

Programming Principles in Python (CSCI 503/490)

Data

Dr. David Koop

Data Frame

```
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 x 17 columns



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...	...	...	...	...	...	...	...	...	...	...
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...	...	...	...	...	...	...	...	...	...	...
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344 rows x 17 columns

Column: df['Island']



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Row: df.loc[2]

Index

344 rows x 17 columns

Column: df['Island']

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```
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```

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	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
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Row: df.loc[2]

Index

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

344 rows x 17 columns

Column: df['Island']

Data Frame

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

Column Names

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Row: df.loc[2]

Index

Missing Data

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

344 rows x 17 columns

Column: df['Island']

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
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344 rows x 17 columns



Filtering

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Reading and Writing Data

- Reading:
 - `df = pd.read_csv(fname)`
- Writing
 - `df.to_csv(fname)`
- Many options also possible on both
 - `sep`: the separator (defaults to comma)
 - `skiprows`: when reading, number of list of lines to skip
 - `index`: set to `None` when writing if unimportant
- Also methods for other formats (json, parquet, sql)
- Methods are `read_*` and `to_*`

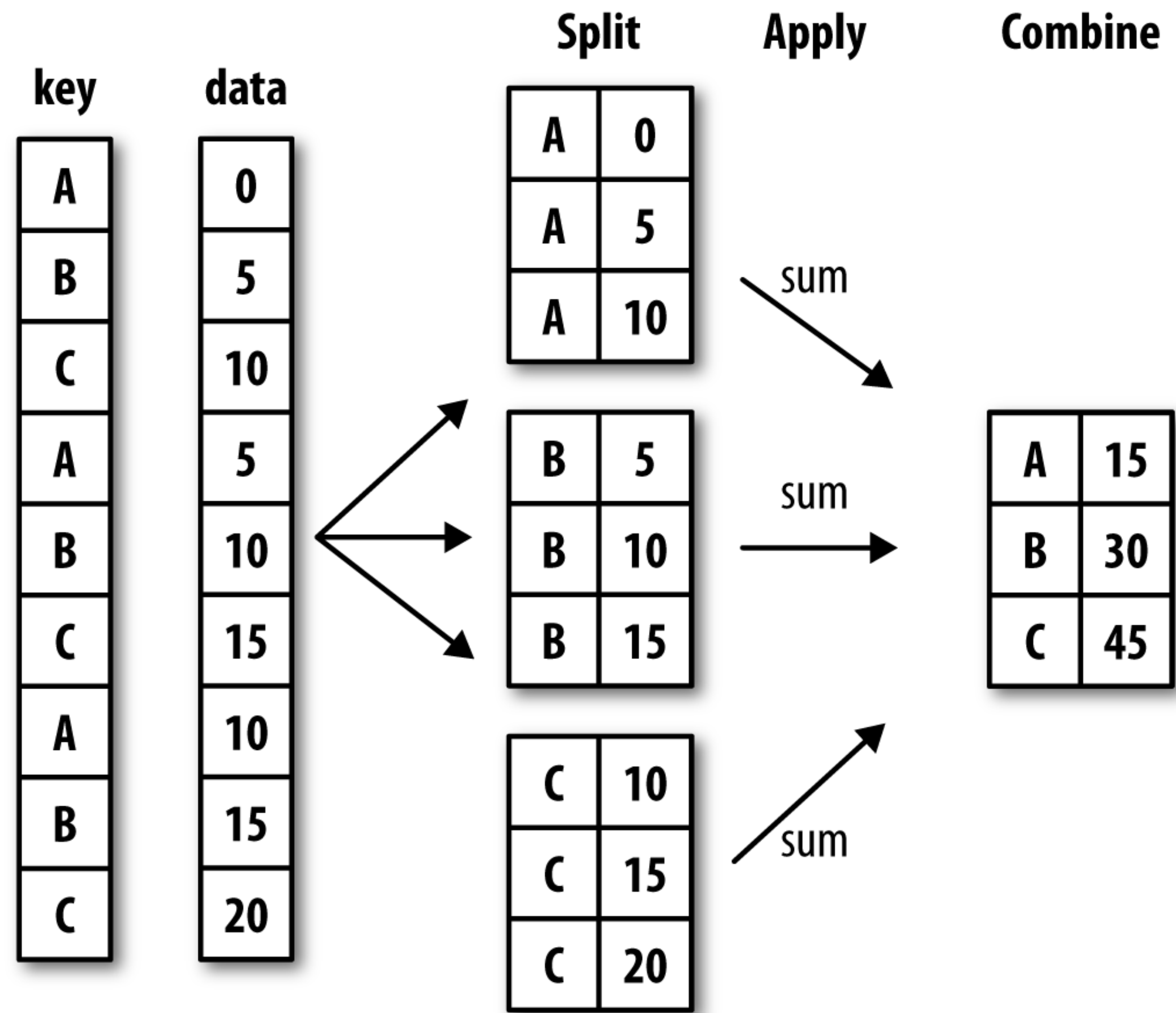
Writing CSV data with pandas

- Basic: `df.to_csv(<fname>)`
- Change delimiter with `sep` kwarg:
 - `df.to_csv('example.dsv', sep='|')`
- Change missing value representation
 - `df.to_csv('example.dsv', na_rep='NULL')`
