LECTURE 7

Regular Expressions

Using string methods and regular expressions to work with textual data

Data 100/Data 200, Fall 2021 @ UC Berkeley

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(content by Josh Hug)

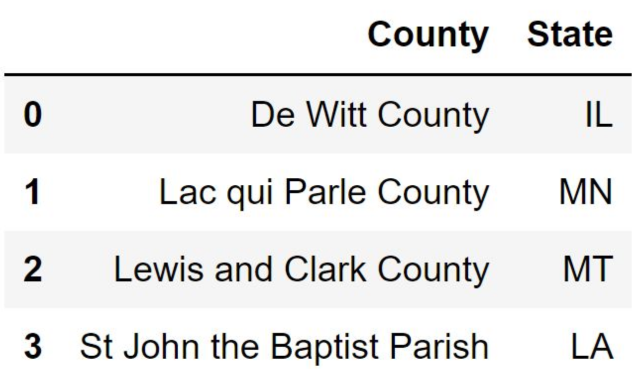
Goals For This Lecture

Working With Text Data

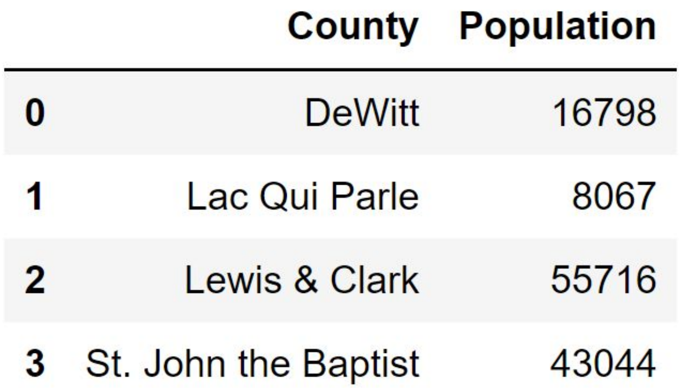
- Canonicalizing text data.
- Extracting data from text.
  - Using **split.**
  - Using **regular expressions.**

String Canonicalization

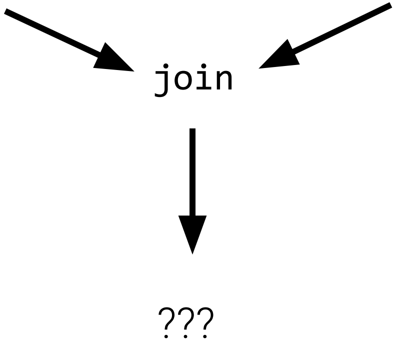
Goal 1: Joining Tables with Mismatched Labels



	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



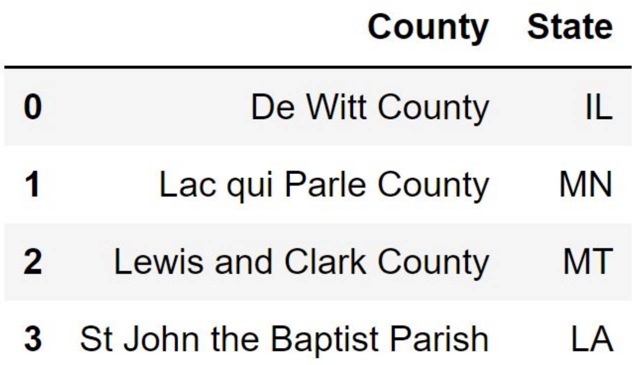
	County	Population
0	DeWitt	16798
1	Lac Qui Parle	8067
2	Lewis & Clark	55716
3	St. John the Baptist	43044



join

???

A Joining Problem



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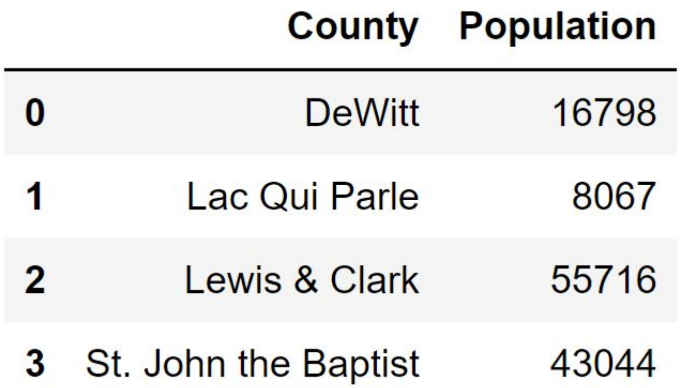

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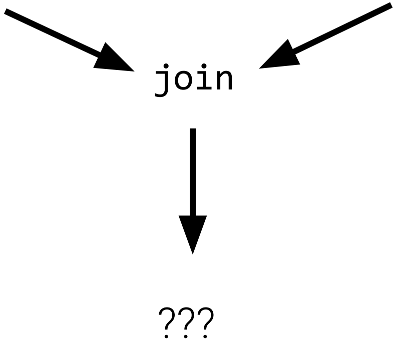


