Introduction to NCBI EDirect Software

Learn how to programmatically search and compile PubMed and related data in a Unix Shell

Spring 2021 UA Libraries Workshop

Vincent F. Scalfani
Science and Engineering Librarian
The University of Alabama
vfscalfani@ua.edu

Disclaimer: Workshop is not affiliated with NCBI/NLM/NIH

Outline

1. Overview of NCBI EDirect
2. Brief Introduction to Unix Shell
3. Searching PubMed and related databases with EDirect
4. Retrieving PubMed XML and extracting information
5. Creating scripts for repeated tasks and workflows

Following Along Today and Further Reading

These slides (PDF and plain text) are available here (MIT license):

https://github.com/vfscalfani/EDirectChemInfo

Go to **Workshops** folder; should be able to copy/paste code snippets from .txt file into your own terminal.

Find/Replace name@xx.edu with your email address before running EDirect code.

Key References and Further Reading:

1. Software Carpentry: The Unix Shell
2. Official NCBI Manual for EDirect - Entrez Direct: E-Utilities on the Unix Command Line
3. NLM EDirect for PubMed Recordings and Materials - EDirect for PubMed
4. NLM EDirect Documentation on xtract
5. NCBI EDirect Cookbook
6. Our PubMed/PubChem EDirect Cookbook, EDirectChemInfo and Unix Introduction

Appropriate EDirect and NCBI Data Usage Notes

Read the NCBI Website and Data Usage Policies and Disclaimers:
https://www.ncbi.nlm.nih.gov/home/about/policies/

See information about abstract copyright in PubMed:
https://www.nlm.nih.gov/databases/download.html

And PubMed Central Copyright Notice:
https://www.ncbi.nlm.nih.gov/pmc/about/copyright/

If you have questions about copyright and fair-use for your particular use-case, please contact The University of Alabama Libraries: https://ask.lib.ua.edu/

What is EDirect [1]?

- Free command-line program from National Center for Biotechnology Information (NCBI) that allows (E-utilities) programmatic access to NCBI databases such as PubMed, PubChem, Gene, Taxonomy, etc. directly within a Unix terminal window.

- Can be installed on Unix, Unix-like (e.g., GNU/Linux) distributions, Mac OS, and Windows with Cygwin Unix-emulation.

Example EDirect Use

```
$ esearch -email name@xx.edu -db pubmed -query "\"ionic liquids\"[MESH] AND imidazolium" | \
> efetch -format xml | \
> xtract -pattern PubmedArticle -element MedlineCitation/PMID -first Author/LastName \
> Author/Initials ISOAbbreviation PubDate/Year Volume Issue MedlinePgn \
> -block ArticleId -if ArticleId@IdType -equals doi -doi ArticleId
33396149                    Hu        LX     Ecotoxicol Environ Saf        2021    208    111629
https://doi.org/10.1016%2Fj.ecoenv.2020.111629
33346267            Kaur      M       Phys Chem Chem Phys   2021    23     1      320-328 https://doi.org/10.1039%2Fd0cp04513f
33253998                  Tashakkori  P      J Chromatogr A 2021    1635   461741     https://doi.org/10.1016%2Fj.chroma.2020.461741
...
...
```

[1] https://www.ncbi.nlm.nih.gov/books/NBK179288/

Why Would I Use EDirect?

1. For accessing NCBI data programmatically, EDirect has a lower learning curve than trying to write your own scripts in a programming language. EDirect constructs the programmatic web URLs for you and includes programs to help you format and process the data into tabular formats. *Can also combine/process data with other Unix programs.*