- Don't write row or column labels:
 - `df.to_csv('example.csv', index=False, header=False)`
- Series may also be written to csv

Derived Data

- Create new columns from existing columns
 - `r["PctFail"] = r['Fail'] / r['Total']`
- Note that operations are computed in a vectorized manner
- Similarities to functional paradigm (map/filter):
 - specify the operation once
 - no loops
 - interpreted as an operation on the entire column

Aggregation: Split-Apply-Combine



[W. McKinney, Python for Data Analysis]

Split-Apply-Combine

- `df.groupby('Island')[['Culmen Length (mm)', 'Culmen Depth (mm)']].mean()`
- `df.groupby('Island').agg({'Culmen Length (mm)': 'mean', 'Culmen Depth (mm)': 'mean'})`
- `df.groupby('Island').agg(cul_length=('Culmen Length (mm)', 'mean'), cul_depth=('Culmen Depth (mm)', 'mean'))`

	cul_length	cul_depth
Island		
Biscoe	45.257485	15.874850
Dream	44.167742	18.344355
Torgersen	38.950980	18.429412

Assignment 7

- Download using requests (490) or aiohttp (503)
- Find matching files
- Use threads to process files using pandas

Tidy Data

Different Data Layouts

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

Initial Data

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

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

Transpose

[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]

Solution: 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]

Melt

- Want to keep each observation separate (tidy), aka pivot_longer

	location	Temperature	Jan-2010	Feb-2010	Mar-2010
0	CityA	Predict	30	45	24
1	CityB	Actual	32	43	22

```
df.melt(id_vars=["location", "Temperature"],  
        var_name="Date", value_name="Value")
```

	location	Temperature	Date	Value
0	CityA	Predict	Jan-2010	30
1	CityB	Actual	Jan-2010	32
2	CityA	Predict	Feb-2010	45
3	CityB	Actual	Feb-2010	43
4	CityA	Predict	Mar-2010	24
5	CityB	Actual	Mar-2010	22

[AB Abhi]

Pivot

- Sometimes, we have data that is given in "long" format and we would like "wide" format (aka pivot_wider)
- Long format: column names are data values...
