Start Recording

- Today:
  - Combinatorix Review
  - Drawing Trees
  - Linux
  - Cluster Computing
  - Regular Expressions
  - Project 1

Housekeeping

- Guest Lectures (August 21 and 23)
- Canvas Responses
- Changing Project Instructions

Combinatorics Review

{ a b c }

- Permutation: how many different orderings?

  (a b c) (a c b) (b a c) (b c a) (c a b) (c b a) $n!$

- Combination: how many different subsets (i.e. of 2)?

  { a b } { a c } { b c } $\binom{n}{k}$

  allowing repetition in the output

  { a a } { a b } { a c } { b b } { b c } { c c }

- Variations: how many different ordered subsets (i.e. of 2)?

  (a b) (a c) (b a) (b c) (c a) (c b) $\frac{n!}{(n-k)!}$

  allowing repetition in the output

  (a a) (a b) (a c) (b a) (b b) (b c) (c a) (c b) (c c) n^{k}

slides adapted from Glenn Slaydon

Combinatorics Practice

- Your company makes you change your password every 6 months and you are too lazy to come up with a new one each time. How long can you get away with re-ordering the digits of your 7-diget phone number (note: repeated passwords are not allowed)
- 543-2046 $\frac{n!}{m!}$ $\frac{7!}{2!} = 2{,}520\ passwords$ $1{,}260\ years$

Combinatorics Practice

- CLMS students are required to take two linguistics electives. If 16 courses are on the list of approved electives, how many ways can this requirement be filled?

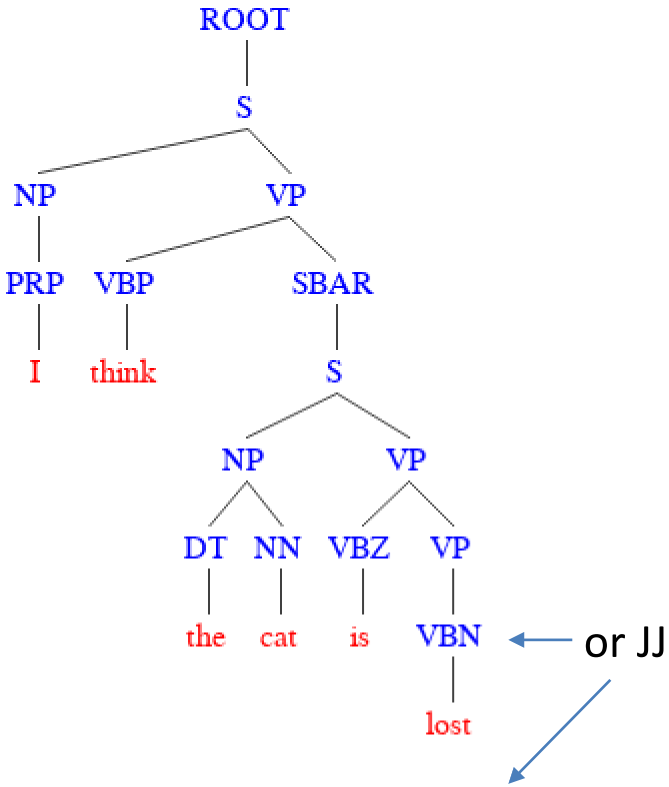
$$\binom{n}{k} = \frac{n!}{(n-k)!\,k!} \qquad \binom{16}{2} = \frac{16!}{(16-2)!\,2!} = 120$$

PTB tag set

CC	Coordinating conjunction	PRP	Possessive pronoun
CD	Cardinal number	RB	Adverb
DT	Determiner	RBR	Adverb, comparative
EX	Existential there	RBS	Adverb, superlative
FW	Foreign word	RP	Particle
IN	Preposition or subordinating conjunction	SYM	Symbol
JJ	Adjective	TO	to
JJR	Adjective, comparative	UH	Interjection
JJS	Adjective, superlative	VB	Verb, base form
LS	List item marker	VBD	Verb, past tense
MD	Modal	VBG	Verb, gerund or present participle
NN	Noun, singular or mass	VBN	Verb, past participle
NNS	Noun, plural	VBP	Verb, non 3rd person singular present
NNP	Proper noun, singular	VBZ	Verb, 3rd person singular present
NNPS	Proper noun, plural	WDT	Wh-determiner
PDT	Predeterminer	WP	Wh-pronoun
POS	Possessive ending	WP	Possessive wh-pronoun
PRP	Personal pronoun	WRB	Wh-adverb