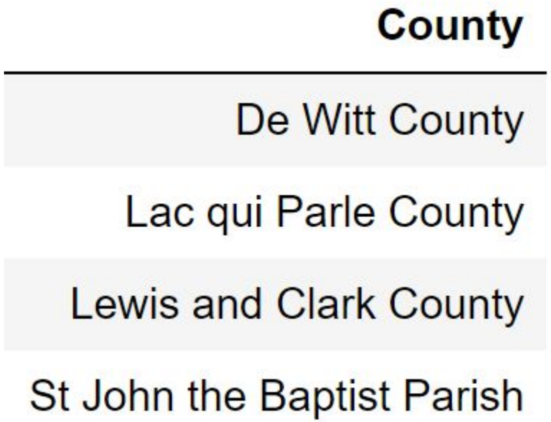
`join`

???

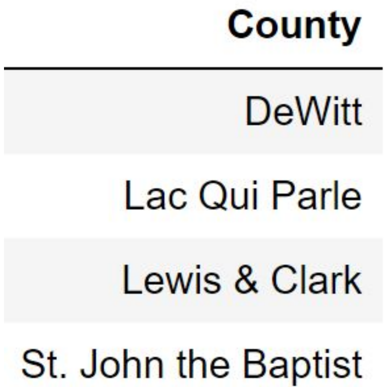
To join our tables we'll need to **canonicalize** the county names.

- Canonicalize: Convert data that has more than one possible presentation into a standard form.

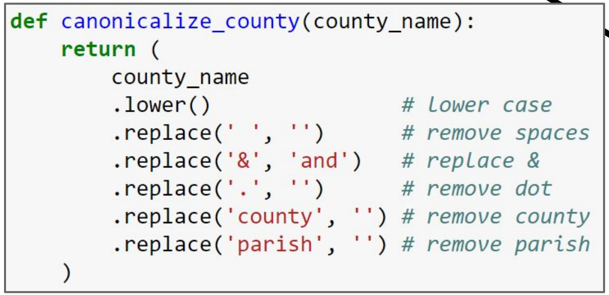
Canonicalizing County Names



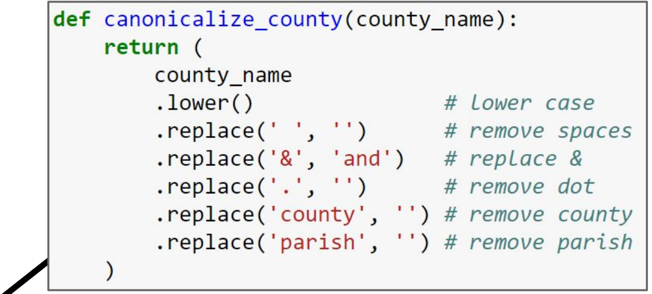
County
De Witt County
Lac qui Parle County
Lewis and Clark County
St John the Baptist Parish



County
DeWitt
Lac Qui Parle
Lewis & Clark
St. John the Baptist



```python
def canonicalize_county(county_name):
    return (
        county_name
        .lower()               # lower case
        .replace(' ', '')      # remove spaces
        .replace('&', 'and')   # replace &
        .replace('.', '')      # remove dot
        .replace('county', '') # remove county
        .replace('parish', '') # remove parish
    )
```



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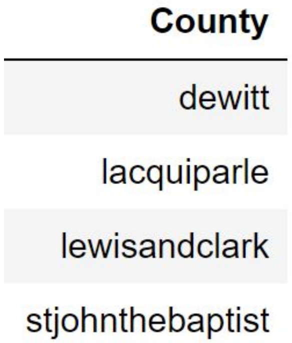


County
dewitt
lacquiparle
lewisandclark
stjohnthebaptist

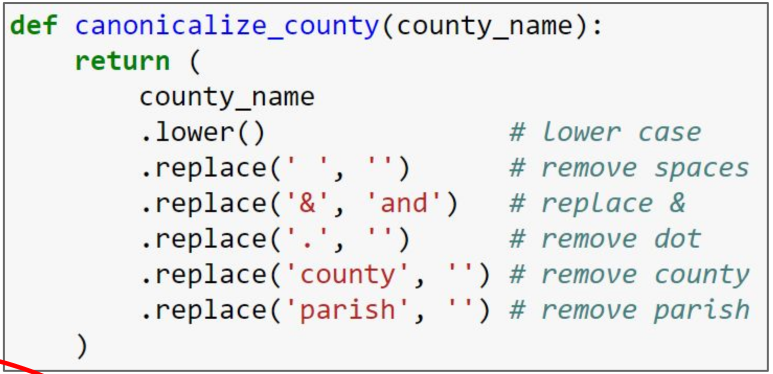
Canonicalization

Canonicalization:

- Replace each string with a unique representation.
- Feels very “hacky”, but messy problems often have messy solutions.

