Programming Principles in Python (CSCI 503/490)

Data

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Quiz

Quiz

1. What is a difference between a pandas Series and a polars Series?
   (a) A pandas Series has an index; a polars Series does not
   (b) A pandas Series has a name; a polars Series does not
   (c) A pandas Series is typed; a polars Series is untyped
   (d) A pandas Series is mutable; a polars Series is immutable

Quiz

2. Which of the following is invalid code?

   (a) `numpy.array([[1.5, 2, 3], [4, 5, 6]], dtype='float')`

   (b) `numpy.array([[1.5, 2, 3], [4, 5, 6]])`

   (c) `numpy.array([[1,2,3],[4,5]])`

   (d) `numpy.array([[1,2,3],[4,5,6]], dtype="float")`

Quiz

3. Which of the following is **true** about numpy arrays and python lists?
   (a) Arrays are mutable; lists are not
   (b) Lists are faster to access than arrays
   (c) Arrays and lists both can have elements of different types
   (d) Assigning to a slice ([a[1:3] = [10,20]) is a valid operation for both arrays and lists

Quiz

4. Evaluate `pd.Series([1,2,3]) + pd.Series([3,2,1],[1,2,0])`.
   (a) `pd.Series([4,4,4],[0,1,2])`
   (b) `pd.Series([2,4,6],[0,1,2])`
   (c) `pd.Series([2,5,5],[0,1,2])`
   (d) There is an error

Quiz

5. Given the array `arr = np.array([[1,2],[3,4],[5,6]])`, what is `arr[:,1].shape`?
   (a) `(3,)`
   (b) `(2,1)`
   (c) `(3,1)`
   (d) `(1,3)`

pandas

- Contains high-level data structures and manipulation tools designed to make data analysis fast and easy in Python
- Originally built on top of NumPy
- Built with the following requirements:
  - Data structures with labeled axes (aligning data)
  - Support time series data
  - Do arithmetic operations that include metadata (labels)
  - Handle missing data
  - Add merge and relational operations

polars

- Contains high-level data structures and manipulation tools designed to make data analysis **"lightning"** fast and easy in Python
  - Built using Apache Arrow
  - Written from scratch using Rust but with a Python API
  - Parallelized (uses multiple cores)
  - Intuitive API

Series

- A one-dimensional data structure (with a type)
  - `s = pl.Series([1,2,3])`
  - `t = pd.Series([1,2,3])`
- May also have a name and dtype
  - `s = pl.Series('name',['a','b','c'],dtype=pl.Float)`
  - `t = pd.Series([1,2,3], name='num',dtype='float')`
- In pandas, a series has an index
  - `ti = pd.Series([1,2,3],['a','b','c']) # index ['a','b','c']`
  - `ti = pd.Series({'a': 1, 'b': 2, 'c': 3}) # same index`
- Indexing: `s[0], t[0], ti['a'], ti.iloc[0], ti.loc['a']`

Series Operations

- Like numpy: elementwise / broadcasting
  - `Series([1,2,3]) + Series([1,2,3]) # Series([2,4,6])`
  - `Series([1,2,3]) + 4 # Series([5,6,7])`
- …but for pandas, with custom indexes, the operations **align** on the index:
  - ```
    pd.Series([1,2,3],index=list('abc') +
    pd.Series([1,2,3],index=list('cba')
                        # pd.Series([4,4,4], index=['a','b','c'])
    ```
  - also have `.add`, `.subtract`, … with `fill_value` argument

[W. McKinney, Python for Data Analysis]
    ```

DataFrame

- A collection of Series (uniquely named)
  - Similar to a table in a database
  - Similar to a sheet in a spreadsheet
- `df = DataFrame({'state': ['Ohio', 'Ohio', 'Ohio', 'Nevada'],`
  `'year': [2000, 2001, 2002, 2001],`
  `'pop': [1.5, 1.7, 3.6, 2.4]})`
- In pandas:
  - Has an index shared with each series
  - Index is automatically assigned just as with a series but can be passed in as well via `index` kwarg

Assignment 7

- Concurrency, System Integration, and Structural Pattern Matching
- Download System Logs
- Locate Logs of Interest
- Read JSON & Binary Data
- Filter suspicious events using structural pattern matching
- Process all files using threading

Schedule

- Next 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
  - Assignment 8 released, due May 1
- April 27 and April 29: Normal lectures (in-person and online)
- May 6: Final Exam (starts at **8:00am**)

DataFrame Indexing and Slicing

- polars:
  - `df[0], df[0:1] #` equivalent, data frame with single row
- pandas:
  - `dfa[0] #` error
  - `dfa.loc[0] #` a Series!
  - `dfa[0:2] #` a data frame with two rows
- pandas with an index (`dfi = dfa.set_index('state')`)
  - `dfi['Texas'], dfi['Ohio'] #` a Series, a DataFrame!
  - `dfi.loc['Ohio':'Texas']` # inclusive slice!
  - `dfi.iloc[0:2] #` not inclusive!

pandas DataFrame Indexing and Slicing

- Same as with NumPy arrays but can use index labels
- Slicing with labels: NumPy is **exclusive**, Pandas is **inclusive**!
  - `s = Series(np.arange(4))`
    `s[0:2] # gives two values like numpy`
  - `s = Series(np.arange(4), index=['a', 'b', 'c', 'd'])`
    `s['a':'c'] # gives three values, not two!`
- Obtaining data subsets
  - `loc`: get rows/cols by label
  - `iloc`: get rows/cols by position (integer index)

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)]`

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

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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
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3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
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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
...	...	...	...	...	...	...	...	...	...	...
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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
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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
...	...	...	...	...	...	...	...	...	...	...
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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
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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
...	...	...	...	...	...	...	...	...	...	...
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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

Column: `df['Island']`

	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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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	
...	...	...	...	...	...	...	...	...	...	...
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344 rows × 17 columns

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
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…	…	…	…	…	…	…	…	…	…
"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
"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]`

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"	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

Row: `df[2]`

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

Missing Data

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"	
...	...	...	...	...	...	...	...	...	...
"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

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

Sorting

- polars: `df.sort('pop')`
- pandas: `dfa.sort_values('pop')`
- Can sort by multiple columns, too
- pandas also has a `sort_index` method to sort by the index
  - `dfa.sort_index()`

Statistics

- Many common statistical methods can be used (min, max, median, etc.)
- `describe`: shortcut for easy stats!

```
In [204]: df.describe()
Out[204]:
              one       two
count    3.000000  2.000000
mean     3.083333 -2.900000
std      3.493685  2.262742
min      0.750000 -4.500000
25%      1.075000 -3.700000
50%      1.400000 -2.900000
75%      4.250000 -2.100000
max      7.100000 -1.300000
```

```
In [205]: obj = Series(['a', 'a', 'b', 'c'] * 4)

In [206]: obj.describe()
Out[206]:
count     16
unique     3
top        a
freq       8
dtype: object
```

Unique Values and Value Counts

- polars: `unique()` returns a Series/DataFrame with duplicates dropped
- pandas is more complicated
  - Series `unique()` returns an array with only the unique values (no index)
    - `s = Series(['c','a','d','a','a','b','b','c','c'])`
      `s.unique() # array(['c', 'a', 'd', 'b'])`
  - Data Frame `drop_duplicates` returns a DataFrame with duplicates dropped
- Also `nunique()/n_unique()` to count number of unique entries
- `value_counts` returns a Series/DataFrame with index frequencies:
  - `s.value_counts() # Series({'c': 3,'a': 3,'b': 2,'d': 1})`