Practice with Trees

I think the cat is lost

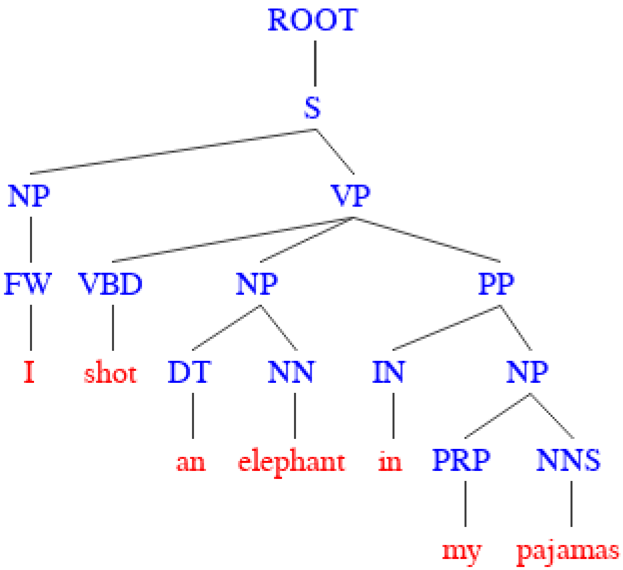


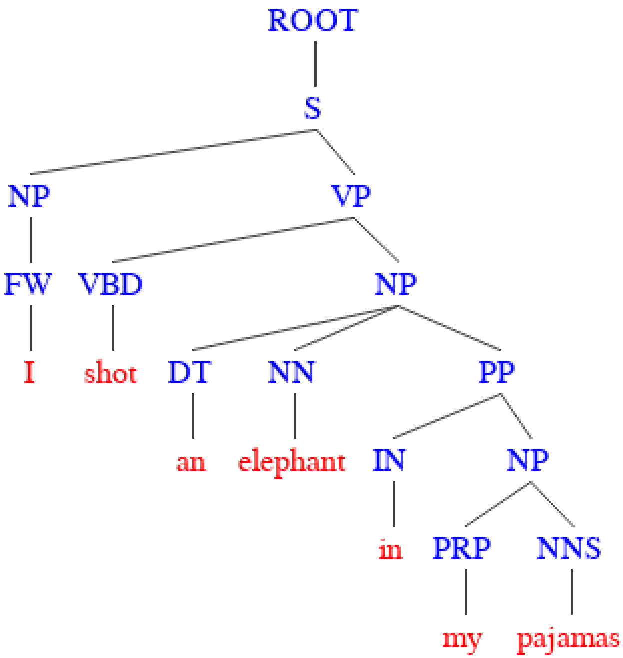
or JJ

(ROOT (S (NP (PRP I)) (VP (VBP think) (SBAR (S (NP (DT the) (NN cat)) (VP (VBZ is) (VP (VNB lost)))))))

Practice with Trees

I shot an elephant in my pajamas





(ROOT (S (NP (FW i)) (VP (VBD shot) (NP (DT an) (NN elephant)) (PP (IN in) (NP (PRP my) (NNS pajamas))))))

(ROOT (S (NP (FW i)) (VP (VBD shot) (NP (DT an) (NN elephant) (PP (IN in) (NP (PRP my) (NNS pajamas)))))))

Assignment 1

- Due to Canvas this Thursday, July 26 at 4:30
- I will go over the solutions at the beginning of class

Unix

- Bell Labs, 1969: Thompson, Ritchie, et al.
- Simple model: a UI-less ‘kernel’ provides process, device, and memory management
- Command line shells provide interactive interaction, if required:
  - sh, csh, ksh, bash
- Historical progression of implementations
  - System V, BSD, POSIX, Linux, Mac OS X
- X-Windows: a graphical interface to the kernel
- KDE, Gnome: graphical desktops

Shell commands: files

$ ls	list files in the current directory
$ pwd	returns current directory
$ cat	show the contents of a file
$ cp	copy a file
$ mv	move or rename a file
$ rm	delete a file
$man	shows instructions for a given command

These are just programs, really.

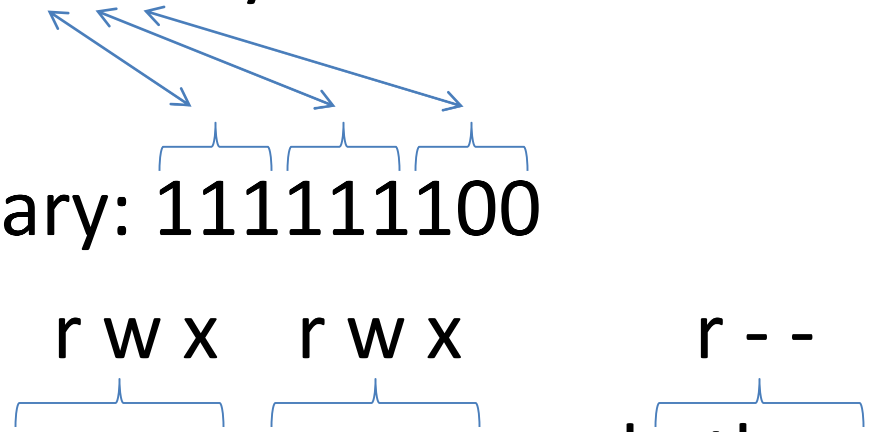
Since filenames are case sensitive, so are these command names.

File permissions

```
$ chmod +x myfile
```

makes myfile executable

```
$ chmod 774 myfile
```



binary: 111111100

set r w x r w x r - -

for owner, group, and others

Shell commands: directories

$ cd	change working directory
$ mkdir	make a new directory
$ rmdir	remove a directory
/	separates directory paths
.	refers to the current directory
..	refers to the parent directory

Unix console control

ctrl-D	end the program, end of stream this is ctrl-Z on DOS
ctrl-S	XOFF, pause the stream (if supported) beware appearance of hang
ctrl-Q	XON, resume the stream (if supported)
ctrl-C	attempt to interrupt the program
ctrl-L	FF, form feed, clear the screen
ctrl-I	HT, horizontal tab
ctrl-M	CR, carriage return (see next slide)
ctrl-J	LF, line feed (see next clide)

slides adapted from Glenn Slaydon

Text file line endings

- Different systems use different conventions for line endings in text files (i.e. corpora)
- Since files are migrated between systems, we will always need to handle these differences correctly

System	Line ending convention	ASCII	Unicode	C
Unix	LF	`0A`	`000A`	`\n`
DOS/Windows	CR LF	`0D 0A`	`000D 000A`	`\r\n`
Macintosh (Pre-OS X)	CR	`0D`	`000D`	`\r`

slides adapted from Glenn Slaydon

Editors

- vi, vim
- emacs
- nano
- pico
- other solutions: local editor with ssh script

Writing in VIM

• vim myfile.txt	creates/opens file
• i	insert/edit
• esc	stop editing
• :w	save
• :q	quit
• :wq	save and quit

Shell scripts

myprog.sh

‘shebang’ →

```
#!/bin/sh

# the hash mark indicates a comment line
ls /
```

to run this program:

```
$ ./myprog.sh
```

notice the mention of the current directory

Standard I/O handles

Unix uses the concept of ‘streams’ of characters.

