LING/C SC/PSYC 438/538

Lecture 11

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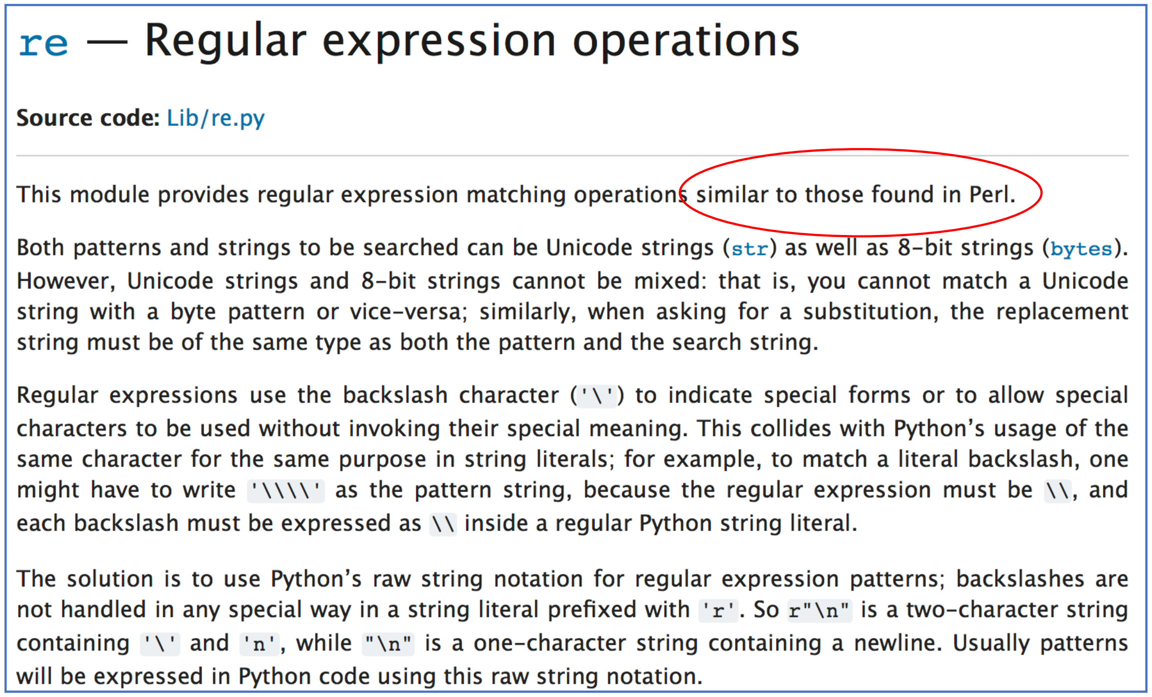
Today's Topics

- Perl regex introduction
- Homework 8

Today's Topics

- **Perl regex**
- Python `re`
  - `import re`
  - slightly complicated string handling: use raw `r'…'` format
  - https://docs.python.org/3/library/re.html
  - (*there's also a 3rd party regex module*)



`re` — Regular expression operations

Source code: Lib/re.py

This module provides regular expression matching operations similar to those found in Perl.

Both patterns and strings to be searched can be Unicode strings (`str`) as well as 8-bit strings (`bytes`). However, Unicode strings and 8-bit strings cannot be mixed: that is, you cannot match a Unicode string with a byte pattern or vice-versa; similarly, when asking for a substitution, the replacement string must be of the same type as both the pattern and the search string.

Regular expressions use the backslash character (`'\'`) to indicate special forms or to allow special characters to be used without invoking their special meaning. This collides with Python's usage of the same character for the same purpose in string literals; for example, to match a literal backslash, one might have to write `'\\\\'` as the pattern string, because the regular expression must be `\\`, and each backslash must be expressed as `\\` inside a regular Python string literal.

The solution is to use Python's raw string notation for regular expression patterns; backslashes are not handled in any special way in a string literal prefixed with `'r'`. So `r"\n"` is a two-character string containing `'\'` and `'n'`, while `"\n"` is a one-character string containing a newline. Usually patterns will be expressed in Python code using this raw string notation.

https://xkcd.com/208/

Regular Expressions to the rescue

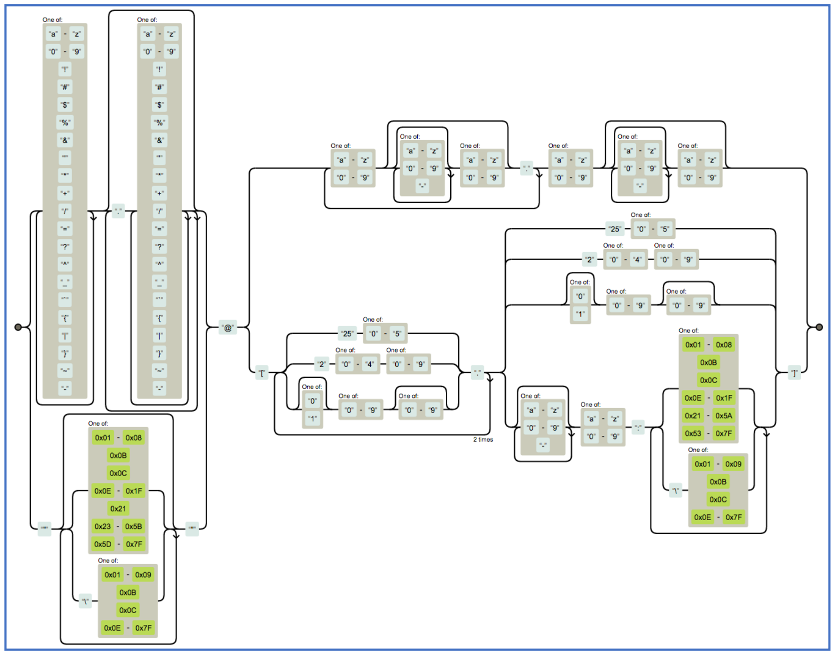
WHENEVER I LEARN A NEW SKILL I CONCOCT ELABORATE FANTASY SCENARIOS WHERE IT LETS ME SAVE THE DAY.
OH NO! THE KILLER MUST HAVE FOLLOWED HER ON VACATION!
BUT TO FIND THEM WE'D HAVE TO SEARCH THROUGH 200 MB OF EMAILS LOOKING FOR SOMETHING FORMATTED LIKE AN ADDRESS!
IT'S HOPELESS!
EVERYBODY STAND BACK.
I KNOW REGULAR EXPRESSIONS.
PERL!
TAP TAP

A regex from Hell

Email validation: RFC 5322 (Internet Message Format):

