

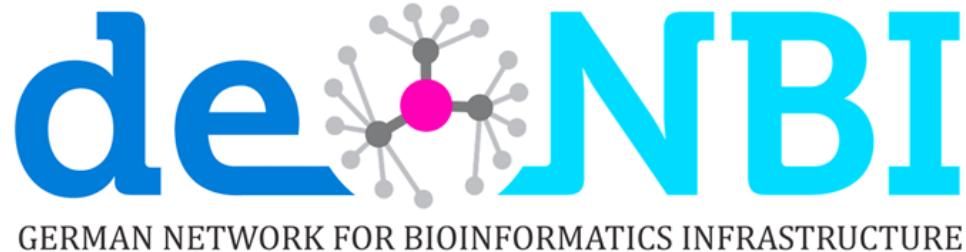
Introduction to sequencing data analysis

Andrea Bagnacani, Markus Wolfien, and Olaf Wolkenhauer

de.NBI Training – 6th March 2019 Rostock

www.sbi.uni-rostock.de





GERMAN NETWORK FOR BIOINFORMATICS INFRASTRUCTURE

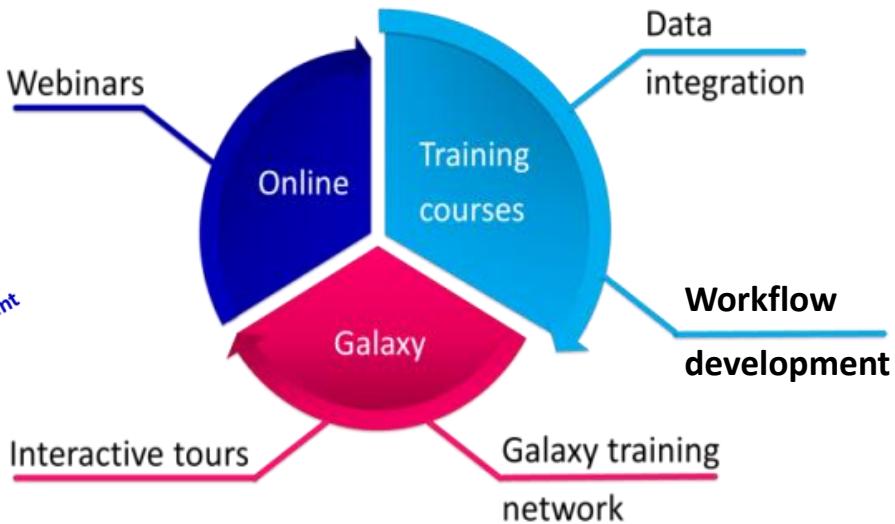
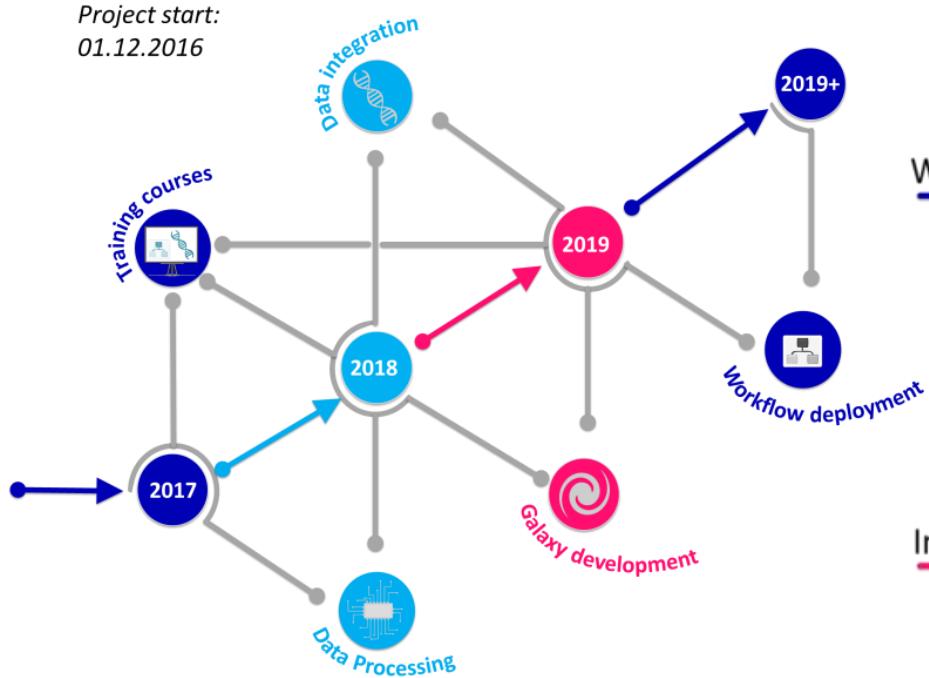


sbi.uni-rostock.de/destair

***Structured Analysis and Integration of
RNA-Seq experiments (de.STAIR)***

Our aim is to enable a comprehensive **analysis of RNA-Seq experiments as a service**. To enable maximum usefulness, interconnectivity, and accessibility for the developed approaches and services, we will provide dedicated **workshops, training programs and screen casts** for bioinformaticians and other life scientists.

Project start:
01.12.2016



Objectives for the training today

- What is medical Big data?
- Why using NGS?
- The Galaxy around me

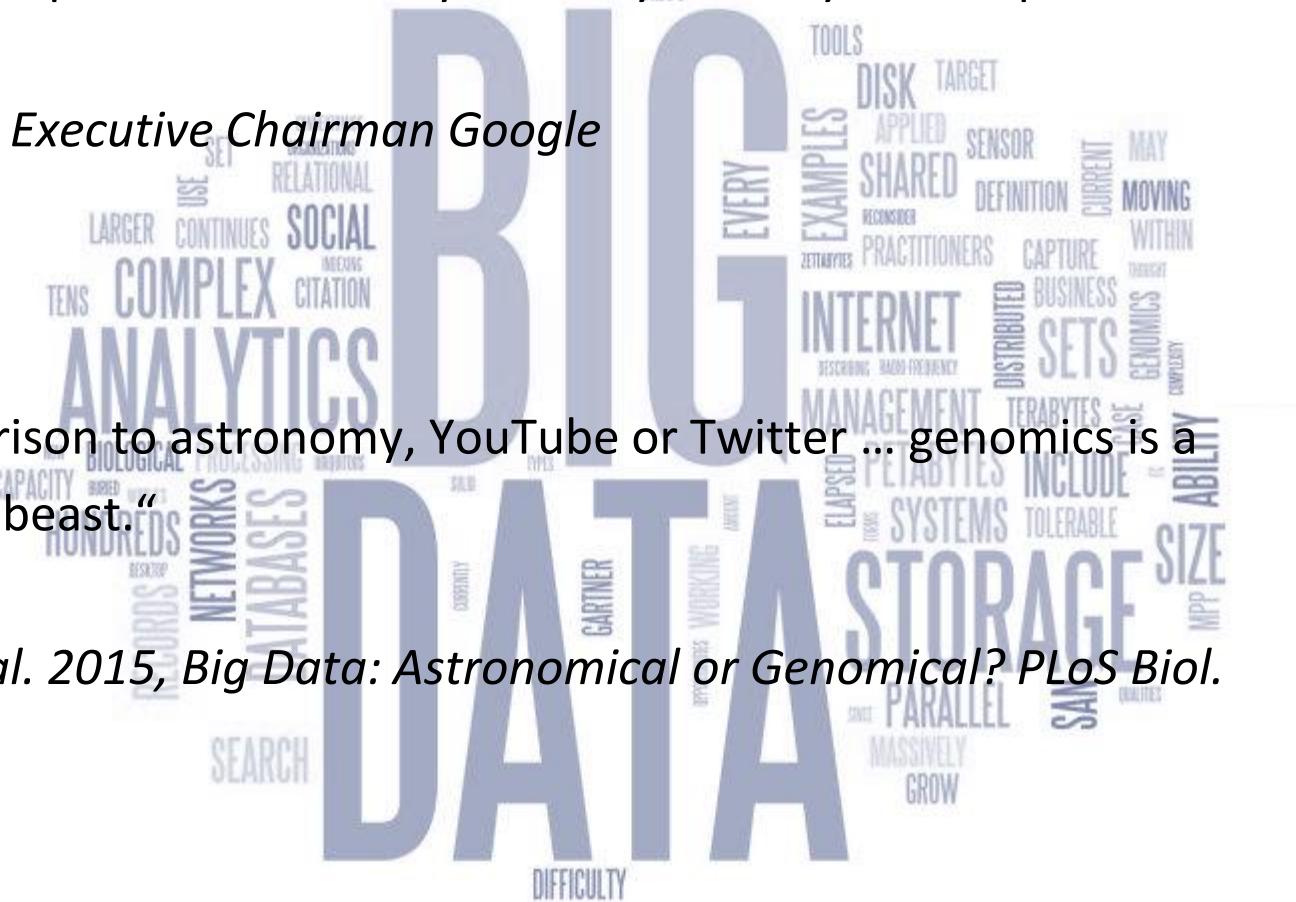
- How do we analyze NGS data?
- Are there best practices?
- Are there automation strategies?

- Explore RNA-Seq data analysis on use cases



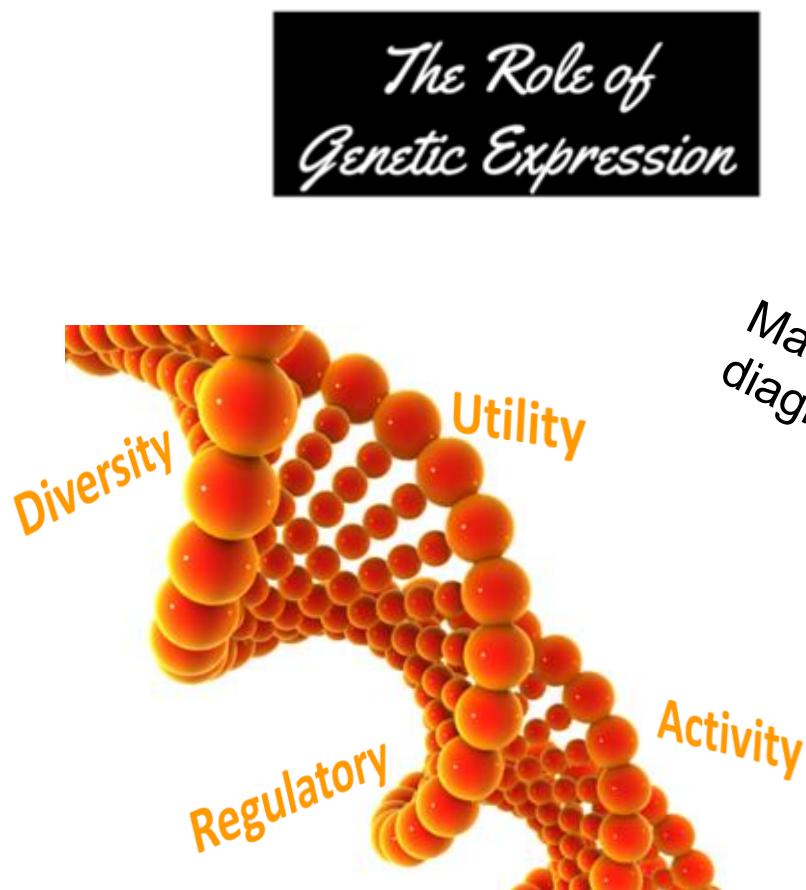
“From the dawn of civilization until 2003, humankind generated five exabytes of data. NOW we produce five exabytes every two days ... and pace is accelerating.”