0	Standard Input	stdin
1	Standard Output	stdout
2	Standard Error	stderr

Pipes and Redirection

`>` redirect output to a new file (overwrites if exists)

`1>` redirect output from stdout to a new file (same as >)

`2>` redirect output from stderr to a new file

`<` redirect input from a file

`>>` append output to a new or existing file

`&>` redirect stdout and stderr to a new file

`|` pipe stdout to the next program as stdin

```
$ ls -l | sort
```

Pipes and Redirection

$ more	show output one screen at a time
$ tail	show the last 10 lines of a file
$ cat foo >bar	redirect contents of ‘foo’ to stdout
$ cat foo 1>bar	same thing

```
$ ./myprog <foo >bar 2>errout
```

execute ‘myprog,’ pass the contents of ‘foo’ in as standard input, capture standard output to ‘bar,’ and capture standard error to ‘errout’

slides adapted from Glenn Slaydon

Text processing utilites

- wc word count
  - arguments `-l, -w, -c` count lines, words, characters
- sort general purpose ASCII or ordinal sort
  - It's not encoding-aware which renders it for serious linguistic use
- tr translate (substitute character ranges)
- grep search for matching patterns
- sed stream editor
- uniq remove duplicate lines (from sorted files)
- diff compare text files

Working with data

- Basic definitions:

bit: a single memory cell that can have the value zero or one

this is the fundamental representation of information

byte: a fixed group of 8 (eight) ordered, distinct bits

therefore, a byte has a value between 0 and $(2^8-1 = 255)$

MSB: the most-significant-bit in a byte
LSB: the least-significant-bit in a byte

KB: one kilobyte: $2^{10} = 1024$ bytes
MB: one megabyte: $2^{20} = 1{,}048{,}576$ bytes
GB: one gigabyte: $2^{30} = 1{,}073{,}741{,}824$ bytes
4 GB: four gigabytes: $2^{32} = 4{,}294{,}967{,}296$ bytes

slides adapted from Glenn Slaydon

8-bit character encodings

- 8-bit: $2^8 = 256$ possible characters

  characters 0-127: usually ASCII, fairly standardized

  characters 127-255: a free-for-all

- Hundreds of different systems for assigning various characters to the 256 available positions
- Each of these is a character encoding

A (partial) list of some 8-bit character encodings

IBM037	IBM EBCDIC (US-Canada)
IBM437	OEM United States
IBM500	IBM EBCDIC (International)
ASMO-708	Arabic (ASMO 708)
DOS-720	Arabic (DOS)
ibm737	Greek (DOS)
ibm775	Baltic (DOS)
ibm850	Western European (DOS)
ibm852	Central European (DOS)
IBM855	OEM Cyrillic
ibm857	Turkish (DOS)
IBM00858	OEM Multilingual Latin I
IBM860	Portuguese (DOS)
ibm861	Icelandic (DOS)
DOS-862	Hebrew (DOS)
IBM863	French Canadian (DOS)
IBM864	Arabic (864)
IBM865	Nordic (DOS)
cp866	Cyrillic (DOS)
ibm869	Greek, Modern (DOS)
IBM870	IBM EBCDIC (Multilingual Latin-2)
windows-874	Thai (Windows)
cp875	IBM EBCDIC (Greek Modern)
shift_jis	Japanese (Shift-JIS)
gb2312	Chinese Simplified (GB2312)
ks_c_5601-1987	Korean
big5	Chinese Traditional (Big5)
IBM1026	IBM EBCDIC (Turkish Latin-5)
IBM01047	IBM Latin-1
IBM01140	IBM EBCDIC (US-Canada-Euro)
IBM01141	IBM EBCDIC (Germany-Euro)
IBM01142	IBM EBCDIC (Denmark-Norway-Euro)
