

BIO392 file formats and tools

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Talk typesetting

- Commands/options are in typewriter font
- URLs are highlighted in blue

Exercise: Web browsing the genome

- Launch the UCSC Genome Browser
- Specify Human Assembly hg19
- Click go

By default, the Genome Browser will render a genomic window with many data layers on it. How are these data encoded?

- Click UCSC Genes from the Genes and Gene Predictions section under the main genomic window.
- Click View table schema opens [knownGene table schema](#)

knownGene table schema

Schema for UCSC Genes - UCSC Genes (RefSeq, GenBank, CCDS, Rfam, tRNAs & Comparative Genomics)

Database: hg19 Primary Table: knownGene Row Count: 82,960 Data last updated: 2013-06-14

Format description: Transcript from default gene set in UCSC browser

| field | example | SQL type | info | description |
|------------|--------------------|------------------|------------------------|--|
| name | uc001aaa.3 | varchar(255) | values | Name of gene |
| chrom | chr1 | varchar(255) | values | Reference sequence chromosome or scaffold |
| strand | + | char(1) | values | + or - for strand |
| txStart | 11873 | int(10) unsigned | range | Transcription start position (or end position for minus strand item) |
| txEnd | 14409 | int(10) unsigned | range | Transcription end position (or start position for minus strand item) |
| cdsStart | 11873 | int(10) unsigned | range | Coding region start (or end position if for minus strand item) |
| cdsEnd | 11873 | int(10) unsigned | range | Coding region end (or start position if for minus strand item) |
| exonCount | 3 | int(10) unsigned | range | Number of exons |
| exonStarts | 11873,12612,13220, | longblob | | Exon start positions (or end positions for minus strand item) |
| exonEnds | 12227,12721,14409, | longblob | | Exon end positions (or start positions for minus strand item) |
| proteinID | | varchar(40) | values | UniProt display ID, UniProt accession, or RefSeq protein ID |
| alignID | uc001aaa.3 | varchar(255) | values | Unique identifier (GENCODE transcript ID for GENCODE Basic) |

knownGene table schema

So they are database entries with **chrom**, **start** and **end** features. This is the most standard data representation in genomics: data referring to genomic coordinates. Why?

Discussion

- Which would be the most efficient file format to store data related to human genomes?

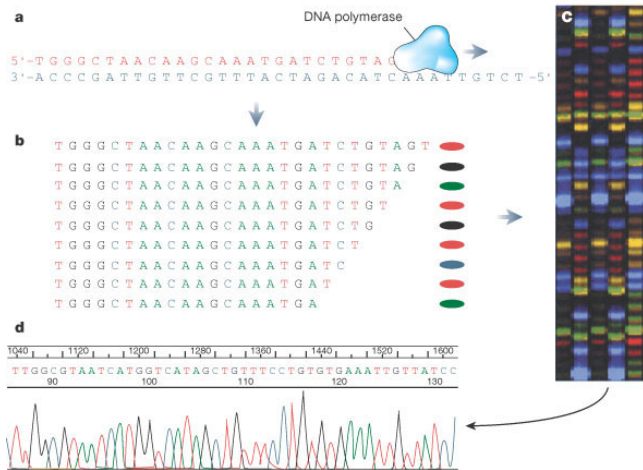
Commonly used formats

- Reference genomes
- Fasta and FastQ (Unaligned sequences)
- SAM/BAM (Alignments)
- BED (Genomic ranges)
- GFF/GTF (Gene annotation)
- BEDgraphs (Genomic ranges)
- Wiggle files, BEDgraphs and BigWigs (Genomic scores).
- Indexed BEDgraphs/Wiggles
- VCFs (variants)

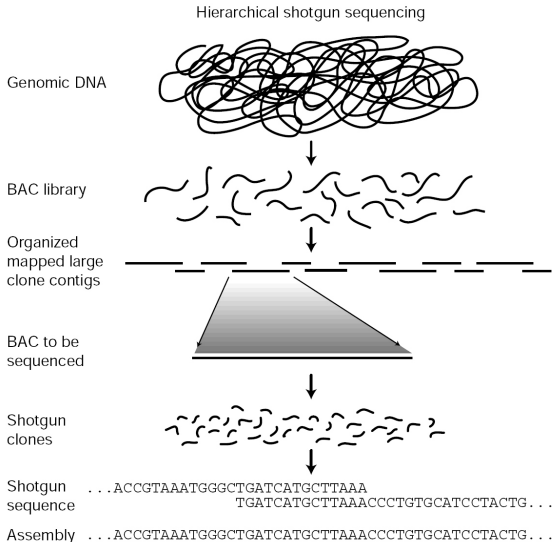
Reference genomes

- Reference genomes describe the 'consensus' DNA sequence
- (The human genome from whom? What does consensus mean?)
- Human variation aside, multiple assemblies have been released (i.e. hg18, hg19...)

