# Finding Patterns in Text with Regular Expressions

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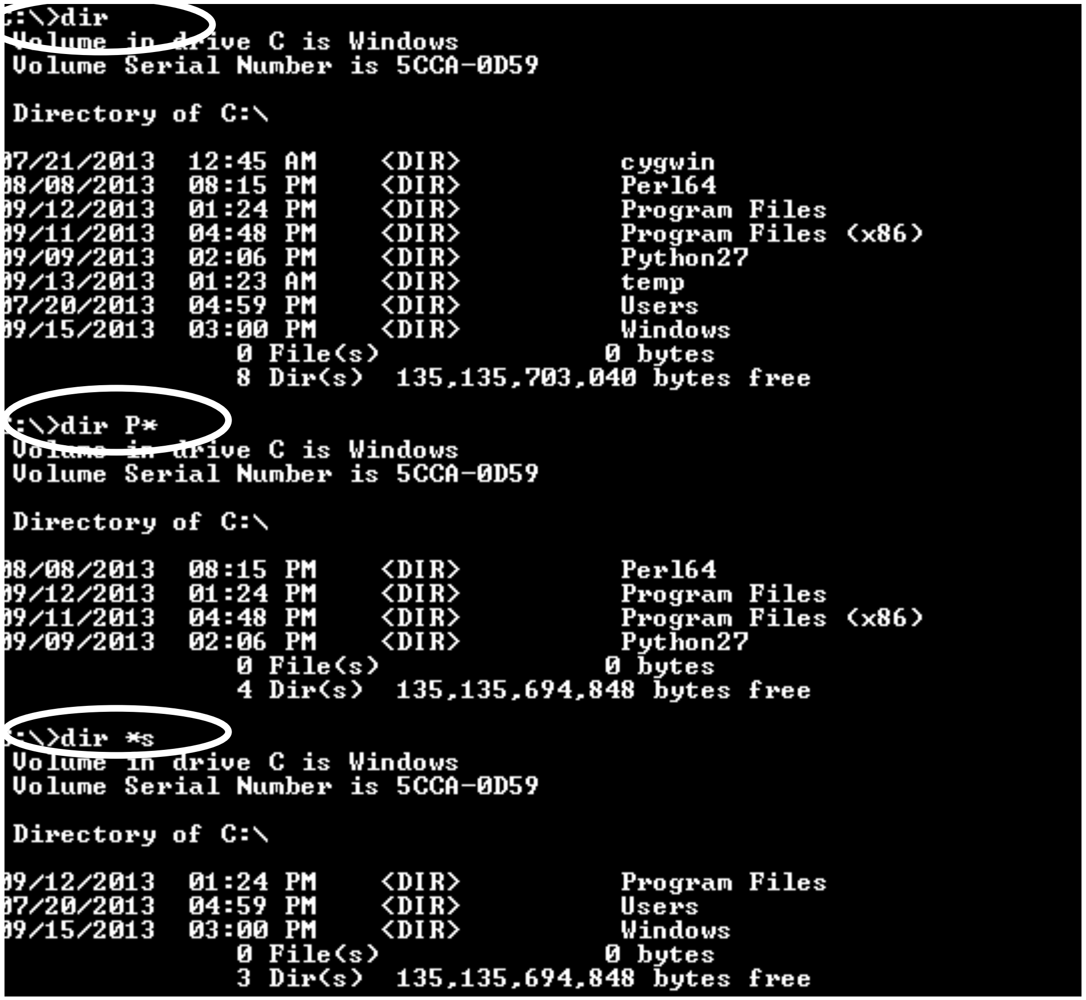
Some material courtesy of: Kevyn Collins-Thompson,  Yuhang Wang, Qiaozhu Mai, Charles Severance, Patrick Dudas