IBM01143	IBM EBCDIC (Finland-Sweden-Euro)
IBM01144	IBM EBCDIC (Italy-Euro)
IBM01145	IBM EBCDIC (Spain-Euro)
IBM01146	IBM EBCDIC (UK-Euro)
IBM01147	IBM EBCDIC (France-Euro)
IBM01148	IBM EBCDIC (International-Euro)
IBM01149	IBM EBCDIC (Icelandic-Euro)
windows-1250	Central European (Windows)
windows-1251	Cyrillic (Windows)
Windows-1252	Western European (Windows)
windows-1253	Greek (Windows)
windows-1254	Turkish (Windows)
windows-1255	Hebrew (Windows)
windows-1256	Arabic (Windows)
windows-1257	Baltic (Windows)
windows-1258	Vietnamese (Windows)
Johab	Korean (Johab)
macintosh	Western European (Mac)
x-mac-japanese	Japanese (Mac)
x-mac-chinesetrad	Chinese Traditional (Mac)
x-mac-korean	Korean (Mac)
x-mac-arabic	Arabic (Mac)
x-mac-hebrew	Hebrew (Mac)
x-mac-greek	Greek (Mac)
x-mac-cyrillic	Cyrillic (Mac)
x-mac-chinesesimp	Chinese Simplified (Mac)
x-mac-romanian	Romanian (Mac)
x-mac-ukrainian	Ukrainian (Mac)
x-mac-thai	Thai (Mac)
x-mac-ce	Central European (Mac)
x-mac-icelandic	Icelandic (Mac)
x-mac-turkish	Turkish (Mac)
x-mac-croatian	Croatian (Mac)
x-Chinese-CNS	Chinese Traditional (CNS)
x-cp20001	TCA Taiwan
x-Chinese-Eten	Chinese Traditional (Eten)
x-cp20003	IBM5550 Taiwan
x-cp20004	TeleText Taiwan
x-cp20005	Wang Taiwan
x-IA5	Western European (IA5)
x-IA5-German	German (IA5)
x-IA5-Swedish	Swedish (IA5)
x-IA5-Norwegian	Norwegian (IA5)
us-ascii	US-ASCII
x-cp20261	T.61
x-cp20269	ISO-6937
IBM273	IBM EBCDIC (Germany)
IBM277	IBM EBCDIC (Denmark-Norway)
IBM278	IBM EBCDIC (Finland-Sweden)
IBM280	IBM EBCDIC (Italy)
IBM284	IBM EBCDIC (Spain)
IBM285	IBM EBCDIC (UK)
IBM290	IBM EBCDIC (Japanese katakana)
IBM297	IBM EBCDIC (France)
IBM420	IBM EBCDIC (Arabic)
IBM423	IBM EBCDIC (Greek)
IBM424	IBM EBCDIC (Hebrew)
x-EBCDIC-KoreanExtended	IBM EBCDIC (Korean Extended)
IBM-Thai	IBM EBCDIC (Thai)
koi8-r	Cyrillic (KOI8-R)
IBM871	IBM EBCDIC (Icelandic)
IBM880	IBM EBCDIC (Cyrillic Russian)
IBM905	IBM EBCDIC (Turkish)
IBM00924	IBM Latin-1
EUC-JP	Japanese (JIS 0208-1990 and 0212-1990)
x-cp20936	Chinese Simplified (GB2312-80)
x-cp20949	Korean Wansung
cp1025	IBM EBCDIC (Cyrillic Serbian-Bulgarian)
koi8-u	Cyrillic (KOI8-U)
iso-8859-1	Western European (ISO)
iso-8859-2	Central European (ISO)
iso-8859-3	Latin 3 (ISO)
iso-8859-4	Baltic (ISO)
iso-8859-5	Cyrillic (ISO)
iso-8859-6	Arabic (ISO)
iso-8859-7	Greek (ISO)
iso-8859-8	Hebrew (ISO-Visual)
iso-8859-9	Turkish (ISO)
iso-8859-13	Estonian (ISO)
iso-8859-15	Latin 9 (ISO)
x-Europa	Europa
iso-8859-8-i	Hebrew (ISO-Logical)
iso-2022-jp	Japanese (JIS)
csISO2022JP	Japanese (JIS-Allow 1 byte Kana)
iso-2022-jp	Japanese (JIS-Allow 1 byte Kana - SO/SI)
iso-2022-kr	Korean (ISO)
x-cp50227	Chinese Simplified (ISO-2022)
euc-jp	Japanese (EUC)
EUC-CN	Chinese Simplified (EUC)
euc-kr	Korean (EUC)
hz-gb-2312	Chinese Simplified (HZ)
GB18030	Chinese Simplified (GB18030)
x-iscii-de	ISCII Devanagari
x-iscii-be	ISCII Bengali
x-iscii-ta	ISCII Tamil
x-iscii-te	ISCII Telugu
x-iscii-as	ISCII Assamese
x-iscii-or	ISCII Oriya
x-iscii-ka	ISCII Kannada
x-iscii-ma	ISCII Malayalam
x-iscii-gu	ISCII Gujarati
x-iscii-pa	ISCII Punjabi

