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Wrapping up these slides from last time!

LECTURE 5

Data Wrangling and EDA

Exploratory Data Analysis and its role in the data science lifecycle.

Data 100/Data 200, Spring 2025 @ UC Berkeley

Narges Norouzi and Josh Grossman

Acknowledgments

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Key Data Properties to Consider in EDA

Structure -- the "shape" of a data file

Granularity -- how fine/coarse is each datum

Temporality -- how is the data situated in time

Faithfulness -- how well does the data capture "reality"

What are Some Potential Issues with this Dataset?

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ID	Category	State	Location	Device	Purchased	...
0	Shoes	CA	CA	1	1	...
1	Socks	NM	NM	1	0	...
2	Socks	XY	XY	1	0	...
3	Shirts	NY	NY	1	NaN	...
4	Shoes	FL	FL	1	0	...
4	Shoes	FL	FL	1	0	...
5	Shirts	CA	CA	1	0	...
6	Pnts	TX	TX	1	1	...
7	Hats	CA	CA	1	-1	...
...	...	...	...	...	...	...

Faithfulness: Do I trust this data?

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Fully Duplicated Records or Fields

Identify and ignore/drop.

Labeling or Spelling Errors

Apply corrections. Only ignore if you have to.

Missing data

Need to think carefully about **why** the data is missing.

Examples

```
"  "          1970, 2000
0, -1         NaN
999, 12345    Null
```

NaN: "Not a Number"

Real zero or NaN placeholder? Sometimes both!

See footnote 12 in onlinelibrary.wiley.com/doi/abs/10.1111/jels.12343

Missing Data: Approaches

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A. Keep as NaN
- A good default.
- If qualitative/categorical → Create a "Missing" category.

B. Drop records with missing values
- Typically a <u>bad</u> default!
- Temperature probe went offline for a minute → Likely **missing at random** → OK to drop
- Police officer never records outcomes of vehicle stops → Likely <u>not</u> missing at random

C. Imputation/Interpolation: Infer missing values

- **Mean/median imputation**: replace NaN with mean/median
- **Hot deck imputation**: use a random non-NaN value
- **Regression imputation**: use a model to predict value
- **Multiple imputation**: multiple random values + check sensitivity

$\}$ (beyond this course)

⚠️ Reminder to start the Zoom recording!