Eric Schmidt, Executive Chairman Google



“... In comparison to astronomy, YouTube or Twitter ... genomics is a four-headed beast.”

Stephens et al. 2015, Big Data: Astronomical or Genomical? PLoS Biol.



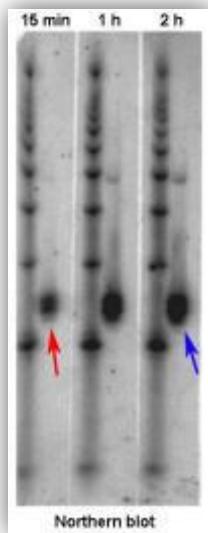
Many different variations and subtypes

Information about regulatory mechanisms

Active and measurable state of the cell ...

... ,but only a snapshot
Many different therapeutical and
diagnostical approaches

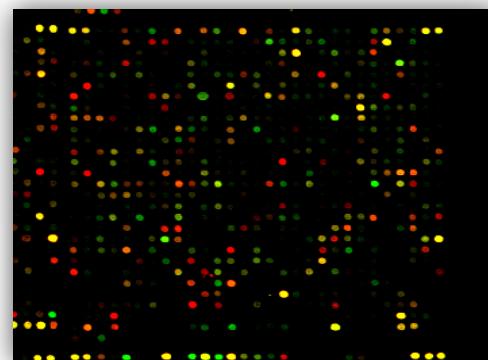
Measuring gene expression



Northern Blot



Reverse Transcription PCR

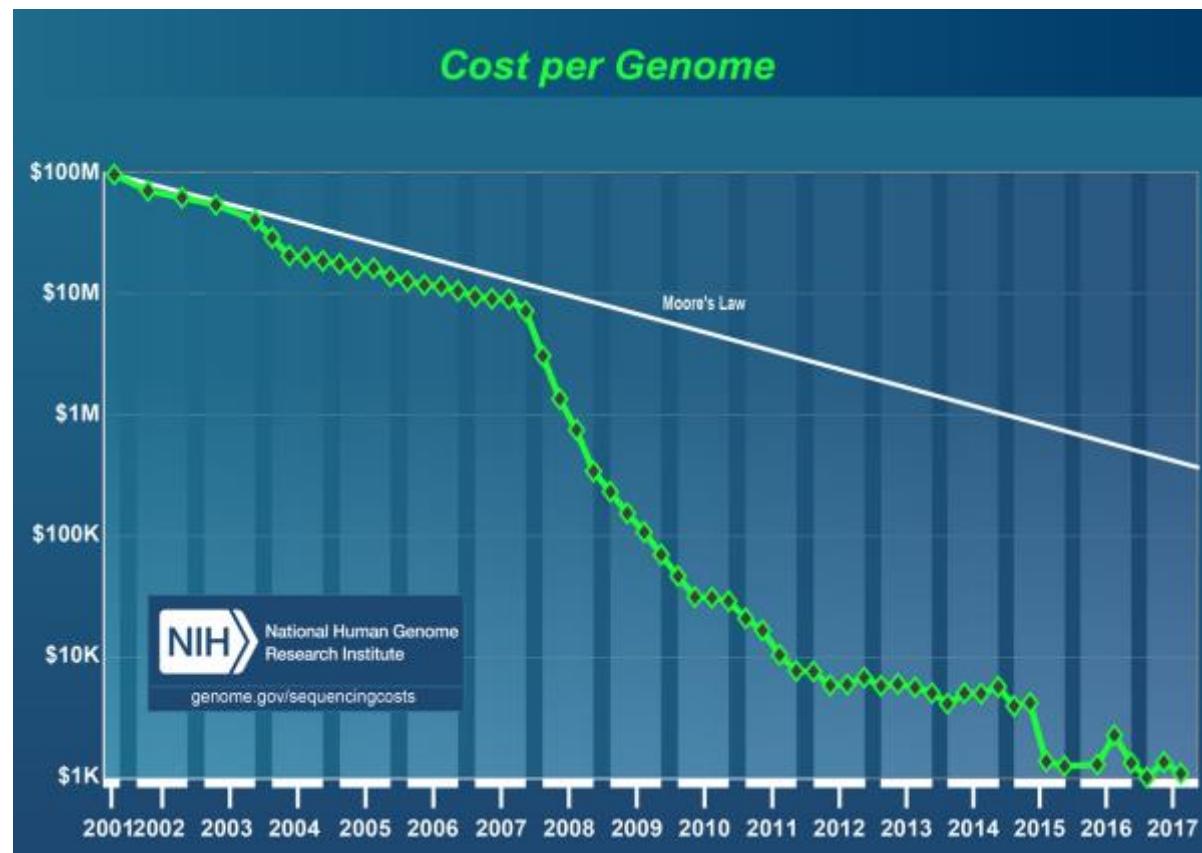


Microarrays



NGS

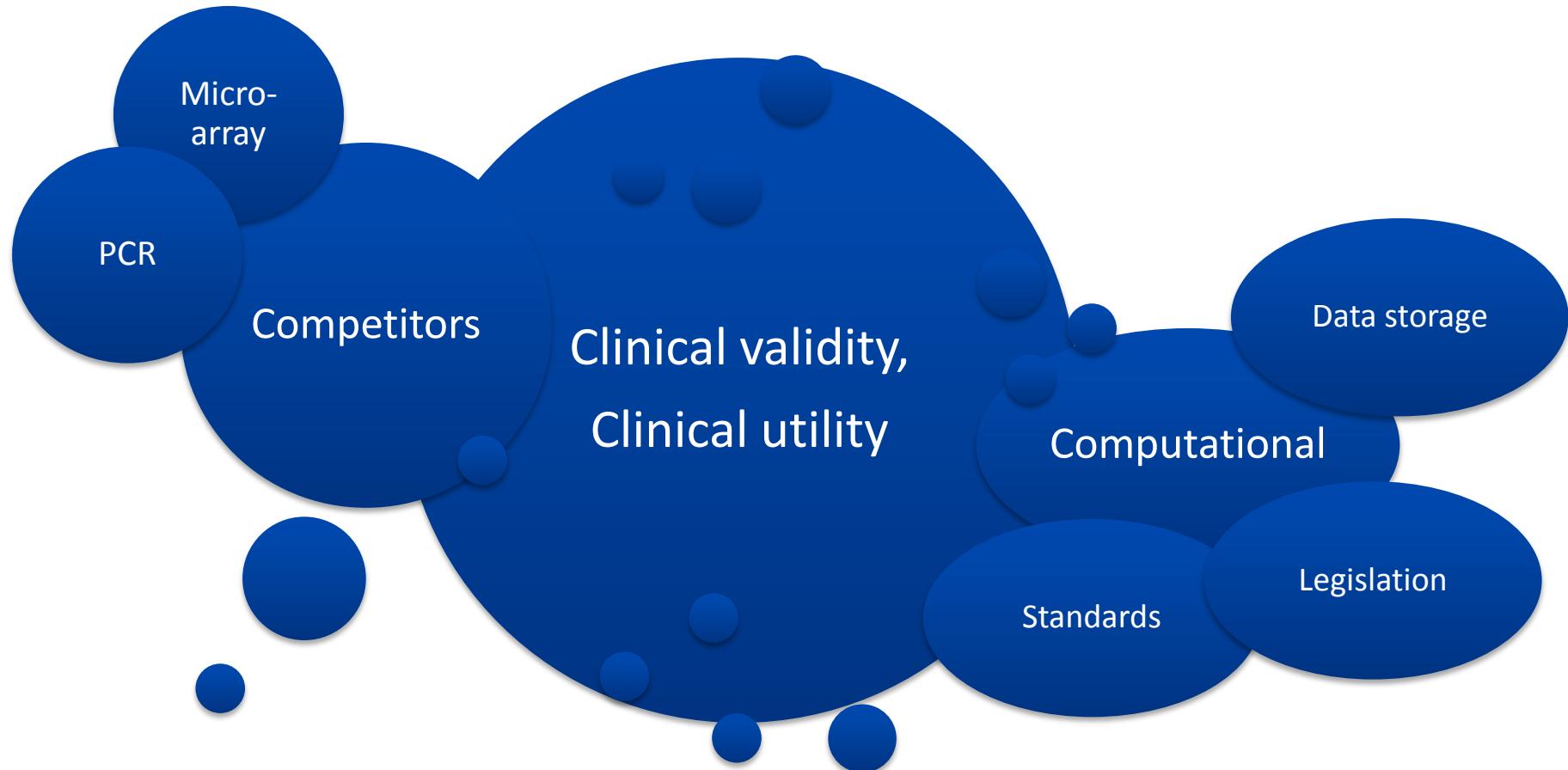
Technical advances lead the way



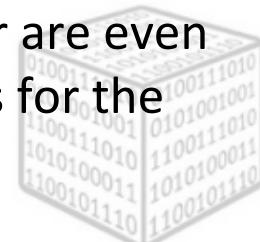


“RNA-Seq is able to identify thousands of differentially expressed genes, tens of thousands of differentially expressed gene isoforms and can detect mutations and germline variations for hundreds to thousands of expressed genetic variants, as well as detecting chimeric gene fusions, transcript isoforms and splice variants.”