Can be done slightly better but not by much →

- Code is very brittle! Requires maintenance.



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        .replace('county', '') # remove county
        .replace('parish', '') # remove parish
    )
```

Tools used:

Replacement	`str.replace(‘&’, ‘and’)`
Deletion	`str.replace(‘ ‘, ‘’)`
Transformation	`str.lower()`

Extracting From Text Using Split

Goal 2: Extracting Date Information

Suppose we want to extract times and dates from web server logs that look like the following:

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

Goal 2: Extracting Date Information

Suppose we want to extract times and dates from web server logs that look like the following:

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

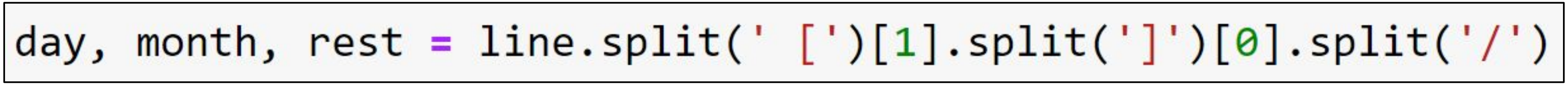
There are existing libraries that do most of the work for us, but let’s try to do it from scratch.

- Will do together, just a little bit at a time.
- Let’s go check out `lec08-working-with-text.ipynb`.

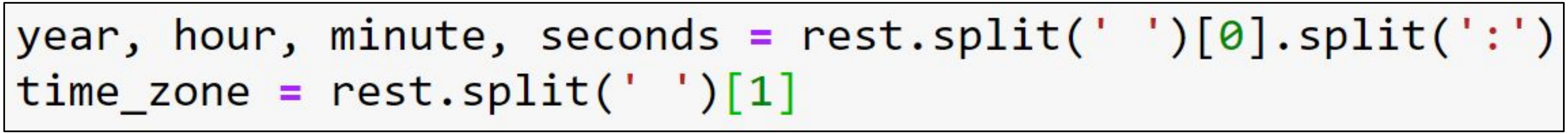
Extracting Date Information

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

One possible solution:



```
day, month, rest = line.split(' [')[1].split(']')[0].split('/')
```



```
year, hour, minute, seconds = rest.split(' ')[0].split(':')
time_zone = rest.split(' ')[1]
```

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/"
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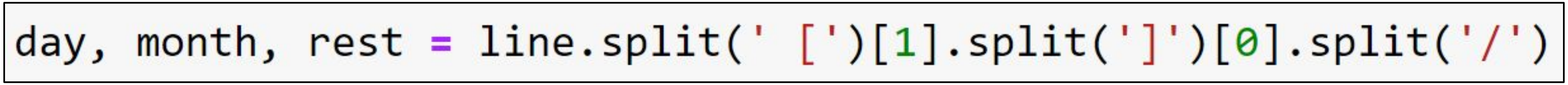

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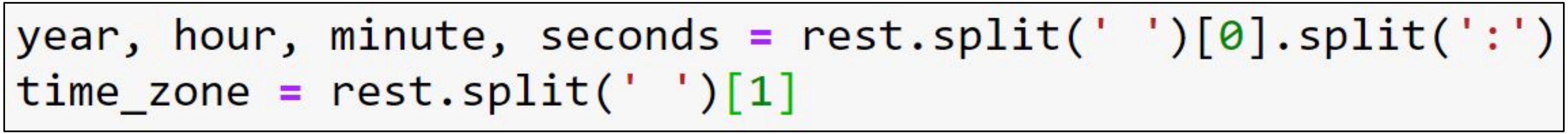