# You may have seen some kinds of regular expressions before



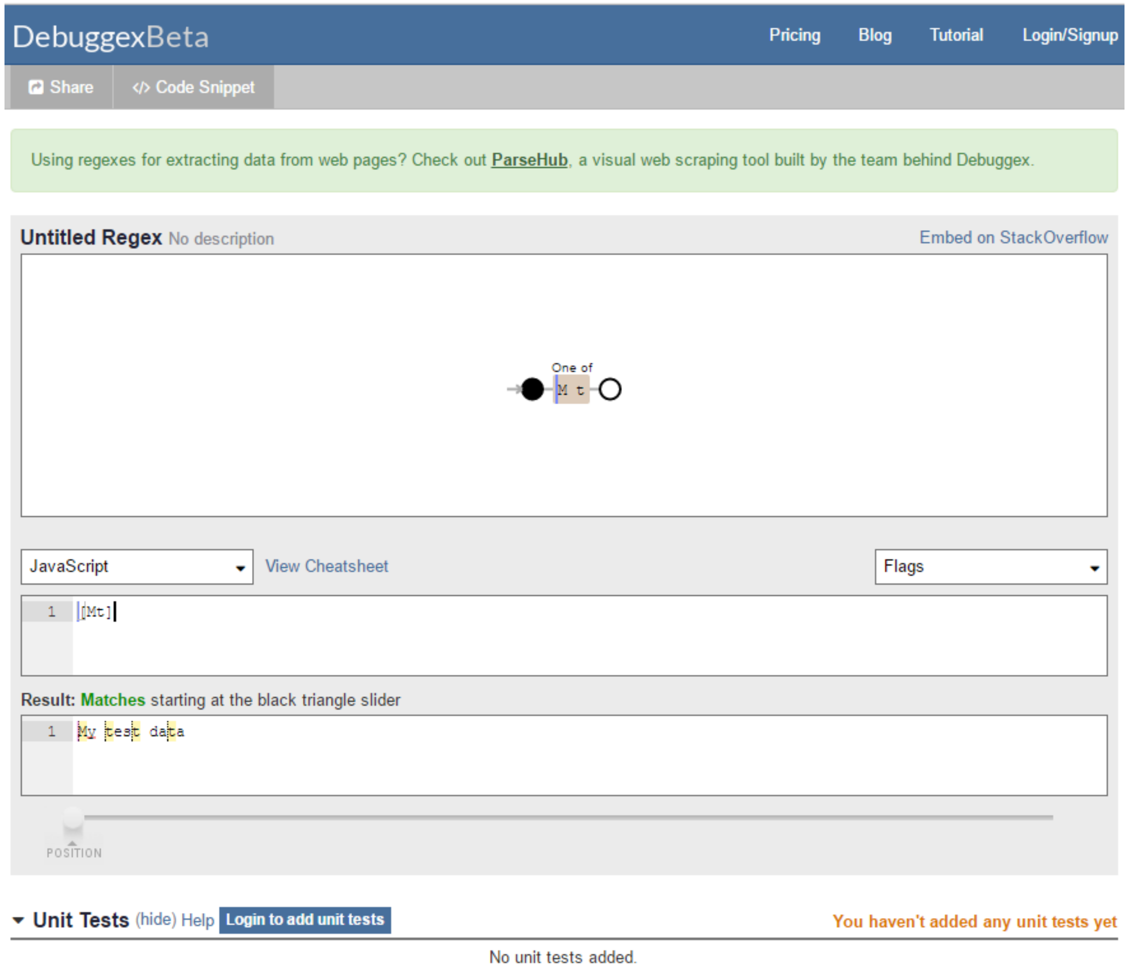
```
:\>dir
 Volume in drive C is Windows
 Volume Serial Number is 5CCA-0D59

 Directory of C:\

7/21/2013  12:45 AM    <DIR>          cygwin
8/08/2013  08:15 PM    <DIR>          Perl64
9/12/2013  01:24 PM    <DIR>          Program Files
9/11/2013  04:48 PM    <DIR>          Program Files (x86)
9/09/2013  02:06 PM    <DIR>          Python27
9/13/2013  01:23 AM    <DIR>          temp
7/20/2013  04:59 PM    <DIR>          Users
9/15/2013  03:00 PM    <DIR>          Windows
               0 File(s)              0 bytes
               8 Dir(s)  135,135,703,040 bytes free

:\>dir P*
 Volume in drive C is Windows
 Volume Serial Number is 5CCA-0D59

 Directory of C:\

8/08/2013  08:15 PM    <DIR>          Perl64
9/12/2013  01:24 PM    <DIR>          Program Files
9/11/2013  04:48 PM    <DIR>          Program Files (x86)
9/09/2013  02:06 PM    <DIR>          Python27
               0 File(s)              0 bytes
               4 Dir(s)  135,135,694,848 bytes free

:\>dir *s
 Volume in drive C is Windows
 Volume Serial Number is 5CCA-0D59

 Directory of C:\

9/12/2013  01:24 PM    <DIR>          Program Files
7/20/2013  04:59 PM    <DIR>          Users
9/15/2013  03:00 PM    <DIR>          Windows
               0 File(s)              0 bytes
               3 Dir(s)  135,135,694,848 bytes free
```