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LECTURE 6

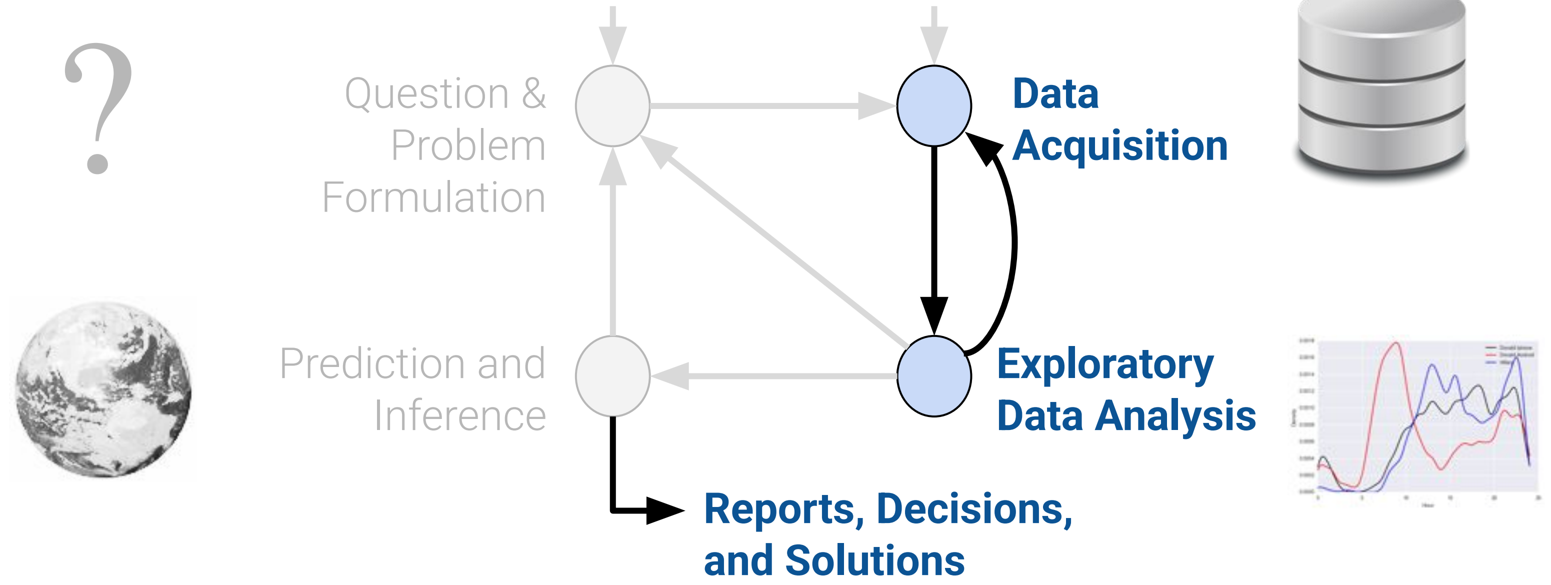
Text Wrangling and Regex

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

Data 100/Data 200, Spring 2025 @ UC Berkeley

Narges Norouzi and Josh Grossman

This Week


Question & Problem Formulation
Data Acquisition
Exploratory Data Analysis
Prediction and Inference
Reports, Decisions, and Solutions

(Last Lecture)

Data Wrangling
Intro to EDA

(Today)

Working with Text Data
Regular Expressions

(Next)

Visualization
Code for plotting data

Goals for this Lecture

Lecture 6, Data 100 Spring 2025

Common EDA task: clean text!

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

Why Work With Text?

Lecture 6, Data 100 Spring 2025

- **Standard Text Manipulation Tasks**
- `pandas str` methods
- Why regex?
- Regex basics
- Regex functions

Why Work With Text? Two Common Goals

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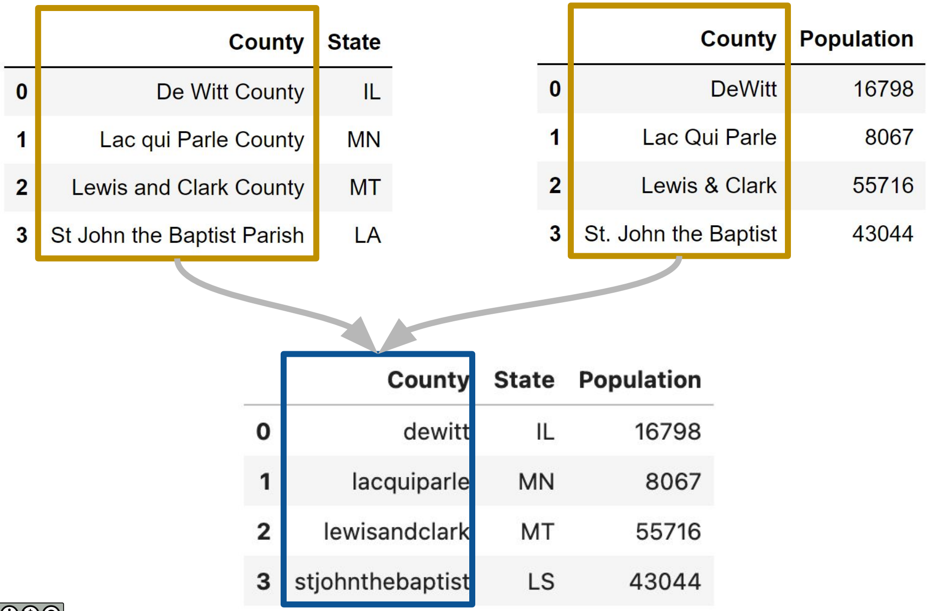
1. **Canonicalization**: Convert data into a standard form.

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

Regex Pipeline for Canonicalizing High School Names

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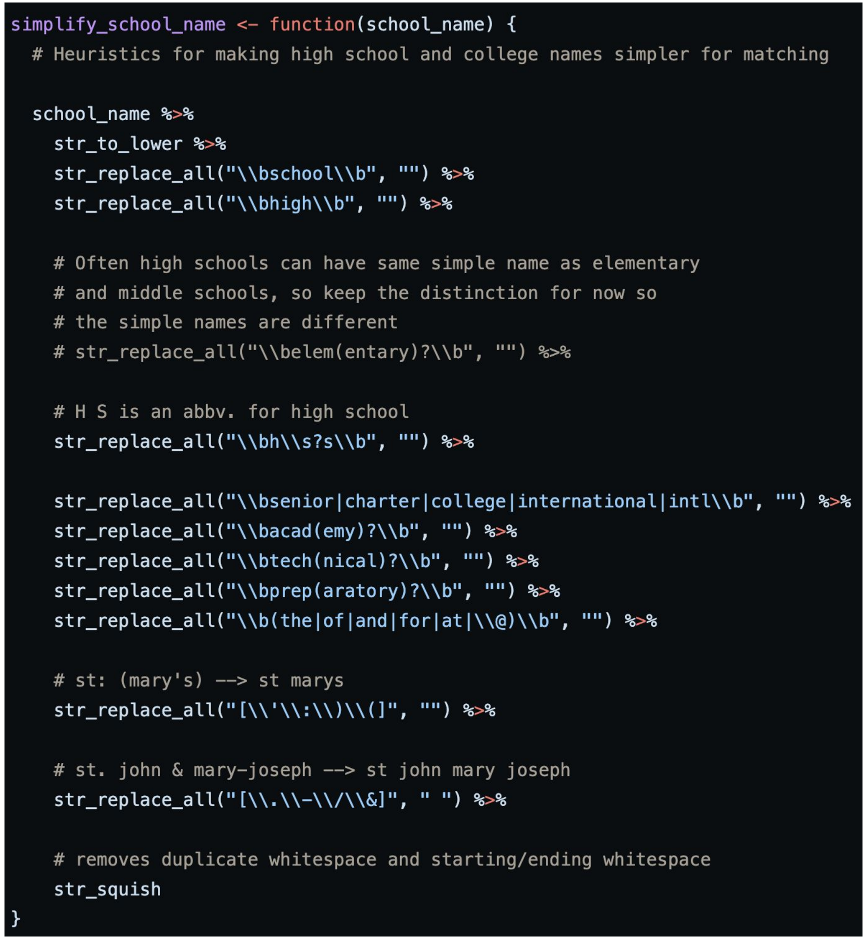
Two datasets needed to be merged based on HS name and location.