2. You want to compile bibliographic data or molecular/biological datasets.

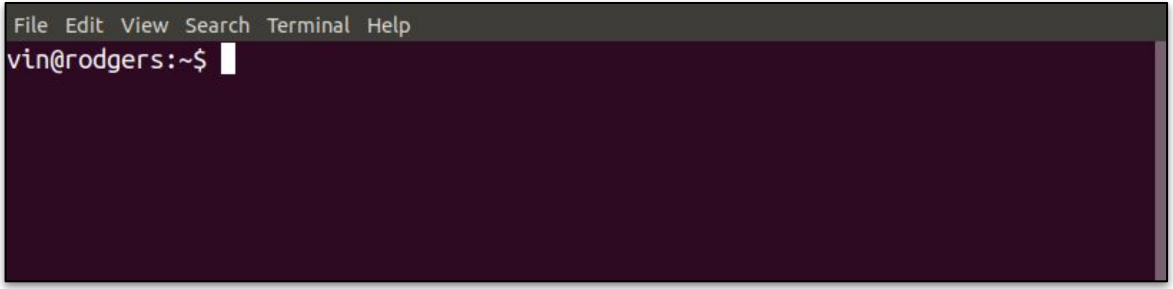
3. You have many search queries (e.g., PubMed) to perform or need to repeat the search frequently. Easy to precisely record your database searches and analysis, which may be useful for systematic reviews.

4. You can quickly answer interesting and specific questions like “Who are the most common authors studying peanut allergies?” or “What is the most common journal indexed in PubMed for research on synthetic chemistry “total synthesis”?

5. Searching NCBI databases in a Unix terminal is a lot of fun.

Unix Terminal

A Unix terminal is a text input/output environment [1]:



```
vin@rodgers:~$ 
```

From the terminal input, a shell then interprets the commands (i.e., a command line interpreter).

> *Most Unix-like operating systems such as GNU/Linux distributions (e.g., Ubuntu) are using the GNU Bash Shell.*

[1] Unix Stack Exchange Thread: What is the exact difference between a 'terminal', a 'shell', a 'tty' and a 'console'?

Unix Programs and Utilities

To run a Unix program, you generally type the name of the program, followed by (optional) -arguments.

Type **`-help`** or **`--help`** after the program name or **`man`** (for manual) before the program name to see specific usage. Example with GNU utilities `cut`:

```
$ cut --help
Usage: cut OPTION... [FILE]...
Print selected parts of lines from each FILE to standard output.

With no FILE, or when FILE is -, read standard input.
Mandatory arguments to long options are mandatory for short options too.
  -b, --bytes=LIST       select only these bytes
  -c, --characters=LIST   select only these characters
  -d, --delimiter=DELIM   use DELIM instead of TAB for field delimiter
  -f, --fields=LIST      select only these fields;  also print any line
                         that contains no delimiter character, unless
                         the -s option is specified
...
$ man cut
```

(outputs manual page for cut, more detailed description, not shown)

Unix Shell Pipelines, Redirect, and Loops [1]

With the Unix shell, we can use Pipelines to create sequences of commands. Each command output is piped into the next command:

```
$ command1 | command2 | command3
```

We can redirect our output from a command or sequence of commands to a file:

```
$ command1 > myfile1.txt
$ command1 | command2 | command3 > myfile3.txt
```

Unix shell is also a programming language, and, for example, we can create loops to repeat tasks:

```
$ for item in list_of_items
> do
>     something_using $item
> done
```

[1] See the Software Carpentry Unix Shell and Bash Reference Manual

EDirect Unix Programs [1]

EDirect contains several individual programs. We will review the following today:

1. **einfo -** prints fields and links indexed in each database
2. **esearch** - performs an NCBI Entrez database search based on a specified database and query
3. **efetch** - downloads the esearch query results in a specified format such as XML
4. **xtract** - extracts selected data values from XML
5. **elink** - finds associated records within a specified database
6. **efilter** - limits results (e.g., by date, information type, etc.)

Typical use-case is to connect these programs with unix pipelines:

```
$ esearch | efetch | xtract
$ esearch | elink | efilter | efetch | xtract
$ esearch | elink | efilter | efetch | xtract | sort | uniq -c
$ esearch | elink | efilter | efetch | xtract > myfile.txt
```

[1] See the official manual for other EDirect programs and examples: https://www.ncbi.nlm.nih.gov/books/NBK179288/

EDirect program syntax and Usage Notes

EDirect programs all have similar syntax:

```
eprogram -argument input

eprogram -email name@ua.edu -argument input
```

All of the EDirect programs accept your email as an input too, this is a really good idea to add so that if you are accidentally causing server issues or violating their usage policies, NCBI can contact you.

