LECTURE 8

Text Wrangling and Regex

Using string methods and regular expressions (regex) to work with textual data

Data Science@ Knowledge Stream

Sana Jabbar

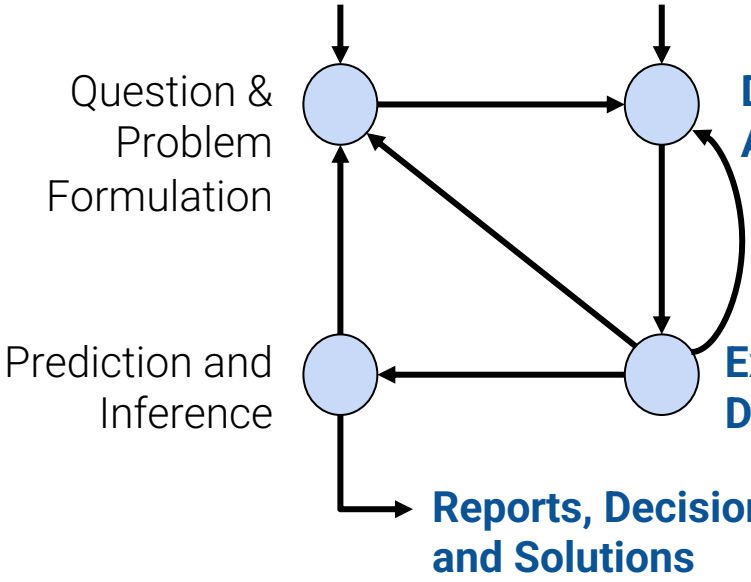
Goals for this Lecture

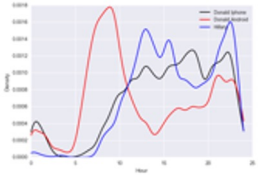
Lecture 08

Deal with a major challenge of EDA: cleaning text

- Operate on text data using `str` methods
- Apply regex to identify patterns in strings

This Week





(Last weeks)

Data Wrangling
Intro to EDA

(Today)

Working with Text Data
Regular Expressions

(Next)

Visualization
Code for plotting data

Agenda

Lecture 08

- Why work with text?
- pandas str methods
- Why regex?
- Regex basics
- Regex functions

Why Work With Text?

Lecture 08

- **Why work with text?**
- `pandas str` methods
- Why regex?
- Regex basics
- Regex functions

Why Work With Text? Two Common Goals

1. **Canonicalization**: Convert data that has more than one possible presentation into a standard form.

Ex Join tables with mismatched labels

	County	State
0	De Witt County	IL
1	Lac qui Parle County	MN
2	Lewis and Clark County	MT
3	St John the Baptist Parish	LA

	County	Population
0	DeWitt	16798
1	Lac Qui Parle	8067
2	Lewis & Clark	55716
3	St. John the Baptist	43044

	County	State	Population
0	dewitt	IL	16798
1	lacquiparle	MN	8067
2	lewisandclark	MT	55716
3	stjohnthebaptist	LS	43044

Why Work With Text? Two Common Goals

1. **Canonicalization**: Convert data that has more than one possible presentation into a standard form.

Ex Join tables with mismatched labels

	County	State
0	De Witt County	IL
1	Lac qui Parle County	MN
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	County	Population
0	DeWitt	16798
1	Lac Qui Parle	8067
2	Lewis & Clark	55716
3	St. John the Baptist	43044

join?

	County	Population	State
0	dewitt	16798	IL
1	lacquiparle	8067	MN
2	lewisandclark	55716	MT
3	stjohnthebaptist	43044	LS

2. **Extract** information into a new feature.

Ex Extract dates and times from log files

```
169.237.46.168 - -
[26/Jan/2014:10:47:58 -0800] "GET
/stat141/Winter04/ HTTP/1.1" 200 2585
"http://anson.ucdavis.edu/courses/"
```

```
day, month, year = "26", "Jan", "2014"
hour, minute, seconds = "10", "47", "58"
```

Pandas str Methods

Lecture 08

- Why work with text?
- **Pandas str methods**
- Why regex?
- Regex basics
- Regex functions

From String to `str`

In “base” Python, we have various string operations to work with text data.