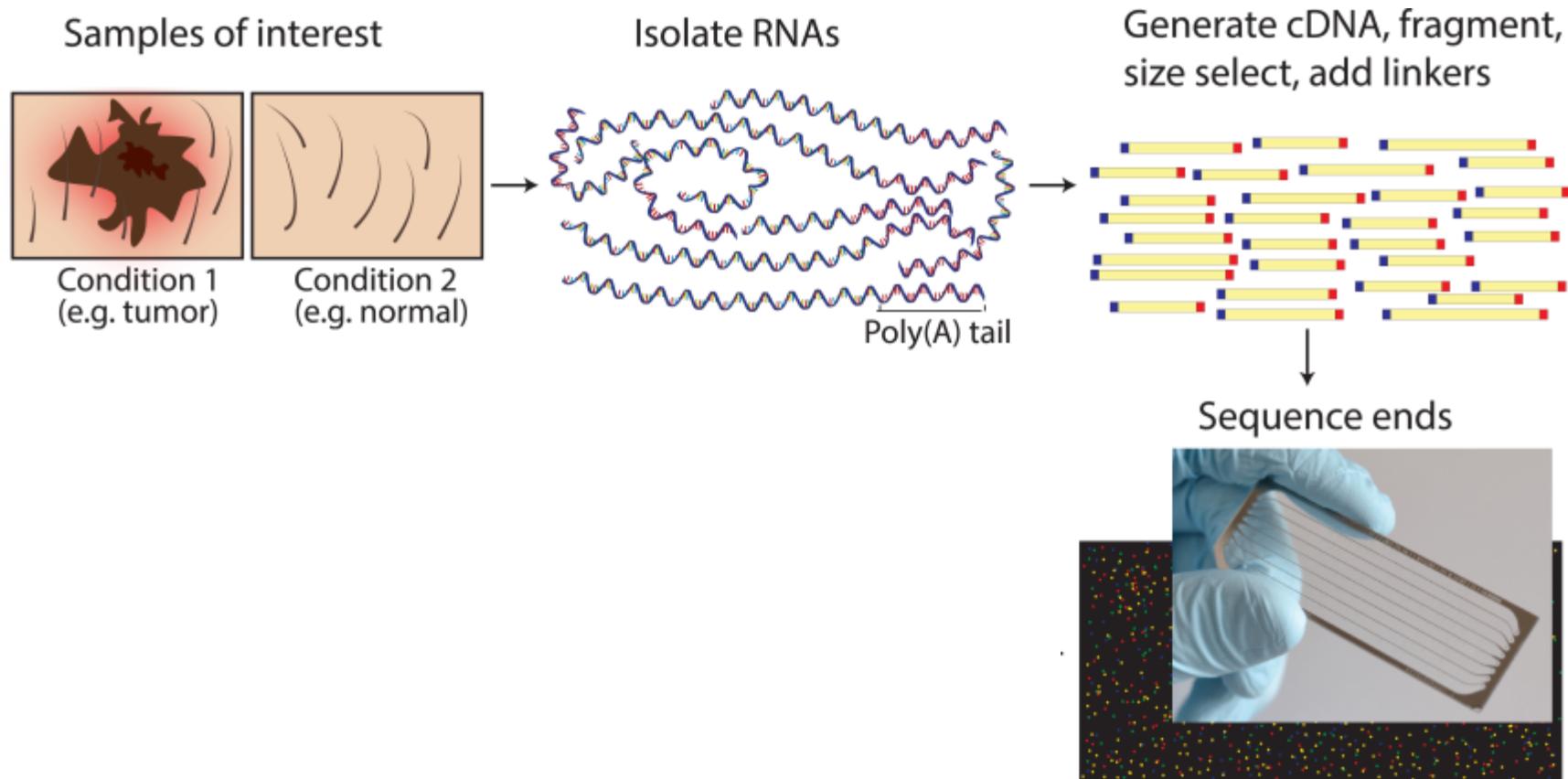
Wang, *Nat Rev. Genet.*, 2009



- Databases, two popular examples
 - Sequence Read Archive (SRA) - <https://www.ncbi.nlm.nih.gov/sra>
 - Makes biological raw sequence data available to the research community to enhance reproducibility and allow for new discoveries by comparing data sets (including Roche 454 GS System, Illumina Genome Analyzer, Applied Biosystems SOLiD System, Helicos Heliscope, Complete Genomics, and Pacific Biosciences SMRT).
 - The Cancer Genome Atlas (TCGA) - <https://portal.gdc.cancer.gov/>
 - Publishing the [Pan-Cancer Atlas](#) : a collection of cross-cancer analyses delving into overarching themes on cancer, including cell-of-origin patterns, oncogenic processes and signaling pathways.
- Experimental partners who have a wet lab for sample preparation or are even equipped with a sequencing device (there are also lots of companies for the sequencing procedure with the latest machines)



From sample to readout

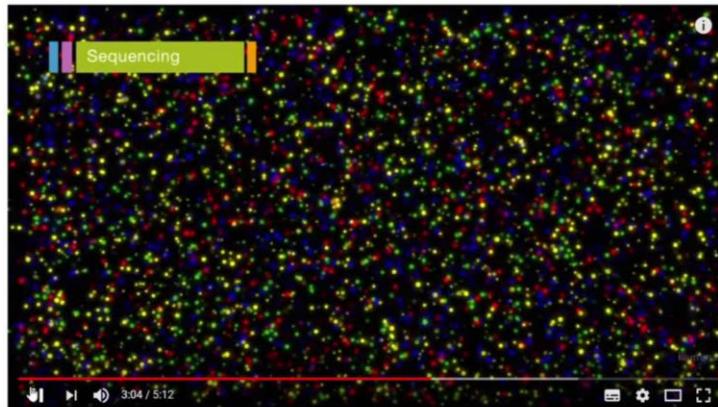
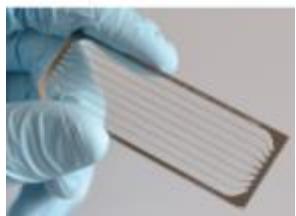
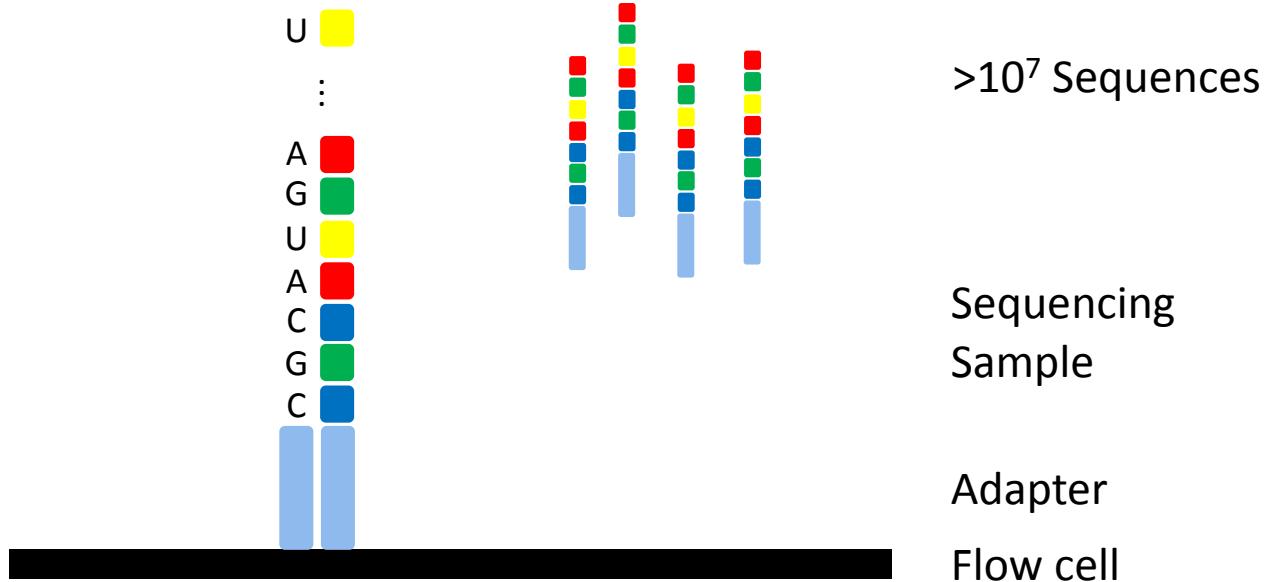


100s of millions of paired reads
10s of billions bases of sequence

Griffith, Plos Comp. Biol., 2015

More accurate with RNA-Sequencing?

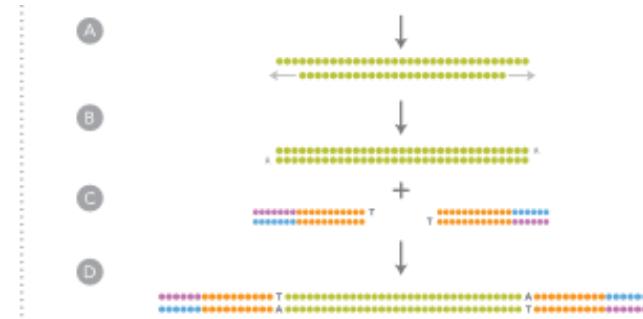
Sequencing procedure:



How do I get my NGS data - detailed?

1 Library Preparation

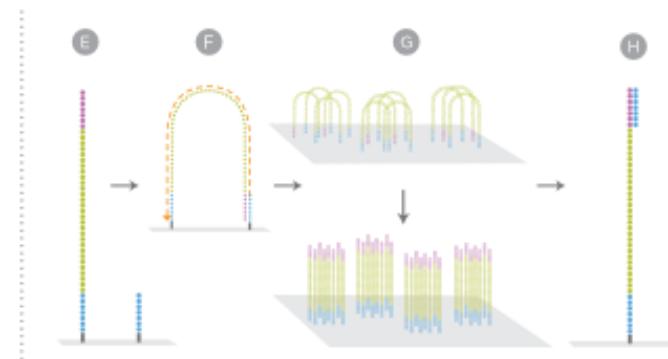
6 hours
3 hours hands-on time



- A** Fragment DNA
- B** Repair ends
Add A overhang
- C** Ligate adapters
- D** Select ligated DNA

2 Cluster Generation

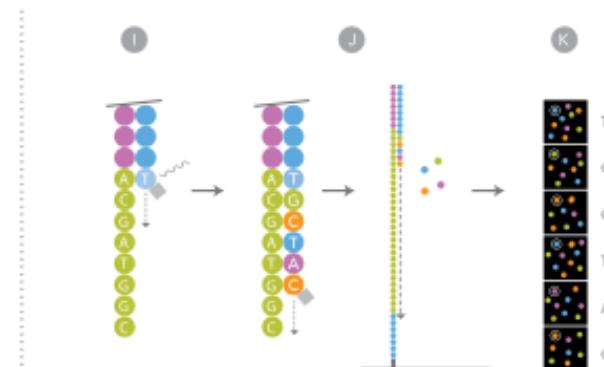
4 hours
< 10 minutes hands-on time
1–96 samples



- E** Attach DNA to flow cell
- F** Perform bridge amplification
- G** Generate clusters
- H** Anneal sequencing primer