# Regular Expressions (or 'regexp' or 'regex')

- A concise and flexible means to "match" (specify and recognize) strings of text, such as particular characters, words, or patterns of characters.
- Similar regular expression syntax appears in many other tools
  - grep, flex, editors, ….
  - So you'll be able to re-apply most of what you learn in many other computing settings

# Online visual regular expression testers

debuggex.com   regexr.com



Using regexes for extracting data from web pages? Check out ParseHub, a visual web scraping tool built by the team behind Debuggex.

**Untitled Regex** No description

JavaScript ▾ View Cheatsheet Flags ▾

```
[Mt]
```

Result: Matches starting at the black triangle slider

```
My test data
```

You haven't added any unit tests yet

No unit tests added.

# The Python `re` module

- `import re`
- Three Python functions:

  `re.search()` finds first occurrence of a pattern anywhere in string

  `re.match()` checks for a match only at beginning of string

  `re.findall()` finds all occurrences of a pattern, not just first one

- Some new regexp-enabled text operations:

```
re.split()
    entries = re.split("\n+", text)
re.sub()
    re.sub(r"(\w)(\w+)(\w)", repl, text)
```

## `re.search`

`search(pattern, string, flags=0)`

Scan through string looking for the first match to the pattern anywhere in the string

Returns:

A MatchObject or None if not found

# `re.match`

`match(pattern, string, flags=0)`

Try to apply the pattern at the start of the string. *Flags will be covered later*.

Returns:

A MatchObject or None if no position in the string matches the pattern

## Basic Patterns

- Ordinary characters just match themselves.

```
match = re.search('dog','The lazy dog went to sleep.')
```

will match 'do[illegible]e right-hand string.

What fancier patterns can we put in here?

https://developers.google.com/edu/python/regular-expressions

# A simple example: re methods return match objects

```
import re

str = 'a simple example!'

# want to see if ‘simple’ appears in the
# test string
match = re.search('simple', str)

if match:
    print('found', match.group())
else:
    print('did not find')
```

Returns a match object or None on failure
Important match object methods:
**`group() start() end() span()`**

## Basic Patterns

- Ordinary characters just match themselves.

```
match = re.search(r'dog','The lazy dog went to sleep.')
```

will match 'do[illegible]e right-hand string.

- Special[illegible]rs:

\\[illegible], \r   tab, newline, return

What fancier patterns can we put in here?

Th[illegible] meta-characters which do not match themselves because they have special meanings are:

```
.  ^  $  *  +  ?  {  } [  ]  \  |  (  )
```

https://developers.google.com/edu/python/regular-expressions

## Very important single-character regular expression symbols

| | |
|---|---|
| `.` | Matches any char except newline `\n` `'F..m:'` |
| | **Yes**: `Farm:` **Yes**: `Foom:` **No**: `Firm.` |
| `\s` | matches whitespace `'Pine`**`\s`**`apple'` |
| | **Yes**: `Pine apple` **No**: `Pinesapple` |
| `\S` | matches non-whitespace `'Pine`**`\S`**`pple'` |
| | **Yes**: `Pineapple` **No**: `Pine pple` |
| `\d` | Decimal digit, 0-9 |
| `\D` | Matches any non-digit character. |

# Very important single-character regular expression symbols

`^` Beginning of the line `'^From: '`

**Yes**: `From: Chris` **No**: `It said, 'From:…`

`$` End of the line (just before newline) `'Michigan$'`

**Yes**: `Michigan`**`\n`** **No**: `Michigan, U.S.A.`**`\n`**

# Escape character

What if we really want to look for `'$'`?