- Wide format: more like spreadsheet format
- Example:

				<code>.pivot('date', 'item', 'value')</code>			
	date	item	value	item	infl	realgdp	unemp
0	1959-03-31	realgdp	2710.349	date			
1	1959-03-31	infl	0.000	1959-03-31	0.00	2710.349	5.8
2	1959-03-31	unemp	5.800	1959-06-30	2.34	2778.801	5.1
3	1959-06-30	realgdp	2778.801	1959-09-30	2.74	2775.488	5.3
4	1959-06-30	infl	2.340	1959-12-31	0.27	2785.204	5.6
5	1959-06-30	unemp	5.100	1960-03-31	2.31	2847.699	5.2
6	1959-09-30	realgdp	2775.488				
7	1959-09-30	infl	2.740				
8	1959-09-30	unemp	5.300				
9	1959-12-31	realgdp	2785.204				

[W. McKinney, Python for Data Analysis]

Reshaping Data

- Reshape/pivoting are fundamental operations
- Can have a nested index in pandas
- Example: Congressional Districts (Ohio's 1st, 2nd, 3rd, Colorado's 1st, 2nd, 3rd) and associated representative rankings
- Could write this in different ways:

number	one	two	three
state			
Ohio	0	1	2
Colorado	3	4	5

state	Ohio	Colorado
number		
one	0	3
two	1	4
three	2	5

state	number	
Ohio	one	0
	two	1
	three	2
Colorado	one	3
	two	4
	three	5

Reshaping Data

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Ohio	0	1	2
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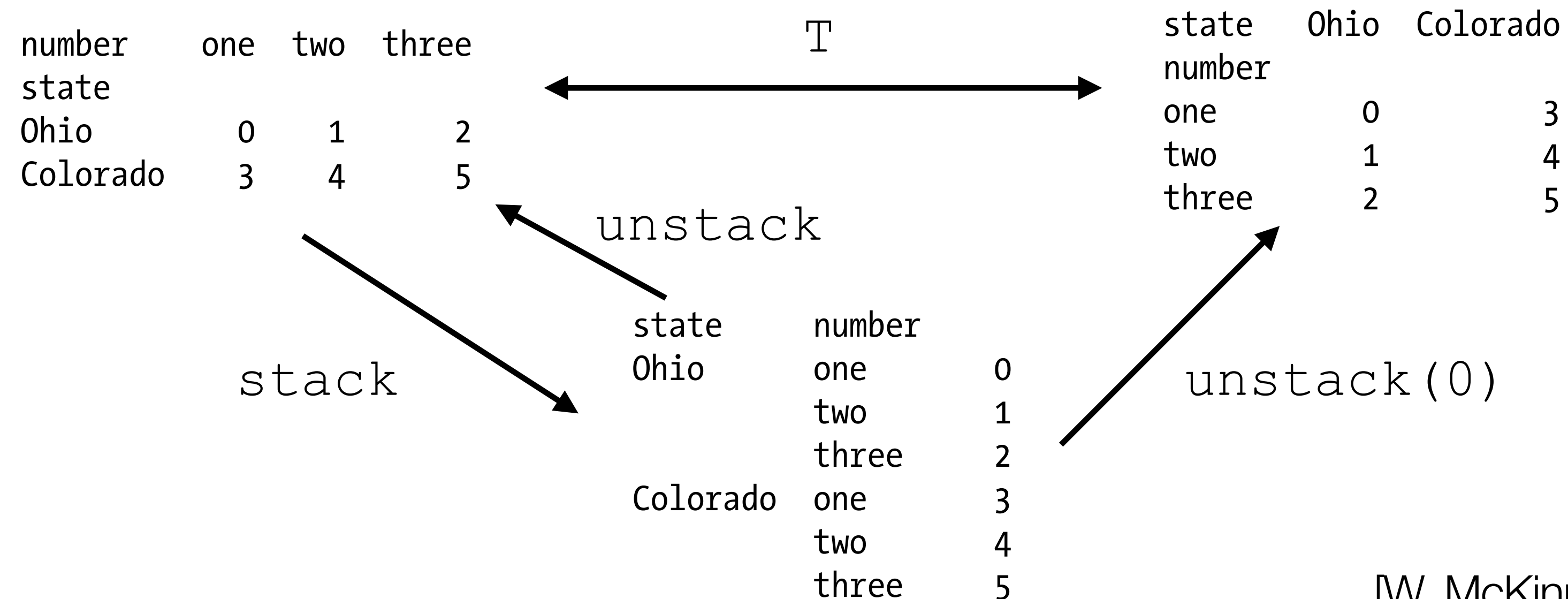
state	Ohio	Colorado
number		
one	0	3
two	1	4
three	2	5

MultilIndex

state	number	
Ohio	one	0
	two	1
	three	2
Colorado	one	3
	two	4
	three	5

Stack and Unstack

- `stack`: pivots from the columns into rows (may produce a Series!)