3 Sequencing

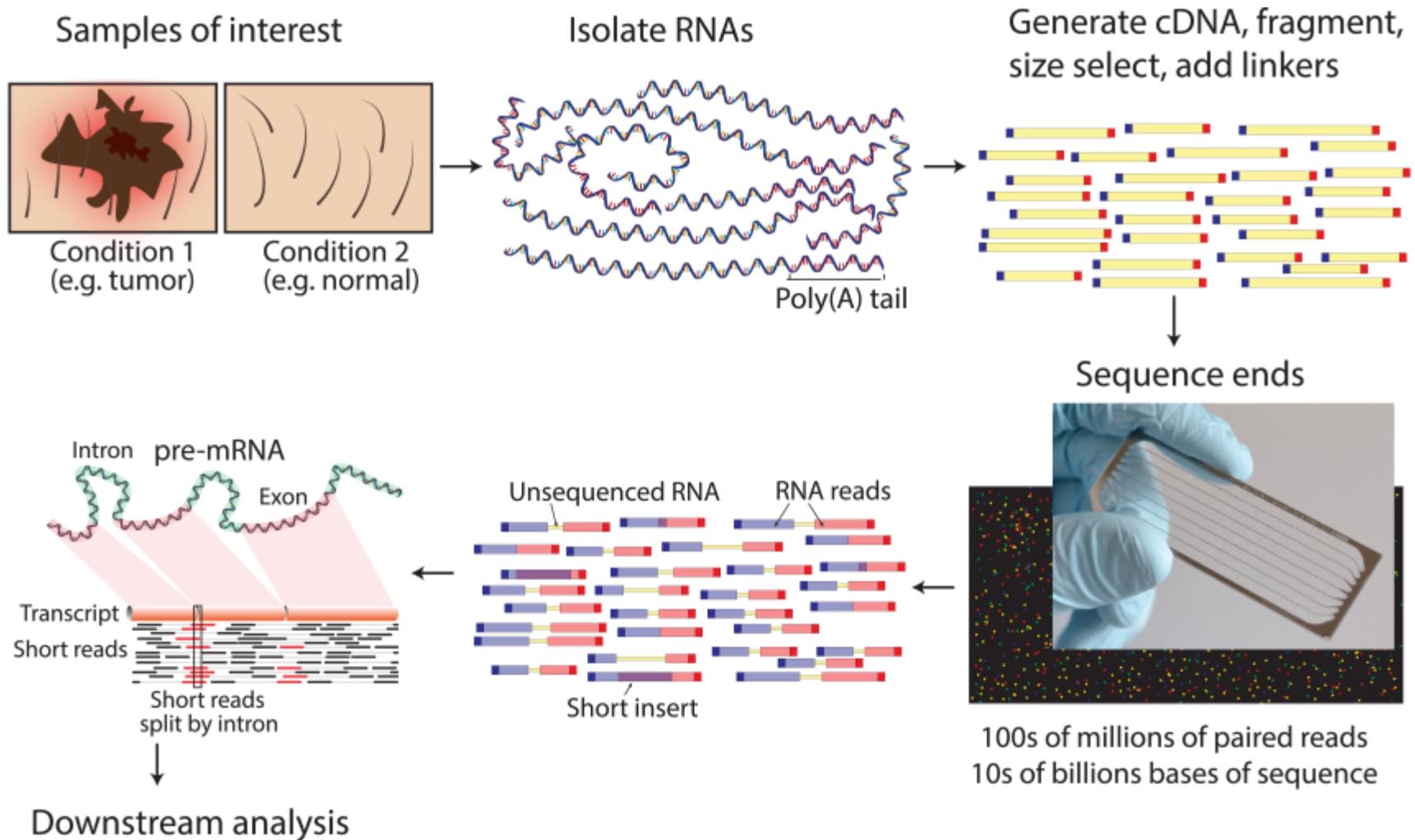
1–3 days single-read run
3–9 days paired-end run
30 minutes hands-on time
8 lanes, up to 96 samples per flow cell (run)



- I** Extend first base, read, and deblock
- J** Repeat step above to extend strand
- K** Generate base calls



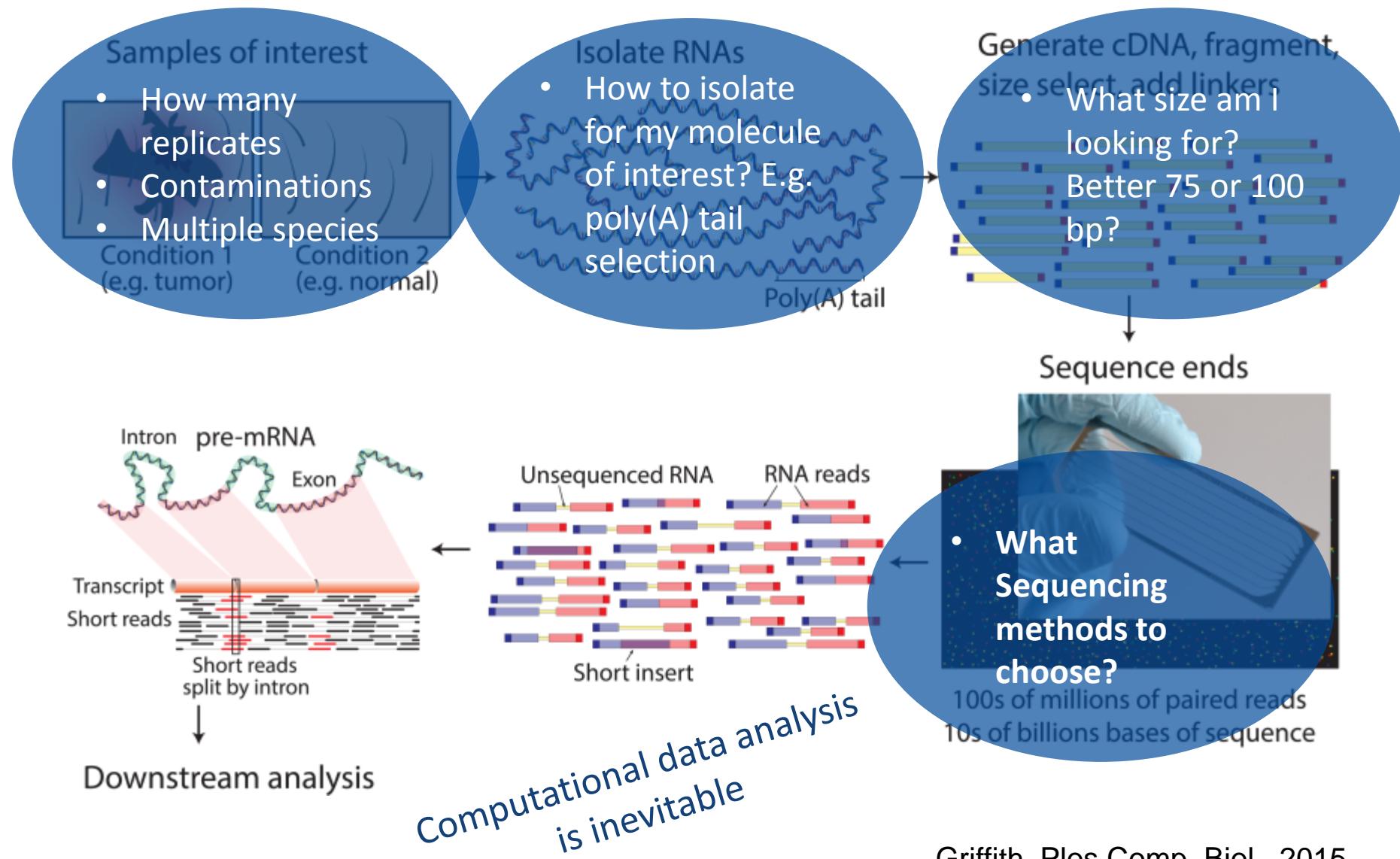
From sample to readout



Griffith, Plos Comp. Biol., 2015



From sample to readout



Griffith, Plos Comp. Biol., 2015

Big Data and the need for new analyses



Supporting new data analysis approaches

- Key performance of Galaxy

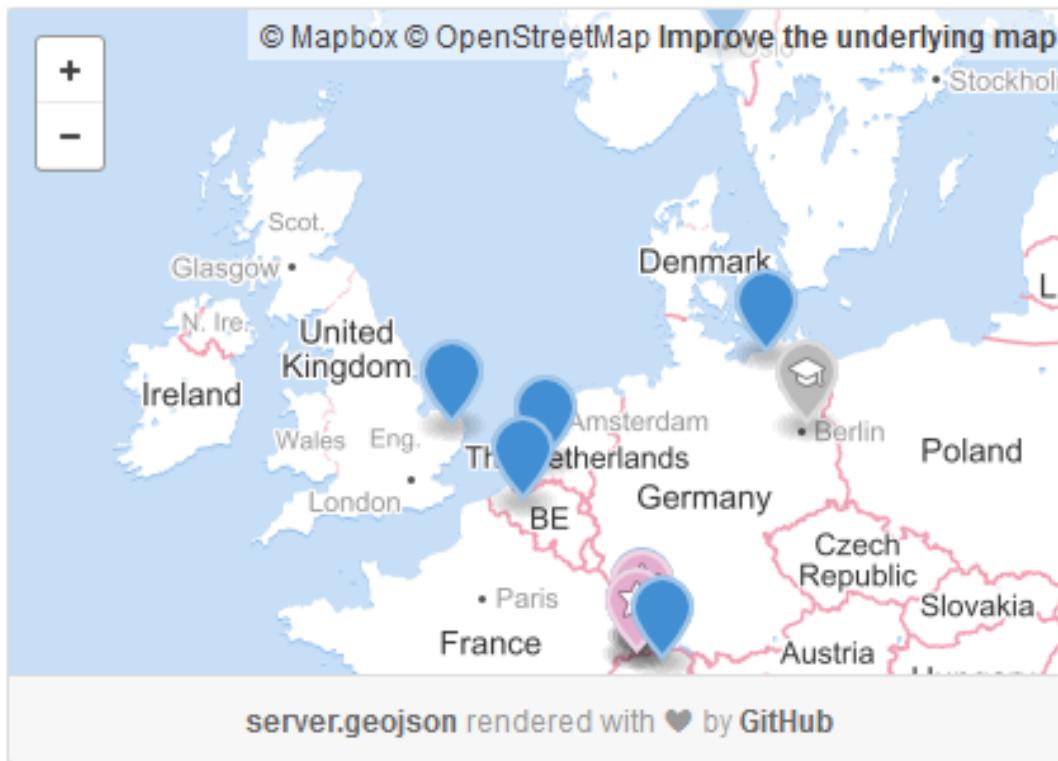
- Accessibility
- Reproducibility
- Transparency



jupyter.org/



usegalaxy.org



elixir-europe.org



- Main galaxy (US): <https://usegalaxy.org/>
- European Galaxy (de.NBI support): <https://usegalaxy.eu/>
- More than 125 dedicated servers about every kind of scientific research
<https://galaxyproject.org/use/>
- Have your own Galaxy with Docker!
 - RNA-Workbench - <https://github.com/bgruening/galaxy-rna-workbench>
 - Galaxy Modular Workflow Generator -
<https://github.com/destairdenbi/galaxy-modular-workflow-generator>