Use an escape character:  BACKSLASH

<u>Examples</u>:

`'\$19\.99'`    will match `$19.99`

`'\\folder'`  will match `\folder`

## Python raw string notation: `r'text'`

- Keeps regular expressions sane
- Without it, every backslash `'\'` in a regexp would need `'\'` prefix
- `r'\n'` is a two-character string containing `'\'` and `'n'`
- `'\n'` is a one-character string containing newline character
- Use `r'\\'` instead of `'\\\\'`

# Special commands for finding words (note upper and lower-case versions)

A word is considered a sequence of letters, digits, or underscore (_)
Any other characters are considered to separate words. Which of these are words?

```
my_token_2
my-token-2
734.83
```

| | |
|---|---|
| `\w` | Matches a 'word' character: a **letter** or **digit** or underscore. Note that although "word" is the mnemonic for this, it only matches a single word char, not a whole word. |
| `\W` | Matches any non-word character. |
| `\b` | Matches boundary between word \w and non-word \W chars: `r'py\b' matches 'py', 'py.', or 'py!'` but not `'python', 'py3', 'py2'` |
| `\B` | Matches NOT at beginning or end of a word. `r'py\B' matches 'python', 'py3', 'py2'` but not `'py', 'py.', or 'py!'` |

https://developers.google.com/edu/python/regular-expressions

# Often we want to search for repeated patterns: Wildcards and matching repetitions

|  |  |
|---|---|
| `*` | **Zero or more** of the previous thing |
| `+` | **One or more** of the previous thing |
| `?` | **Zero or one** of the previous thing |
| `{3}` | Matches exactly 3 of the previous thing |
| `{3,6}` | Matches between 3 and 6 of the previous thing |
| `{3,}` | Matches 3 or more of the previous thing |

# Wildcard examples

`ab*` will match

- ‘a’ (must have)
- followed by <u>zero or more</u> 'b's

`ab+` will match

- ‘a’ (must have)
- followed by <u>one or more</u> ‘b’s.
  It will not match just ‘a’.

`ab?` will match

- ‘a’ (must have)
- Followed by <u>zero or one</u> b's

## Sets, ranges and alternatives

## Specifying a set of characters using `[ ]`

- `[aeiou]` Matches a single character in the given set {a, e, i, o, u}
- `[^aeiou]` Matches a single character NOT in the given set {a, e, i, o, u}

Example:
What substrings does `[aeiou]{2,}` match in

```
The eerie wind said "Oooo" and "Rrr".
```

```
The eerie wind said "Oooo" and "Rrr".
```

Why not O?

# How you would use this in Python

```
>>> import re
>>> s = "The eerie wind said Oooo and Rrrr"
>>> match = re.search('[aeiou]{2,}', s)
```

Note that there are multiple matches for this pattern in the text. `re.search` will only find the first one.

`re.findall` will return all strings that match the pattern.

```
>>> re.findall("[aeiou]{2,}", s)
['ee', 'ie', 'ai', 'ooo']
```

## The `finditer()` method returns a list of <u>match objects</u> (not just strings)

```
>>> s = "The eerie wind said Oooo and Rrrr"
>>> matches = re.finditer("[aeiou]{2,}", s)
>>> for m in matches:
...   print(m.group())
...
ee
ie
ai
ooo
```

# A range of characters can be defined using dash (-) as part of a set `[ ]`

- Valid:

| | |
|---|---|
| `[A-Z]` | Upper Case Roman Alphabet |
| `[a-z]` | Lower Case Roman Alphabet |
| `[A-Za-z]` | Upper/Lower Case |
| `[A-F]` | Upper Case (only A – F) |
| `[0-9]` | All Digits \d |
| `[a-zA-Z0-9_]` | \w |

- Invalid:

```
[a-Z]
[F-A]
[9-0]
```

# Example application: extracting email spam headers

```
X-DSPAM-Confidence: 0.8475
X-DSPAM-Probability: 0.0000
```

We need to extract numbers from lines with the above syntax.

We don’t just want any floating-point numbers from any email lines.

We can construct the following regular expression to select the lines:

```
^X-.*:\s[0-9.]+
```

# Example using multiple operators

```
X-DSPAM-Confidence: 0.8475
```

```
^X-.*:\s[0-9.]+
```

- What does this say?
  - We want strings that start (`'^'`) with `X-`
  - Followed by zero or more of any character `'.*'`
  - Then a colon (`':'`) and a whitespace `\s` char.
  - After the whitespace, look for **one or more** characters
    - That are either a digit (0-9) or a period
- Note that special characters are not active inside ranges, so `'.'` is treated as a period.