Sanger sequencing Nature 409, 863 (2001)



Hierarchical shotgun Nature 409, 863 (2001)



Reference genomes

GRCh stands for 'Genome Reference Consortium'

- Human [GRCh37](#) (hg19)
- Human [GRCh38](#)
- Mouse [mm10](#)
- Mouse [GRCm38](#)
- Zebrafish, chicken and others:
<https://www.ncbi.nlm.nih.gov/grc> The Genome Reference consortium

Activity: sequence retrieval

- Retrieve the sequence of the human mitochondrial genome
- (Tip: where (databases)? how? which format? does the human mitochondrial genome exist?)

Automation

- Using a Web browser to retrieve genomic sequences is not efficient nor reproducible: programmatic alternatives exist
- Need of standardizing data analysis using reproducible workflows
 - Scripts for data retrieval (in bioinformatics often R or python)
 - Keeping track of data analysis steps and avoiding manual editing
 - Data storage: standards (fasta, fastq, sam, vcf...)

Reproducibility

- What do we mean by data science reproducibility?
- In data science: avoid manual steps of data analysis using scripts plus version control systems
- Spreadsheet editors used with sequences of mouse clicks are not reproducible

Reproducibility: reading

- Paper: <https://www.nature.com/news/1-500-scientists-lift-the-lid-on-reproducibility-1.19970>

How could we increase reproducibility?

- In data analysis: keeping track of all steps (using scripts)
- Using data standards
- What if we don't know how to program?
- Still, switching to command-line tools and keeping track of the commands used
- Using control version systems

The terminal

- Simple command line interface
- Present in MacOS and GNU/Linux computers
- Interprets the Unix shell language (commonly bash)

UNIX

- Efficient
- Scalable
- Portable
- Open

Unix philosophy

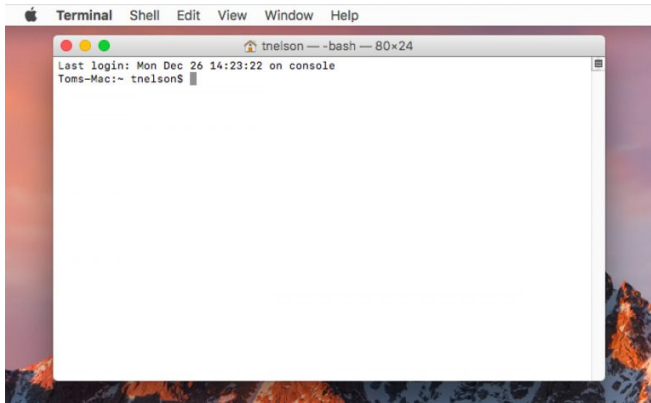
According to Peter H. Salus in A Quarter-Century of Unix (1994):

- Write programs that do one thing and do it well.
- Write programs to work together.
- Write programs to handle text streams, because that is a universal interface.

Why in bioinformatics?

- We interpret DNA, proteins as text; Unix is for text streams.
- Data are big (millions of lines of text, easily a couple of GB); spreadsheet software (Excel) cannot handle them.
- We need to keep track of our analysis for the sake of reproducibility: bash scripts.

Opening a terminal in MacOS



The shell (Unix shell)

- The Unix shell allows to save the sequential commands in a reproducible manner
- Activity for next day: run the tutorial by the Swiss Institute of Bioinformatics

https://edu.sib.swiss/pluginfile.php/2878/mod_resource/content/4/couselab-html/content.html