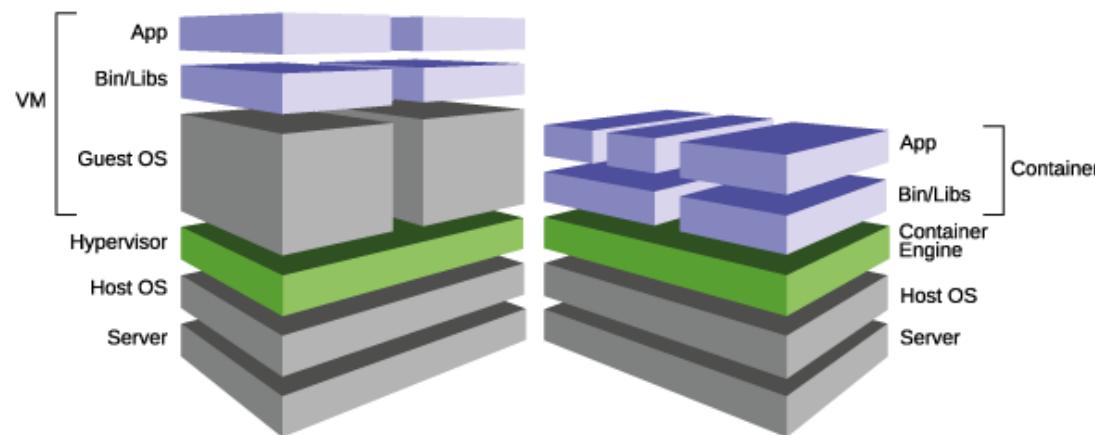


What is Docker?



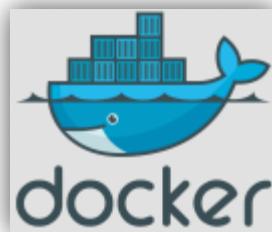
Docker is used to run software packages called "**containers**". Containers are isolated from each other and bundle their own application, tools, libraries and configuration files; they can communicate with each other through well-defined channels.

- Build for scale
- Extensible and flexible
- E.g. used by Ebay, GE, illumina, Spotify





+



= Symbiosis!



- Tailor-made, user specific and integration into a general framework to develop workflows addressing the users need and facilitating a reuse

- Stand-alone Docker container which “conserves” your whole tool compilation (for an easy use – one command line or kitematic.com click!)

```
docker run -p 8080:80 bgruening/galaxy-rna-workbench
```

- Get a single minimized Docker container for every tool and obtain a maximum flexibility (more advanced)



- Specialized Galaxy instance for RNA analyses provided by the RBC
- Contains +50 tools for structure analyses, annotation, alignment and many more

github.com/bgruening/galaxy-rna-workbench

Galaxy / RNA workbench

Analyze Data Workflow Shared Data Visualization Help User Using 0 bytes

Tools

Get Data

Collection Operations

Text Manipulation

Filter and Sort

Join, Subtract and Group

Convert Formats

Extract Features

Fetch Sequences

Fetch Alignments

Statistics

Graph/Display Data

Mapping

Quality Control

deepTools

BED Tools

SAM Tools

RNA-Seq

RNA Structure Analysis

RNA Alignment

RNA-protein Interaction

RNA Annotation

Ribosome Profiling

RNA Target Prediction

Hello, your RNA workbench is running!

Configuring Galaxy »

Installing Tools »

Guided Tour »

Galaxy RNA Workbench

History

search datasets

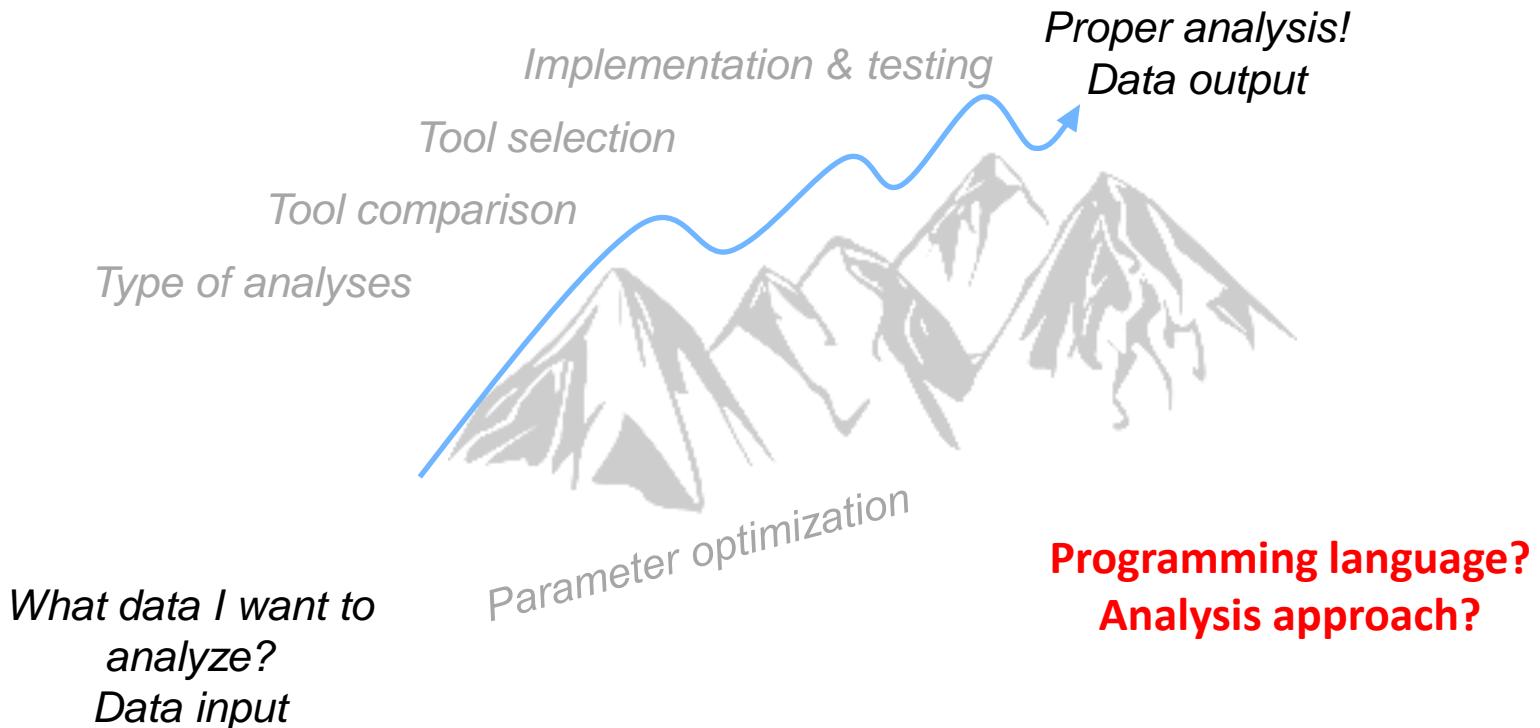
Unnamed history (empty)

This history is empty. You can load your own data or get.data from an external source

Galaxy is an open platform for supporting data intensive research. Galaxy is developed by [The Galaxy Team](#) with the support of many contributors. The Galaxy Docker project is supported by the University of Freiburg, part of de.NBI.

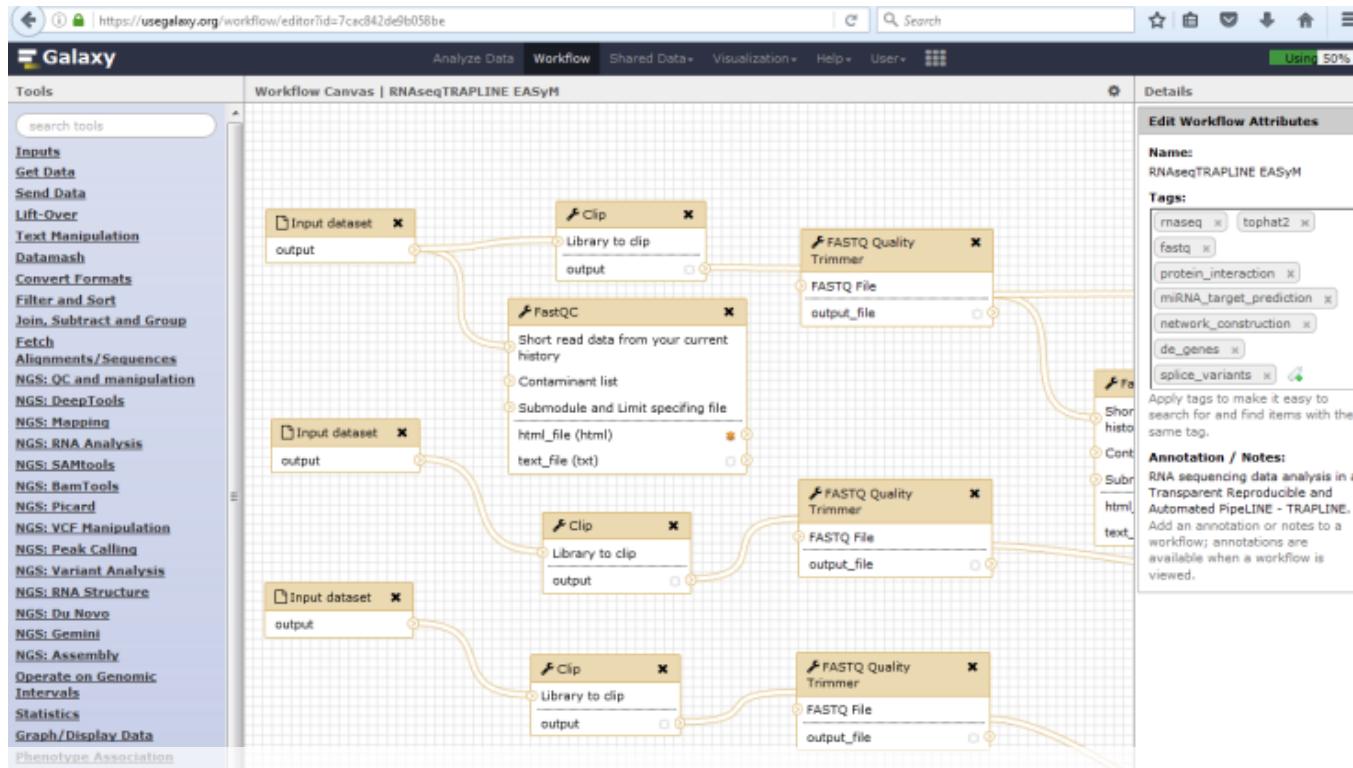
The Galaxy Project is supported in part by NHGRI, NSF, The Huck Institutes of the Life Sciences, The Institute for CyberScience at Penn State, The German Network for Bioinformatics Infrastructure (de.NBI), Johns Hopkins University, and University of Freiburg.

