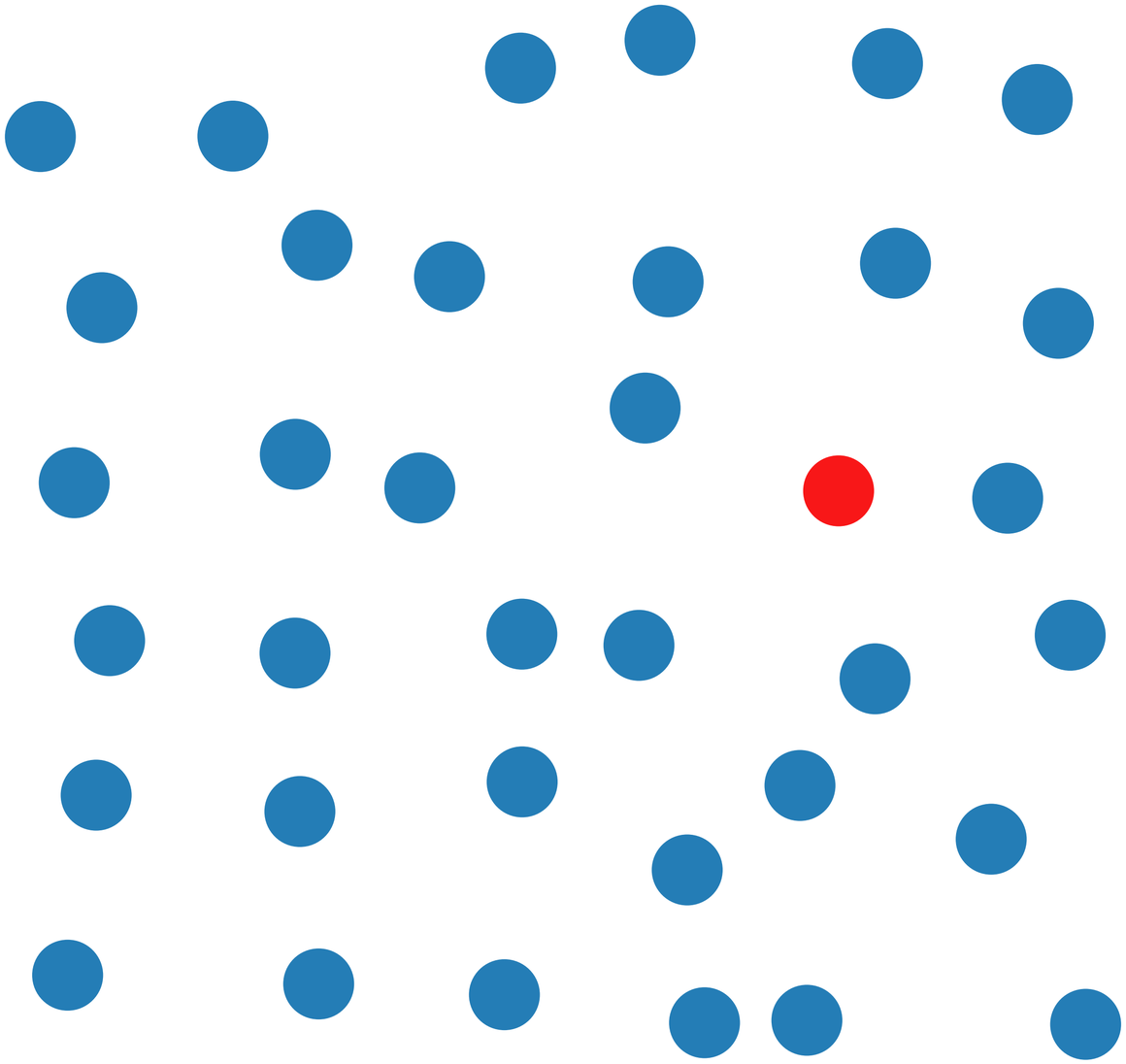
[F. J. Anscombe]