Recall:

transformation	`s.lower()` `s.upper()`
split	`s.split(…)`
membership	`'ab' in s`

replacement/ deletion	`s.replace(…)`
substring	`s[1:4]`
length	`len(s)`

Problem: Python assumes we are working with one string at a time
Need to loop over each entry – slow in large datasets!

`str` Methods

Fortunately, pandas offers a method of **vectorizing** text operations: the `.str` operator

```
Series.str.string_operation()
```

Apply the function `string_operation` to *every* string contained in the `Series`

```
populations["County"].str.lower()
```

```
0                  dewitt
1            lac qui parle
2            lewis & clark
3    st. john the baptist
Name: County, dtype: object
```

```
populations["County"].str.replace('&', 'and')
```

```
0                  DeWitt
1            Lac Qui Parle
2          Lewis and Clark
3    St. John the Baptist
Name: County, dtype: object
```

`.str` Methods

Most base Python string operations have a `pandas str` equivalent

Operation	Python (single string)	pandas (Series of strings)
transformation	`s.lower()` `s.upper()`	`ser.str.lower()` `ser.str.upper()`
replacement/ deletion	`s.replace(…)`	`ser.str.replace(…)`
split	`s.split(…)`	`ser.str.split(…)`
substring	`s[1:4]`	`ser.str[1:4]`
membership	`'ab' in s`	`ser.str.contains(…)`
length	`len(s)`	`ser.str.len()`

Example

Demo 1: Canonicalization

	County	State
0	De Witt County	IL
1	Lac qui Parle County	MN
2	Lewis and Clark County	MT
3	St John the Baptist Parish	LA

	County	Population
0	DeWitt	16798
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	County	State	Population
0	dewitt	IL	16798
1	lacquiparle	MN	8067
2	lewisandclark	MT	55716
3	stjohnthebaptist	LS	43044

```
def canonicalize_county(county_series):
 return (county_series
              .str.lower() # lowercase
              .str.replace(' ', '')  # remove space
              .str.replace('&', 'and')   # replace &
              .str.replace('.', '')      # remove dot
               .str.replace('county', '')
               .str.replace('parish', '')  )
```

Why regex?

Lecture 08

- Why work with text?
- `pandas str` methods
- **Why regex?**
- Regex basics
- Regex functions

Flexibility Matters!

```
169.237.46.168 - -
[26/Jan/2014:10:47:58 -0800] "GET
/stat141/Winter04/ HTTP/1.1" 200 2585
"http://anson.ucdavis.edu/courses/"
```

```
193.205.203.3 - -
[2/Feb/2005:17:23:6 -0800] "GET
/stat141/Notes/dim.html HTTP/1.0" 404 302
"http://eeyore.ucdavis.edu/stat141/Notes/
session.html"
```

Formatting varies:

- Different # of characters before the date
- Different format for the day of the month
- Different # of characters after the date

We don’t always know the exact format of our data in advance.

Flexibility Matters!

We made a big assumption in the previous example: knowing for certain what changes needed to be made to the text. “Eyeballing” the steps needed for canonicalization.

Consider our data extraction task from before – pulling out dates from log data:

```
169.237.46.168 - -
[26/Jan/2014:10:47:58 -0800] "GET
/stat141/Winter04/ HTTP/1.1" 200 2585
"http://anson.ucdavis.edu/courses/"
```

```
193.205.203.3 - -
[2/Feb/2005:17:23:6 -0800] "GET
/stat141/Notes/dim.html HTTP/1.0" 404 302
"http://eeyore.ucdavis.edu/stat141/Notes/
session.html"
```

Example

Demo: Extracting Date Information

```
169.237.46.168 - -
[26/Jan/2014:10:47:58 -0800] "GET
/stat141/Winter04/ HTTP/1.1" 200 2585
"http://anson.ucdavis.edu/courses/"
```



```
day, month, year = "26", "Jan", "2014"
hour, minute, seconds = "10", "47", "58"
```

One possible solution:

```
pertinent = line.split("[")[1].split(']')[0]
day, month, rest  = pertinent.split('/')
year, hour, minute, rest = rest.split(':')
seconds, time_zone       = rest.split(' ')
```

String Extraction: An Alternate Approach

While we can hack together code that uses **`replace/split`**…

```
pertinent = line.split("[")[1].split(']')[0]
day, month, rest = pertinent.split('/')
year, hour, minute, rest = rest.split(':')
seconds, time_zone = rest.split(' ')
```

An alternate approach is to use a **regular expression**:

- Implementation provided in the Python **`re`** library and the pandas **`str`** accessor.
- Next, we'll spend some time working up to expressions like this one:

```
import re
pattern = r'\[(\d+)\/(\w+)\/(\d+):(\d+):(\d+):(\d+) (.+)\]'
day, month, year, hour, minute, second, time_zone = re.findall(pattern, line)[0]
```

Related: How would you extract all the **moon**-like patterns in this string?

```
"moon moo mooooooon mon moooon"
```

Seem impossible?