See earlier slide 4 entitled, “Appropriate EDirect and NCBI Data Usage Notes.”

einfo

einfo - prints fields and links indexed in each database

```
einfo -help

einfo -email name@xx.edu -dbs

einfo -email name@xx.edu -db pubmed -fields

einfo -email name@xx.edu -db pubmed -links
```

EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/

esearch

esearch - performs an NCBI Entrez database search based on a specified database and query

```
esearch -help

esearch -email name@xx.edu -db pubmed -query "17630804"[UID]

esearch -email name@xx.edu -db pubmed -query "imidazolium AND bacteria"
```

As queries become more complex, use the `-debug` flag to check the query translation:

```
esearch -email name@xx.edu -db pubmed -query "hydrogel-based drug delivery" -debug

nquire -url https://eutils.ncbi.nlm.nih.gov/entrez/eutils/ esearch.fcgi -retmax 0
-usehistory y -db pubmed -term "hydrogel-based drug delivery" | xtract -pattern
eSearchResult -element QueryTranslation
```

(more on xtract later…)

EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/

esearch

esearch - performs an NCBI Entrez database search based on a specified database and query

Escape , \ , internal quotes and use parentheses for complex searches:

```
esearch -email name@xx.edu -db pubmed -query "\"Artificial Intelligence\"[MESH] AND \"drug
discovery\"[ALL]"

esearch -email name@xx.edu -db pubmed -query "(university of alabama[AFFL]) NOT
(birmingham[AFFL] OR huntsville[AFFL])"
```

Again, try the -debug flag for testing, and it is also helpful to build queries online with the PubMed Advanced Search Builder: https://pubmed.ncbi.nlm.nih.gov/advanced/, though **e-utilities based searches may be different than the web based PubMed.**

EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/

efetch

efetch - downloads the esearch query results in a specified format such as XML

```
efetch -help

esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format abstract


esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml


esearch -email name@xx.edu -db pubmed -query "\"Artificial Intelligence\"[MESH] AND \"drug
discovery\"[ALL]" | \
efetch -format xml
```

EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/

xtract

xtract - extracts selected data values from XML

```
xtract -help
```

Very powerful tool, we will look at some basics today.

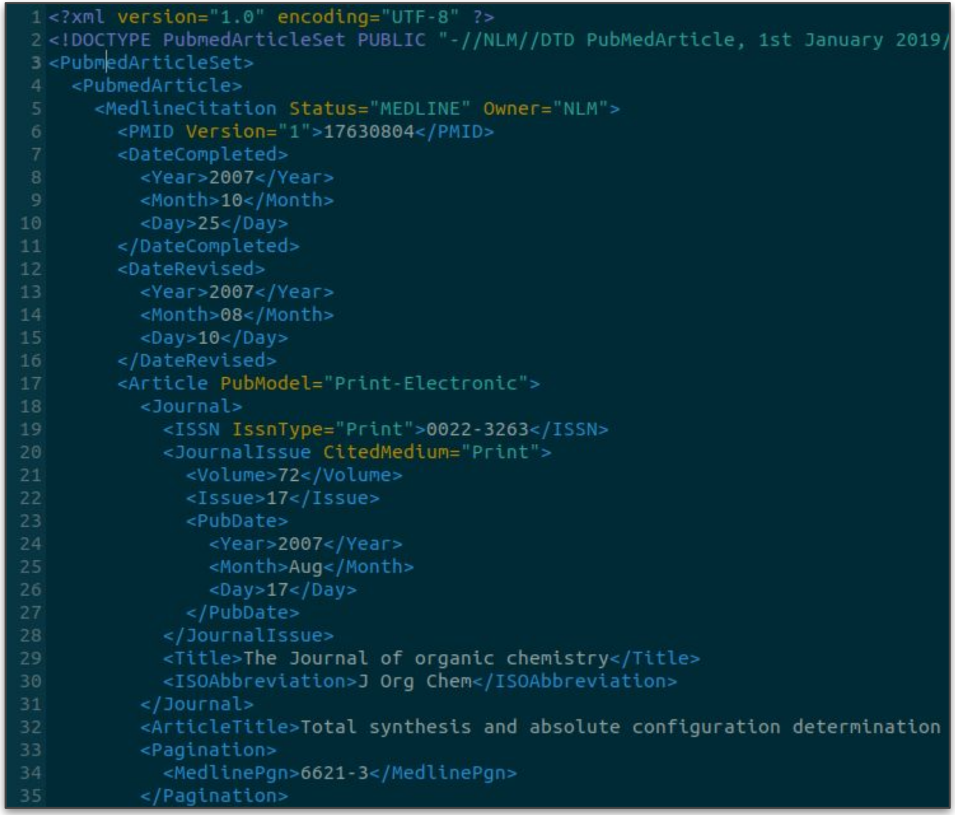
```
esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml

esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml | \
xtract -outline
```