- `unstack`: pivots from rows into columns
- unstacking may add missing data
- stacking filters out missing data (unless `dropna=False`)
- can unstack at a different level by passing it (e.g. 0), defaults to innermost level



[W. McKinney, Python for Data Analysis]

String Methods

- Can do many of the same methods used for single strings on entire columns
- Requires `.str` prefix before calling the method
 - `violations.value.str.strip().str.split(' - Comments:')`
- Also helps when extracting from a list
 - `comments.str[1]`

String Methods

Argument	Description
<code>count</code>	Return the number of non-overlapping occurrences of substring in the string.
<code>endswith</code>	Returns <code>True</code> if string ends with suffix.
<code>startswith</code>	Returns <code>True</code> if string starts with prefix.
<code>join</code>	Use string as delimiter for concatenating a sequence of other strings.
<code>index</code>	Return position of first character in substring if found in the string; raises <code>ValueError</code> if not found.
<code>find</code>	Return position of first character of <i>first</i> occurrence of substring in the string; like <code>index</code> , but returns <code>-1</code> if not found.
<code>rfind</code>	Return position of first character of <i>last</i> occurrence of substring in the string; returns <code>-1</code> if not found.
<code>replace</code>	Replace occurrences of string with another string.
<code>strip</code> , <code>rstrip</code> , <code>lstrip</code>	Trim whitespace, including newlines; equivalent to <code>x.strip()</code> (and <code>rstrip</code> , <code>lstrip</code> , respectively) for each element.
<code>split</code>	Break string into list of substrings using passed delimiter.
<code>lower</code>	Convert alphabet characters to lowercase.
<code>upper</code>	Convert alphabet characters to uppercase.
<code>casefold</code>	Convert characters to lowercase, and convert any region-specific variable character combinations to a common comparable form.
<code>ljust</code> , <code>rjust</code>	Left justify or right justify, respectively; pad opposite side of string with spaces (or some other fill character) to return a string with a minimum width.

[W. McKinney, Python for Data Analysis]

Support for Datetime

- Python has datetime library to support dates and times
- pandas has a Timestamp data type that functions somewhat similarly
- Pandas can convert timestamps
 - `pd.to_datetime`: versatile, can often guess format
- Like string methods, also a `.dt` accessor for datetime methods/properties
- With a timestamp, filtering based on datetimes becomes easier
 - `df[df['Inspection Date'] > '2021']`

Method chaining in pandas

- Tom Augspurger's [post](#)
- [Towards Data Science post](#) by Adiamann Keerthi
- Functions written for chaining, and pipe allows custom functions
- ```
def read(fp):
 df = (pd.read_csv(fp)
 .rename(columns=str.lower)
 .drop('unnamed: 36', axis=1)
 .pipe(extract_city_name)
 .pipe(time_to_datetime, ['dep_time', 'arr_time',
 'crs_arr_time', 'crs_dep_time'])
 .assign(fl_date=lambda x: pd.to_datetime(x['fl_date']),
 dest=lambda x: pd.Categorical(x['dest']),
 origin=lambda x: pd.Categorical(x['origin']),
 tail_num=lambda x: pd.Categorical(x['tail_num']),
 unique_carrier=lambda x: pd.Categorical(x['unique_carrier']),
 cancellation_code=lambda x: pd.Categorical(x['cancellation_code'])))
 return df
```

# Example: Inspect Intermediate Results

---

- ```
def csnap(df, fn=lambda x: x.shape, msg=None):  
    """ Custom Help function to print things in method chaining.  
        Returns back the df to further use in chaining.  
    """  
    if msg:  
        print(msg)  
    display(fn(df))  
    return df
```
- ```
wine.pipe(csnap) # display data frame
 .rename(columns={"color_intensity": "ci"})
 .assign(color_filter=lambda x: np.where(x.hue > 1, 1, 0))
 .pipe(csnap) # display data frame
...
```



# Food Inspections Example

# Teaching Evaluations