## Example using multiple operators

```
^X-.*:\s[0-9.]+
```

Match? `xX-abd:_487.3` No

Match? `X-abd:_487.34.2` Yes

Match? `X-:_.` Yes

Match? `X-abd:_iii.3` No

## Using the wildcard in Python with `finditer()`

```
>>> etext = read_email_text("email.txt")
>>> matches = re.finditer(r"^X-.*:\s[0-9.]+", etext)
>>> for m in matches:
...   print(m.group())
...
X-DSPAM-Confidence: 0.8475
X-Mail-Word-Count: 873
X-DSPAM-Confidence: 0.7323
(and more matches…)
```

# Negation of Ranges of Regular Expressions

| | |
|---|---|
| `[^0-9]` | Anything BUT digits |
| `[^a]` | Anything BUT a lower case a |
| `[^A-Z]` | Anything BUT upper case letters |
| `[^,]` | Anything BUT , |

What kind of strings does this match?

`^[^^]`

Match? `^foo` No

Match? `foo^` Yes

Strings that start with a character that is NOT `'^'`

## Defining alternatives using the pipe | metacharacter

- `th(is|at|e other)`
  - matches 'this', 'that', or 'the other'
- `tha[nt]|re`
  - matches 'than' 'that' or 're'
- Each alternative can be a regular expression

```
(success | failure code: [0-9]+ | maybe[!?]*)
```

- Pipe is never greedy. As the target string is scanned:
  - REs separated by `'|'` are tried from left to right.
  - When one pattern completely matches, that branch is accepted.
  - This means that once A matches, B will not be tested further.
  - Even if it would produce a longer overall match.
- What does this match?

  `^(T|t)oday`

## Group Extraction: A more sophisticated type of match

Problem:

Often you want to extract parts of the matching text for later use. e.g. find email addresses, and extract user and hostname.

Solution: Use parentheses to create groups showing the parts you want to save for later.

```
str =  'My email addre Group 1 anta@ Group 2 edu. Hohoho.'
match = re.search(r'([\w.-]+)@([\w.-]+)', str)
if match:
  print(match.group())    # the whole match
  print(match.group(1))   # the username part
  print(match.group(2))   # the hostname part
```

# `re.findall` with groups

`findall(pattern, string, flags=0)`

- <u>Returns</u> a list of <u>all</u> non-overlapping matches as a list of strings
- If one or more groups are present in the pattern, return a list of groups.
- This will be a list of tuples if the pattern has more than one group.
- Empty matches are included in the result.

## findall() Example

```
str = 'I have two email addresses: santa@umich.edu \
and santa@northpole.org. Hohoho.'

# Here re.findall() returns a list of all the found
# email strings
emails = re.findall(r'[\w\.-]+@[\w\.-]+', str)

findall returns a list of strings.

['santa@umich.edu', 'santa@northpole.org']
```

## findall() and Group Extraction

```
str = 'I have two email addresses: santa@umich.edu \
and santa@northpole.org. Hohoho.'

# Here re.findall() returns a list of all the found
# email strings
emails = re.findall(r'([\w\.-]+)@([\w\.-]+)', str)
email[0] = ('santa', 'umich.edu')
email[1] = ('santa', 'northpole.org')
```

# finditer() and Group Extraction

| | | |
|---|---|---|
| `m.group(0)` | The <u>entire</u> match string | `santa@umich.edu` |
| `m.group(1)` | The first group | `santa` |
| `m.group(2)` | The second group | `umich.edu` |

```
str = 'I have two email addresses: santa@umich.edu \ and
santa@northpole.org. Hohoho.'

>>> matches = re.finditer(r"([\w\.-]+)@([\w\.-]+)", str)
>>> for m in matches:
...   print("first group: "+m.group(1)+", second group: "+m.group(2))
...
first group: santa, second group: umich.edu
first group: santa, second group: northpole.org.
```

## `re.search()` returns a match object, so groups work there too

| | | |
|---|---|---|
| `m.group(0)` | The entire match string | `santa@umich.edu` |
| `m.group(1)` | The first group | `santa` |
| `m.group(2)` | The second group | `umich.edu` |

```
str = 'I have two email addresses: santa@umich.edu \ and
santa@northpole.org. Hohoho.'

>>> m = re.search(r"([\w\.-]+)@([\w\.-]+)", str)
>>> print("first group: "+m.group(1)+", second group: "+m.group(2))
first group: santa, second group: umich.edu
```