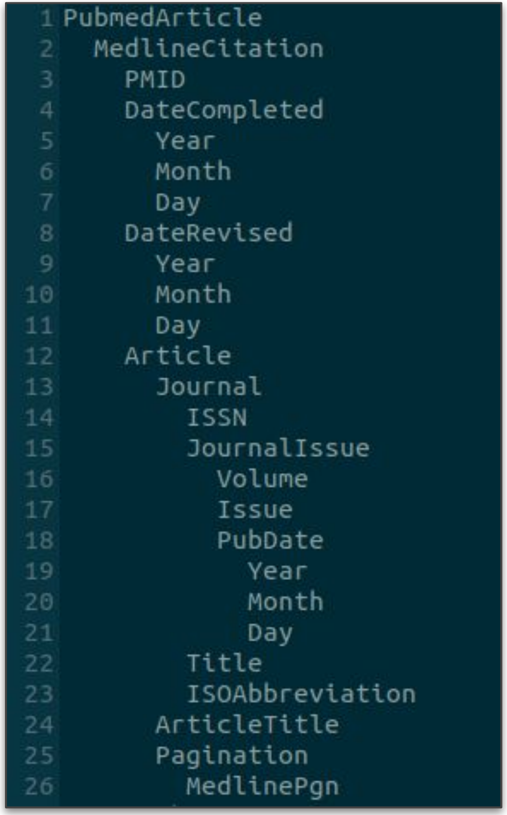
Let’s take a closer look at the PubMed XML

EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/

PubMed XML example



```xml
<?xml version="1.0" encoding="UTF-8" ?>
<!DOCTYPE PubmedArticleSet PUBLIC "-//NLM//DTD PubMedArticle, 1st January 2019/
<PubmedArticleSet>
  <PubmedArticle>
    <MedlineCitation Status="MEDLINE" Owner="NLM">
      <PMID Version="1">17630804</PMID>
      <DateCompleted>
        <Year>2007</Year>
        <Month>10</Month>
        <Day>25</Day>
      </DateCompleted>
      <DateRevised>
        <Year>2007</Year>
        <Month>08</Month>
        <Day>10</Day>
      </DateRevised>
      <Article PubModel="Print-Electronic">
        <Journal>
          <ISSN IssnType="Print">0022-3263</ISSN>
          <JournalIssue CitedMedium="Print">
            <Volume>72</Volume>
            <Issue>17</Issue>
            <PubDate>
              <Year>2007</Year>
              <Month>Aug</Month>
              <Day>17</Day>
            </PubDate>
          </JournalIssue>
          <Title>The Journal of organic chemistry</Title>
          <ISOAbbreviation>J Org Chem</ISOAbbreviation>
        </Journal>
        <ArticleTitle>Total synthesis and absolute configuration determination
        <Pagination>
          <MedlinePgn>6621-3</MedlinePgn>
        </Pagination>
```



```
PubmedArticle
  MedlineCitation
    PMID
    DateCompleted
      Year
      Month
      Day
    DateRevised
      Year
      Month
      Day
    Article
      Journal
        ISSN
        JournalIssue
          Volume
          Issue
          PubDate
            Year
            Month
            Day
        Title
        ISOAbbreviation
      ArticleTitle
      Pagination
        MedlinePgn
```

Xtract [1]

Basic usage today:

$ xtract **-pattern** A **-element** B C...