Problem: HS names not canonicalized.

For example: "The Bear Preparatory High School" and "Bear Prep"

Solution: Canonicalize with regex! →



```r
simplify_school_name <- function(school_name) {
  # Heuristics for making high school and college names simpler for matching

  school_name %>%
    str_to_lower %>%
    str_replace_all("\\bschool\\b", "") %>%
    str_replace_all("\\bhigh\\b", "") %>%

    # Often high schools can have same simple name as elementary
    # and middle schools, so keep the distinction for now so
    # the simple names are different
    # str_replace_all("\\belem(entary)?\\b", "") %>%

    # H S is an abbv. for high school
    str_replace_all("\\bh\\s?s\\b", "") %>%

    str_replace_all("\\bsenior|charter|college|international|intl\\b", "") %>%
    str_replace_all("\\bacad(emy)?\\b", "") %>%
    str_replace_all("\\btech(nical)?\\b", "") %>%
    str_replace_all("\\bprep(aratory)?\\b", "") %>%
    str_replace_all("\\b(the|of|and|for|at|\\@)\\b", "") %>%

    # st: (mary's) --> st marys
    str_replace_all("[\\'\\:\\)\\(]", "") %>%

    # st. john & mary-joseph --> st john mary joseph
    str_replace_all("[\\.\\-\\/\\&]", " ") %>%

    # removes duplicate whitespace and starting/ending whitespace
    str_squish
}
```

Research Paper: Tomkins et al. (2023)

Why Work With Text? Two Common Goals

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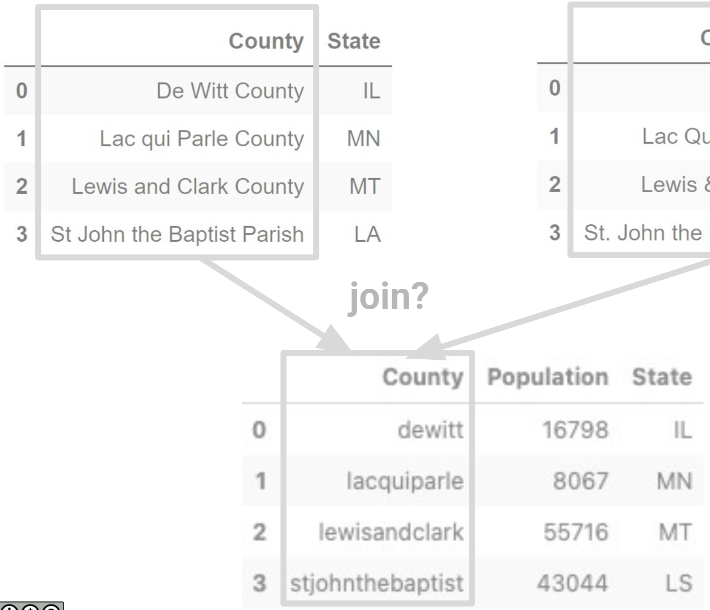
1. **Canonicalization**: Convert data into a standard form.

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

join?

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

2. **Extract** information.