Regex Basics

Lecture 08

- Why work with text?
- `pandas str` methods
- Why regex?
- **Regex basics**
- Regex functions

A Regular Expression Describes a Set of Strings Through *Patterns*

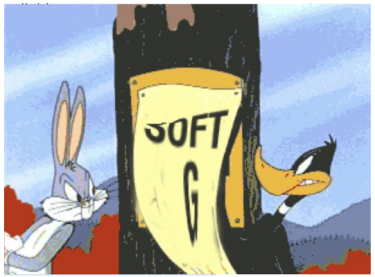
A regular expression (“regex”) is a sequence of characters that specifies a search *pattern*.

Example: `[0-9]{3}-[0-9]{2}-[0-9]{4}`

3 of any digit, then a dash,
then 2 of any digit, then a dash,
then 4 of any digit.

The language of Social Security Numbers is described by this regular expression.

Formal language, described implicitly



“Regex” pronunciation?

Goals for regex

The goal of today is NOT to memorize regex!

Instead:

1. Understand what regex is capable of.
2. Parse and create regex, **with a reference table**.

high-level

3. Use vocabulary (metacharacter, escape character, groups, etc.) to **describe regex** metacharacters.
4. **Differentiate** between `( )`, `[ ]`, `{}`
5. Design your own **character classes** with `\d`, `\w`, `\s`, `[ …-… ]`, `^`, etc.
6. Use Python and `pandas` regex methods.

details; hone with practice

Regex Basics

There are four basic operations in regex.

Concatenation – "look for consecutive characters"

`AABAAB` matches `AABAAB`

`|` – "or"

`AA|BAAB` matches `AA` *or* `BAAB`

`*` – "zero or more"

`AB*A` matches `AA, ABA, ABBA, …`

`()` – "consider a group"

`(AB)*A` matches `A, ABA, ABABA, …`
`A(A|B)AAB` matches `AAAAB` *or* `ABAAB`

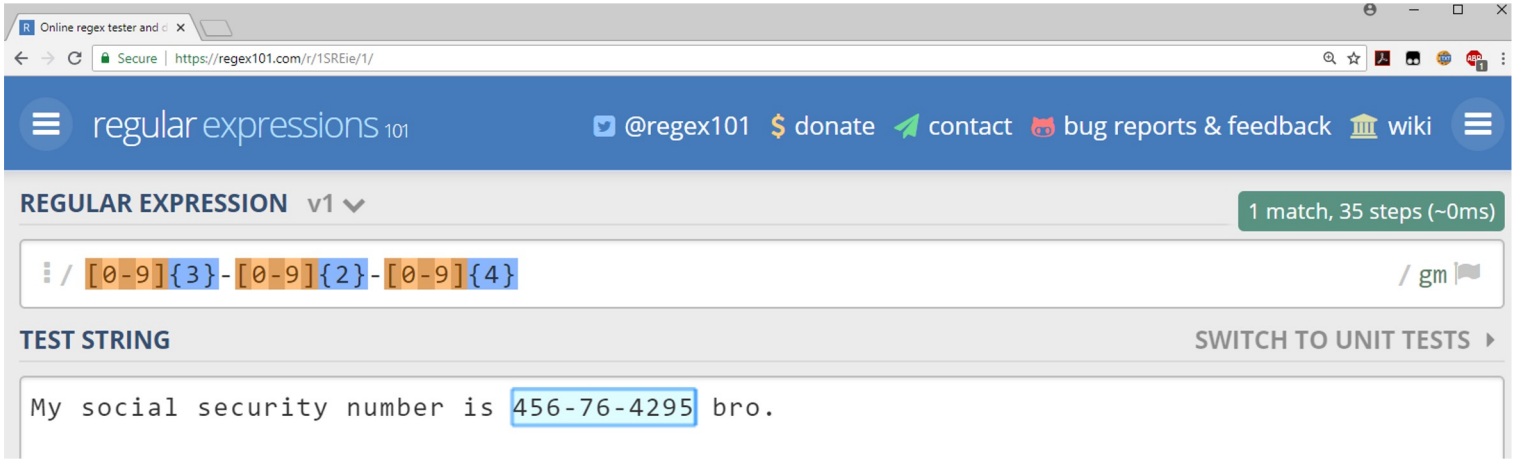
*, ( ), and | are called **metacharacters** – they represent an operation, rather than a literal text character