```
year, hour, minute, seconds = rest.split(' ')[0].split(':')
time_zone = rest.split(' ')[1]
```

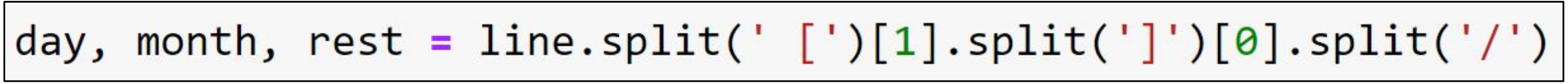
What if webserver
changes log formats,
or has a bug?

⇒ *This solution breaks!! (brittle)*

Regular Expression Basics

Extracting Date Information

Earlier we saw that we can hack together code that uses split to extract info:



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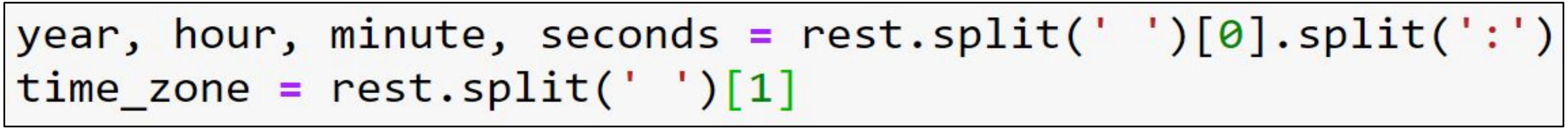
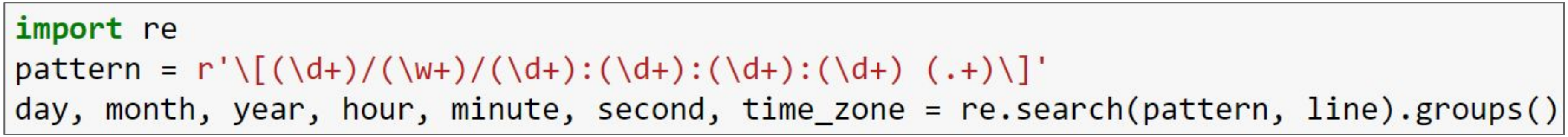
day, month, rest = line.split(' [')[1].split(']')[0].split('/')
```



```
year, hour, minute, seconds = rest.split(' ')[0].split(':')
time_zone = rest.split(' ')[1]
```

An alternate approach is to use a so-called “regular expression”:

- Implementation provided in the **re** library built into Python.
- We’ll spend some time today working up to expressions like shown below.



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

Regular Expressions

A *formal language* is a set of strings, typically described implicitly.

- Example: “The set of all strings of length < 10 that contain ‘horse’”

A *regular language* is a formal language that can be described by a *regular expression* (which we will define soon).

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

The language of SSNs is described by this regular expression.

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

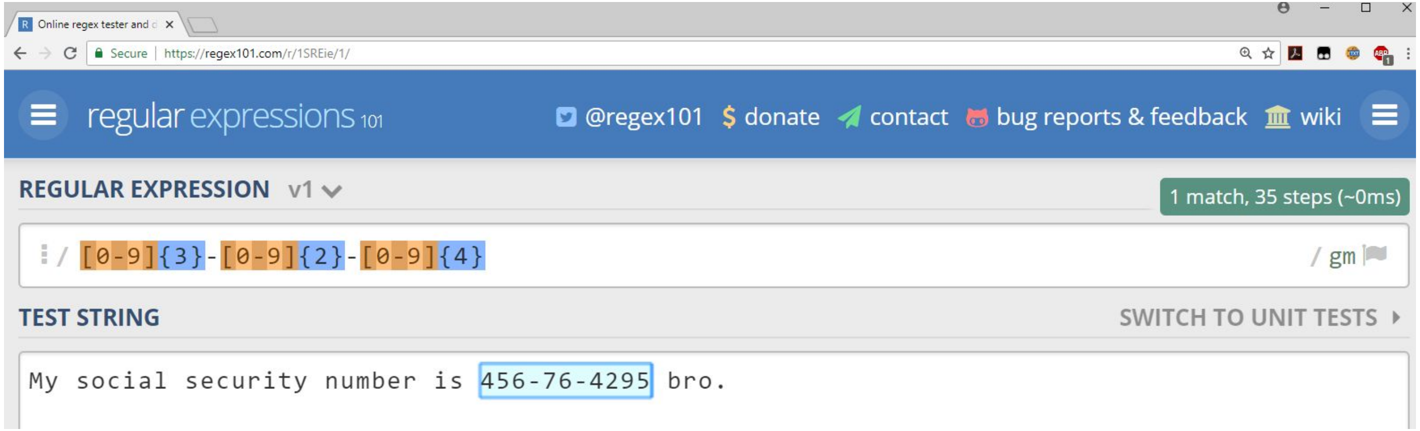
```
text = "My social security number is 123-45-6789.";
pattern = r"[0-9]{3}-[0-9]{2}-[0-9]{4}"
re.findall(pattern, text)
```

Regex101.com (or the online tutorial regexone.com)

There are a ton of nice resources out there to experiment with regular expressions (e.g. regex101.com, regexone.com, sublime text, python, etc).

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

- Example: https://regex101.com/r/1SREie/1



```
/ [0-9]{3}-[0-9]{2}-[0-9]{4} / gm
```

```
My social security number is 456-76-4295 bro.
```

Regular Expression Syntax

The four basic operations for regular expressions.