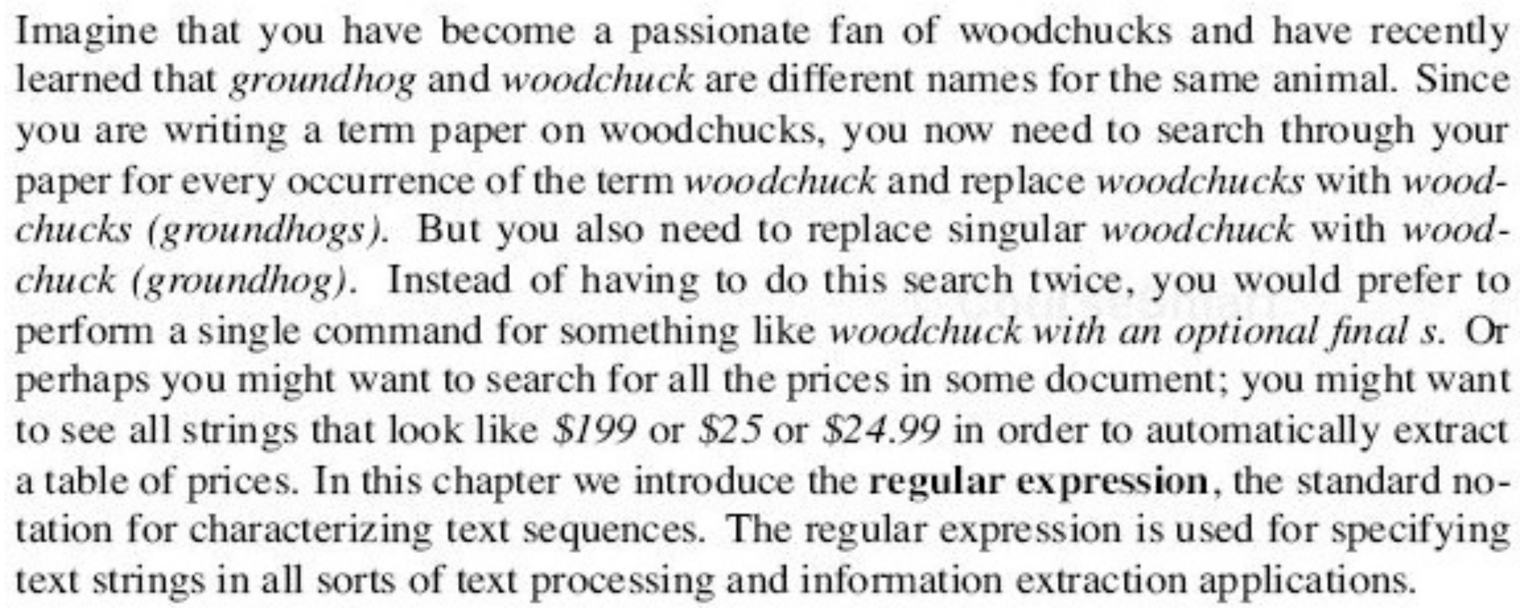
```
(?:[a-z0-9!#$%&'*+/=?^_`{|}~-]+(?:\.[a-
z0-9!#$%&'*+/=?^_`{|}~-]+)*|"(?:[\x01-
\x08\x0b\x0c\x0e-\x1f\x21\x23-\x5b\x5d-
\x7f]|\\[\x01-\x09\x0b\x0c\x0e-
\x7f])*")@(?:(?:[a-z0-9](?:[a-z0-9-]*[a-
z0-9])?\.)+[a-z0-9](?:[a-z0-9-]*[a-z0-
9])?|\[(?:(?:(2(5[0-5]|[0-4][0-9])|1[0-
9][0-9]|[1-9]?[0-9]))\.){3}(?:(2(5[0-
5]|[0-4][0-9])|1[0-9][0-9]|[1-9]?[0-
9])|[a-z0-9-]*[a-z0-9]:(?:[\x01-
\x08\x0b\x0c\x0e-\x1f\x21-\x5a\x53-
\x7f]|\\[\x01-\x09\x0b\x0c\x0e-
\x7f])+)\])
```

https://www.rfc-editor.org/rfc/rfc5322



regex

- Read textbook chapter 2: section 1 on regex (*if you have it*)



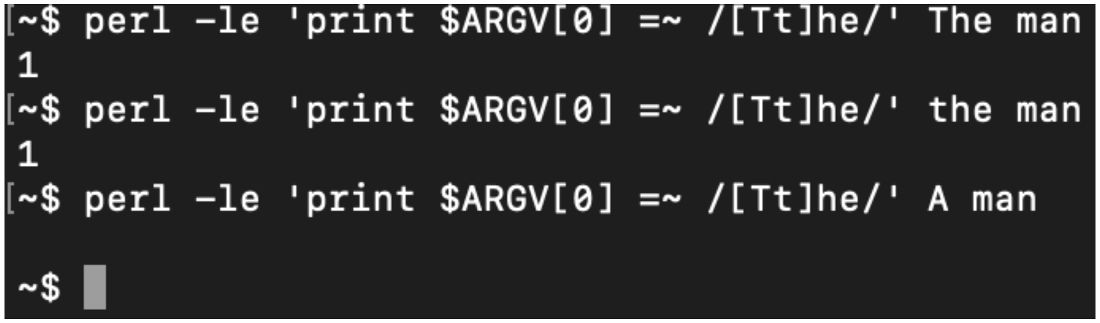
Imagine that you have become a passionate fan of woodchucks and have recently learned that *groundhog* and *woodchuck* are different names for the same animal. Since you are writing a term paper on woodchucks, you now need to search through your paper for every occurrence of the term *woodchuck* and replace *woodchucks* with *woodchucks (groundhogs)*. But you also need to replace singular *woodchuck* with *woodchuck (groundhog)*. Instead of having to do this search twice, you would prefer to perform a single command for something like *woodchuck with an optional final s*. Or perhaps you might want to search for all the prices in some document; you might want to see all strings that look like *$199* or *$25* or *$24.99* in order to automatically extract a table of prices. In this chapter we introduce the **regular expression**, the standard notation for characterizing text sequences. The regular expression is used for specifying text strings in all sorts of text processing and information extraction applications.