Visualization Goals

- "The purpose of visualization is **insight**, not pictures" – B. Shneiderman

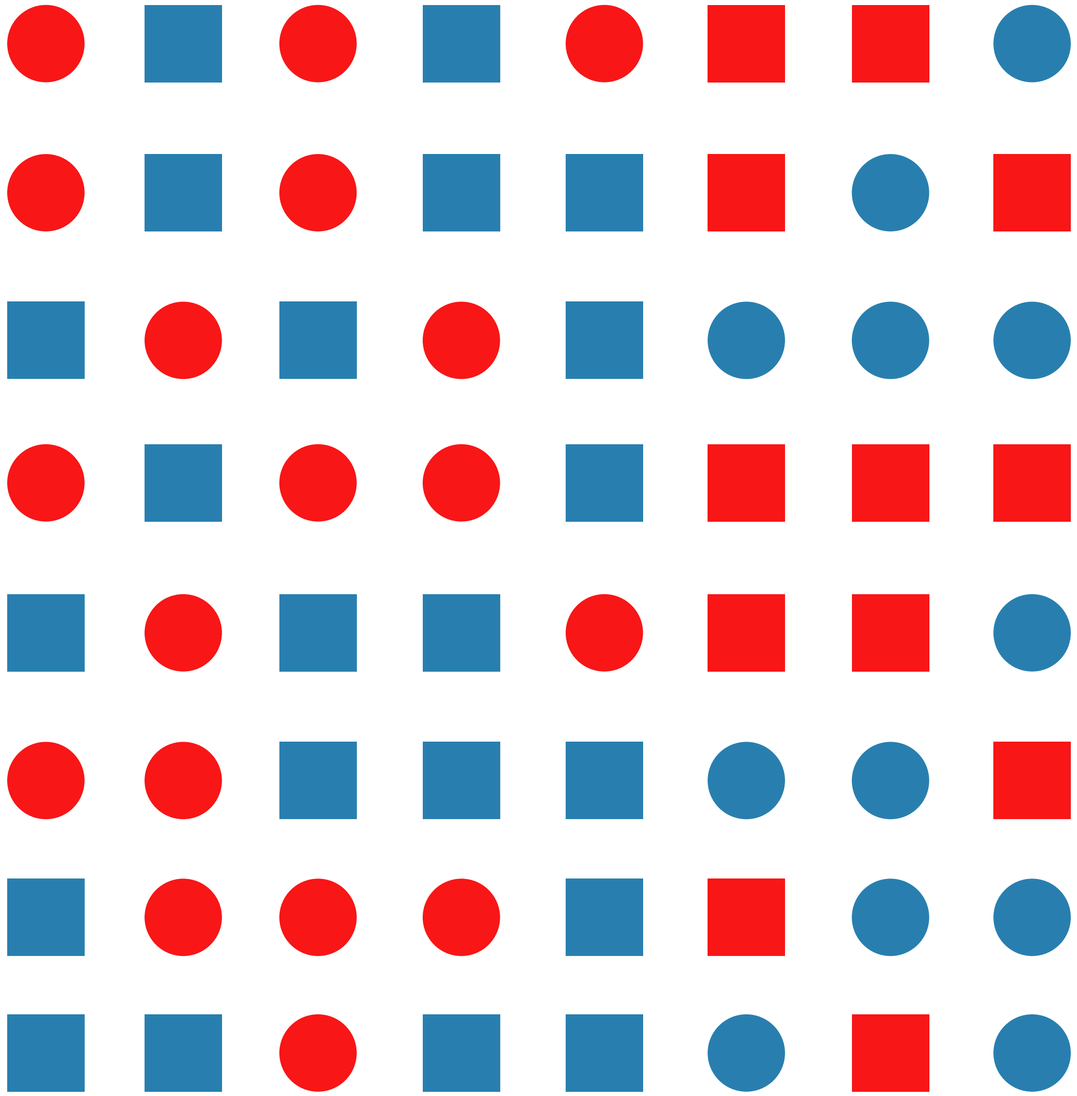
- Identify patterns, trends
- Spot outliers
- Find similarities, correlation

