LECTURE 5

Text as Data: Regular Expressions

Using string methods and regular expressions to work with textual data

Text is a very important format of data

- String methods
- Regular expressions
- Word encoding
    - Bag of words
    - TF-IDF
    - Word2Vec (Not covered)
    - BERT (Not covered)

Today's Roadmap

Why Work with Text?

Python String Methods

Regular Expressions (Regex) Basics

Regex Expanded

Convenient Regex

Regex in Python/Pandas (Regex groups)

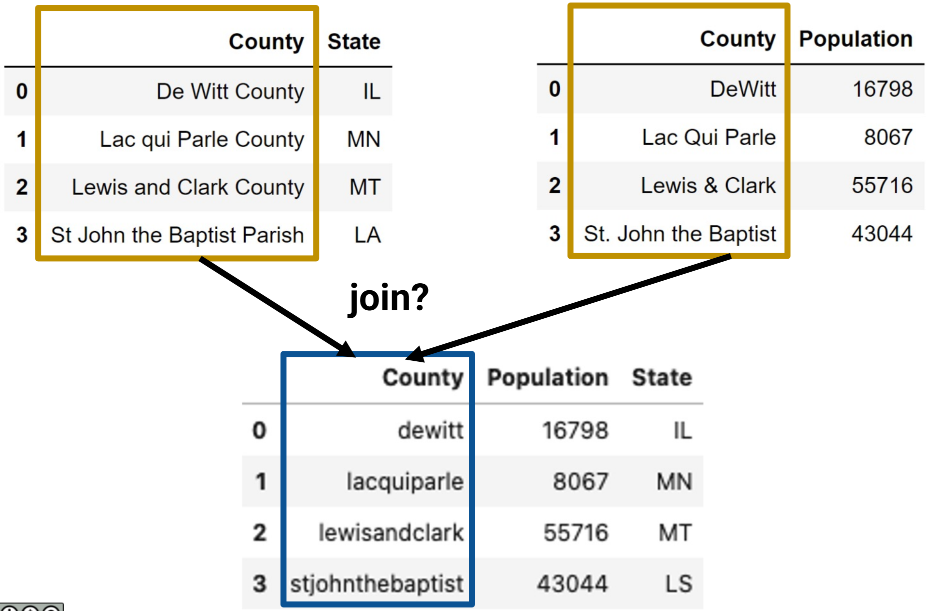
Demo on Restaurant Data

Bonus: Yes, More Regex Syntax

Why work with text? Two Main 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	Population	State
0	dewitt	16798	IL
1	lacquiparle	8067	MN
2	lewisandclark	55716	MT
3	stjohnthebaptist	43044	LS

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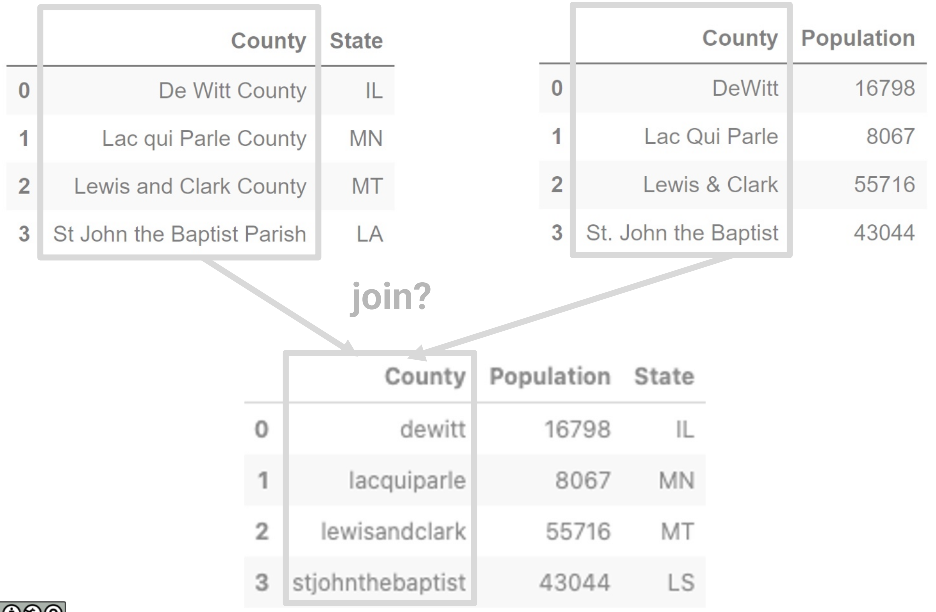

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	County	Population	State
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2. **Extract** information into a new feature.