- Can technically do anything with just these basic four (albeit tediously).

operation	order	example	matches	does not match
concatenation	3	`AABAAB`	AABAAB	every other string
or	4	`AA|BAAB`	AA BAAB	every other string
closure (zero or more)	2	`AB*A`	AA ABBBBBBA	AB ABABA
parenthesis	1	`A(A|B)AAB`	AAAAB ABAAB	every other string
		`(AB)*A`	A ABABABABA	AA ABBA

Regular Expression Syntax

AB*: A then zero or more copies of B: A, AB, ABB, ABBB

(AB)*: Zero or more copies of AB: ABABABAB, ABAB, AB,

Matches the empty string!

operation	order	example	matches	does not match
concatenation	3	AABAAB	AABAAB	every other string
or	4	AA|BAAB	AA BAAB	every other string
closure (zero or more)	2	AB*A	AA ABBBBBBA	AB ABABA
parenthesis	1	A(A|B)AAB	AAAAB ABAAB	every other string
		(AB)*A	A ABABABABA	AA ABBA

Puzzle: Use regex101.com to test! Or tinyurl.com/reg913z

operation	order	example	matches	does not match
concatenation	3	AABAAB	AABAAB	every other string
or	4	AA|BAAB	AA BAAB	every other string
closure (zero or more)	2	AB*A	AA ABBBBBBA	AB ABABA
parenthesis	1	A(A|B)AAB	AAAAB ABAAB	every other string
		(AB)*A	A ABABABABA	AA ABBA

Give a regular expression that matches moon, moooon, etc. Your expression should match any **even** number of os except zero (i.e. don’t match mn).

Puzzle Solution

operation	order	example	matches	does not match
concatenation	3	AABAAB	AABAAB	every other string
or	4	AA|BAAB	AA BAAB	every other string
closure (zero or more)	2	AB*A	AA ABBBBBBA	AB ABABA
parenthesis	1	A(A|B)AAB	AAAAB ABAAB	every other string
		(AB)*A	A ABABABABA	AA ABBA

Solution to puzzle on previous slide: moo(oo)*n

Regular Expression moo(oo)*n: https://tinyurl.com/reg913m

operation	order	example	matches	does not match
concatenation	3	AABAAB	AABAAB	every other string
or	4	AA|BAAB	AA BAAB	every other string
closure (zero or more)	2	AB*A	AA ABBBBBBA	AB ABABA
parenthesis	1	A(A|B)AAB	AAAAB ABAAB	every other string
		(AB)*A	A ABABABABA	AA ABBA

Give a regex that matches muun, muuuun, moon, moooon, etc. Your expression should match any even number of us or os except zero (i.e. don’t match mn).

Puzzle Solution

operation	order	example	matches	does not match
concatenation	3	AABAAB	AABAAB	every other string
or	4	AA|BAAB	AA BAAB	every other string
closure (zero or more)	2	AB*A	AA ABBBBBBA	AB ABABA
parenthesis	1	A(A|B)AAB	AAAAB ABAAB	every other string
		(AB)*A	A ABABABABA	AA ABBA

Solution to puzzle on previous slide: `m(uu(uu)*|oo(oo)*)n`

- Note: `m(uu(uu)*)|(oo(oo)*)n` is not correct! OR must be in parentheses!

Order of Operations in Regexes

`m(uu(uu)*|oo(oo)*)n`

- Matches starting with m and ending with n, with either of the following in the middle:
  - `uu(uu)*`
  - `oo(oo)*`

Match examples:

```
muun
muuuun
moon
moooon
```

Order of Operations in Regexes

`m(uu(uu)*|oo(oo)*)n`

- Matches starting with m and ending with n, with either of the following in the middle:
  - `uu(uu)*`
  - `oo(oo)*`

Match examples:

```
muun
muuuun
moon
moooon
```

`m(uu(uu)*)|(oo(oo)*)n`

- Matches either of the following
  - `m` followed by `uu(uu)*`
  - `oo(oo)*` followed by n

Match examples:

```
muu
muuuu
oon
oooon
```

In regexes | comes last.

Expanded Regular Expressions Syntax

Expanded Regex Syntax

operation	example	matches	does not match
any character (except newline)	one .U.U.U.	CUMULUS JUGULUM	2. SUCCUBUS TUMULTUOUS
character class	[A-Za-z][a-z]*	word Capitalized	upper camelCase numeric 4illegal
at least one	jo+hn	john jooooohn	0 jhn jjohn x0
zero or one *	joh?n	jon john	any other string
repeated exactly {a} times	j[aeiou]{3}hn 3>	jaoehn jooohn	0 jhn jaeiouhn 5
repeated from a to b times: {a,b}	j[ou]{1,2}hn	john juohn	jhn 0 jooohn 3

More Regular Expression Examples

regex	matches	does not match
.*SPB.*	RASPBERRY CRISPBREAD	no [SPB] SUBSPACE SUBSPECIES
[0-9]{3}-[0-9]{2}-[0-9]{4}	231-41-5121 573-57-1821	no hyphen 231415121 57-3571821 2 1 6
[a-z]+@([a-z]+\.)+(edu|com)	horse@pizza.com horse@pizza.food.com	frank_99@yahoo.com hug@cs no ".com"

Expanded Regex Puzzle: https://tinyurl.com/reg913w

operation	example	matches	does not match
any character (except newline)	.U.U.U.	CUMULUS JUGULUM	SUCCUBUS TUMULTUOUS
character class	[A-Za-z][a-z]*	word Capitalized	camelCase 4illegal
at least one	jo+hn	john	jhn
zero or one	joh?n	jon john	any other string
repeated exactly {a} times	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

Challenge: Give a regular expression for any lowercase string that has a repeated vowel (i.e. noon, peel, festoon, looop, etc).