File encodings

- A file with 8-bit characters generally has no internal provision for identifying which encoding it uses
- This information must be specified in some kind of metadata
  - out-of-band
    - the file name extension?
    - perhaps you just happen to know
    - somebody told you
    - you guess (or use a probabilistic model) by inspecting the contents

Tim Baldwin and Marco Lui. 2010. Language Identification: The Long and the Short of the Matter. *Human Language Technologies: The 2010 Annual Conference of the North American Chapter of the ACL*. ACL

  - in-band
    - i.e. HTML:

<meta http-equiv="Content-Type" content="text/html; charset=TIS-620" />

8-bit encodings

- Great for 1968
  - why?
- Not so great for 2015
  - why?

slides adapted from Glenn Slaydon

Unicode

- Unicode uses 16-bits to store each character

  $2^{16} = 65535$ possible characters

  – Major languages are well represented
  – Standard assignments: no conflicting characters
  – Combining characters for accents, ligatures
  – Compatible: characters 0-127 are the same as ASCII
- A single Unicode character is called a code point
- Unicode text is a stream of code points

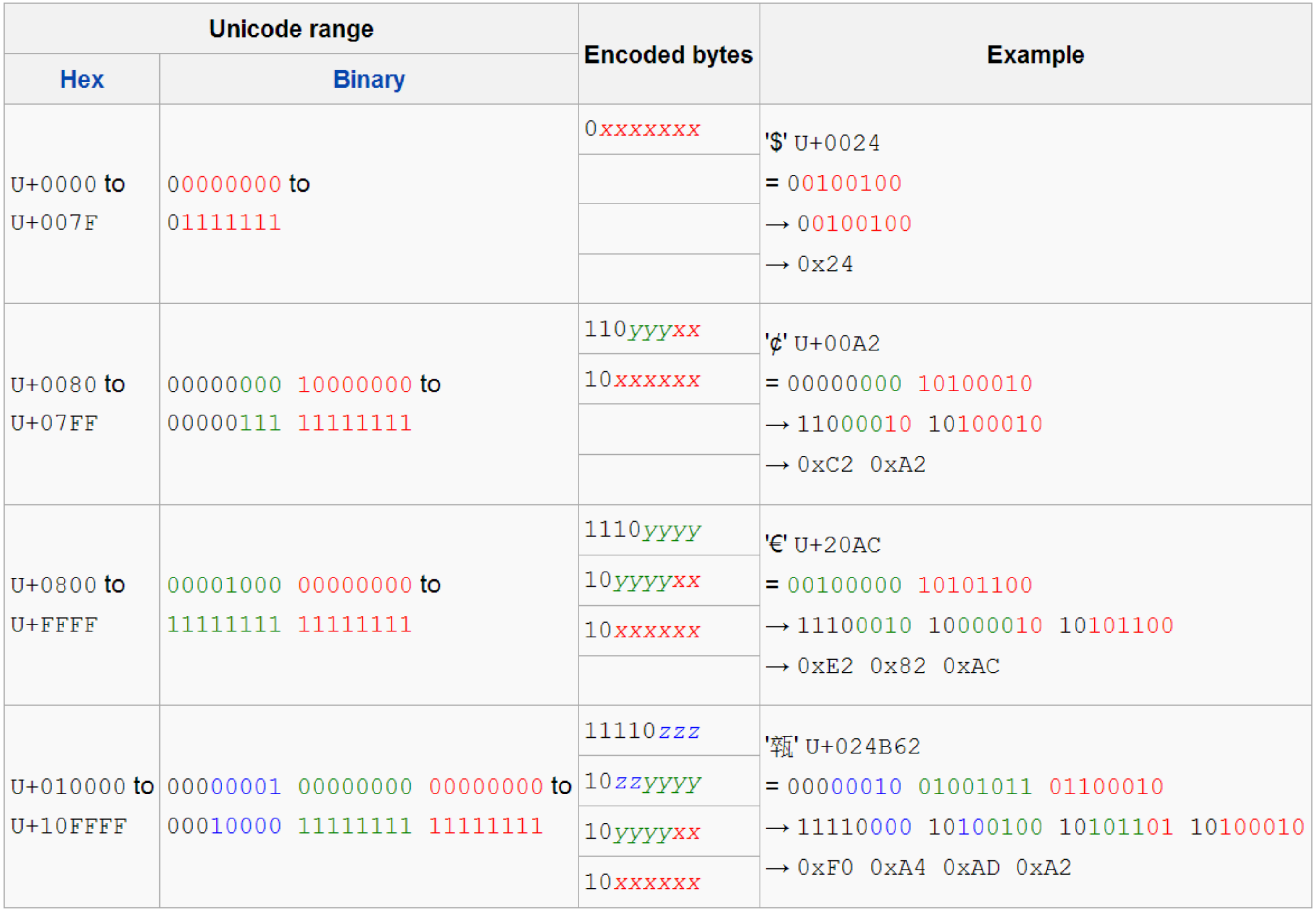
slides adapted from Glenn Slaydon

UTF-8

- Unicode is nice, but hey, my documents are 99% English. Why do they have to be twice as big?
- 8-bit Unicode Transformation Format (UTF-8) uses a variable number of bytes to encode Unicode characters
- In fact, if you only use ASCII, the UTF-8 stream looks like an 8-bit ASCII stream
- 1, 2, 3, or 4 bytes per character are used
  - this means that some Unicode streams get *larger* using UTF-8
  - This will probably be true for alphabets/languages other than:

    Extended Latin alphabet, Romance languages, Greek, Cyrillic, Coptic, Armenian, Hebrew, Arabic, Syriac, Tāna

How does UTF-8 work?



Unicode range		Encoded bytes	Example
Hex	Binary		
U+0000 to U+007F	00000000 to 01111111	0xxxxxxx	'$' U+0024 = 00100100 → 00100100 → 0x24
U+0080 to U+07FF	00000000 10000000 to 00000111 11111111	110yyyxx 10xxxxxx	'¢' U+00A2 = 00000000 10100010 → 11000010 10100010 → 0xC2 0xA2
U+0800 to U+FFFF	00001000 00000000 to 11111111 11111111	1110yyyy 10yyyyxx 10xxxxxx	'€' U+20AC = 00100000 10101100 → 11100010 10000010 10101100 → 0xE2 0x82 0xAC
U+010000 to U+10FFFF	00000001 00000000 00000000 to 00010000 11111111 11111111	11110zzz 10zzyyyy 10yyyyxx 10xxxxxx	'𤭢' U+024B62 = 00000010 01001011 01100010 → 11110000 10100100 10101101 10100010 → 0xF0 0xA4 0xAD 0xA2

slides adapted from Glenn Slaydon

Using HTML <meta> tag to specify encoding

```
<meta http-equiv="Content-Type" content="text/html; charset=UTF-8" />
```

This is nice, but it you still have to:

- Save the file using the specified encoding
  - This requires using an editor that is capable of doing so
- Configure the web server to send a matching HTTP header
  - This is an out-of-band mechanism for specifying the content encoding of every single web page

```
HTTP/1.1 200 OK
Date: Mon, 23 May 2005 22:38:34 GMT
Server: Apache/1.3.3.7 (Unix)  (Red-Hat/Linux)
Last-Modified: Wed, 08 Jan 2003 23:11:55 GMT
Etag: "3f80f-1b6-3e1cb03b"
Accept-Ranges: bytes
Content-Length: 438
Connection: close
Content-Type: text/html; charset=UTF-8
```