Resources for Practicing regex

There are many nice resources out there to experiment with regular expressions (e.g. regex101.com, regexone.com, Sublime Text).

I recommend trying out regex101.com, which provides a visually appealing and easy to use platform for experimenting with regular expressions.

- **Important:** choose the Python “flavor” in the left sidebar



In the Python docs: the RegEx HOWTO, *Not* The re Module Documentation

The Python Regular Expression HOWTO: https://docs.python.org/3/howto/regex.html.

Make an empty notebook and play with the examples therein. Regex101 is phenomenal for learning basic regex *syntax,* but less so for learning the full functionality of regular expressions in programming (matching, splitting, search and replace, group management, …).

The examples can be pasted in directly:

```
>>> import re
>>> p = re.compile('[a-z]+')
>>> p
re.compile('[a-z]+')
```

In the Python docs: the RegEx HOWTO, *Not* The re Module Documentation

The Python Regular Expression HOWTO: https://docs.python.org/3/howto/regex.html.

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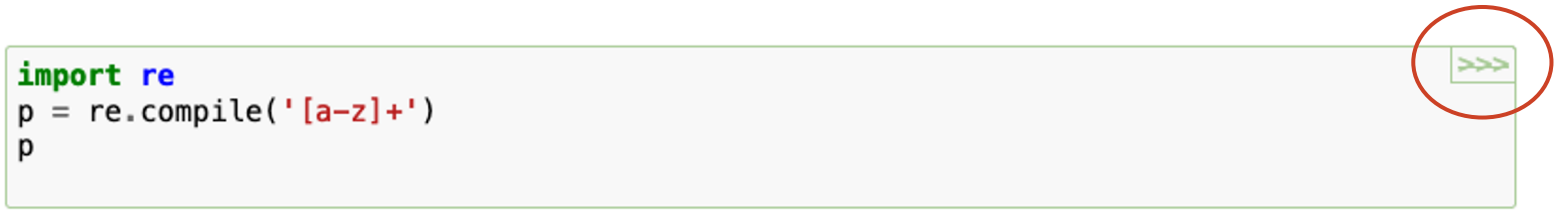

Summary So Far

Operation	Order	Example	Matches	Doesn't match
concatenation (consecutive chars)	3	`AABAAB`	`AABAAB`	every other string
or, |	4	`AA|BAAB`	`AA` `BAAB`	every other string
***** (zero or more)	2	`AB*A`	`AA` `ABBBBBBA`	`AB` `ABABA`
group (parenthesis)	1	`A(A|B)AAB`	`AAAAB` `ABAAB`	every other string
		`(AB)*A`	`A` `ABABABABA`	`AA` `ABBA`

The regex order of operations. Grouping is evaluated first.

Regex Expanded

Six more regex operations.

. – "look for *any* character"

`.U.U.U.` matches `CUMULUS, JUGULUM`

[ ] – "define a character class"

`[A-Za-z]` matches `A, a, B, b…`

+ – "one or more"

`AB+` matches `AB, ABB, ABBB, …`

? – "zero or one" ("optional")

`AB?` matches `A, AB`

{x} – "repeat exactly x times"

`AB{2}` matches `ABB`

{x, y} – "repeat between x and y times"

`AB{0,2}` matches `A, AB, ABB`

(yes, it means these are the same: ***** = **{0,}**, **+** = **{1,}**, and **?** = **{0,1}**)

Character Classes

A character class describes a set of characters belonging to the class.