Perl regex

- Read up on the syntax of Perl regular expressions
- Online tutorials
  - http://perldoc.perl.org/perlrequick.html
  - http://perldoc.perl.org/perlretut.html

Perl regex

- Perl regex matching:
  - `$s =~ /foo/`   (`/…/` contains a regex)
  - can use in a conditional:
    - e.g. `if ($s =~ /foo/)` …
    - evaluates to true/false depending on what's in `$s`
  - can also use as a statement:
    - e.g. `$s =~ /foo/;`
    - global variable $& contains the match
- **Examples**:

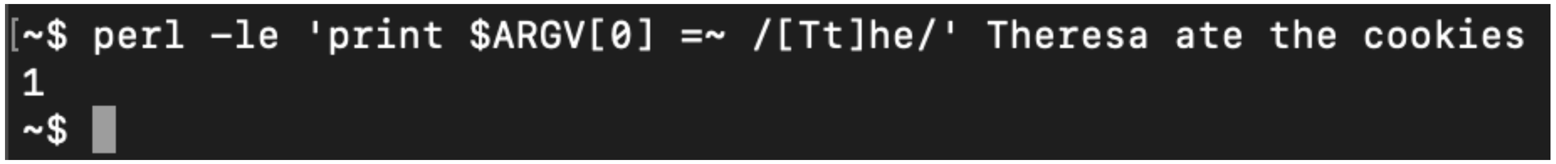


```
[~$ perl -le 'print $ARGV[0] =~ /[Tt]he/' The man
1
[~$ perl -le 'print $ARGV[0] =~ /[Tt]he/' the man
1
[~$ perl -le 'print $ARGV[0] =~ /[Tt]he/' A man

~$ 
```

Perl regex

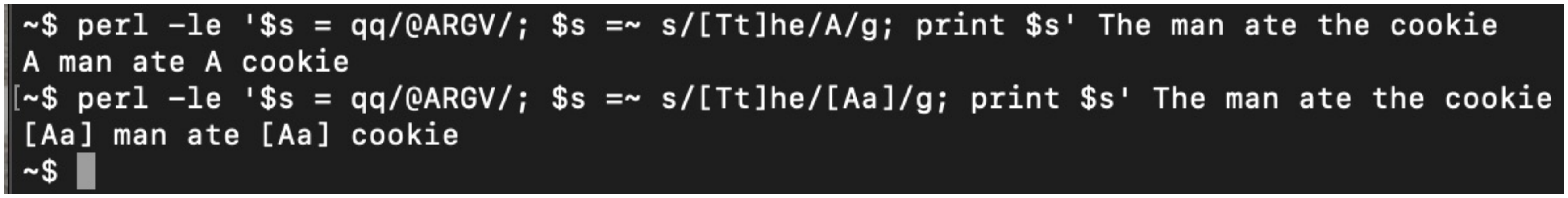
- Match is not exact:



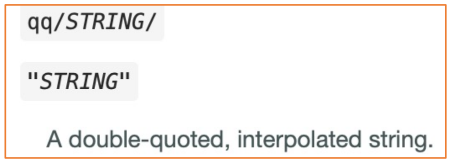
```
[~$ perl -le 'print $ARGV[0] =~ /[Tt]he/' Theresa ate the cookies
1
~$ 
```

Perl regex

- Perl regex match and substitute:
    - `$s =~ s/foo/bar/`
    - `s/…`*`match`*`… /…`*`substitute`*`… /` contains two expressions
    - will modify `$s` by looking for a **single** occurrence of *`match`* and replacing that with *`substitute`*
    - `s/…`*`match`*`… /…`*`substitute`*`… /g` global substitution
- **Examples:**



```
~$ perl -le '$s = qq/@ARGV/; $s =~ s/[Tt]he/A/g; print $s' The man ate the cookie
A man ate A cookie
[~$ perl -le '$s = qq/@ARGV/; $s =~ s/[Tt]he/[Aa]/g; print $s' The man ate the cookie
[Aa] man ate [Aa] cookie
~$
```



`qq/STRING/`

`"STRING"`

A double-quoted, interpolated string.

https://perldoc.perl.org/perlop#Quote-Like-Operators

Perl regex

- Most useful with `template.perl` for reading in a file line-by-line:

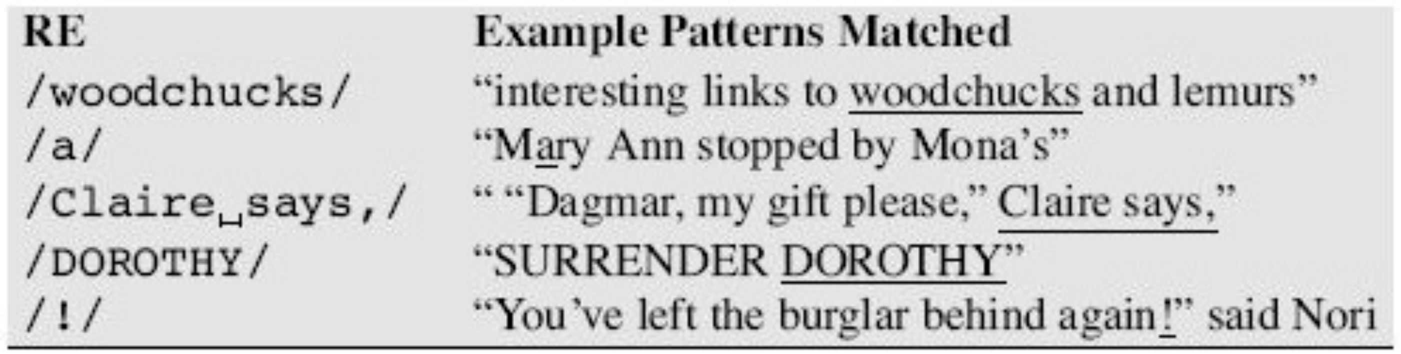
```
open($fh, $ARGV[0]) or die "$ARGV[0] not found!\n";
while ($line = <$fh>) {
  $line =~ /…/
}
close($fh)
```

- Or on the command line in abbreviated form as:

```
perl –le 'open $f, filename; while (<$f>) {while (/regex/g)
{print $&}}'
```

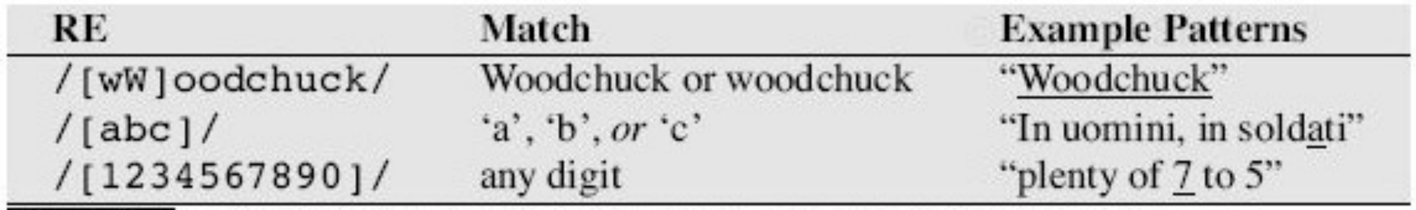
- Let’s practice this after we've introduced the notation …

Chapter 2: JM



spaces matter!