Endianness

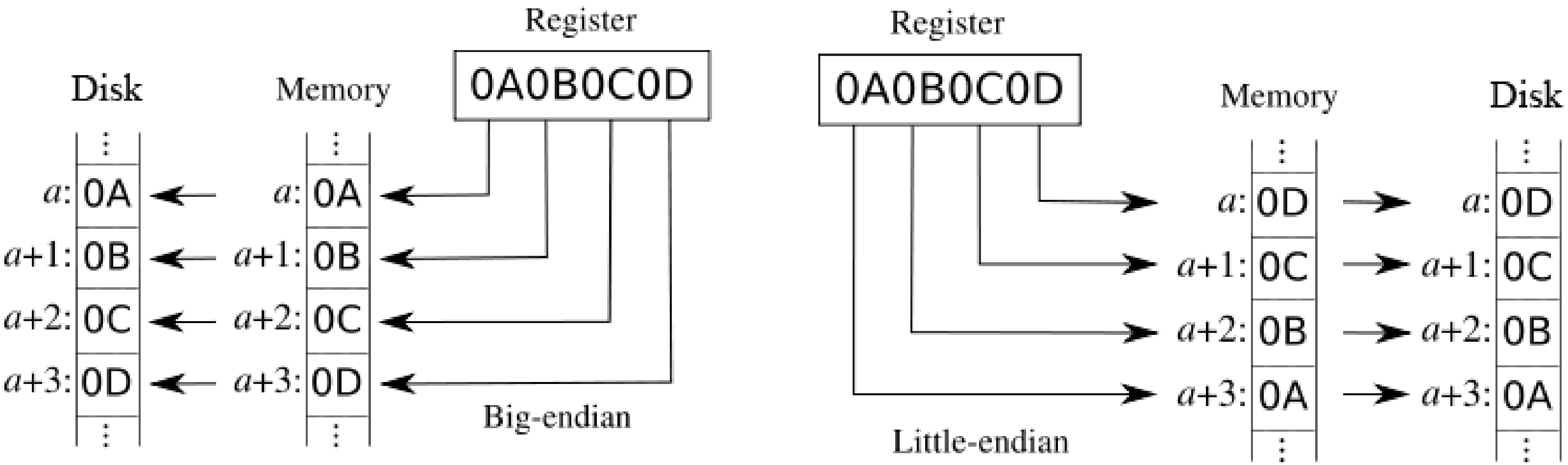
- The layout of 16-bit or 32-bit values in memory is microprocessor dependent
  - nowadays, this is not an issue for bytes
- If a disk file is just a copy of a memory image, then this difference can persist in the file
  - big endian:

    most-significant-byte … least-significant-byte
  - little endian:

    least-significant-byte … most-significant-byte

Why this matters to computational linguistics

- Since unicode uses 16-bits per character, endianness sometimes matters



- UTF-8 is defined a stream of bytes, however, so it is not affected by this issue

slides adapted from Glenn Slaydon

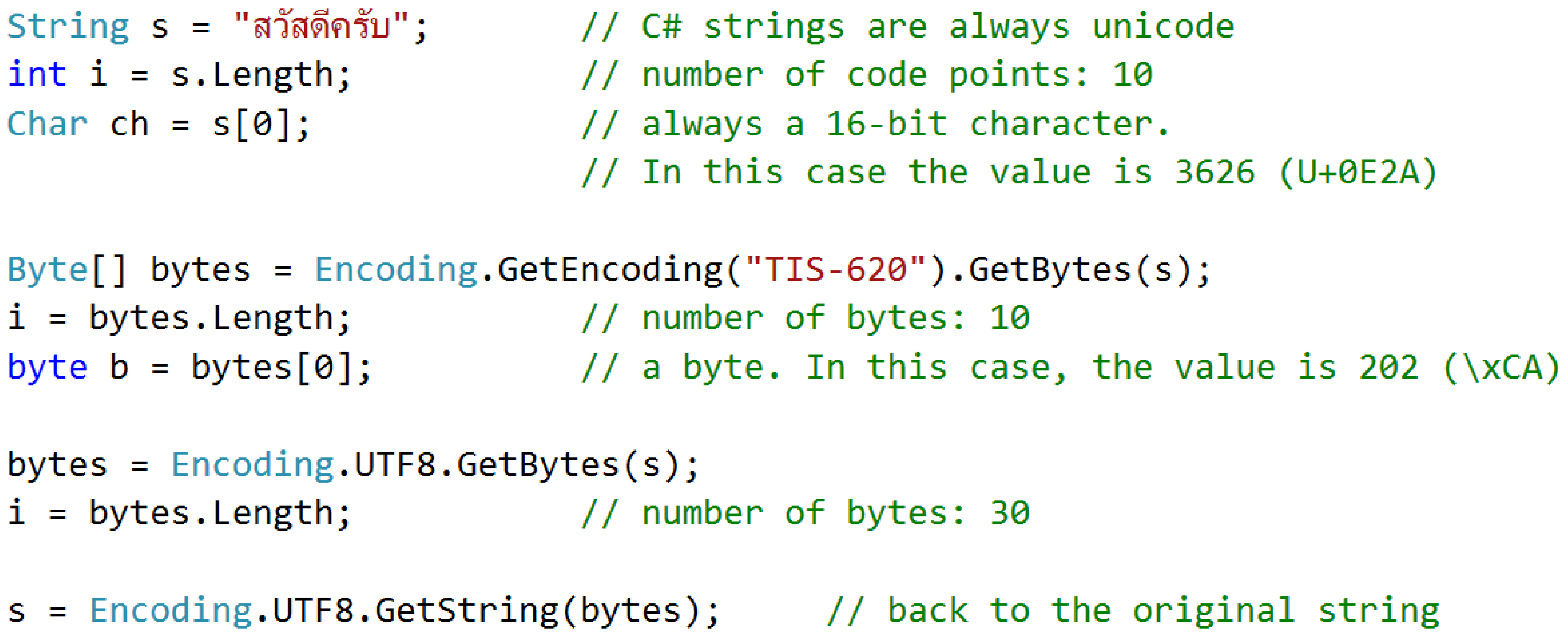
Byte-order Mark (BOM)

- Solving the ‘endian-ness’ problem for Unicode files
- But also used as in-band means for distinguishing Unicode file formats UTF-8 and UTF-16
- Infrequently used, but important for computational linguists to be aware of
- Examine the first few bytes of a text file for the BOM

Encoding	Representation (hexadecimal)	Representation (decimal)	Representation (ISO-8859-1)
UTF-8	EF BB BF	239 187 191	ï»¿
UTF-16 (BE)	FE FF	254 255	þÿ
UTF-16 (LE)	FF FE	255 254	ÿþ