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/"
```

$\downarrow$

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

Python String Methods

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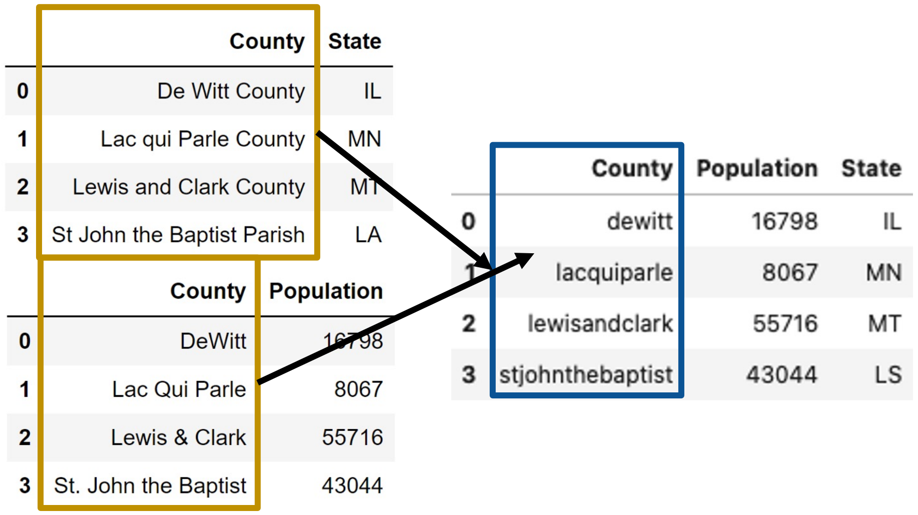
Demo Slides

1. Canonicalization



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	County	Population	State
0	dewitt	16798	IL
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2	lewisandclark	55716	MT
3	stjohnthebaptist	43044	LS

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

Demo Slides

2. 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(' ')
```

Summary: Python String Methods

Canonicalization and **Extraction**

- Parse/replace/split substrings.
- Feels very “hacky,” but messy problems often have messy solutions.

Python string functions:

- Are very **brittle**! Requires maintenance.
- Have **limited flexibility**.

operation	Python	pandas (Series)
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()`

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

```
"moon moo mooooooon mon mooooon"
```

Seem impossible?