Expanded Regex Puzzle Solution

operation	example	matches	does not match
any character (except newline)	.U.U.U.	CUMULUS JUGULUM	SUCCUBUS TUMULTUOUS
character class	[A-Za-z][a-z]*	word Capitalized	camelCase 4illegal
at least one	jo+hn	john	jhn
zero or one	joh?n	jon john	any other string
repeated exactly {a} times	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

Challenge: Give a regular expression for any lowercase string that has a repeated vowel (i.e. noon, peel, festoon, looop, etc): `[a-z]*(aa|ee|ii|oo|uu)[a-z]*`

Expanded Regex Syntax Puzzle: https://tinyurl.com/reg913v

operation	example	matches	does not match
any character (except newline)	.U.U.U.	CUMULUS JUGULUM	SUCCUBUS TUMULTUOUS
character class	[A-Za-z][a-z]*	word Capitalized	camelCase 4illegal
at least one	jo+hn	john	jhn
zero or one	joh?n	jon john	any other string
repeated exactly {a} times	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

Select “Unit Tests” then click “Run Tests” to test your regex.

Challenge: Give a regular expression for any string that contains both a lowercase letter and a number.

Expanded Regex Syntax Solution: https://tinyurl.com/reg913v

operation	example	matches	does not match
any character (except newline)	`.U.U.U.`	CUMULUS JUGULUM	SUCCUBUS TUMULTUOUS
character class	`[A-Za-z][a-z]*`	word Capitalized	camelCase 4illegal
at least one	`jo+hn`	john	jhn
zero or one	`joh?n`	jon john	any other string
repeated exactly {a} times	`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

Select “Unit Tests” then click “Run Tests” to test your regex.

Challenge: Give a regular expression for any string that contains both a lowercase letter and a number: `(.*[0-9].*[a-z].*)|(.*[a-z].*[0-9].*)`

More Advanced Regular Expressions Syntax

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.

> "Some people, when confronted with a problem, think ‘I know, I'll use regular expressions.’ Now they have two problems." - Jamie Zawinski (Source)

Regular expressions sometimes jokingly referred to as a “write only language”.

Regular expressions are terrible at certain types of problems. Examples:

- For parsing a hierarchical structure, such as JSON, use a parser, not a regex!
- Complex features (e.g. valid email address).
- Counting (same number of instances of a and b). (impossible)
- Complex properties (palindromes, balanced parentheses). (impossible)

Email Address Regular Expression (a probably bad idea)

The regular expression for email addresses (for the Perl programming language):

```
(?:(?:\r\n)?[ \t])*(?:(?:(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?: \r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[
\t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*))*@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\]
\000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\ ](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?: (?:\r\n)?[ \t])*))*|(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[
\t]))*"(?:(?:\r\n) ?[ \t])*)*\<(?:(?:\r\n)?[ \t])*(?:@(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[
\t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t] )*))*(?:,@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])* )(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*) *:(?:(?:\r\n)?[ \t])*)?(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r \n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t ]))*"(?:(?:\r\n)?[ \t])*))*@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\]( ?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(? :\r\n)?[ \t])*))*\>(?:(?:\r\n)?[ \t])*)|(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)? [ \t]))*"(?:(?:\r\n)?[ \t])*)*:(?:(?:\r\n)?[ \t])*(?:(?:(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]| \\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"
(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*))*@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\ ".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[
\t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[ \]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*|(?:[^()<>@,;:\\".\[\]
\000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|( ?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*)*\<(?:(?:\r\n)?[ \t])*(?:@(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([ ^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\
]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*(?:,@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\ r\\]|\\.)*\](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[
\t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\] |\\.)*\](?:(?:\r\n)?[ \t])*))*)*:(?:(?:\r\n)?[ \t])*)?(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\ .|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|"(?
:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*))*@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\". \[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[
\t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\] ]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*\>(?:(?:\r\n)?[
\t])*)(?:,\s*(?:(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\ ".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\]
\000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[ \["()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[ \t])*))*@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t
])+|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|
\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*|(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\".\[\ ]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[
\t]))*"(?:(?:\r\n)?[ \t])*)*\<(?:(?:\r\n)?[ \t])*(?:@(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\[" ()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[
\t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<> @,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*(?:,@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[
\t])+|\Z|(?=[\["()<>@, ;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\
".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*)*:(?:(?:\r\n)?[ \t])*)?(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\["()<>@,;:\\". \[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[
\t]))*"(?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z|(?=[\[ "()<>@,;:\\".\[\]]))|"(?:[^\"\r\\]|\\.|(?:(?:\r\n)?[ \t]))*"(?:(?:\r\n)?[
\t])*))*@(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\] \000-\031]+(?:(?:(?:\r\n)?[ \t]) +|\Z|(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*)(?:\.(?:(?:\r\n)?[ \t])*(?:[^()<>@,;:\\".\[\]
\000-\031]+(?:(?:(?:\r\n)?[ \t])+|\Z |(?=[\["()<>@,;:\\".\[\]]))|\[([^\[\]\r\\]|\\.)*\](?:(?:\r\n)?[ \t])*))*\>(?:(?:\r\n)?[ \t])*))*)?;\s*)
```