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"
```

Project with a Federal District Court

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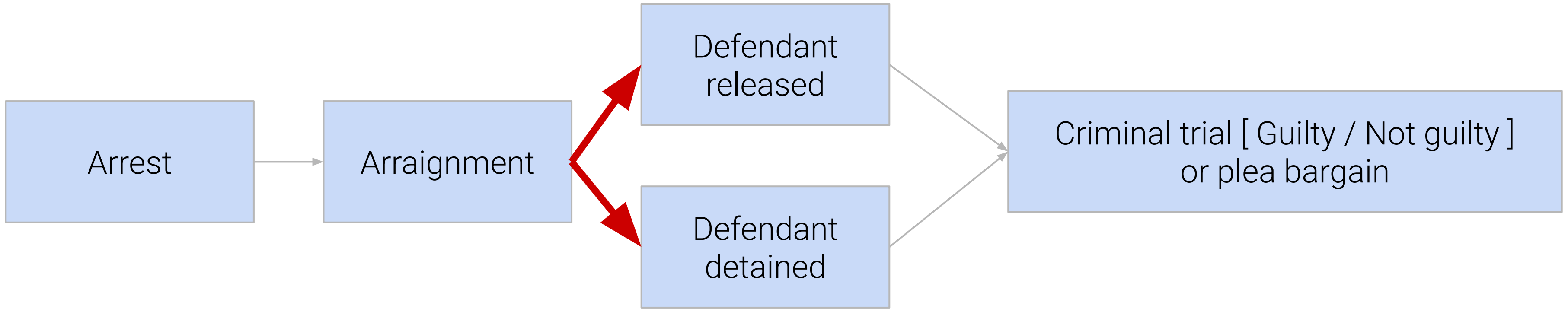
Motivating question: Can we make **pretrial detention** decisions more equitably?



Defendant Info in PDF Bail Reports

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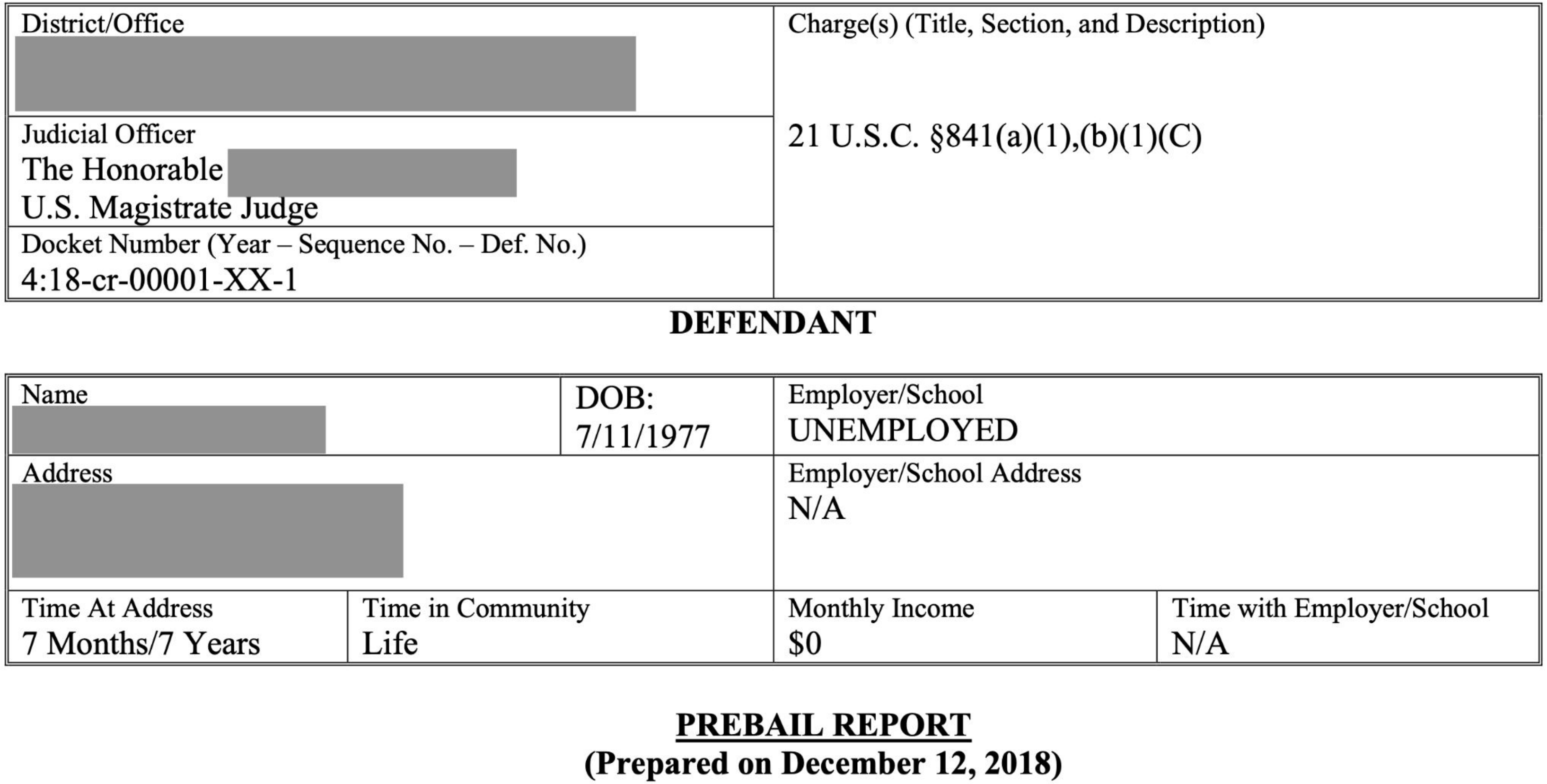


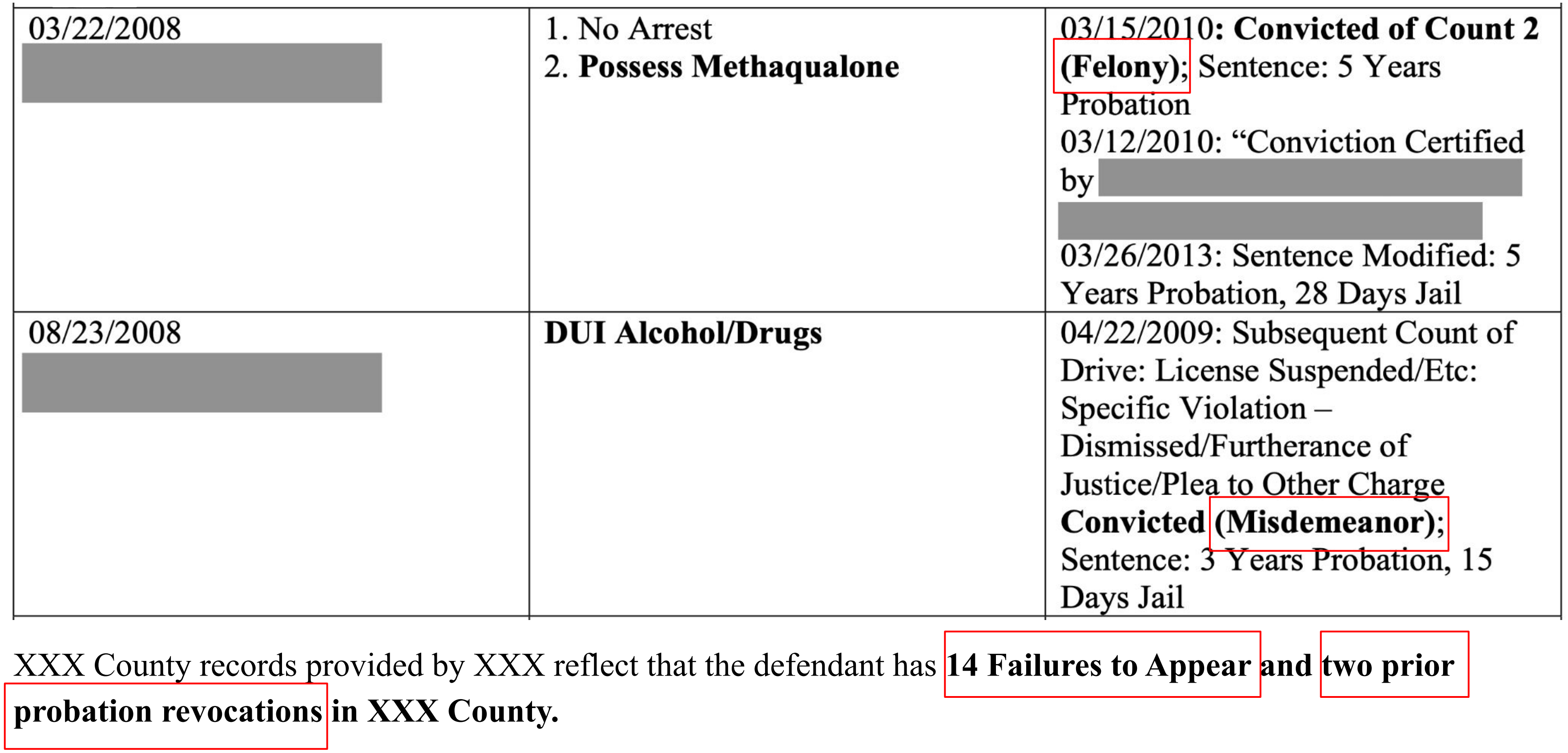
District/Office [redacted]	Charge(s) (Title, Section, and Description) 21 U.S.C. §841(a)(1),(b)(1)(C)
Judicial Officer The Honorable [redacted] U.S. Magistrate Judge	
Docket Number (Year – Sequence No. – Def. No.) 4:18-cr-00001-XX-1	

DEFENDANT

Name [redacted]	DOB: 7/11/1977	Employer/School UNEMPLOYED	
Address [redacted]		Employer/School Address N/A	
Time At Address 7 Months/7 Years	Time in Community Life	Monthly Income $0	Time with Employer/School N/A

PREBAIL REPORT
(Prepared on December 12, 2018)

Defendant Info in PDF Bail Reports



03/22/2008 [redacted]	1. No Arrest 2. **Possess Methaqualone**	03/15/2010: **Convicted of Count 2 (Felony)**; Sentence: 5 Years Probation 03/12/2010: “Conviction Certified by [redacted] 03/26/2013: Sentence Modified: 5 Years Probation, 28 Days Jail
08/23/2008 [redacted]	**DUI Alcohol/Drugs**	04/22/2009: Subsequent Count of Drive: License Suspended/Etc: Specific Violation – Dismissed/Furtherance of Justice/Plea to Other Charge **Convicted (Misdemeanor)**; Sentence: 3 Years Probation, 15 Days Jail

XXX County records provided by XXX reflect that the defendant has **14 Failures to Appear and two prior probation revocations in XXX County.**

Identify and Extract Data Using Patterns in Text