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.
- We'll spend some time today 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]
```

Regex Basics

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What Is a Regular Expression?

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

- Example: “The set of all strings of length < 10 that contain `'data'`”

A **regular language** is a formal language that can be described by a **regular expression**.

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.

Goals of Today's Lecture

The goal of today is :

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

$\left.\vphantom{\begin{matrix}a\\b\\c\end{matrix}}\right\}$ high-level

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

$\left.\vphantom{\begin{matrix}a\\b\\c\\d\\e\end{matrix}}\right\}$ details; hone with practice

References:

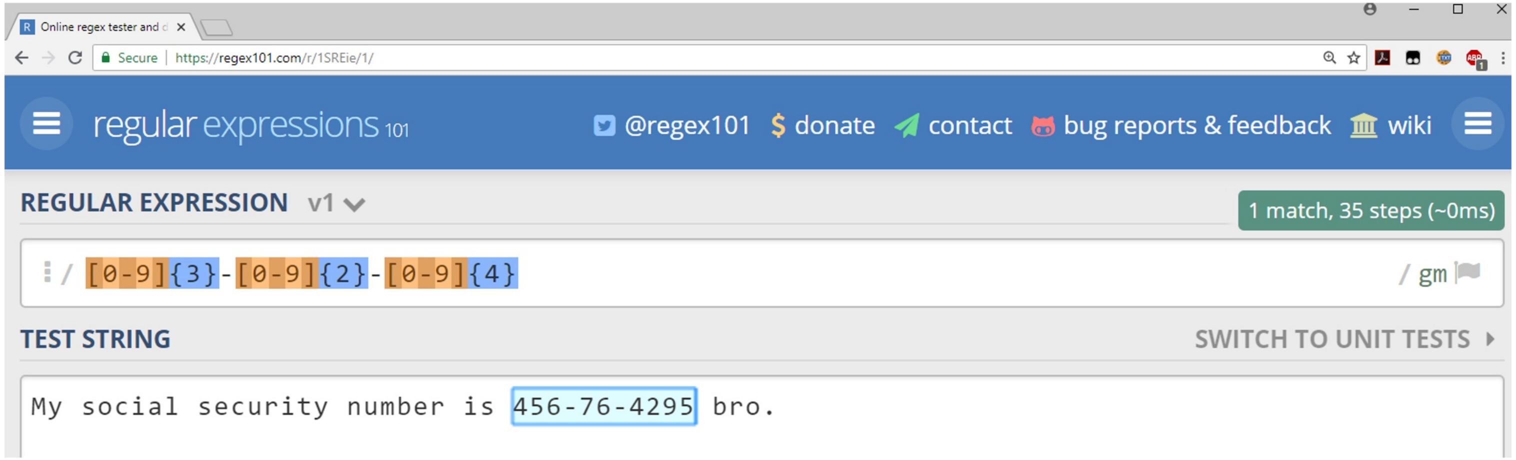
- The official guide is good! https://docs.python.org/3/howto/regex.html

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



1 match, 35 steps (~0ms)

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

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

Basic Regex Syntax

The four basic operations for regular expressions.

You can technically do anything with just these basic four (albeit tediously).

|, *, () are **metacharacters**. They manipulate adjacent characters.

operation	order	example	matches	doesn't 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`
group (parenthesis)	1	`A(A|B)AAB`	`AAAAB` `ABAAB`	every other string
		`(AB)*A`	`A` `ABABABABA`	`AA` `ABBA`

`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!

ABBA

operation	order	example	matches	doesn't 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
group (parenthesis)	1	A(A|B)AAB	AAAAB ABAAB	every other string
		~~(AB)*A~~	A ABABABABA	AA ABBA

Puzzle

Starting off: regex101.com/r/8tkQ23/1 ← Click to test on regex101.com!

operation	order	example	matches	doesn't 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
group (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).

Solution

operation	order	example	matches	doesn't match
concatenation	3	`AABAAB`	`AABAAB`	every other string
or	4	`AA|BAAB`	`AA` `BAAB`	every other string
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		`(AB)*A`	`A` `ABABABABA`	`AA` `ABBA`

Answer: `moo(oo)*n`

Puzzle

Order of Operations: regex101.com/r/RAnuqE/1

operation	order	example	matches	doesn't match
concatenation	3	`AABAAB`	AABAAB	every other string
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group (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 <u>or</u> os** except zero (i.e. don't match **mn**).

Solution

operation	order	example	matches	doesn't 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
group (parenthesis)	1	A(A|B)AAB	AAAAB ABAAB	every other string
		(AB)*A	A ABABABABA	AA ABBA

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

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

Solution

Explanation

✅ `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

Concatenation precedes OR!

Match examples:
```
muu
muuuu
oon
ooooon
```

OR metacharacter `|` comes last in order of operations.

Regex Expanded

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Expanded Regex Syntax

wildcard .
Consider: `.*`

character class:
Match one character in [ ]

Repeat preceding item {…} times

Compare/contrast:
`o*`, `o+`, `o?`

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 jooooohn	jhn jjohn
zero or one	`joh?n`	jon john	any other string

Expanded Regex Syntax

wildcard .
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Compare/contrast:
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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` `joooooohn`	`jhn` `jjohn`
zero or one	`joh?n`	`jon` `john`	any other string

Expanded Regex examples

wildcard .
Consider: .*

character class:
Match one character in [ ]

Repeat preceding item {…} times

Compare/contrast:
o*, o+, o?

matches	does not match
`.*SPB.*`	
RASPBERRY SPBOO	SUBSPACE SUBSPECIES
`[0-9]{3}-[0-9]{2}-[0-9]{4}`	
231-41-5121 573-57-1821	231415121 57-3571821
`[a-z]+@([a-z]+\.)+(edu|com)`	
horse@pizza.com horse@pizza.food.com	frank_99@yahoo.com hug@cs

\ **escapes** the next character, so **\.** matches a period.

Puzzle

Expanded Regex Puzzle 1: regex101.com/r/g0tP0I/1

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` `jooooohn`	`jhn` `jjohn`
zero or one	`joh?n`	`jon` `john`	any other string

Give a regular expression for any lowercase string that has a repeated vowel (**noon, peel, festoon, loop**, **oodles**, etc).

Solution

Expanded Regex Puzzle 1

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` `joooooohn`	`jhn` `jjohn`
zero or one	`joh?n`	`jon` `john`	any other string

Answer: `[a-z]*(aa|ee|ii|oo|uu)[a-z]*`

Puzzle

Expanded Regex Puzzle 2: https://regex101.com/r/aKyP2r/3

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 joooooohn	jhn jjohn
zero or one	`joh?n`	jon john	any other string

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

Solution

Expanded Regex Puzzle 2

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` `jooooohn`	`jhn` `jjohn`
zero or one	`joh?n`	`jon` `john`	any other string

Answer: `(.*[0-9].*[a-z].*)|(.*[a-z].*[0-9].*)`

Interlude

https://alf.nu/RegexGolf

Interlude

Email Address Regular Expression (probably a 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|(?=[
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])+|\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*)
```

source, StackOverflow discussion

Convenient Regex

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Convenient Regex Syntax

\w	[A-Za-z0-9_]
\d	[0-9]
\s	whitespace
+	at least one

[^...] negates entire character class

"take this next character literally"

operation	example	matches	doesn't match

built-in **character classes**	`\w+`
	`\d+`
	`\s+`
		`Fawef_03`
		`231231`
		whitespace
			`this person`
			`423 people`
			non-whitespace