RE	Example Patterns Matched
`/woodchucks/`	"interesting links to woodchucks and lemurs"
`/a/`	"Mary Ann stopped by Mona's"
`/Claire␣says,/`	" "Dagmar, my gift please," Claire says,"
`/DOROTHY/`	"SURRENDER DOROTHY"
`/!/`	"You've left the burglar behind again!" said Nori



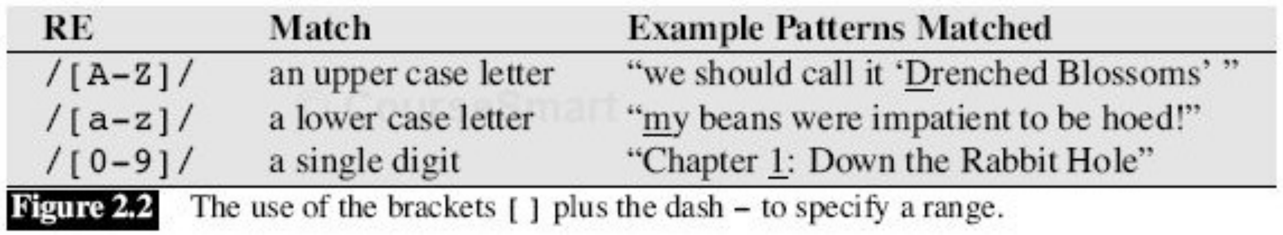
RE	Match	Example Patterns
`/[wW]oodchuck/`	Woodchuck or woodchuck	"Woodchuck"
`/[abc]/`	'a', 'b', *or* 'c'	"In uomini, in soldati"
`/[1234567890]/`	any digit	"plenty of 7 to 5"

Figure 2.1 The use of the brackets `[]` to specify a disjunction of characters.

character class: Perl lingo

Chapter 2: JM

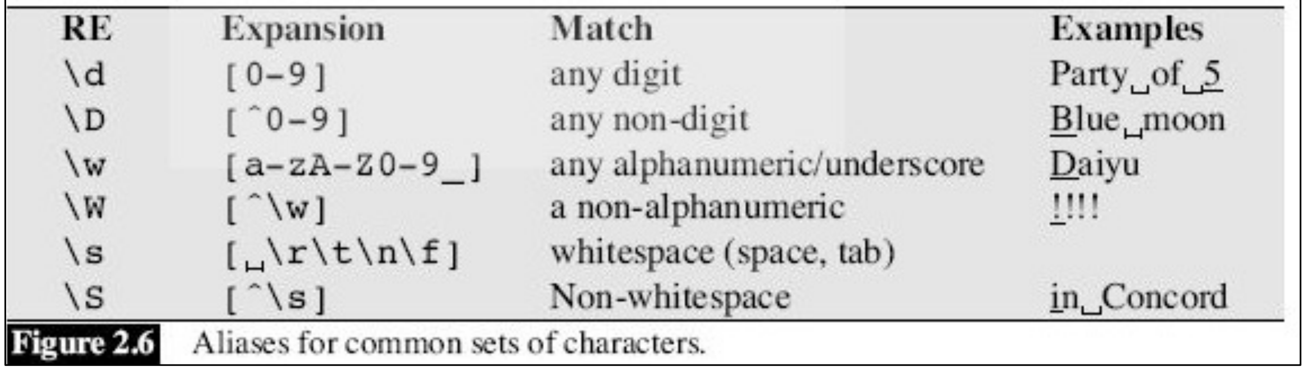
range: in ASCII table



RE	Match	Example Patterns Matched
`/[A-Z]/`	an upper case letter	"we should call it 'Drenched Blossoms' "
`/[a-z]/`	a lower case letter	"my beans were impatient to be hoed!"
`/[0-9]/`	a single digit	"Chapter 1: Down the Rabbit Hole"

Figure 2.2 The use of the brackets `[ ]` plus the dash `-` to specify a range.

backslash lowercase letter for class
Uppercase variant for **all but** class



RE	Expansion	Match	Examples
`\d`	`[0-9]`	any digit	Party␣of␣5
`\D`	`[^0-9]`	any non-digit	Blue␣moon
`\w`	`[a-zA-Z0-9_]`	any alphanumeric/underscore	Daiyu
`\W`	`[^\w]`	a non-alphanumeric	!!!!
`\s`	`[␣\r\t\n\f]`	whitespace (space, tab)	
`\S`	`[^\s]`	Non-whitespace	in␣Concord

Figure 2.6 Aliases for common sets of characters.

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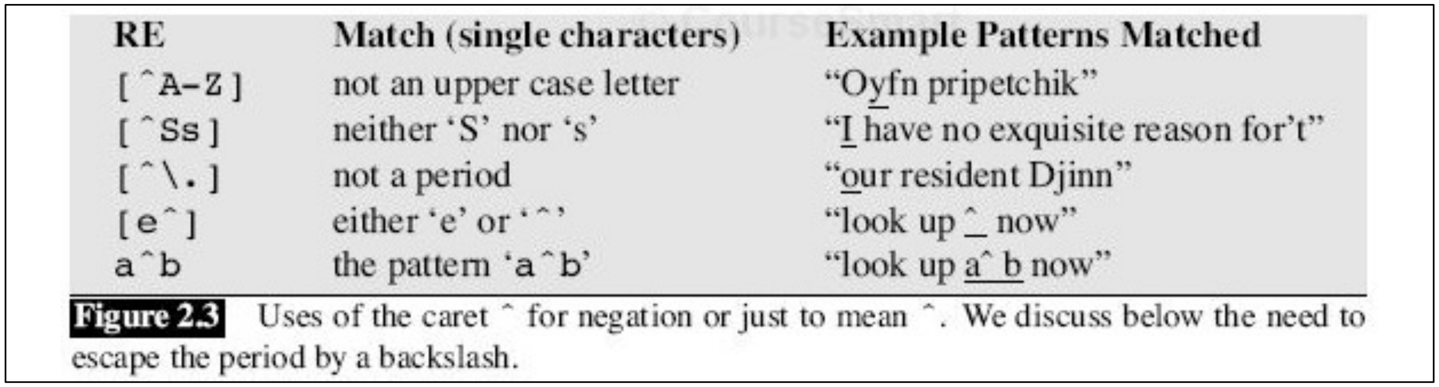
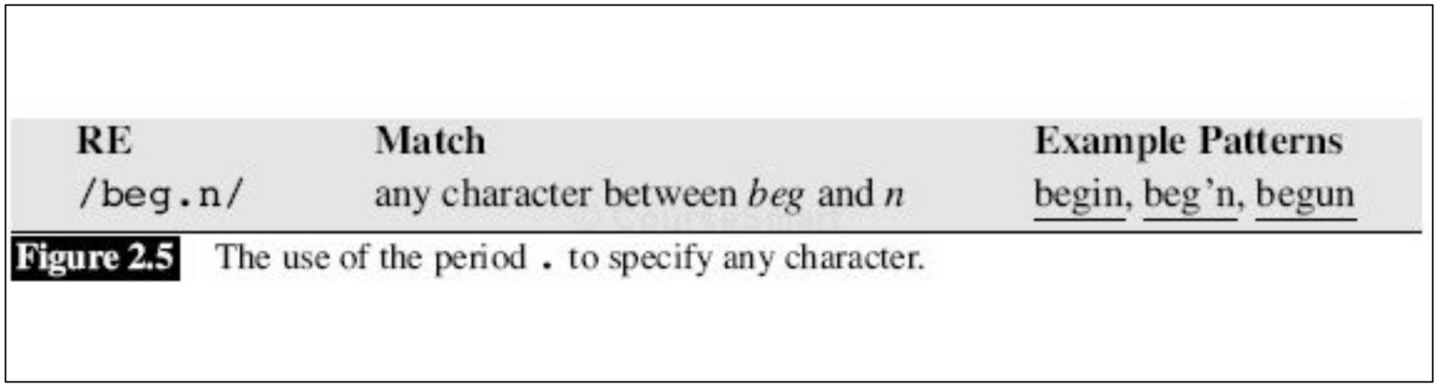