Firefox browser does not like to see a BOM at the top of an HTML file

Programming language support for encodings



```
String s = "สวัสดีครับ";      // C# strings are always unicode
int i = s.Length;           // number of code points: 10
Char ch = s[0];             // always a 16-bit character.
                            // In this case the value is 3626 (U+0E2A)

Byte[] bytes = Encoding.GetEncoding("TIS-620").GetBytes(s);
i = bytes.Length;           // number of bytes: 10
byte b = bytes[0];          // a byte. In this case, the value is 202 (\xCA)

bytes = Encoding.UTF8.GetBytes(s);
i = bytes.Length;           // number of bytes: 30

s = Encoding.UTF8.GetString(bytes);     // back to the original string
```

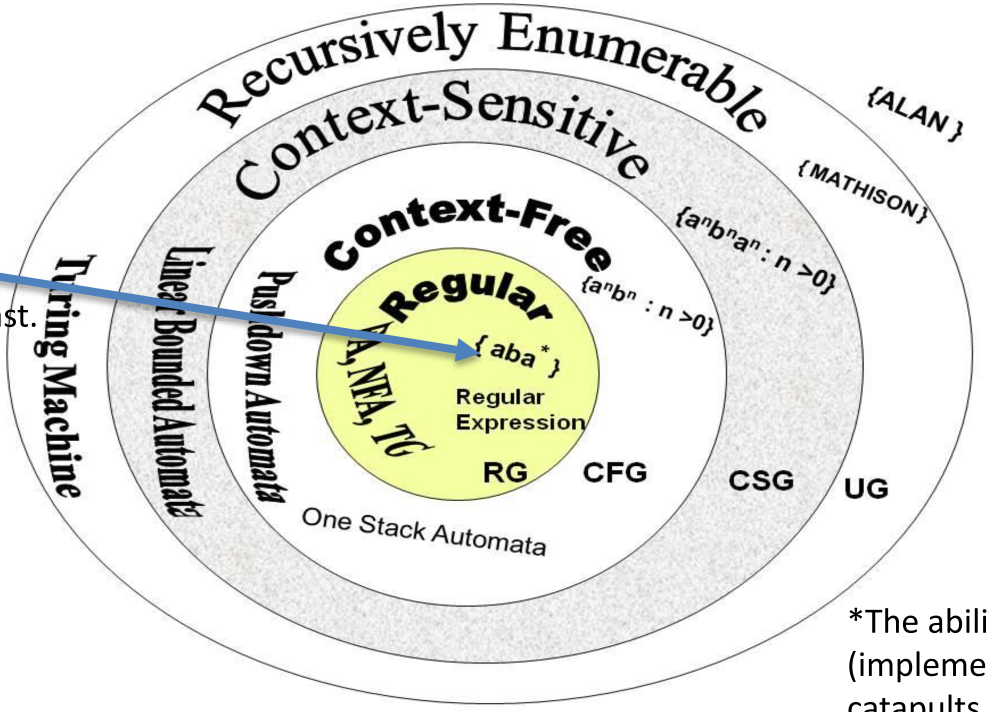
Syntax Machines

- Grammars (in the generic sense) are machines for manipulating strings.
- Less powerful grammars cannot distinguish between as many strings, but are faster
- More powerful grammars can distinguish between more strings (rule things out), and are slower
- The study of grammars and computational complexity is part of automata theory

slides adapted from David Inman

Syntax Machines

Regular expressions are here.*
Not powerful, but fast.



*The ability to remember strings (implemented in most regex languages) catapults regexes beyond regular language

slides adapted from David Inman

Regular Expressions

- A syntax for matching patterns in text.
  - Big theoretical contributors: Stephen Kleene, Ken Thompson
  - Fast, but simple (and limited)

slides adapted from David Inman

Basic RegEx

^ matches the start of a line

$ matches the end of a line

. matches any one character (except newline)

[*xyz*] matches any one character from the set

[^*pdq*] matches any one character not in the set

| accepts either its left or its right side

\ escape to specify special characters

anything else: must match exactly

More RegEx

* accepts zero or more of the preceding element

this is the canonical ‘greedy’ operator

? accepts zero or one of the preceding element(s)

+ accepts one or more of the preceding element(s)

{*n*} accepts *n* of the preceding element(s)

{*n*,} accepts *n* or more of the preceding element(s)

{*n*,*m*} accepts *n* to *m* of the preceding element(s)