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

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

Puzzle

Back to Our Log File, Part 1: https://regex101.com/r/bJ9vUn/1

operation	example	matches	doesn't match

built-in **character classes**	`\w+`
	`\d+`
	`\s+`
		`Fawef_03`
		`231231`
		whitespace
			`this person`
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			non-whitespace

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

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

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

Give a regular expression that matches the gold portion above.

Solution

Back to Our Log File, Part 1

operation	example	matches	doesn't match

built-in **character classes**	`\w+`
	`\d+`
	`\s+`
		`Fawef_03`
		`231231`
		whitespace
			`this person`
			`423 people`
			non-whitespace

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

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

Answer: `\[.*\]`

Even More Regular Expression Features

A few additional common regex features are listed above.

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

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`

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

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

hell
Greedy: h.+l matches hell
Lazy: h.+?l matches hel.

<em>Hello World</em>
Greedy: <.+> will match <em>Hello World</em>
Lazy: <.+?> will match <em> and </em>

Regex in Python and Pandas (Regex groups)

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Canonicalization: Python

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

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
```

Canonicalization: Pandas

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

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
```

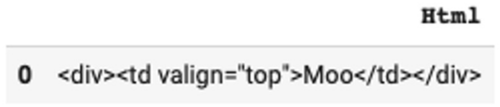
```
Moo
```

`pattern` is a **raw string**. `r"..."`

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

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

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



	Html
0	<div><td valign="top">Moo</td></div>

```
0            Moo
Name: Html, dtype: object
```

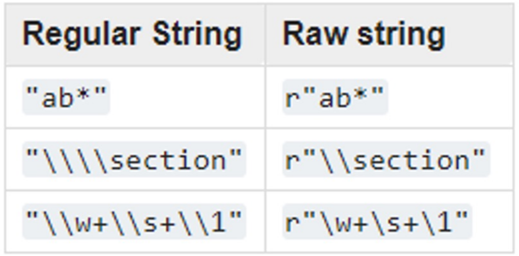
Sidenote: Raw Strings in Python

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

- A raw string is created using `r""` or `r''` instead of just `""` or `''`.

```
pattern = r"<[^>]+>"
```

- 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#the-backslash-plague

Extraction

`re.findall(pattern, text)`

docs

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']
```

Extraction

`re.findall(pattern, text)`

docs

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)
```

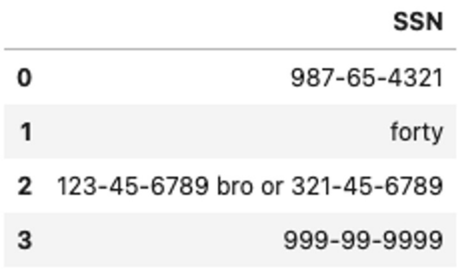
```
['123-45-6789', '321-45-6789']
```

`ser.str.findall(pattern)`

docs

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
```

Regular Expression Capture Groups

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

Parenthesis have **another meaning**:

- Every set of parentheses specifies a **match/capture group**.
- In Python, matches are returned as tuples of groups.

```
text = """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, text)
```

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

There's more than one way to regex, e.g. `(\d\d)` vs `(\d{2})`

Back to Our Log File, Part 2

With this notion of groups, let’s come back to the regex presented without explanation earlier.

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

operation	example	matches	doesn’t match

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

at least one	`jo+hn`	`john` `joooooohn`	`jhn` `jjohn`
escape character	`cow\.com`	`cow.com`	`cowscom`
any character (except newline)	`.U.U.U.`	`CUMULUS` `JUGULUM`	`SUCCUBUS` `TUMULTUOUS`

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

```
('26', 'Jan', '2014', '10',
      '47', '58', '-0800')
```

Finding regex groups

`re.findall(pattern, text)` docs

(Python) Return a list of all matches to `pattern`.

`ser.str.findall(pattern)` docs

Returns a Series of lists of all matches.

`ser.str.extract(pattern)` docs

Returns a DataFrame of first match,
one group per column

`ser.str.extractall(pattern)` docs

Returns a DataFrame of all matches,
one group per column, one row per match

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:

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

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

Demo on Restaurant Data

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String function summary

Today we saw many, many different string manipulation tools (highlighted).

- There are many many more!
- With just this basic set of tools, you can do most of what you'll need to wrangle text data!

Python String	re	pandas Series

`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()`

Bonus: Yes, More Regex Syntax

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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)
```

BONUS MATERIAL

Of these concepts, **named groups** is the most useful for **extraction**.