Key concepts:

1. pattern defines new rows (e.g., PubMedArticle)

2. element defines new columns (e.g., ArticleTitle, Volume, Issue)

3. Attributes of XML elements (e.g., <PMID **Version**="1">17630804</PMID>) can be selected with @:
   a. PMID@Version

4. In cases where elements have the same name (e.g., Year), use a / to define your selection as Parent/Child hierarchy
   a. PubDate/Year versus DateRevised/Year

[1] https://dataguide.nlm.nih.gov/edirect/xtract.html

xtract Examples

# extract author names as 1 author per line [1]

```
esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml | \
xtract -pattern Author -element Author/LastName Author/Initials
```

# extract author names as 1 article per line [1]

```
esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml | \
xtract -pattern PubmedArticle -element Author/LastName Author/Initials
```

[1] https://dataguide.nlm.nih.gov/edirect/xtract.html

xtract Examples

```
# Extract PMID and other bibliographic information [1]

esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml | \
xtract -pattern PubmedArticle -element MedlineCitation/PMID ArticleTitle \
ISOAbbreviation PubDate/Year Volume Issue MedlinePgn
```

```
# Add in author names [1]

esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml | \
xtract -pattern PubmedArticle -element MedlineCitation/PMID Author/LastName \
Author/Initials ArticleTitle ISOAbbreviation PubDate/Year Volume Issue MedlinePgn
```

[1] https://dataguide.nlm.nih.gov/edirect/xtract.html

xtract Examples

# Reformat author names using the xtract -block argument [1]

```
esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml | \
xtract -pattern PubmedArticle -element MedlineCitation/PMID ArticleTitle ISOAbbreviation
PubDate/Year Volume Issue MedlinePgn \
-block Author -element LastName Initials
```

# extract only first author names using the xtract -first argument [2]

```
esearch -email name@xx.edu -db pubmed -query "17630804"[PMID] | \
efetch -format xml | \
xtract -pattern PubmedArticle -element MedlineCitation/PMID -first Author/LastName \
Author/Initials ArticleTitle ISOAbbreviation PubDate/Year Volume Issue MedlinePgn
```

[1] https://dataguide.nlm.nih.gov/edirect/xtract.html; [2] https://github.com/vfscalfani/EDirectChemInfo

xtract Examples

# Good idea to use the xtract default field (-def) value to handle missing fields [1]

```
esearch -email name@xx.edu -db pubmed -query "25818947"[PMID] | \
efetch -format xml | \
xtract -pattern PubmedArticle -def "N/A" -element MedlineCitation/PMID -first
Author/LastName Author/Initials ArticleTitle ISOAbbreviation PubDate/Year Volume Issue
MedlinePgn
```

# Add in the DOI with the -block and conditional -if [1]

```
esearch -email name@xx.edu -db pubmed -query "25818947"[PMID] | \
efetch -format xml | \
xtract -pattern PubmedArticle -def "N/A" -element MedlineCitation/PMID -first
Author/LastName \
Author/Initials ArticleTitle ISOAbbreviation PubDate/Year Volume Issue MedlinePgn \
-block ArticleId -if ArticleId@IdType -equals doi -doi ArticleId
```