```
03/22/2008
XXX County, XXX
1. No Arrest
2. Possess Methaqualone
03/15/2010: Convicted of Count 2
(Felony); Sentence: 5 Years
Probation
03/12/2010: "Conviction
Certified
by XXX, Court Clerk, XXX County"
03/26/2013: Sentence Modified: 5
Years Probation, 28 Days Jail
08/23/2008
...
```

```
XXX, XXX
DUI Alcohol/Drugs 04/22/2009:
Subsequent Count of
Drive: License Suspended/Etc:
Specific Violation -
Dismissed/Furtherance of
Justice/Plea to Other Charge
Convicted (Misdemeanor);
Sentence: 3 Years Probation, 15
Days Jail
...
XXX County records provided by
XXX reflect that the defendant
has 14 Failures to Appear
and two prior probation
revocations in XXX County.
...
```

For a more detailed description, see footnote 12 in onlinelibrary.wiley.com/doi/abs/10.1111/jels.12343

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`pandas str` Methods

Lecture 6, Data 100 Spring 2025

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

From String to `str`

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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**. Looping can be slow!

`str` Methods

Pandas `str` methods are **vectorized**. No looping; simultaneous computation!

```
Series.str.<string_operation>()
```

Apply the function `<string_operation>` to every string in the `Series`

```
populations["County"]
```

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

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

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

.str Methods

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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()`

Demo

lec06.ipynb

Demo 1: Canonicalization

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

```python
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', '')
          )
```

Demo 2: Extracting Date Info (The Long Way)

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```
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, rest2 = rest.split(':')
seconds, time_zone         = rest2.split(' ')
```

Note: While you should understand the code in this part of the demo, regex is a sleeker way to solve the problem above.

Demo

lec06.ipynb

Why regex?