The struggle for the right approaches



Lott, Wolfien, Riege, Bagnacani, et al., *J.Biotech*, 2017

Using workflow development

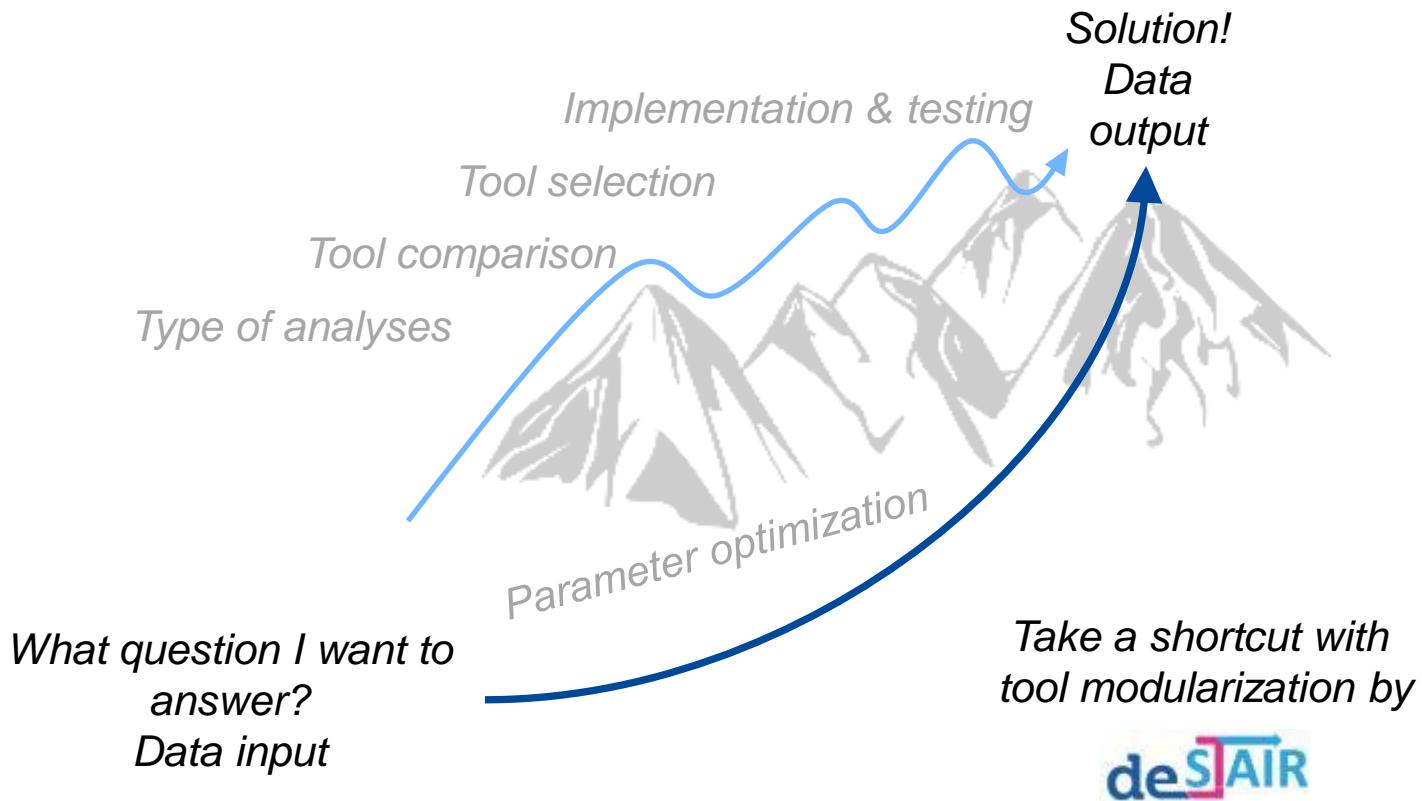


- Workflows are build and maintained by experts
- Workflows are modular and can be easily adapted to other tasks
- Implementation of other tools can be done (quickly)
- Application of workflows and tools is targeted for non-computational users



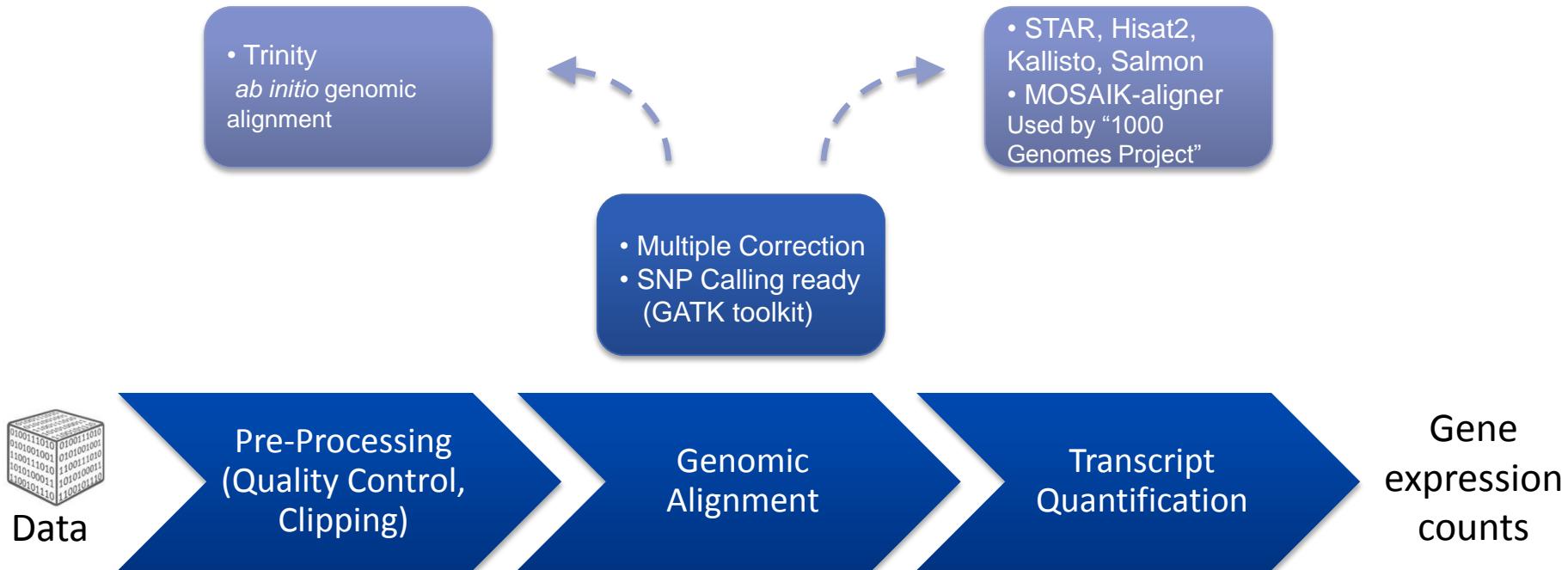


Why using workflows?



Lott, Wolfien, Riege, Bagnacani, et al., *J.Biotech*, 2017

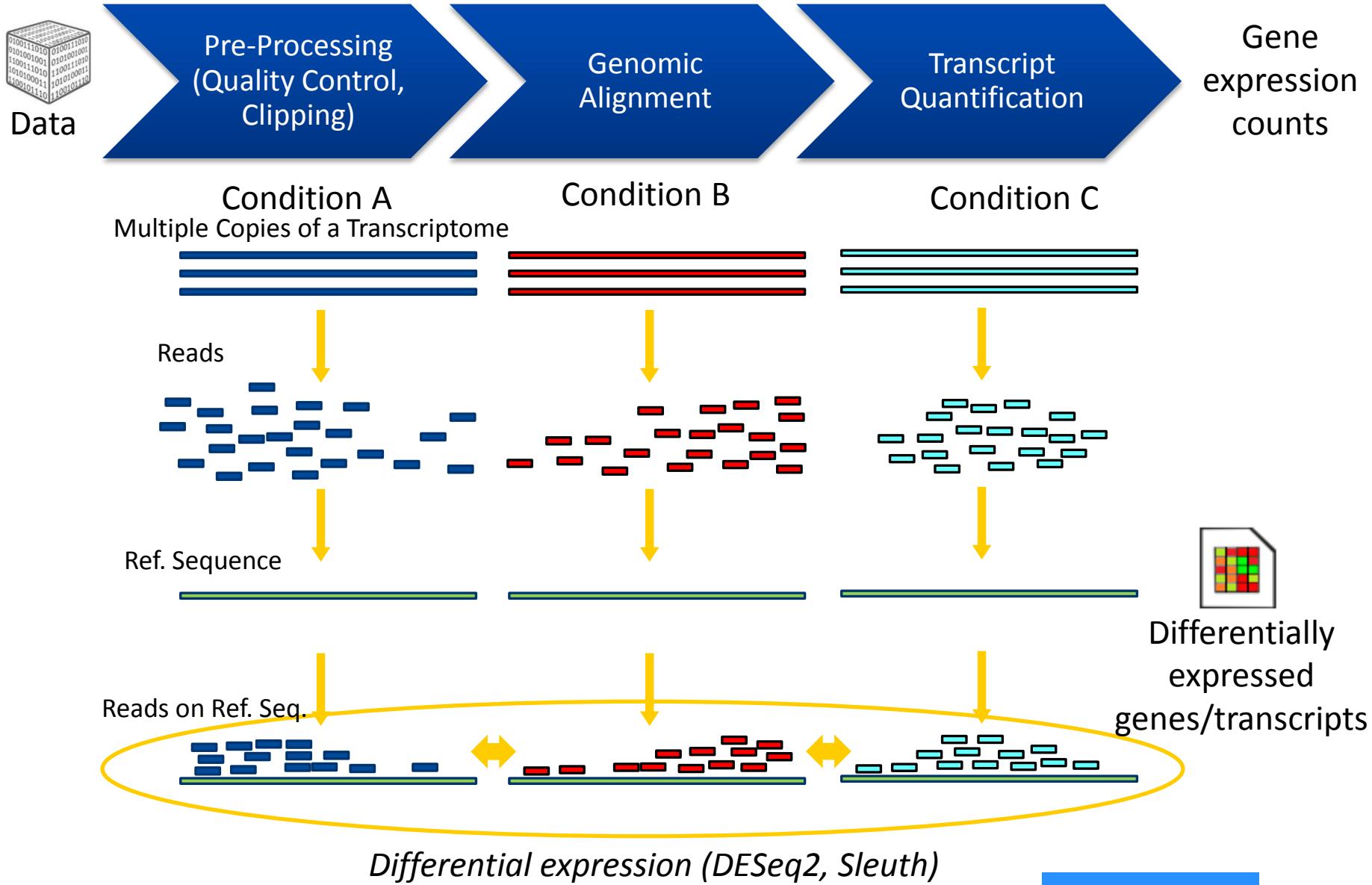
Basic workflow for differential expression analysis