[1] https://dataguide.nlm.nih.gov/edirect/xtract.html

xtract Examples

# the same xtract commands can work for queries that return multiple articles [1,2]

```
esearch -email name@xx.edu -db pubmed -query "Anthraquinones/chemical synthesis"[MESH] | \
efetch -format xml | \
xtract -pattern PubmedArticle -def "N/A" -element MedlineCitation/PMID -first Author/LastName \
Author/Initials ArticleTitle ISOAbbreviation PubDate/Year Volume Issue MedlinePgn \
-block ArticleId -if ArticleId@IdType -equals doi -doi ArticleId
```

[1] https://dataguide.nlm.nih.gov/edirect/xtract.html; [2] https://github.com/vfscalfani/EDirectChemInfo

elink

elink - finds associated records within a specified database

Citation information from NIH Open Citation Collection

```
elink -help

elink -cited          (references to this article)
elink -cites          (article reference list)
elink -related        (neighbors in same database)
```

# Get article citations for PMID 31254167

```
esearch -email name@xx.edu -db pubmed -query "31254167[PMID]" | \
elink -cited | \
efetch -format xml | \
xtract -pattern PubmedArticle -element MedlineCitation/PMID -first Author/LastName \
Author/Initials ISOAbbreviation PubDate/Year Volume Issue MedlinePgn \
-block ArticleId -if ArticleId@IdType -equals doi -doi ArticleId
```

EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/

elink Example

elink - finds associated records within a specified database

Can also specify another database:

```
elink -target new_database -name related-link
```

Recall: `einfo -db pubmed -links`

# Get related PubChem compounds from a PubMed search [1]

```
esearch -email name@xx.edu -db pubmed -query "Anthraquinones/chemical synthesis"[MESH] | \
elink -target pccompound -name pubmed_pccompound | \
efetch -format docsum | \
xtract -pattern DocumentSummary -element IsomericSmiles CID InChIKey
```

[1] https://github.com/vfscalfani/EDirectChemInfo

efilter

efilter - limits results (e.g., by date, information type, etc.)

```
efilter -help
```

Basic example use:

```
efilter -query
efilter -pub review
efilter -mindate 2017
```

Sometimes these can be incorporated directly into esearch.

EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/

efilter examples

# limit PubMed results to review articles only

```
esearch -email name@xx.edu -db pubmed -query "Anthraquinones/chemical synthesis"[MESH] | \
efilter -pub review | \
efetch -format xml | \
xtract -pattern PubmedArticle -def "N/A" -element MedlineCitation/PMID -first
Author/LastName Author/Initials ArticleTitle ISOAbbreviation PubDate/Year Volume Issue
MedlinePgn -block ArticleId -if ArticleId@IdType -equals doi -doi ArticleId
```

# limit PubMed results from a linked PubChem search to a specific Journal [1]

```
esearch -email name@xx.edu -db pccompound -query 174076[uid] | \
elink -target pubmed -name pccompound_pubmed | \
efilter -query "Phys Chem Chem Phys"[JOUR] | \
efetch -format xml | \
xtract -pattern PubmedArticle -def "N/A" -element MedlineCitation/PMID -first
Author/LastName Author/Initials ArticleTitle ISOAbbreviation PubDate/Year Volume Issue
MedlinePgn -block ArticleId -if ArticleId@IdType -equals doi -doi ArticleId
```

[1] https://github.com/vfscalfani/EDirectChemInfo

Creating a For Loop for multiple Queries [1,2]

# Let’s say I have a list of PMIDs and want bibliographic information for each one:

```
for refs in \
      "20426451" \
      "21982300" \
      "21948594" \
      "12653513" \
      "11259830" \
      "10592235" \
      "16796559" \
      "27899562" \
      "26400175" \
      "8709122"
do
      esearch -email name@xx.edu -db pubmed -query "$refs[PMID]" |
      efetch -format xml |
      xtract -pattern PubmedArticle -def "N/A" -element MedlineCitation/PMID -first Author/LastName \
      Author/Initials ISOAbbreviation PubDate/Year Volume Issue MedlinePgn \
      -block ArticleId -if ArticleId@IdType -equals doi -doi ArticleId
      sleep 1
done
```

[1] EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/; [2] https://github.com/vfscalfani/EDirectChemInfo