Visual Pop-out



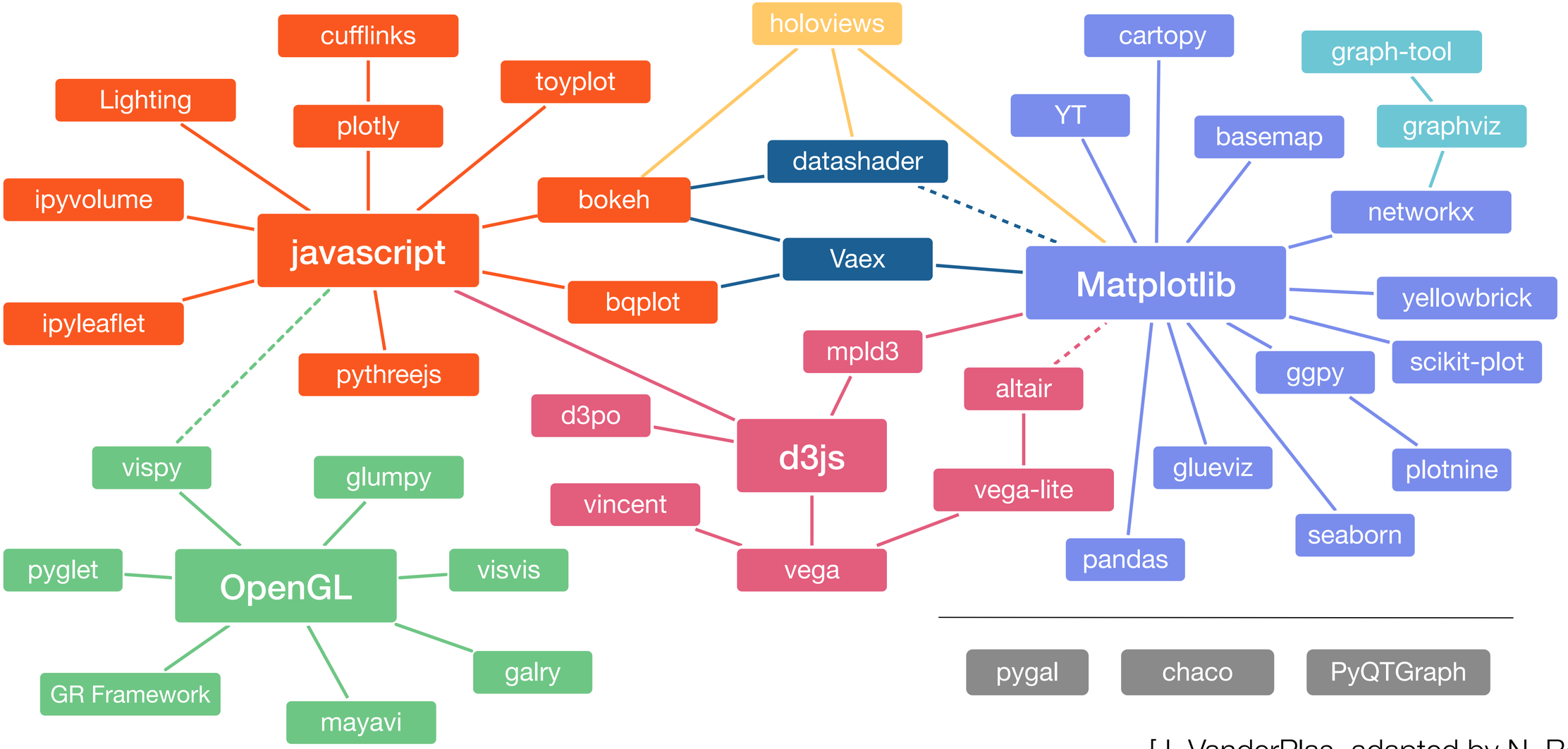
[C. G. Healey]