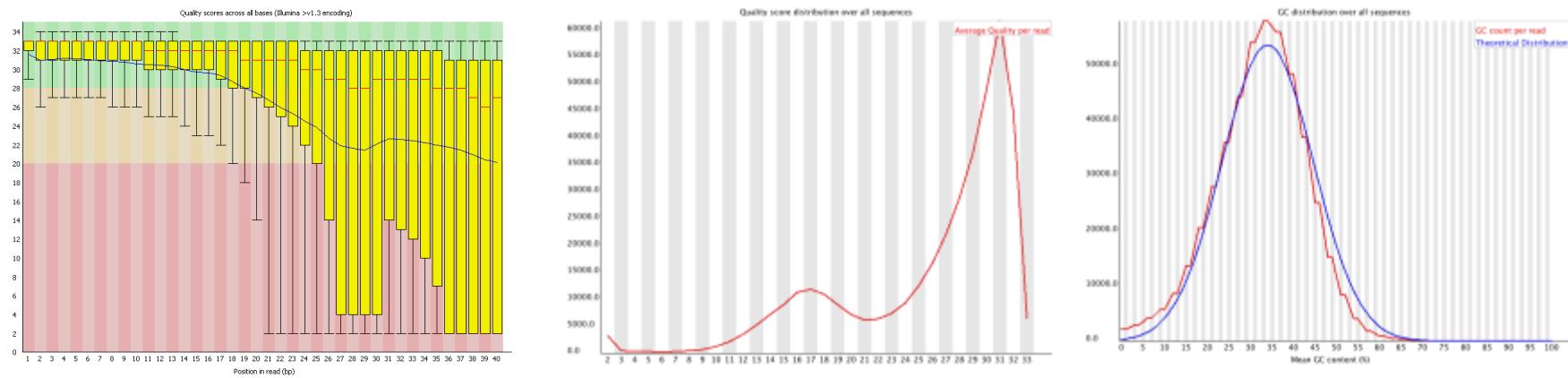
- Evaluate Reads (e.g. Sequence Quality, GC Content, Read length)