RE	Match (single characters)	Example Patterns Matched
`[^A-Z]`	not an upper case letter	"Oyfn pripetchik"
`[^Ss]`	neither 'S' nor 's'	"I have no exquisite reason for't"
`[^\.]`	not a period	"our resident Djinn"
`[e^]`	either 'e' or '^'	"look up ^ now"
`a^b`	the pattern 'a^b'	"look up a^ b now"

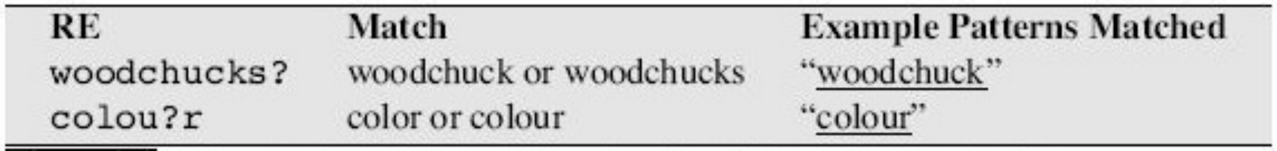
Figure 2.3 Uses of the caret ^ for negation or just to mean ^. We discuss below the need to escape the period by a backslash.



RE	Match	Example Patterns
`/beg.n/`	any character between *beg* and *n*	begin, beg'n, begun

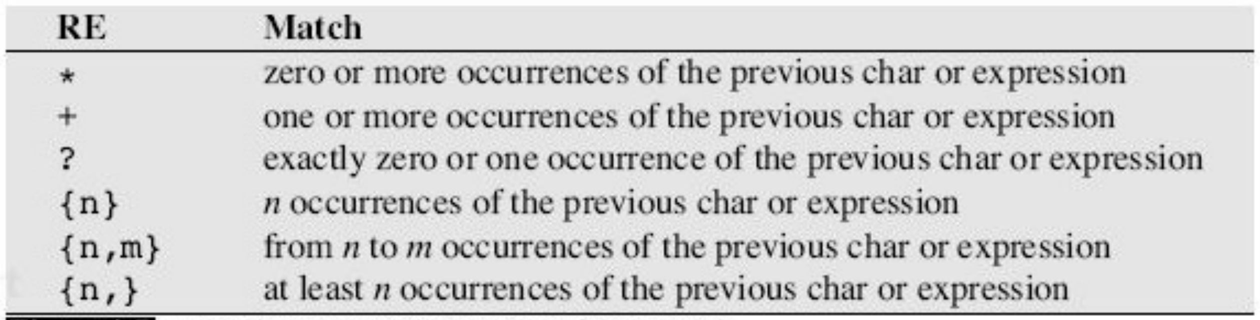
Figure 2.5 The use of the period `.` to specify any character.

Chapter 2: JM



RE	Match	Example Patterns Matched
`woodchucks?`	woodchuck or woodchucks	"woodchuck"
`colou?r`	color or colour	"colour"

Figure 2.4 The question mark `?` marks optionality of the previous expression.

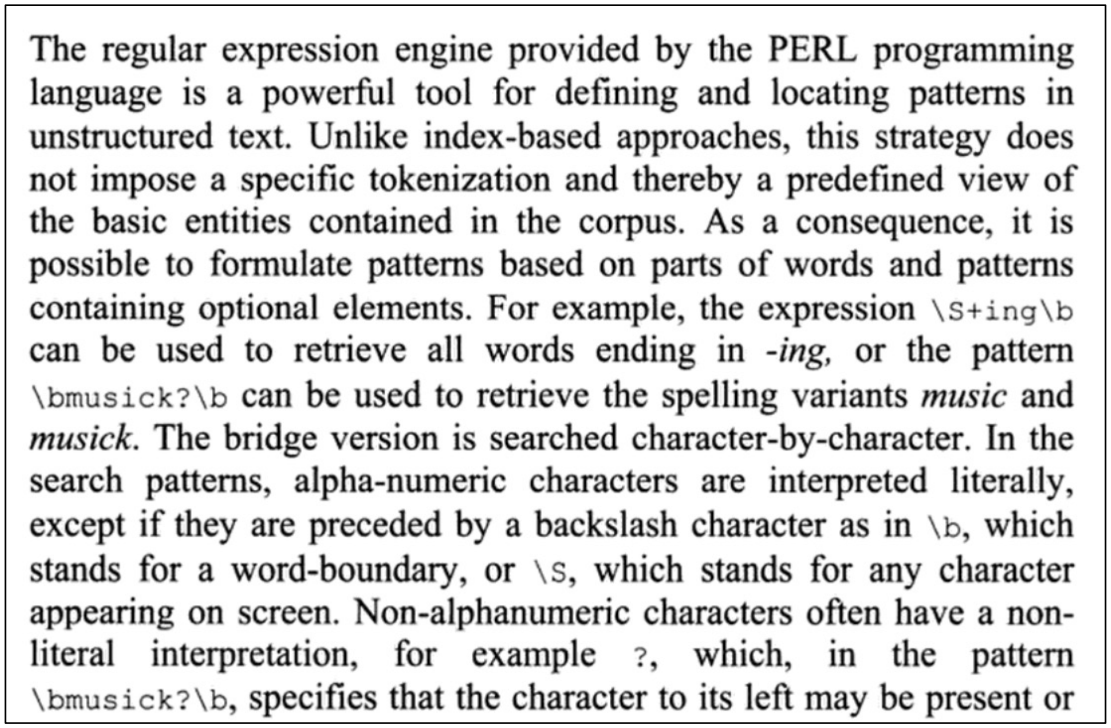


RE	Match
`*`	zero or more occurrences of the previous char or expression
`+`	one or more occurrences of the previous char or expression
`?`	exactly zero or one occurrence of the previous char or expression
`{n}`	*n* occurrences of the previous char or expression
`{n,m}`	from *n* to *m* occurrences of the previous char or expression
`{n,}`	at least *n* occurrences of the previous char or expression

Figure 2.7 Regular expression operators for counting.