Visual Perception Limitations



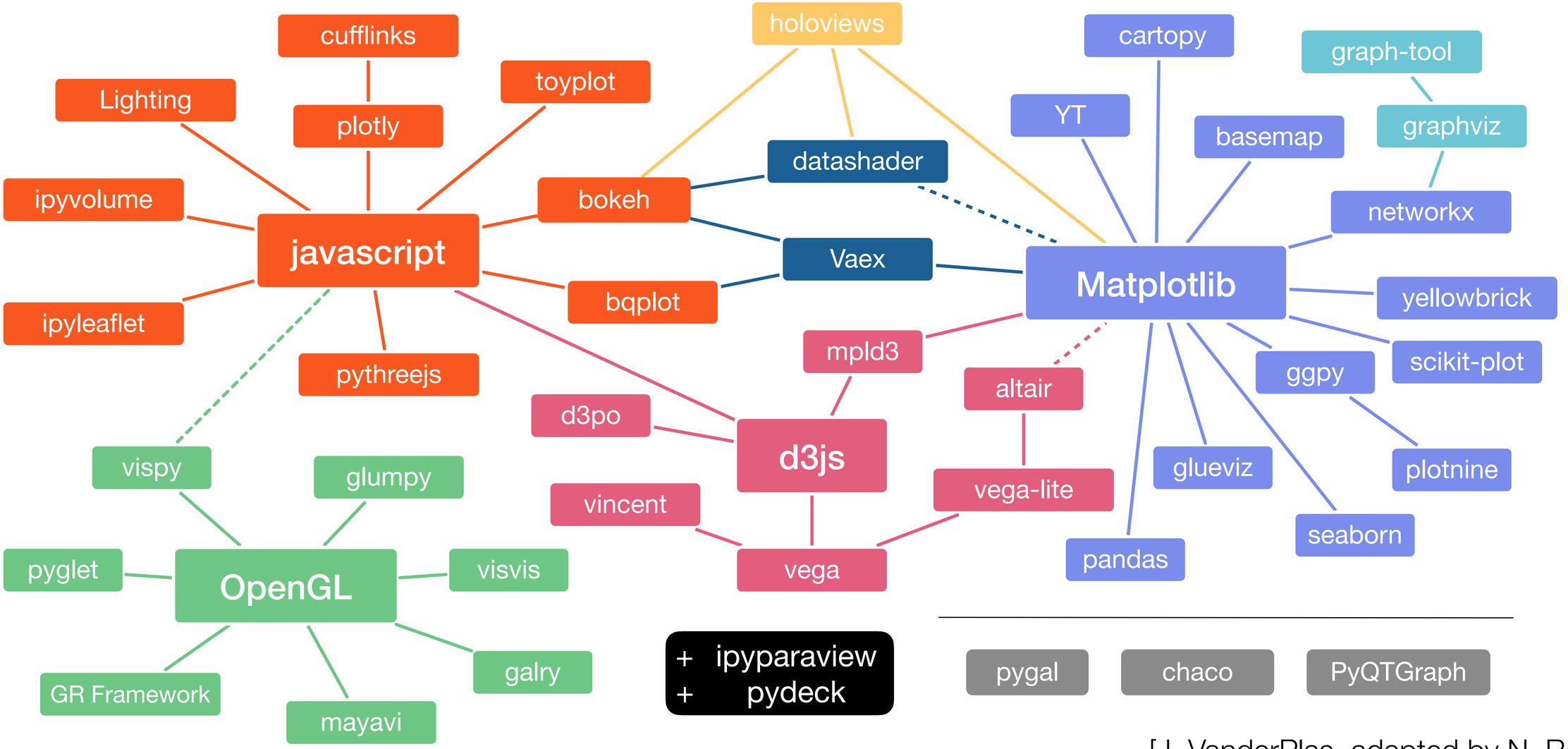
[C. G. Healey]

The Python Visualization Landscape



[J. VanderPlas, adapted by N. Rougier]

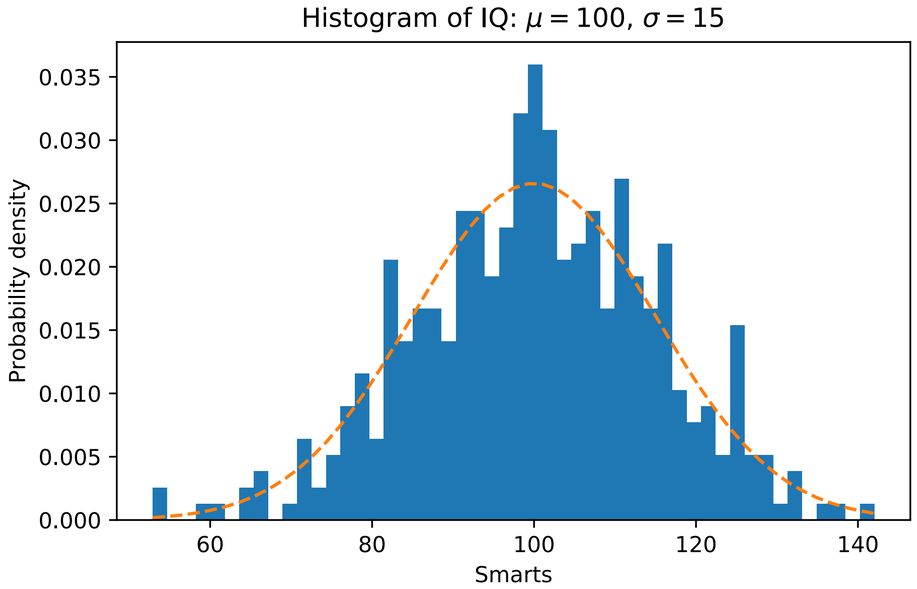
The Python Visualization Landscape



[J. VanderPlas, adapted by N. Rougier]

matplotlib

- Strengths:
  - Designed like Matlab
  - Many rendering backends
  - Can reproduce almost any plot
  - Proven, well-tested
- Weaknesses:
  - API is imperative
  - Not originally designed for the web
  - Dated styles



Vega-Altair

- Declarative Visualization
  - Specify **what** instead of how
  - Separate specification from execution
- Based on Vega-Lite which is browser-based
- Strengths:
  - Declarative visualization
  - Web technologies
- Drawbacks:
  - Moving data between Python and JS
  - Sometimes longer specifications