Creating a For Loop for multiple Queries [1,2]

# Or maybe we want the number of cited references for each PMID:

```
for refs in \
      "20426451" \
      "21982300" \
      "21948594" \
      "12653513" \
      "11259830" \
      "10592235" \
      "16796559" \
      "27899562" \
      "26400175" \
      "8709122"
do
      esearch -email name@xx.edu -db pubmed -query "$refs[PMID]" |
      elink -cited |
      xtract -pattern ENTREZ_DIRECT -lbl "$refs" -element Count
      sleep 1
done
```

[1] EDirect manual: https://www.ncbi.nlm.nih.gov/books/NBK179288/; [2] https://github.com/vfscalfani/EDirectChemInfo

Answering Specific Questions

# most common UA chemistry authors indexed in PubMed [1]:

```
esearch -email name@xx.edu -db pubmed -query "(university of alabama[AFFL] AND
tuscaloosa[AFFL])" | \
efetch -format xml | \
xtract -pattern Author -if Affiliation -contains chemistry -and Affiliation -contains
tuscaloosa -element LastName Initials | \
sort-uniq-count-rank
```

[1] N.B. affiliation query and xtract pattern is not perfect, see more here: https://github.com/vfscalfani/EDirectChemInfo/blob/master/05_EDirect_PubMed_Recipes.md

[2] sort-uniq-count-rank: https://dataguide.nlm.nih.gov/edirect/sort-uniq-count-rank.html

Answering Specific Questions

# most Frequent Journals for a PubMed Query [1]

```
esearch -email name@xx.edu -db pubmed -query "\"Artificial Intelligence\"[MESH] AND \"drug discovery\"[ALL]" | \
efetch -format xml | \
xtract -pattern PubmedArticle -element ISOAbbreviation | \
sort-uniq-count-rank
```

[1] https://github.com/vfscalfani/EDirectChemInfo

Answering Specific Questions

# how many records are being added to PubMed by create date each month? [1]

```
for date in \
     "2020/01" \
     "2020/02" \
     "2020/03" \
     "2020/04" \
     "2020/05" \
     "2020/06"
do
     esearch -email name@xx.edu -db pubmed -query "$date[CRDT]" |
     xtract -pattern ENTREZ_DIRECT -lbl "$date" -element Count
     sleep 1
done
```

[1] https://github.com/vfscalfani/EDirectChemInfo

Answering Specific Questions

# number of records for a PubMed query that are available in PubMed Central [1]:

```
esearch -email name@xx.edu -db pubmed -query "J Chem Inf Model[JOUR]" | \
elink -target pmc -name pubmed_pmc | \
efetch -format docsum | \
xtract -pattern DocumentSummary -element PubDate | \
cut -d " " -f 1 | \
sort-uniq-count-rank | \
sort -k2,2
```

[1] https://github.com/vfscalfani/EDirectChemInfo

Answering Specific Questions

```
# most frequent article title words from a PubMed query

esearch -email name@xx.edu -db pubmed -query "J Cheminform[JOUR]" | \
efetch -format xml | \
xtract -pattern PubmedArticle -element ArticleTitle | \
tr '\n' ' ' | \
word-at-a-time | \
sort-uniq-count-rank > titlewords.txt
```

And many more possibilities, use your imagination and look at linked resources on the next slide.

word-at-a-time: https://dataguide.nlm.nih.gov/edirect/word-at-a-time.html

Thanks!

Key References and Further Reading:

1. Software Carpentry: The Unix Shell
2. Official NCBI Manual for EDirect - Entrez Direct: E-Utilities on the Unix Command Line
3. NLM EDirect for PubMed Recordings and Materials - EDirect for PubMed
4. NLM EDirect Documentation on xtract
5. NCBI EDirect Cookbook
6. Our PubMed/PubChem EDirect Cookbook, EDirectChemInfo and Unix Introduction

Need help?

Get in touch!

Vincent F. Scalfani
Science and Engineering Librarian
The University of Alabama
vfscalfani@ua.edu