From: http://www.ex-parrot.com/~pdw/Mail-RFC822-Address.html

Even More Regular Expression Syntax

operation	example	matches	does not match
built-in character classes	\w+ word \d+ digit	fawef 231231	this person 423 people
character class negation	not lower case [^a-z]+	PEPPERS3982 17211!↑å	porch CLAmS
escape character	cow\.com	cow.com	cowscom

Suppose you want to match one of our special characters like . or [or]

- In these cases, you must “escape” the character using the backslash.
- You can think of the backslash as meaning “take this next character literally”.

Regular Expressions Puzzle: tinyurl.com/reg913a

operation	example	matches	does not match

built-in character classes	`\w+`
	`\d+`
		`fawef`
		`231231`
			`this person`
			`423 people`

character class negation	`[^a-z]+`	`PEPPERS3982`
		`17211!↑å`
			`porch`
			`CLAmS`

escape character	`cow\.com`	`cow.com`	`cowscom`

Create a regular expression that matches the red portion below.

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

Regular Expressions Puzzle Solution: tinyurl.com/reg913a

operation	example	matches	does not match

built-in character classes	`\w+`
	`\d+`
		`fawef`
		`231231`
			`this person`
			`423 people`

character class negation	`[^a-z]+`	`PEPPERS3982`
		`17211!↑å`
			`porch`
			`CLAmS`

escape character	`cow\.com`	`cow.com`	`cowscom`

Create a regular expression that matches the red portion below: `\[.*\]`

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

Quiz

Regex101 link: https://tinyurl.com/reg913

operation	example	matches	does not match

built-in character classes	`\w+`
	`\d+`
		`fawef`
		`231231`
			`this person`
			`423 people`

character class negation	`[^a-z]+`	`PEPPERS3982`
		`17211!↑å`
			`porch`
			`CLAmS`

escape character	`cow\.com`	`cow.com`	`cowscom`

Create a regular expression that matches anything inside of angle brackets <>, but none of the string outside of angle brackets.

- Example: `<div><td valign="top">Moo</td></div>`
- Moo should not match because it is not between < and >.
- Note: This is equivalent to the problem of matching HTML tags.

Even More Regular Expression Features

operation	example	matches	does not match

beginning of line	beginning
	`^ark`
		`ark two`
		`ark o ark`
			`dark`

end of line	`ark$`	`dark`
		`ark o ark`
			`ark two`

lazy version of zero or more *?	`5.*?5`	`5005`
		`55`
			`5005005`

try to match this part

5.*5 would match this!

A few additional common regex features are listed above.

- Won't discuss these in class, but might come up in discussion or hw.
- There are even more out there!

The official guide is good! https://docs.python.org/3/howto/regex.html

Regular Expressions in Python
(and Regex Groups)

re.findall in Python

In Python, `re.findall(pattern, text)` will return a list of all matches.

```
text = "My social security number is 456-76-4295 bro, or
actually maybe it’s 456-67-4295.";
pattern = r"[0-9]{3}-[0-9]{2}-[0-9]{4}"
m = re.findall(pattern, text)
print(m)
```

```
   ['456-76-4295', '456-67-4295']
```

re.sub in Python

In Python, **re.sub(pattern, repl, text)** will return **text** with all instances of **pattern** replaced by **repl**.

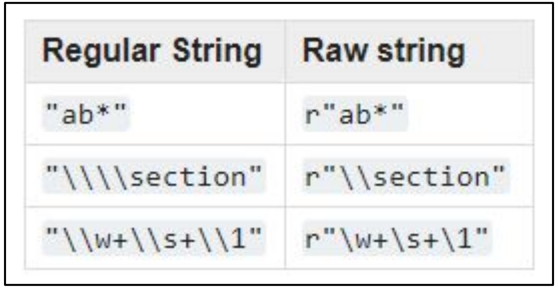
```
text = '<div><td valign="top">Moo</td></div>'
pattern = r"<[^>]+>"
cleaned = re.sub(pattern, '', text)
print(cleaned)
```

```
'Moo'
```

Raw Strings in Python

Note: When specifying a pattern, we strongly suggest using “raw strings”.