Can use parentheses (…) to group around a sub-expression if > 1 char
e.g. (ab)* vs. ab*

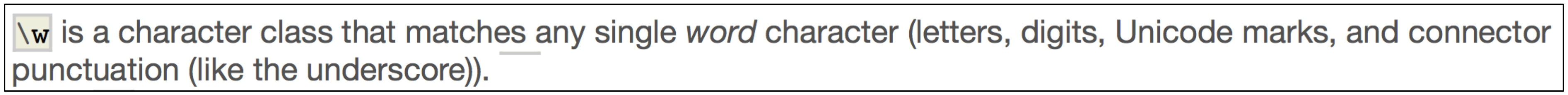
Perl regex



The regular expression engine provided by the PERL programming language is a powerful tool for defining and locating patterns in unstructured text. Unlike index-based approaches, this strategy does not impose a specific tokenization and thereby a predefined view of the basic entities contained in the corpus. As a consequence, it is possible to formulate patterns based on parts of words and patterns containing optional elements. For example, the expression `\S+ing\b` can be used to retrieve all words ending in *-ing,* or the pattern `\bmusick?\b` can be used to retrieve the spelling variants *music* and *musick*. The bridge version is searched character-by-character. In the search patterns, alpha-numeric characters are interpreted literally, except if they are preceded by a backslash character as in `\b`, which stands for a word-boundary, or `\S`, which stands for any character appearing on screen. Non-alphanumeric characters often have a non-literal interpretation, for example `?`, which, in the pattern `\bmusick?\b`, specifies that the character to its left may be present or

Example: `\S+ing\b`

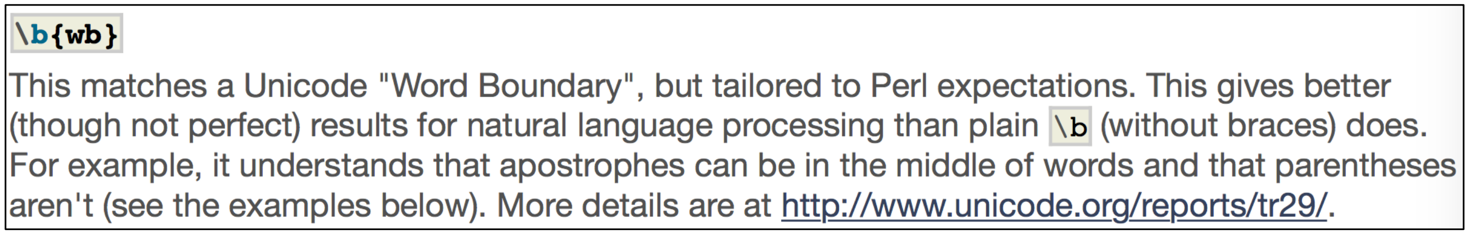
- \s is a whitespace, so \S is a non-whitespace
- + is repetition (1 or more)
- \b is a word boundary, (words are made up of \w characters)



`\w` is a character class that matches any single *word* character (letters, digits, Unicode marks, and connector punctuation (like the underscore)).

Perl regex

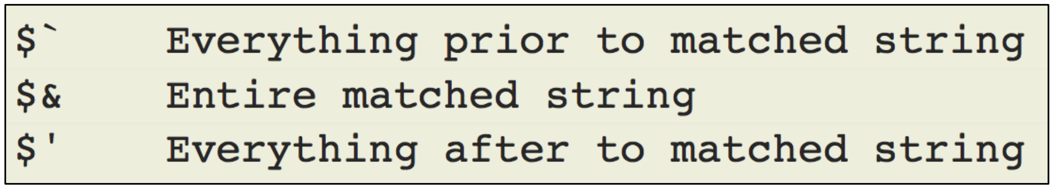
- \b or \b{wb}



`\b{wb}`

This matches a Unicode "Word Boundary", but tailored to Perl expectations. This gives better (though not perfect) results for natural language processing than plain `\b` (without braces) does. For example, it understands that apostrophes can be in the middle of words and that parentheses aren't (see the examples below). More details are at http://www.unicode.org/reports/tr29/.

- Perl global variables set during regex matching:

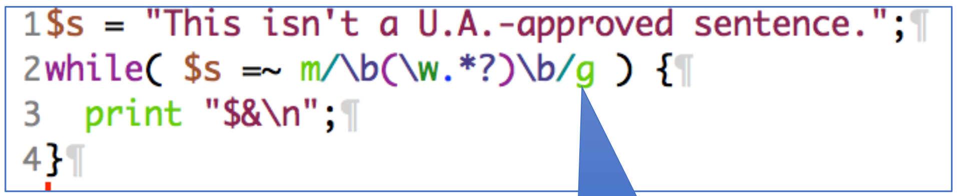


$`	Everything prior to matched string
$&	Entire matched string
$'	Everything after to matched string

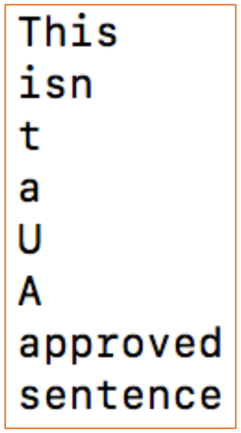
- other boundary metacharacters: ^ (beginning of line), $ (end of line)

Perl regex: Unicode and \b

\b



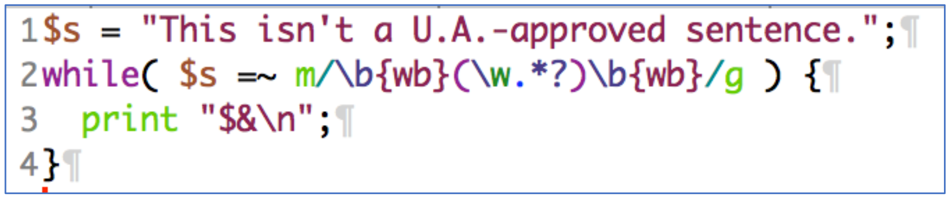
```
$s = "This isn't a U.A.-approved sentence.";
while( $s =~ m/\b(\w.*?)\b/g ) {
  print "$&\n";
}
```



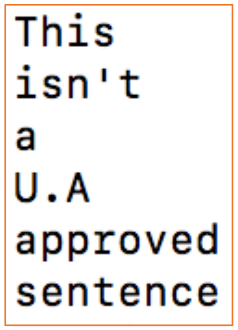
```
This
isn
t
a
U
A
approved
sentence
```

Note: global match in while-loop

\b{wb}



```
$s = "This isn't a U.A.-approved sentence.";
while( $s =~ m/\b{wb}(\w.*?)\b{wb}/g ) {
  print "$&\n";
}
```



```
This
isn't
a
U.A
approved
sentence
```