Exercise

1. Which strings contain a match for the following regular expression, `"1+1$"`? The character `"␣"` represents a single space.

   ◯ A. `What␣is␣1+1` ◯ B. `Make␣a␣wish␣at␣11:11` ◯ C. `111␣Ways␣to␣Succeed`

B

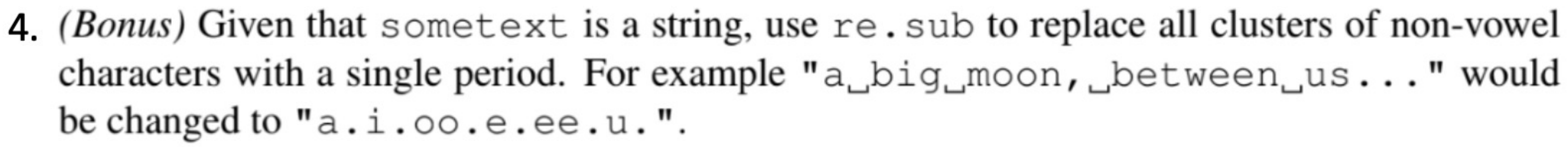
2. Write a regular expression that matches strings (including the empty string) that only contain lowercase letters and numbers.

^[a-z0-9]*$

3. Given `sometext = "I've␣got␣10␣eggs,␣20␣gooses,␣and␣30␣giants."`, use `re.findall` to extract all the items and quantities from the string. The result should look like **`['10 eggs', '20 gooses', '30 giants']`**. You may assume that a space separates quantity and type, and that each item ends in s.

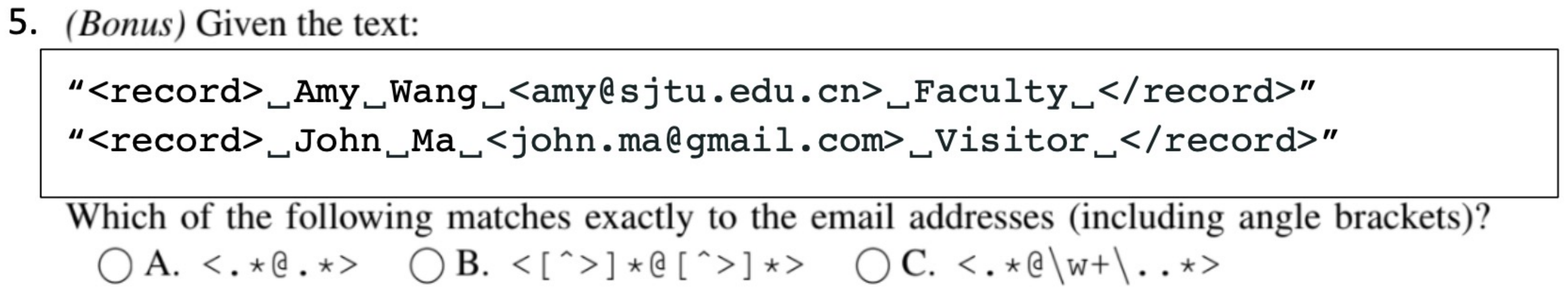
[0-9]
re.findall(r"\d\d\s\w+s",sometext)

Exercise



4. *(Bonus)* Given that `sometext` is a string, use `re.sub` to replace all clusters of non-vowel characters with a single period. For example `"a␣big␣moon,␣between␣us..."` would be changed to `"a.i.oo.e.ee.u."`.

re.sub(r"[^aeiou]+",".",sometext)



5. *(Bonus)* Given the text:

```
"<record>␣Amy␣Wang␣<amy@sjtu.edu.cn>␣Faculty␣</record>"
"<record>␣John␣Ma␣<john.ma@gmail.com>␣Visitor␣</record>"
```

Which of the following matches exactly to the email addresses (including angle brackets)?

◯ A. `<.*@.*>` ◯ B. `<[^>]*@[^>]*>` ◯ C. `<.*@\w+\..*>`

(B)