- A raw string is created using r“” or r‘’ instead of just “” or ‘’.
- The exact reason is a bit tedious.
    - Rough idea: Regular expressions and Python strings both use \ as an escape character.
    - Using non-raw strings leads to uglier regular expressions.



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.

Regular Expression Groups

Earlier we used parentheses to specify the order of operations.

Parenthesis have another meaning:

- Every set of parentheses specifies a so-called “group”.
- Regular expression matchers (e.g. **`re.findall`**, regex101.com) will return matches organized by groups. In Python, returned as tuples.

```
s = """Observations: 03:04:53 - Horse awakens.
03:05:14 - Horse goes back to sleep."""
pattern = "(\d\d):(\d\d):(\d\d) - (.*)"
matches = re.findall(pattern, s)
```

```
[('03', '04', '53', 'Horse awakens.'),
 ('03', '05', '14', 'Horse goes back to sleep.')]
```

Regex Puzzle

Fill in the regex below so that after code executes, day is “26”, month is “Jan”, and year is “2014”.

- See `lec08-working-with-text.ipynb` or https://tinyurl.com/reg913s.

```
pattern = "YOUR REGEX HERE"
matches = re.findall(pattern, log[0])
day, month, year = matches[0]
```

`log[0]:`

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

Regex Puzzle (One Possible Solution)

Fill in the regex below so that after it executes, day is “26”, month is “Jan”, and year is “2014”.

```
pattern = "\[(\d{2})/(\w{3})/(\d{4})"
matches = re.findall(pattern, log[0])
day, month, year = matches[0]
```

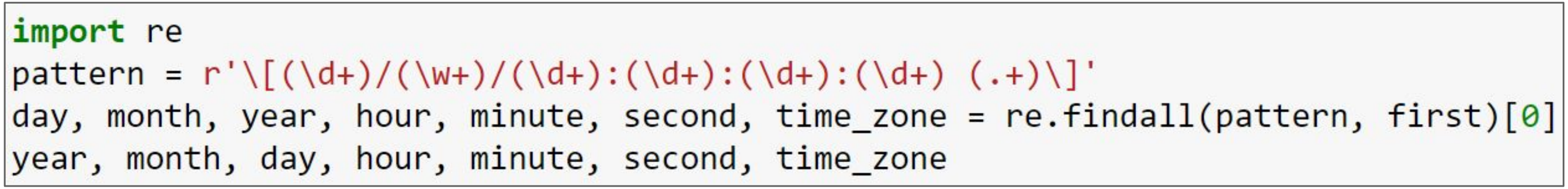
log[0]:

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

Extracting Date Information

With a little more work, we can do something similar and extract day, month, year, hour, minutes, seconds, and time zone all in one regular expression.

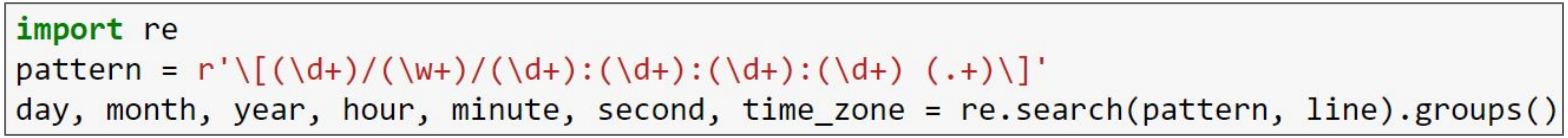
- Derivation is left as an exercise for you



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

You will also see code that uses `re.search` instead of `re.findall`.

- Beyond the scope of our lecture today.



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

Case Studies on Police Data and Restaurant Data

See lec08-working-with-text.ipynb

Summary

Today we saw many different string manipulation tools.

- There are many many more!
- With just this basic set of tools, you can do most of what you’ll need.

basic python	re	pandas
	re.findall	df.str.findall
str.replace	re.sub	df.str.replace
str.split	re.split	df.str.split
’ab’ in str	re.search	df.str.contain
len(str)		df.str.len
str[1:4]		df.str[1:4]

Even More Regex Syntax (Bonus)

Optional (but Handy) Regex Concepts

These regex features aren't going to be on an exam, but they are useful:

- **Lookaround**: match "good" if it's not preceded by "not": `(?<!not )good`
- **Backreferences**: match HTML tags of the same name: `<(\w+)>.*</\1>`
- **Named groups**: match a vowel as a named group: `(?P<vowel>[aeiou])`
- **Free Space**: Allow free space and comments in a pattern:

```
# Match a 20th or 21st century date in yyyy-mm-dd format
(19|20)\d\d                 # year (group 1)
[- /.]                      # separator
(0[1-9]|1[012])             # month (group 2)
[- /.]                      # separator
(0[1-9]|[12][0-9]|3[01])    # day (group 3)
```