Note: `.*?` is the non-greedy version of `.*`

Perl regex: Unicode and \w

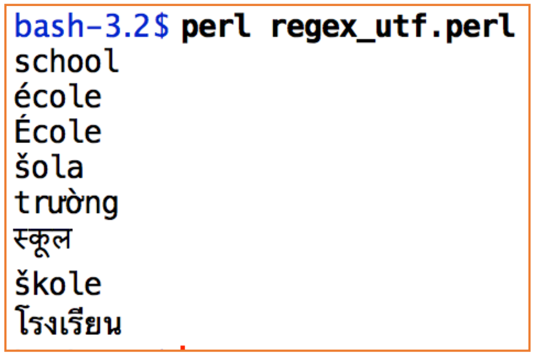
- `\w is [0-9A-Za-z_]`

Definition is expanded for Unicode:

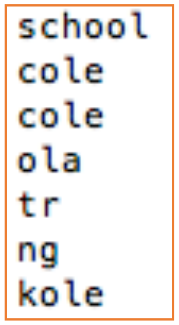
use **pragma:** https://perldoc.perl.org/open.html

```
use utf8;
use open qw(:std :utf8);
my $str = "school école École šola trường स्कूल škole โรงเรียน";
@words = ($str =~ /(\w+)/g);
foreach $word (@words) { print "$word\n" }
```

list context

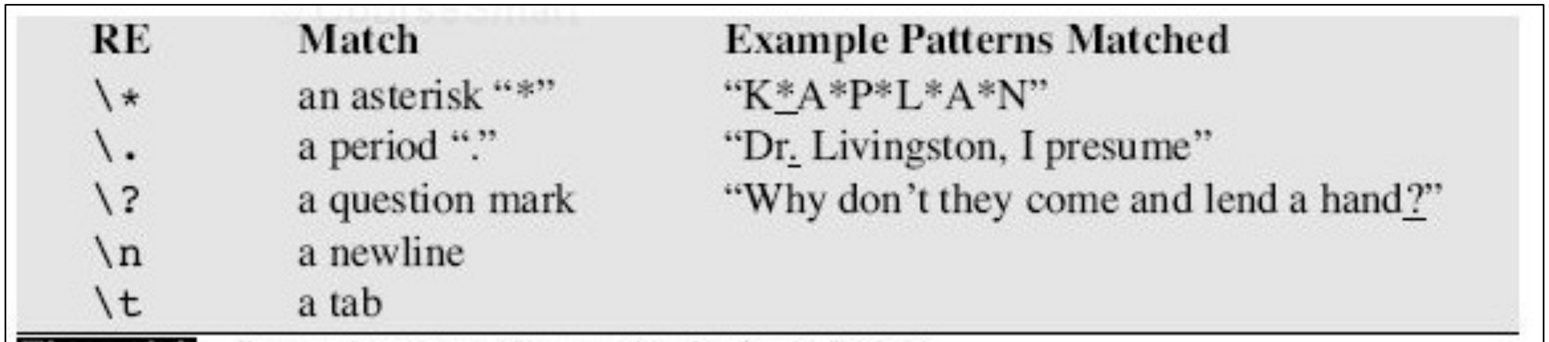


```
bash-3.2$ perl regex_utf.perl
school
école
École
šola
trường
स्कूल
škole
โรงเรียน
```



```
school
cole
cole
ola
tr
ng
kole
```

Chapter 2: JM



RE	Match	Example Patterns Matched
`\*`	an asterisk "*"	"K*A*P*L*A*N"
`\.`	a period "."	"Dr. Livingston, I presume"
`\?`	a question mark	"Why don't they come and lend a hand?"
`\n`	a newline	
`\t`	a tab	

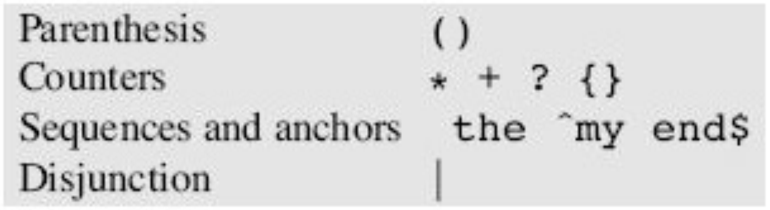
Figure 2.8 Some characters that need to be backslashed.

Why is a backslash needed?

- * means zero or more repetitions of the previous char/expr
- . means any single character
- ? means previous char/expr is optional (zero or one occurrence)

Chapter 2: JM

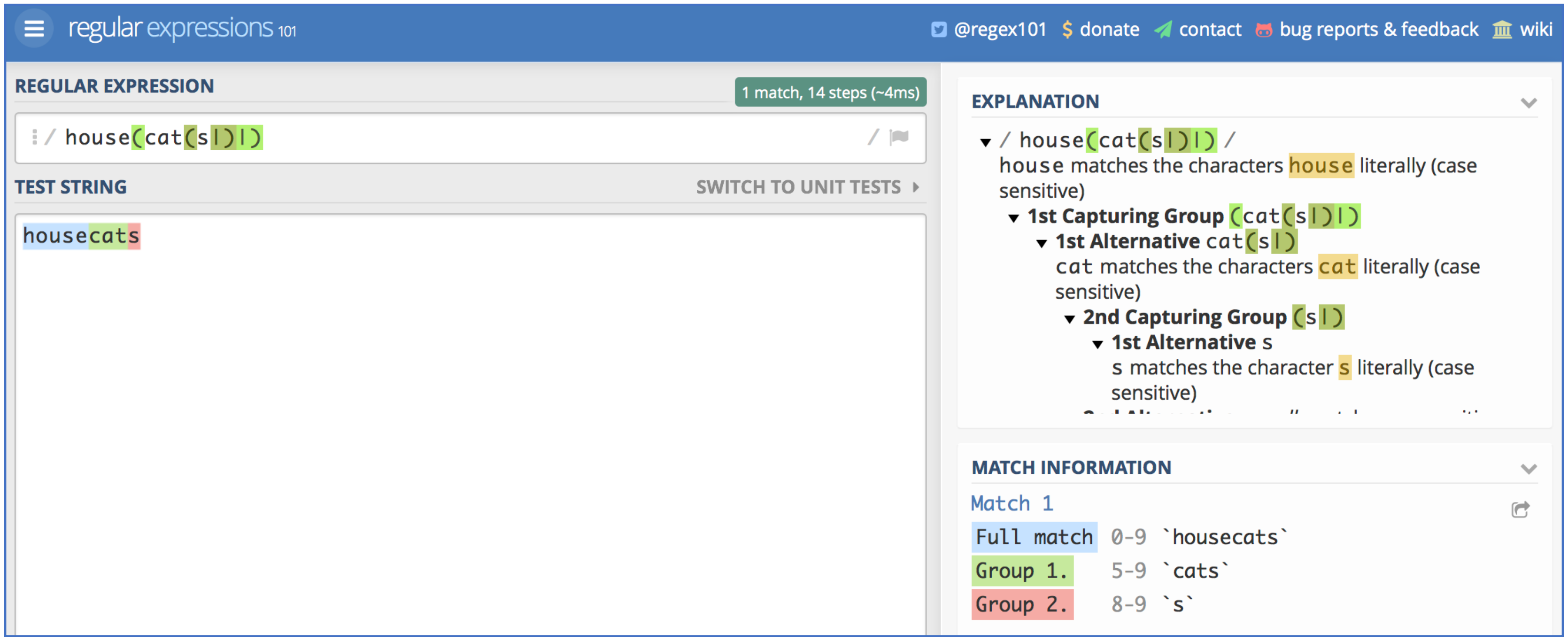
- Precedence of operators
  - Example: Column 1 Column 2 Column 3 …
  - `/Column [0-9]+ *⁄`
  - `/(Column [0-9]+ *)*/` space
  - `/house(cat(s|)|)/` (| = disjunction; ? = optional)
- Perl:
  - in a regular expression the pattern matched by within the pair of parentheses is stored in global variables $1 (and $2 and so on).
  - `(?: … )` group but exclude from $*n* variable storage
- Precedence Hierarchy:



Parenthesis	`()`
Counters	`* + ? {}`
Sequences and anchors	`the ^my end$`
Disjunction	`|`

Online regex tester

https://regex101.com



REGULAR EXPRESSION

1 match, 14 steps (~4ms)

```
/ house(cat(s|)|) /
```

TEST STRING

```
housecats
```

EXPLANATION

- / house(cat(s|)|) /
  `house` matches the characters house literally (case sensitive)
  - **1st Capturing Group** (cat(s|)|)
    - **1st Alternative** cat(s|)
      `cat` matches the characters cat literally (case sensitive)
      - **2nd Capturing Group** (s|)
        - **1st Alternative** s
          s matches the character s literally (case sensitive)

MATCH INFORMATION

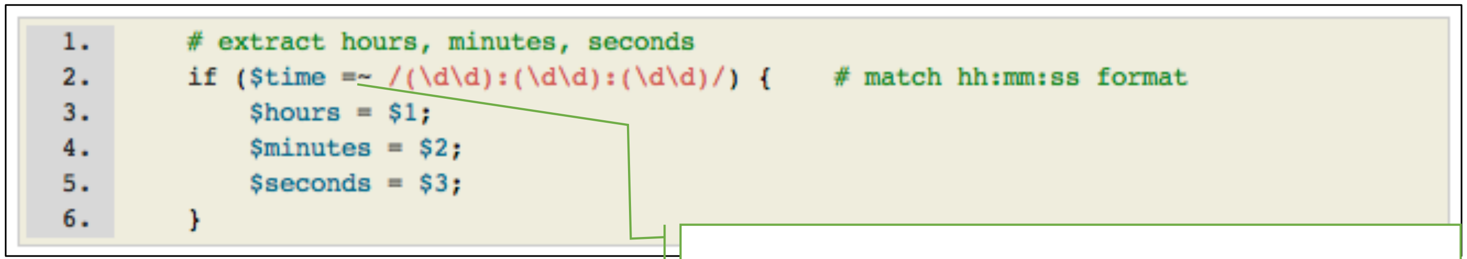
Match 1

```
Full match  0-9  `housecats`
Group 1.    5-9  `cats`
Group 2.    8-9  `s`
```

Perl regex

Recall last lecture about time?

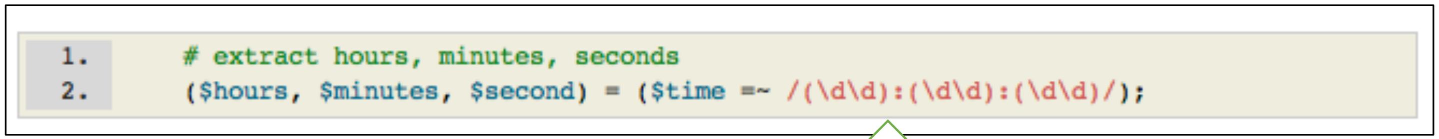
`http://perldoc.perl.org/perlretut.html`



```
    # extract hours, minutes, seconds
    if ($time =~ /(\d\d):(\d\d):(\d\d)/) {    # match hh:mm:ss format
        $hours = $1;
        $minutes = $2;
        $seconds = $3;
    }
```

returns 1 (true) or "" (empty if false)

A shortcut: **list** context for matching



```
    # extract hours, minutes, seconds
    ($hours, $minutes, $second) = ($time =~ /(\d\d):(\d\d):(\d\d)/);
```

returns a list

Homework 8

- Background:
  - "*The Pandora Papers is a leak of almost 12 million documents and files exposing the secret wealth and dealings of world leaders, politicians and billionaires.*"
- Text file (utf-8): `bbc_pandora.txt`
- Let's datamine this for *named entities* using Perl regex and see who/what we find!
- What are named entities (NE)?
  - *person*, *organization*, *place name*, *time expression*, *monetary value*, etc.
- Recall earlier slide, we have:

  -
    ```
    perl -le 'open $f, "bbc_pandora.txt"; while (<$f>) {while (/regex/g) {print $&}}'
    ```

Homework 8

- **Question 1:** in English, names typically begin with an Upper case letter. Other characters may be lower/upper case or include a dash (-), e.g. `Al–Ghad`. Write a regex and find all the matching **words** in the article. How many are there?
- **Question 1 bonus 1:** an earlier slide mentions `use open qw(:std :utf8);` Find a difference in the words reported when running your code with this declaration, i.e. when using:
  - `perl –le ' use open qw(:std :utf8); open $f, "`*`bbc–pandora.txt`*`";…'`
  - **Hint**: you may want to think about `[A–Za–z–]` vs `[\w–]`
- **Question 1 bonus 2:** do all name words begin with an Upper case letter? Find one that doesn't.

Homework 8

- **Question 2:** abbreviations/acronyms often consist of words, #letters ≥2, containing only Upper case letters,e.g. `TV NTV US EPA`. Write a regex for this. How many are there?
- **Question 3:** many names are *n*-grams, for *n*≥2, a sequence of words each beginning with an Upper case letter, **optionally** beginning with a title, e.g. Mr/Ms/Mrs/Dr, Prime Minister, President or King/Queen, e.g. `Mr Zelensky, President Vladimir Putin or King Abdullah II`. Write a regex and find all the matching sequences (*#words* ≥2) beginning with a title in the article. Print them. How many are there?

Homework 8

- **Question 4**: write a regex to find all the monetary values quoted in the article. Note currency symbols, comma separators and abbreviations such as m for million. Print them. How many are there?

following is optional for 438, mandatory for 538.

- **Question 5**: using the Perl hash table described in a previous lecture, re-do question 3 and collect together mentions of names, e.g. King `Abdullah` occurs multiple times. Then print names and number of occurrences in tabular form, e.g.
  - `Mr Piñera                                2`