[A-Z] – any uppercase letter between A and Z

[0-9] – any digit between 0 and 9

[A-Za-z0-9] – any letter, any digit

Regex built-in classes:

\w is equivalent to [A-Za-z0-9]

\d is equivalent to [0-9]

\s matches whitespace

Use **^** to negate a class = match any character *other* than what follows

[^A-Z] – anything that is *not* an uppercase letter between A and Z

Equivalently, the capital versions of the regex built-in classes are negations: `\W`, `\D`, and `\S`

Summary So Far

Operation	Example	Matches	Doesn't match
any character (except newline)	`.U.U.U.`	`CUMULUS` `JUGULUM`	`SUCCUBUS` `TUMULTUOUS`
character class	`[A-Za-z][a-z]*`	`word` `Capitalized`	`camelCase` `4illegal`
repeated exactly a times: {a}	`j[aeiou]{3}hn`	`jaoehn` `jooohn`	`jhn` `jaeiouhn`
repeated from a to b times: {a,b}	`j[ou]{1,2}hn`	`john` `juohn`	`jhn` `jooohn`
at least one	`jo+hn`	`john` `jooooooohn`	`jhn` `jjohn`

Greediness

Regex is **greedy** – it will look for the *longest possible* match in a string

```
<div>.*</div>
```

“This is a ** example ** of greediness in regular expressions.”

Greediness

Regex is **greedy** – it will look for the *longest possible* match in a string

```
<div>.*</div>
```

In English:

- “Look for the exact string "
- then, “look for any character 0 or more times”
- then, “look for the exact string "

> “This is a ** example ** of greediness in regular expressions.”

Greediness

Regex is **greedy** – it will look for the *longest possible* match in a string

```
<div>.*</div>
```

In English:

- "Look for the exact string "
- then, "look for any character 0 or more times"
- then, "look for the exact string "

> "This is a ** example ** of greediness in regular expressions."

We can fix this by making the pattern **non-greedy:**

```
<div>.*?</div>
```

Regex *Even More* Expanded

The last set.

**** – "read the next character literally"

`a\+b` matches `a+b`

^ – "match the beginning of a string"

`^abc` does not match "`123 abc`"

$ – "match the end of a string"

`abc$` does not match "`abc 123`"

Be careful: ^ has different behavior inside/outside of character classes!

Summary So Far

Operation	Example	Matches	Doesn't match
beginning of line	`^ark`	`ark two` `ark o ark`	`dark`
end of line	`ark$`	`dark` `ark o ark`	`ark two`
escape character	`cow\.com`	`cow.com`	`cowscom`

Regex Functions

Lecture 08

- Why work with text?
- `pandas str` methods
- Why regex?
- Regex basics
- **Regex functions**

Before We Begin: Raw Strings in Python

When specifying a pattern, we strongly suggest using **raw strings**.

- A raw string is created by prepending **`r`** to the string delimiters (**`r"..."`**, **`r'...'`**, **`r"""..."""`**, **`r'''...'''`**)
- The exact reason is a bit tedious.
  - Rough idea: Regular expressions and Python strings both use `\` as a special character.
  - Using non-raw strings leads to uglier regular expressions.

```
pattern = r"[0-9]+"
```

Regular String	Raw string
`"ab*"`	`r"ab*"`
`"\\\\section"`	`r"\\section"`
`"\\w+\\s+\\1"`	`r"\w+\s+\1"`

For more information see “The Backslash Plague” under
https://docs.python.org/3/howto/regex.html#the-backslash-plague

Extraction

`re.findall(pattern, text)`

Return a list of all matches to `pattern`.

```
text = "My social security number is 123-45-6789 bro, or actually maybe it's 321-45-6789.";
pattern = r"[0-9]{3}-[0-9]{2}-[0-9]{4}"
re.findall(pattern, text)
```

```
['123-45-6789', '321-45-6789']
```

A **match** is a substring that matches the provided regex.

Extraction

`re.findall(pattern, text)`

Return a list of all matches to `pattern`.

```
text = "My social security number is 123-45-6789 bro, or actually maybe it's 321-45-6789.";
pattern = r"[0-9]{3}-[0-9]{2}-[0-9]{4}"
re.findall(pattern, text)
```

```
['123-45-6789', '321-45-6789']
```

`ser.str.findall(pattern)`

Returns a Series of lists

```
df["SSN"].str.findall(pattern)
```

	SSN
0	987-65-4321
1	forty
2	123-45-6789 bro or 321-45-6789
3	999-99-9999

```
0                  [987-65-4321]
1                             []
2  [123-45-6789, 321-45-6789]
3                  [999-99-9999]
Name: SSN, dtype: object
```

Extraction with Capture Groups

Earlier we used parentheses to specify the **order of operations**.