## Advanced matching: more subtle ways to modify searching

- Greedy vs. non-greedy matching
- Zero-width lookahead

## Greedy Matching is the Default

- Python always tries to match as much as possible.
- Example:

```
str = 'the cat in the hat'
match = re.search(r'^(.*)(at)(.*)$', str)
```

Now, what do we have in

`match.group(1), match.group(2), match.group(3)?`

```
'the cat in the h'
'at'
''
```

# Non-greedy Matching: Add an extra `?` To your wildcard

- Non-greedy versions try to match as minimally as possible.
  `??` ,`*?` , `+?`, and `{}?`
- Example 1:

```
x = 'the cat in the hat';
 match = re.search(r'^(.*?)(at)(.*)$', str)
```

Now, what do we have in

```
match.group(1), match.group(2) and match.group(3)?
 'the c'    'at'   ' in the hat'
```

- Example 2: `<H1>title</H1>`
  `<.*>` will match the whole string .
  `<.*?>` will match `<H1>`

## Very useful power: You can refer back to an earlier group match within the same regular expression. How?

- \N where N is the group number
- \1 matches group 1 result

Example:

`r'<(.*?)>(.*?)</`**`\1`**`>'`

Matches tag pairs with matching begin/end tags

<**X**>foobar</**X**>    <**ABCD**>baz<**/ABCD**>

# Stop and look ahead (without adding to the current match): zero-width matching

- Problem:
  - We want to match any single character *q* that is not followed by *u*?
  - Why not use `q[^u]`

    Means: `q` followed by a character that is not a `u`

  `Iraqi population`

  `q[^u]` returns `qi` (q followed by i). This is two characters.
- What's the problem?
  - The regexp matcher has just 'used up' the `i` as part of this match and is now looking past it, at the 'space' character.
- But the 'i' may be important in an upcoming regexp match
  - Solution: check for the presence of 'not u' without letting regexp 'eat' it…
  - You do this by using a zero-width *negative lookahead assertion* **`q(?!u)`**
- Assertions do not 'use up' characters: they are zero-width, like start/end of line, or start/end of word
- This will match the single character *q only,* not trailing letters

## Other types of zero-width assertions

- *Negative look<u>behind</u> assertion*:

  **(?<!**`abc`**)**`def` will <u>not</u> match `abcdef`, but will match `acbdef`
- *Positive look<u>behind</u> assertion* **(?<=**`abc`**)**`def` will first match `def`, then back up 3 characters and check for the contained pattern `abc`.
- What does `(?<=-)\w+` do?
  - Matches a word preceded by a hyphen

```
m = re.search('(?<=-)\w+','hard-boiled')
m.group(0): 'boiled'
```

# Options

- The option flag can be added as an extra argument to search(), findall() etc.,
  - e.g. `re.search(pat, str, `**`re.IGNORECASE`**`)`

- `re.IGNORECASE` Ignore upper/lowercase differences for matching, so 'a' matches both 'a' and 'A'.
- `re.DOTALL` Make the '.' special character match any character at all, including a newline; without this flag, '.' will match anything *except* a newline.
- `re.MULTILINE` Within a string made of many lines, allow ^ and $ to match the start and end of each line. Normally ^/$ would just match the start and end of the whole string.
- `re.UNICODE` Match against Unicode strings: invoke Unicode character properties for word-vs-nonword characters, etc.

# Substitution

```
sub(pattern, repl, string, count=0,
flags=0)
```

- Return the string obtained by replacing the leftmost non-overlapping occurrences of the pattern in string by the replacement repl.
- repl can be either a string or a callable.
- If a string, backslash escapes in it are processed.
- If it is a callable, it's passed the match object and must return a replacement string to be used.

## Substitution Example

```
str = 'My email is santa@umich.edu. Hohoho.’

print(re.sub(r'@[\w\.-]+', '@northpole.org', str))
```

# prints out My email is santa@northpole.org Hohoho.

# Compile regex Patterns

- If a regex pattern is going to be reused, it is a good idea to compile it first.
- Example:

```
p = re.compile('\d+')
# search demo
m = p.search('12 drummers drumming, 11 pipers piping, 10
lords a-leaping')
if m:
  print('Match found: ', m.group())
else:
  print('No match’)
# findall demo
print(p.findall('12 drummers drumming, 11 pipers piping,
10 lords a-leaping'))
```

# What you should know

- How to write useful types of text matching patterns as regular expressions
- How to specify and extract groups in a match
- How to use the python `re` library functions to search and extract all matches in a text