Lecture 6, Data 100 Spring 2025

String Extraction: An Alternate Approach

While we can sometimes "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(' ')
```

It often won't work.

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

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

Circa 2013 meme, "Moon moon"

String Extraction: An Alternate Approach

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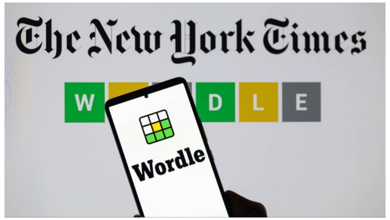
An alternate approach is to use a **regular expression**.

- Implementation provided in the Python **re** library and the pandas **str** accessor.
- We can simplify the code in the previous demo with regex:

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



Productive mindset to adopt: Think of regex problems like **word puzzles**!

Regex Basics

Lecture 6, Data 100 Spring 2025

Regular Expressions Specify Patterns in Strings

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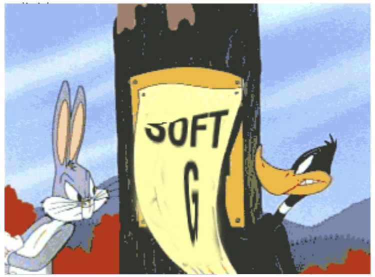
A **reg**ular **ex**pression ("**regex**") is a sequence of characters that specifies a search **pattern**.

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 (e.g., 123-45-6789) is described by this regular expression.



"Regex" pronunciation? (as in Re**g**ular)
Check out English Stackexchange discussion

Goals for regex

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The goal of today is NOT to memorize the language of regular expressions!

Instead:

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

Resources for Practicing Regex

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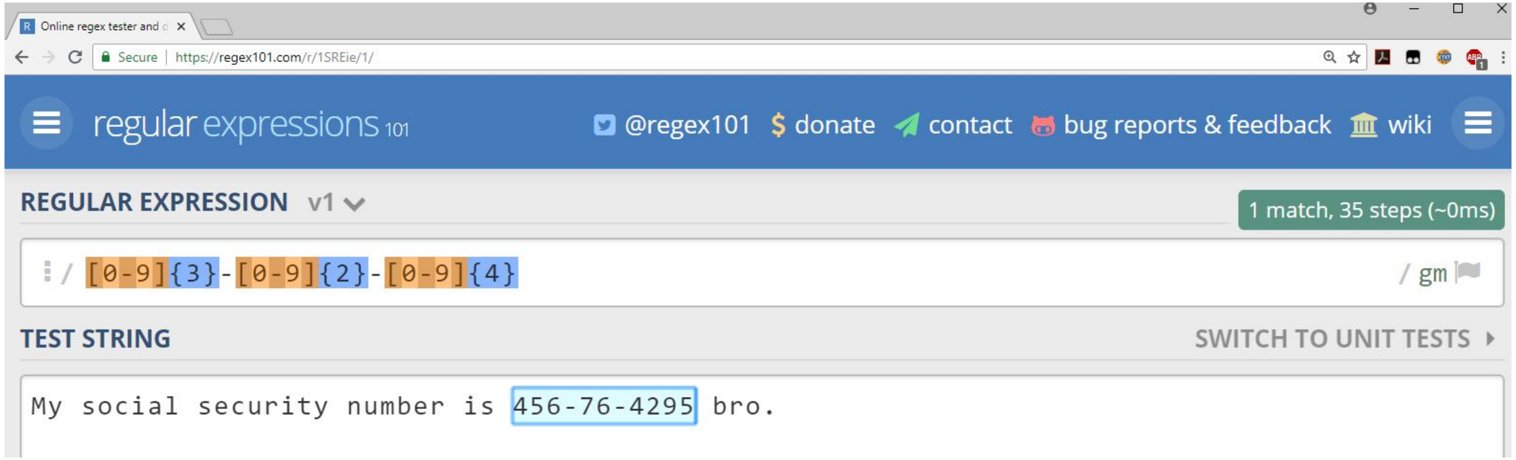
Many resources to experiment with regexes (e.g., regex101.com, regexone.com, ...)

For experimenting, we recommend regex101.com. We will use it during today's demos.

- **Important:** Choose the Python "flavor" in the left sidebar. We'll explain the **r"** soon!
- Note the reference table in the bottom right.



Online regex tester and d

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

REGULAR EXPRESSION v1

1 match, 35 steps (~0ms)

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

TEST STRING

SWITCH TO UNIT TESTS

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

Regex Basics

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There are four basic operations in regex.

Concatenation – "look for consecutive characters"

`BAAB` matches `BAAB`

| – "or"

`BAB|BAAB` matches `BAB` *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

Summary So Far

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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.

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Which pattern matches moon, mooooon, etc? Your expression should match any *even* number of "o"s except zero (i.e., don't match mn, mooon).

Try it yourself!

regex101.com/r/8tkQ23/1

moo(oo)*n

Regex Expanded

Six more regex operations.

. – "look for *any* character other than \n"

`.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`

Keep in mind: ***** = **{0,}**, **+** = **{1,}**, and **?** = **{0,1}** = **{,1}**

Character Classes

[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 space, tab or newline

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

Capitalized shortcuts: **[^A-Za-z0-9] = [^\w] = `\W`** **[^\d] = `\D`** **[^\s]=`\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` `jooooohn`	`jhn` `jjohn`

1-minute stretch!

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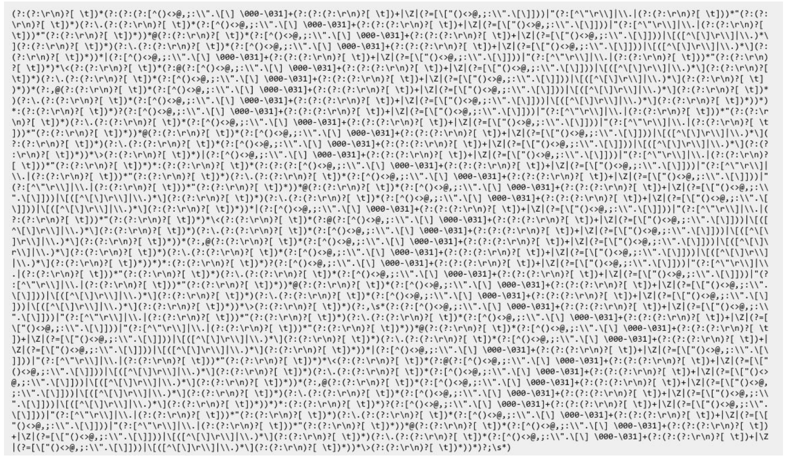
How Josh learned regex: regexcrossword.com

Email Address Regular Expression (probably a bad idea)



```
(?:(?:\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)?
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\\.|(?:(?:\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\\]|\\.|(
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]\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

Greediness

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

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

regex101.com/r/HATiTH/1

"This is an **<div>example</div> of greediness <div>in</div>** regular expressions."