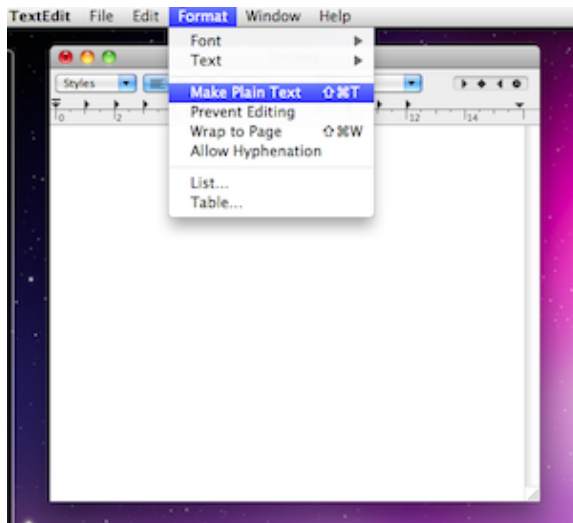
A quick reminder on computer files

- Files are data representations stored in computers as arrays of bytes.
- File type is defined by its bytes and not by the filename extension.
- Files contain metadata.
- Importantly, plain text files are composed by bytes mapped directly to ASCII characters.
- Text editors (notepad, gedit, vim...) allow editing plain text files.
- (text files can be read without proprietary software)

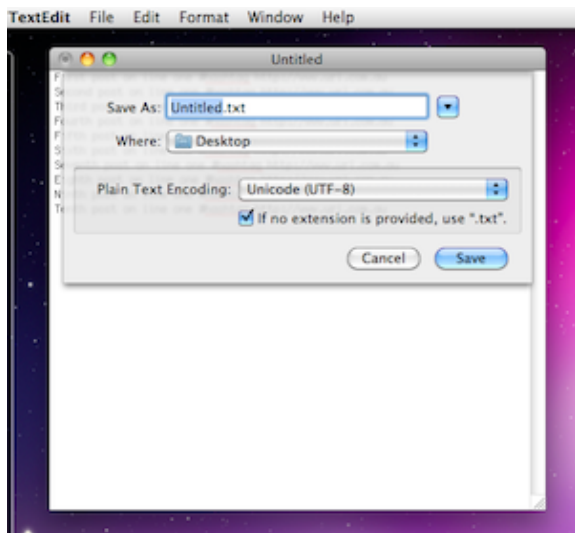
Setting up the Mac text editor to save text

- Create new file
- Go to Format and select Make Plain Text
- For saving, go to File, Save As and Plain Text Encoding setting: Unicode (UTF-8).

Avoiding RTF: plain text



Avoiding RTF: plain text



Turning off autospell check

- UNIX commands are case sensitive
- By default, TextEdit capitalizes/spell checks contents
- Exercise: disable this feature
- <http://osxdaily.com/2014/05/06/turn-off-autocorrect-pages-textedit-mac/>

Organizing a shell script

- Write on top the shebang
- Write the date and what's the script about, your name and date
- Tip: comment lines start with `#`
- Tip: multiline chunks are split by a `\`
- Introduce the commands (one line each)

Scripting

- Save the file (script) somewhere with a back-up system
- You could run the script to run the commands in batch typing
`bash name_of_the_script.sh`

Reproducibility for software

- UNIX solves the reproducibility, scalability and openness for data (text) streams, but extra software might be needed
- The importance of software versioning for reproducibility: keeping track of the software installed
- Using open source software (no blackboxes!)
- Installs can be run command-line, so specific versions can be stored and included into the analysis script

Software installs

(The code is available at the exercises file)

```
cd ~ # to your home folder
mkdir -p soft/kent
cd soft/kent

curl http://hgdownload.soe.ucsc.edu/admin/exe/macOSX.x86_64/bedToBigBed \
> bedToBigBed
curl http://gattaca.imppc.org/groups/maplab/imallona/teaching/hg19.genome \
> hg19.genome
curl http://gattaca.imppc.org/groups/maplab/imallona/teaching/example.bed \
> example.bed

## adding exec permissions to the binary
chmod a+x bedToBigBed

## running the actual command
./bedToBigBed example.bed hg19.genome out.bb
```

Compiling bedtools

- BEDtools as toolset
- Activity: read paper <https://academic.oup.com/bioinformatics/article/26/6/841/244688>

Compiling software in Unix

- The importance of Makefiles
- Activity: read <https://en.wikipedia.org/wiki/Makefile>
- Activity: read <https://academic.oup.com/bioinformatics/article/33/21/3502/3806980>

Compiling bedtools

(The code is available at the exercises file)

```
cd # to your home directory or wherever you decide
cd soft # the folder was created before (for kent utils)

curl -L https://github.com/arq5x/bedtools2/releases/download/v2.25.0/bedtools-2.25.0.tar.gz \
  > bedtools-2.25.0.tar.gz

tar zxvf bedtools-2.25.0.tar.gz
cd bedtools2
make
alias bedtools='./bin/bedtools'
```