Parenthesis can have another meaning:

- When using certain regex functions, ( ) specifies a **capture group**.
- Extract *only* the portion of the regex pattern inside the capture group

```
text = """I will meet you at 08:30:00 pm tomorrow"""
pattern = "(\d\d):(\d\d):(\d\d)"
matches = re.findall(pattern, text)
matches
```

```
[('08', '30', '00')]
```


The capture groups each capture two digits.

Extraction with Capture Groups

`ser.str.extract(pattern)`

Returns a DataFrame of each capture group's **first** match in the string

```
pattern_cg = r"([0-9]{3})-([0-9]{2})-([0-9]{4})"
df["SSN"].str.extract(pattern_cg)
```

	SSN
0	987-65-4321
1	forty
2	123-45-6789 bro or 321-45-6789
3	999-99-9999

	0	1	2
0	987	65	4321
1	NaN	NaN	NaN
2	123	45	6789
3	999	99	9999

`ser.str.extractall(pattern)`

Returns a multi-indexed DataFrame of **all** matches for each capture group

```
df["SSN"].str.extractall(pattern_cg)
```

	SSN
0	987-65-4321
1	forty
2	123-45-6789 bro or 321-45-6789
3	999-99-9999

		0	1	2
	match			
0	0	987	65	4321
2	0	123	45	6789
	1	321	45	6789
3	0	999	99	9999

Substitution

`re.sub(pattern, repl, text)`

Returns text with all instances of **`pattern`** replaced by **`repl`**.

```
text = '<div><tdvalign="top">Moo</td></div>'
pattern = r"<[^>]+>"
re.sub(pattern, '', text) # returns Moo
```


`Moo`

How it works:

- **`pattern`** matches HTML tags
- Then, sub/replace HTML tags with **`repl=''`** (i.e., empty string)

Substitution

`re.sub(pattern, repl, text)`

Returns text with all instances of **`pattern`** replaced by **`repl`**.

```
text = '<div><td
valign="top">Moo</td></div>'
pattern = r"<[^>]+>"
re.sub(pattern, '', text) # returns Moo
```

```
Moo
```

How it works:

- **`pattern`** matches HTML tags
- Then, sub/replace HTML tags with **`repl=''`** (i.e., empty string)

`ser.str.replace(pattern, repl, regex=True )`

Returns Series with all instances of **`pattern`** in Series **`ser`** replaced by **`repl`**.

```
df["Html"].str.replace(pattern, '')
```

	Html
0	<td valign="top">Moo</td>
1	Link
2	Bold text

```
0          Moo
1         Link
2    Bold text
Name: Html, dtype: object
```

String Function Summary

Base Python	re	pandas str
`s.lower()` `s.upper()`		`ser.str.lower()` `ser.str.upper()`
`s.replace(…)`	`re.sub(…)`	`ser.str.replace(…)`
`s.split(…)`	`re.split(…)`	`ser.str.split(…)`
`s[1:4]`		`ser.str[1:4]`

	`re.findall(…)`	`ser.str.findall(…)`
		`ser.str.extractall(…)`
		`ser.str.extract(…)`

`'ab' in s`	`re.search(…)`	`ser.str.contains(…)`
`len(s)`		`ser.str.len()`
`s.strip()`		`ser.str.strip()`

Limitations of Regular Expressions

Writing regular expressions is like writing a program.

- Need to know the syntax well.
- Can be easier to write than to read.
- Can be difficult to debug.

Regular expressions sometimes jokingly referred to as a "**write only language**". A famous 1997 quote from Jamie Zawinski (co-creator of Firefox's predecessor)

> *Some people, when confronted with a problem, think "I know, I'll use regular expressions." Now they have two problems.*

Regular expressions are terrible at certain types of problems:

- For parsing a hierarchical structure, such as JSON, use the `json.load()` parser, not regex!
- Parsing real-world HTML/xml (lots of ...<tag>..</tag>..): use `html.parser`.
- Complex features (e.g. valid email address).
- Counting (same number of instances of a and b). (impossible)

However, regular expressions are decent at **wrangling text data**.

Start Work on notebook