(*pattern*) defines a capture group which can be referred to later via \1

RegEx Examples

- Find the English stops followed by a liquid

```
grep [PDKBDGpdkbdg][lr]
```

- Find any two vowels together

```
grep [aeiou][aeiou]
```

- Find the same letter, repeated

```
egrep '([a-z])\1'
```

- Lines where sentences end with ‘to’

```
egrep '( |^)to.'
```

slides adapted from Glenn Slaydon

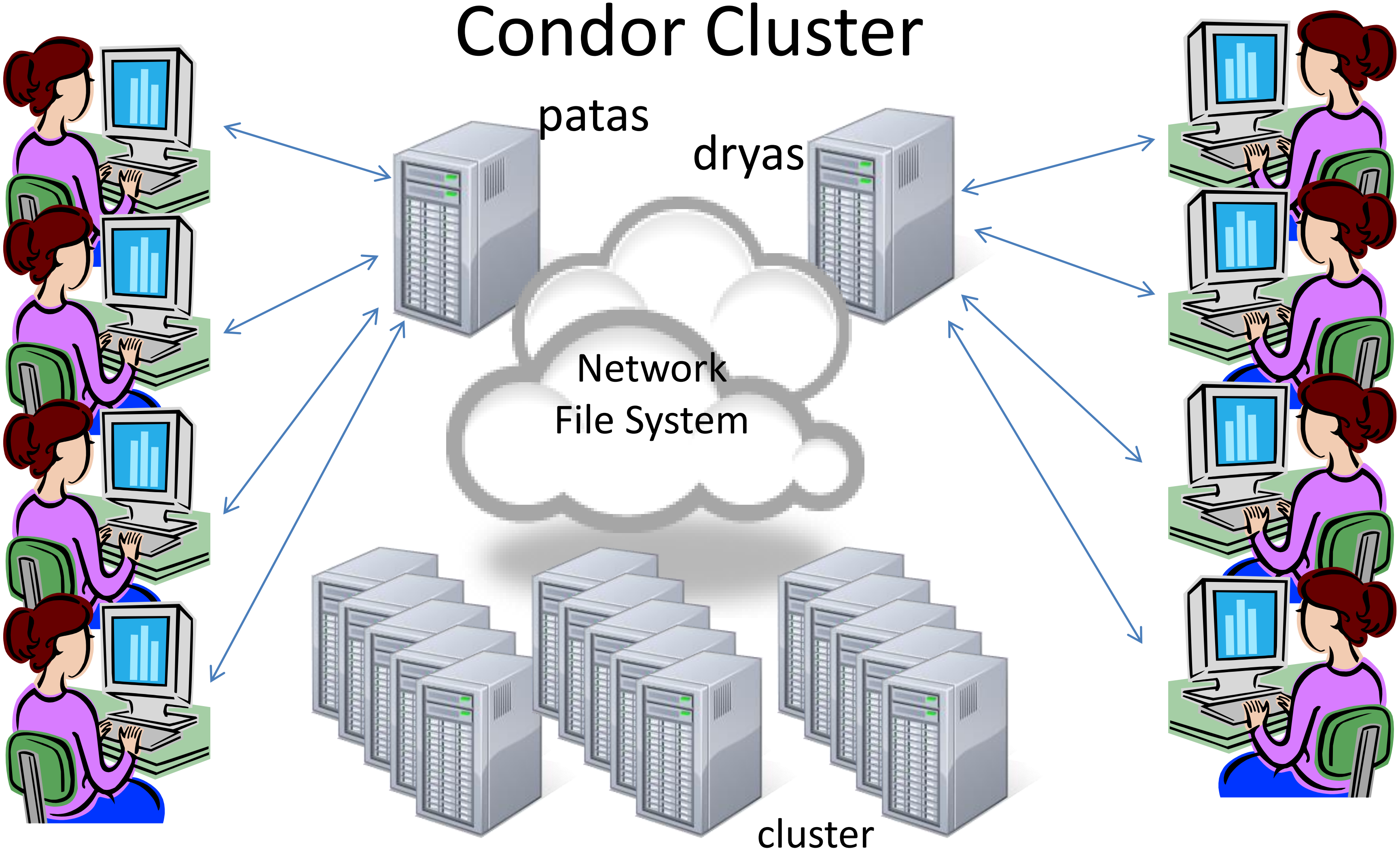
RegEX Practice

- Find hyphenated words
- Find English words with a consonant doubled by the English spelling rule (eg. hitting from hit)
- Find consonant clusters of two or more
- Check for words preceded by the wrong form of a/an

Primitive tokenization

```
$ cat moby_dick.html |                # echo the text
tr [:upper:] [:lower:] |              # convert to lower case
tr ' ' '\n' |                         # put each word on a line
grep -v ^$ |                          # get rid of blank lines
grep -v '<' |                         # get rid of HTML tags
grep -o "[a-z']*" |                   # only want letters and '
sort |                                # sort the words
uniq |                                # find the vocabulary
wc -l                                 # count them
   3956
```

Condor Cluster



slides adapted from Glenn Slaydon

Condor

```
$ condor_submit myjob.cmd
```

```
universe            = vanilla
executable          = /usr/bin/python
getenv              = true
input               = myinput.in
output              = myoutput.out
error               = myerror.err
log                 = /tmp/kphowell/mylogfile.log
arguments           = myprogram.py -x
transfer_executable = false
queue
```

The system will send you email when your job is complete.

slides adapted from Glenn Slaydon

Using variables in Condor files

`flexible.job`

```
file_ext              = $(depth)_$(gain)
universe              = vanilla
executable            = /opt/mono/bin/mono
getenv                = true
output                = acc_file.$(file_ext)
error                 = q4.err
log                   = /tmp/gslayden/q4.log
arguments             = myprog.exe model_file.$(file_ext) sys_file.$(file_ext)
transfer_executable = false
queue
```

```
$ condor_submit -append "depth=20” -append "gain=4" flexible.job
```

slides adapted from Glenn Slaydon

Project 1

- Due Thursday August 2, 11:45 p.m.
- See Project1.pdf on Canvas
- Counting syntactic constituents in a corpus
- You may use regular expressions for this
  - (not a requirement if you prefer procedural code)
- Using Linux
- Using the Condor system
- Packaging and submitting assignments
- Submit tar file to Canvas

Project 1

Write a program to count the number of syntactic constituent types that occur in an annotated corpus

- Process all files in the directory (you are not permitted to download these files!)
- Fill out the table, indicating how many syntactic elements of each time are annotated in the corpus
- Constituents are counted equally at whatever level they appear

Project 1

Constituent	PTB symbol	Count
Sentence	(S ...)	
Noun Phrase	(NP ...)	
Verb Phrase	(VP ...)	
Ditransitive Verb Phrase	(VP verb (NP ...) (NP ...))	
Intransitive Verb Phrase	(VP verb)	

Project 1

- Python, Java or C#
- Regular expressions or procedural code
- Absolute paths to reference corpora
- Relative paths to submission files

Project 1

- Output Format: constituent tab count

```
Sentence	10
Noun Phrase		23
Verb Phrase		14
Ditransitive Verb Phrase 2
Intransitive Verb Phrase 2
```

Project 1

- Submission Files:
  - compile.sh (if necessary)
  - run.sh
  - condor.cmd
  - output
  - readme.{pdf, txt}
  - source code and binary files
- I will upload a new rubric

Next Time

- Events, Probability, Distributions
- Reminder: Assignment 1 due to Canvas this Thursday, July 26 at 4:30