Greediness

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

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

In English:

- "Look for the exact string <div>"
- then, "grab every character except \n..."
- "... until the **FINAL** instance of the string </div>"

"This is an **<div>**example</div> of greediness <div>in**</div>** regular expressions."

Greediness

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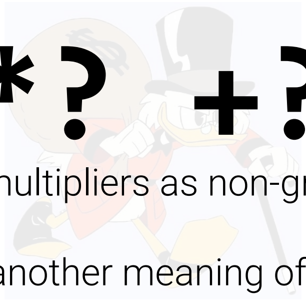
Regex is **greedy** – it will look for the *longest possible* match in a string

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



***? +?**

? tags multipliers as non-greedy. Docs.

This is another meaning of the **?** modifier!

In English:

- "Look for the exact string <div>"
- then, "grab every character except \n…"
- "… until the **FIRST** instance of the string </div>"

"This is an **<div>**example</div> of greediness **<div>**in</div> regular expressions."

Regex *Even More* Expanded

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The last set!

\ – "read the next character literally"

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

^ – "match the beginning of a string"

`^abc` matches "**`abc 123`**", not "**`123 abc`**"

$ – "match the end of a string"

`abc$` matches "**`123 abc`**", not "**`abc 123`**"

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

[^abc] → Match any single character other than a, b, or c

Evan Misshula: Ex-presidents often end up rich.
You **start** with **power ^** and **end** with **money $**

Summary So Far

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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`

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Which of the following strings matches the regex expression: ^w+\.be?r(oco|ke)l+.*\.(edu|com)$

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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

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

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

Additional Regex Functionality

Regex101.com is great for learning basic regex *syntax*.

For full functionality of regex in programming (matching, splitting, search and replace, group management, …), see **The Python Regex HOWTO**: docs.python.org/3/howto/regex.html.

Regex is also a sleek way to find+replace in your favorite text editor (even Google Slides!)

Regex Functions

Lecture 6, Data 100 Spring 2025

Before We Begin: Raw Strings in Python

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When specifying a pattern, use **raw strings**.

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

Create by putting **r** before string delimiters:
(**`r"..." r'...', r"""...""", r'''...'''`**)

Python **<u>and</u>** Regex each use backlash (\) as the **escape character.**

Regular string	Raw string	Matches
`"ab*"`	`r"ab*"`	`a, ab, abb, ...`
`"\\w+\\s+"`	`r"\w+\s+"`	`One or more of [A-Za-z0-9], then one or more spaces`
`"\\\\section"`	`r"\\section"`	`\section`

For more information see "The Backslash Plague"

Why we need four backslashes \\\\ to match one backlash

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Suppose we want to match the **literal text '\n'** in a document (i.e, NOT a newline)

print('**\n**') prints a newline

print('**\\n**') prints '\n', which regex would interpret as the literal character 'n'

print('**\\\n**') prints a literal \, followed by a newline

print('**\\\\n**') prints '\\n', which regex would interpret as the literal string '\n' → Done… 🥲

print(**r'\\n'**) prints '\\n' → Easier! 😎

Note: All of these examples are in the demo!

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']
```

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

Extraction

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`re.findall(pattern, text)` docs

Return a **list** of all matches to `pattern`.

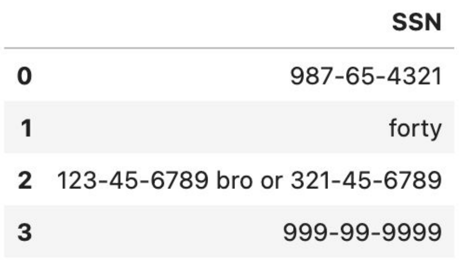
```
text = "My social security number is
123-45-6789 bro, or actually maybe it's
321-45-6789.";
pattern = r"[0-9]{3}-[0-9]{2}-[0-9]{4}"
re.findall(pattern, text)
```

```
['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
```

Extraction with Capture Groups

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

( ) also specifies a **capture group**.

- Some **`re`** functions extract *only* the text matched by capture groups, if they are specified

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

The capture groups each capture two digits.

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

Extraction with Capture Groups

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`ser.str.extract(pattern)` docs

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)` docs

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)` 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)
```

```
Moo
```

How it works:

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

Substitution

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`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)
```

```
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 )` docs

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

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

	Html
0	<div><td valign="top">Moo</td></div>
1	<a href="http://ds100.org">Link</a>
2	<b>Bold text</b>

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

Demo

lec06.ipynb

re.sub and ser.str.replace

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findall → list of matches

extract → DataFrame of matches

sub/replace → Convert matches

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

Easier to write than to read.

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 <div>...<tag>..</tag>..</div>): use `html.parser.`
- Counting (same number of instances of a and b). (impossible)

LLMs can also be good at regex tasks! But, potentially unreliable + computationally expensive.

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LECTURE 6

Text Wrangling and Regex

Content credit: Acknowledgments