- FeatureCounts
- Check RPKM Normalization
- Bias Correction

Basic workflow for differential expression analysis

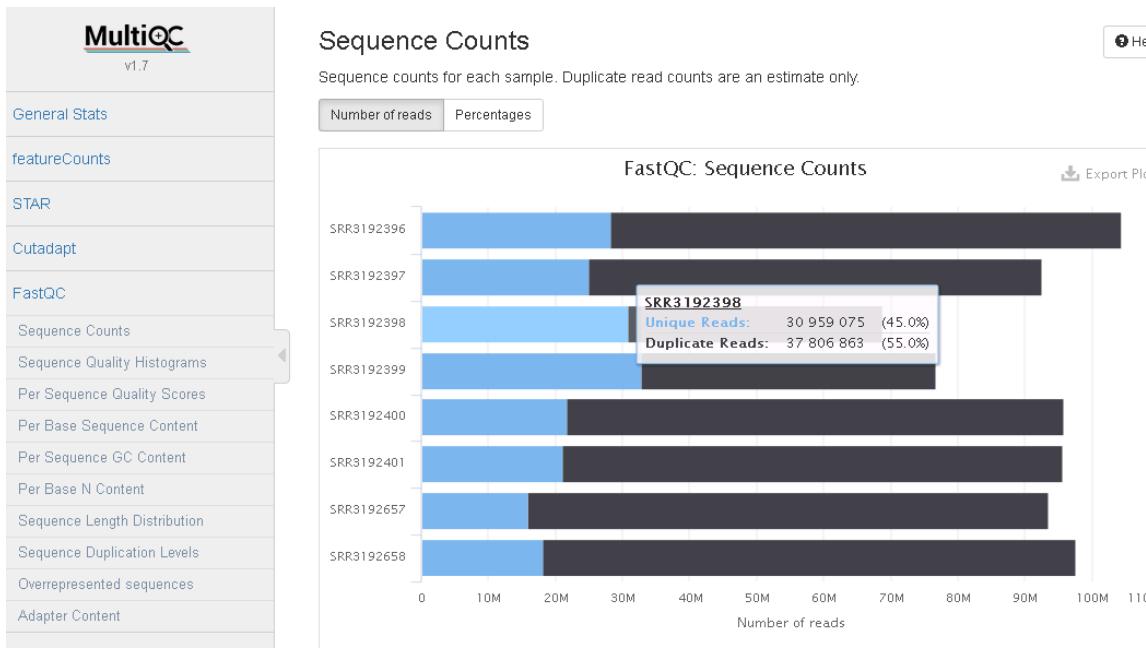


Visualization of pre-processing results

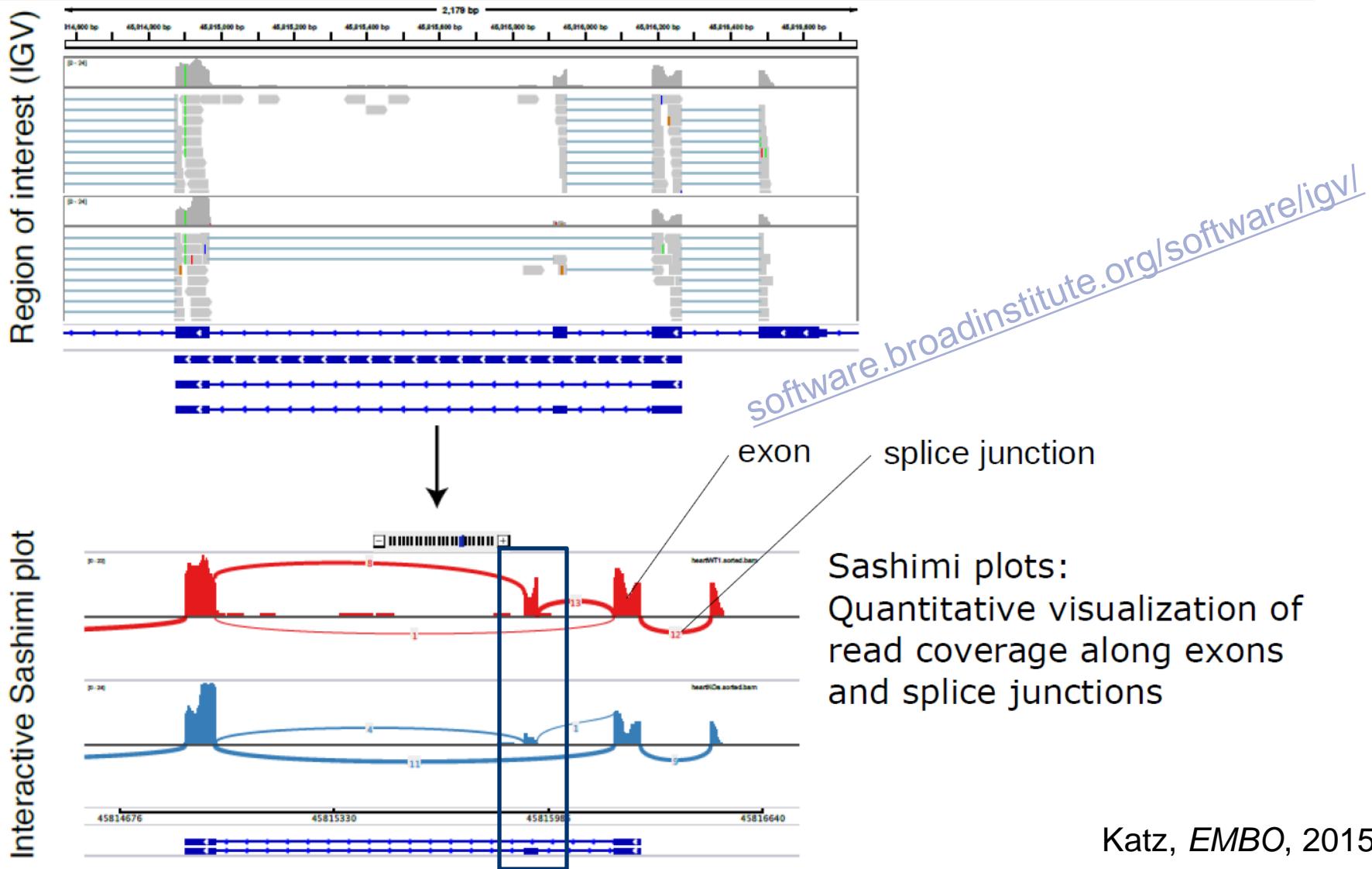


FastQC - <https://www.bioinformatics.babraham.ac.uk/projects/fastqc/>

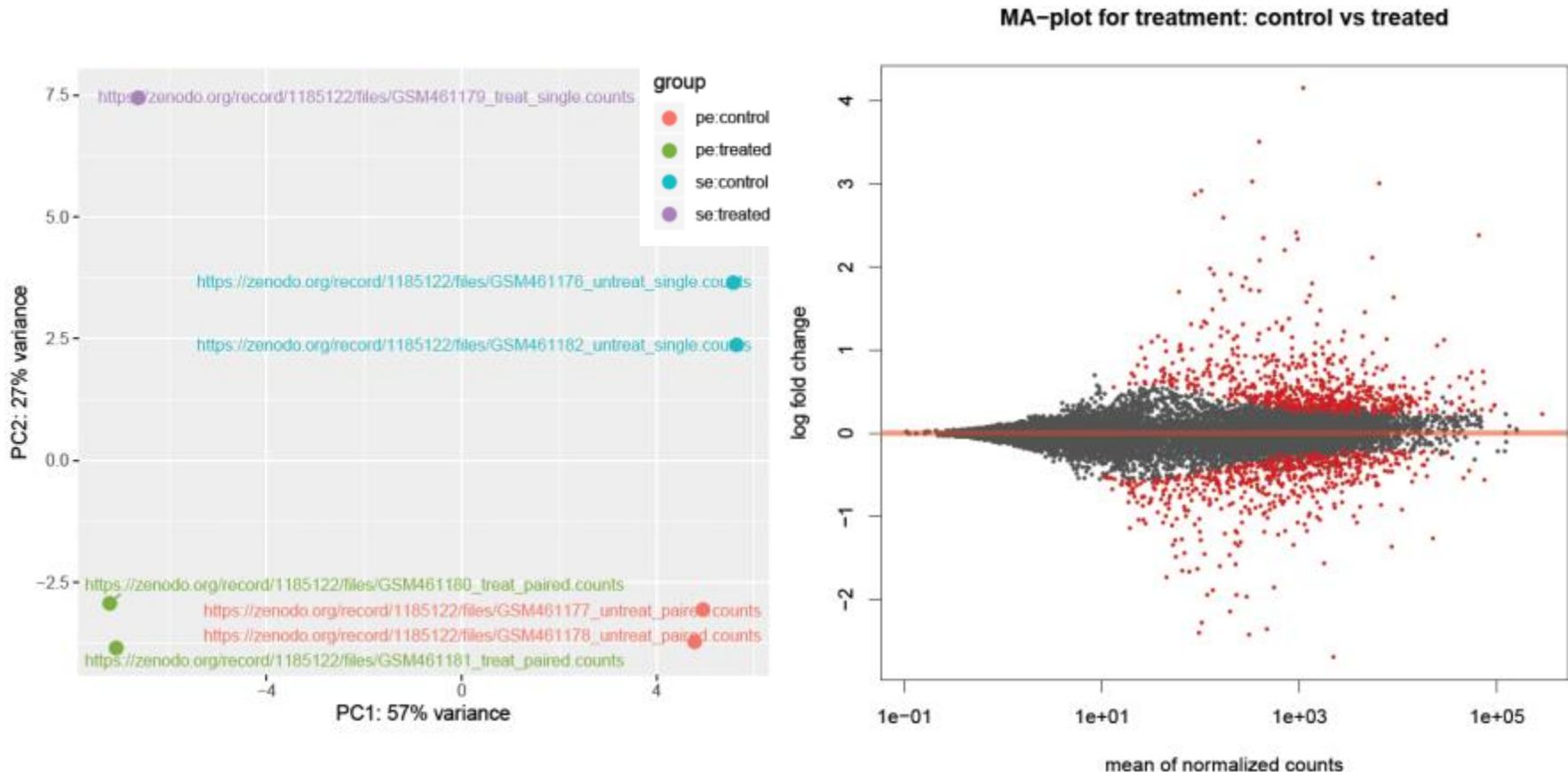
MultiQC - <https://multiqc.info/>



Visualization of mapping results



Visualization of quantification results



DESeq2- Love et al. 2014

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4302049/>

Sequencing experimentation and data analysis summary

Extract RNA from samples



Generate sequence reads



C T C A
A A A A
0 G T T
0 T A A
1 G O G
1 1 1 1
0 1 1
1
1

T T C A
G A A A
1 G T G
0 T A C
1 G O A
0 1 0 1
0 0 0 0
0 1 1
1 1

Map reads to a reference



Quantify/Compare reads



Identify novel transcripts

Experiment

Sample preparation

- Amount of replicates ($n \leq 3$) for the desired experiment
- No contaminations that effect the RNA level
- Multiple species within a sample (e.g. metatranscriptomics)
- Cell culture routine with/out antibiotics

RNA isolation

- Choice of isolation (e.g. Poly(A)-selection)
- Use latest purification kits
- Work RNAase free
- Low number of cell passage
- Use globin depletion kit for whole blood

Library generation

- Selection of suitable polymerases, thermocycling times and buffer conditions
- Quickly transfer RNA into cDNA
- Choice for desired amount and size of reads
- Choice for suitable sequencing method

Data analysis

Preprocessing

- Demultiplex data and remove barcodes
- Do quality control (check for GC content, read size, sequencing errors in lanes & cycles)
- Perform adapter clipping and quality trimming
- Check again for the quality

Genomic alignment

- Use the latest reference genome (e.g. UCSC, Ensembl)
- Choose correct aligner for your task (e.g. RNA quantification, *de novo* alignment, gene-fusion detection, etc.)

Quantification

- Use the latest annotation set
- Normalize your data (e.g. RPKM, TPM)
- Use different statistics to identify significantly differentially expressed transcripts
- Fold-change > 2
- q-value < 0.05

Wolfien *et al.* 2019

- Lott SC, Wolfien M, Riege K, Bagnacani A, Wolkenhauer O, Hoffmann S, et al. Customized workflow development and data modularization concepts for RNA-Sequencing and metatranscriptome experiments. *J Biotechnol.* 2017 Jul; Available from: <http://linkinghub.elsevier.com/retrieve/pii/S0168165617314992>
- Conesa A, Madrigal P, Tarazona S, Gomez-Cabrero D, Cervera A, McPherson A, et al. A survey of best practices for RNA-seq data analysis. *Genome Biol.* 2016. Available from: <http://genomebiology.com/2016/17/1/13>
- Wolfien M, Brauer DL, Bagnacani A, Wolkenhauer O. Workflow Development for the Functional Characterization of ncRNAs. In *Springer Nature*, New York, NY; 2019. Available from: http://link.springer.com/10.1007/978-1-4939-8982-9_5

Welcome to Galaxy Training!

Collection of tutorials developed and maintained by the worldwide Galaxy community

Galaxy for Scientists

Topic	Tutorials
Introduction to Galaxy Analyses	7
Assembly	4
ChIP-Seq data analysis	3
Epigenetics	3
Genome Annotation	3
Metabolomics	2
Metagenomics	2
Proteomics	12
Sequence analysis	5
Statistics and machine learning	3
Transcriptomics	17
Variant Analysis	6

Galaxy Tips & Tricks

Topic	Tutorials
Data Manipulation	4
User Interface and Features	3

Galaxy for Developers and Admins

Topic	Tutorials
Galaxy Server administration	34
Development in Galaxy	13



<http://galaxyproject.github.io/training-material/>



Course material: <https://github.com/destairdenbi/trainings>



Training material: <http://galaxyproject.github.io/training-material/>

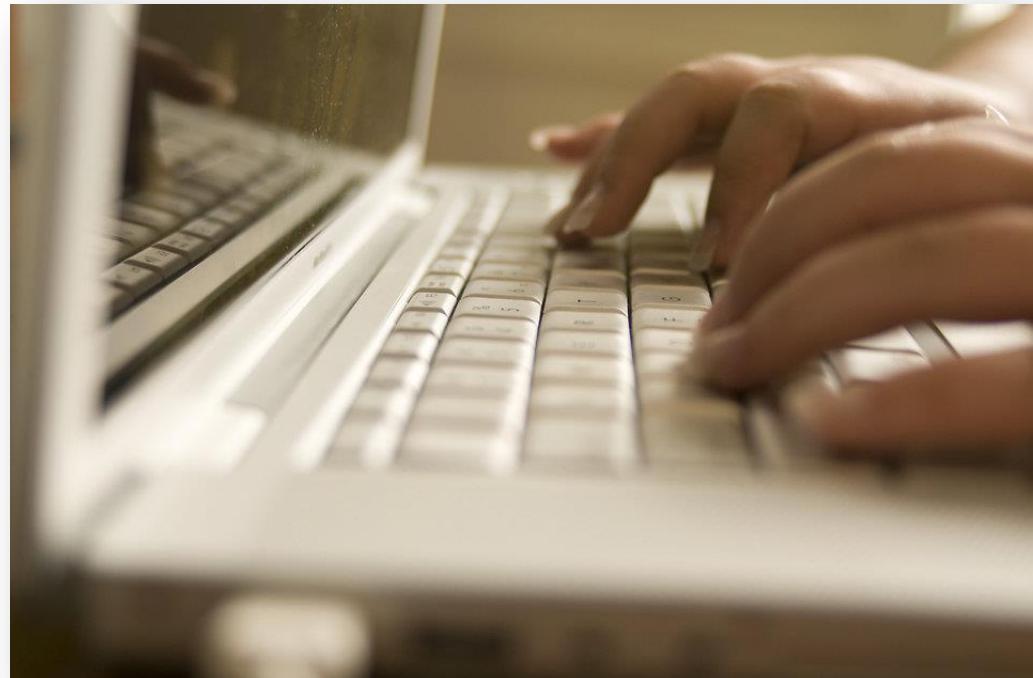
Manuscript: [https://www.cell.com/cell-systems/fulltext/S2405-4712\(18\)30230-8](https://www.cell.com/cell-systems/fulltext/S2405-4712(18)30230-8)

Hands-on part 1

11:15 – 12:00

“Introduction to Galaxy”

Material: <https://galaxyproject.github.io/training-material/topics/introduction/>





12:00 – 13:45

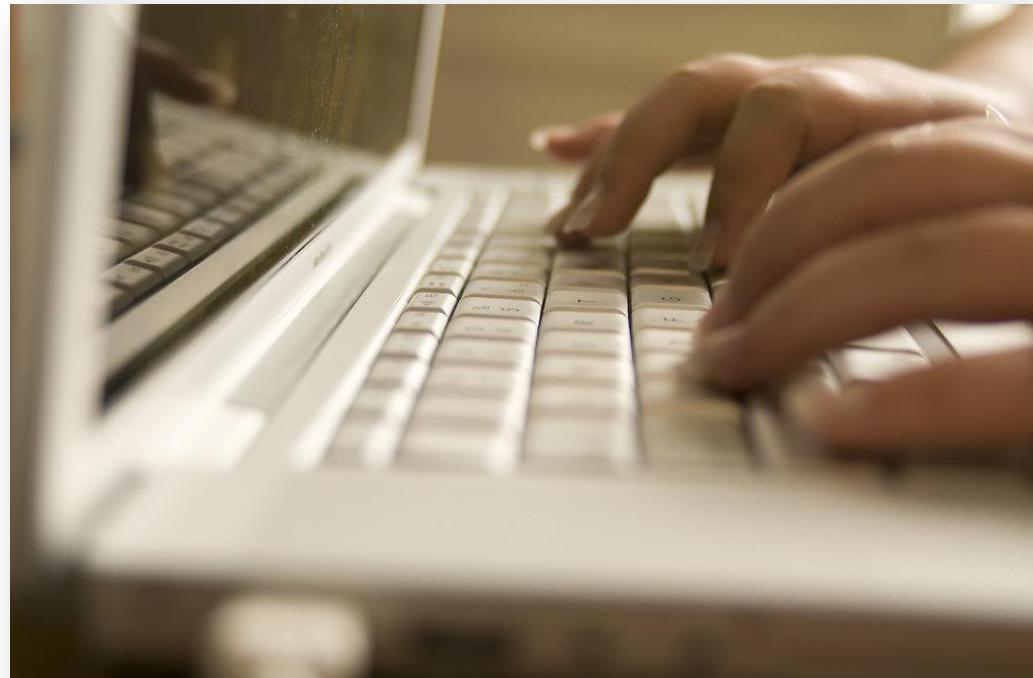


Hands-on part 2

13:45 – 14:30

“RNA-Seq data preprocessing and quality control”

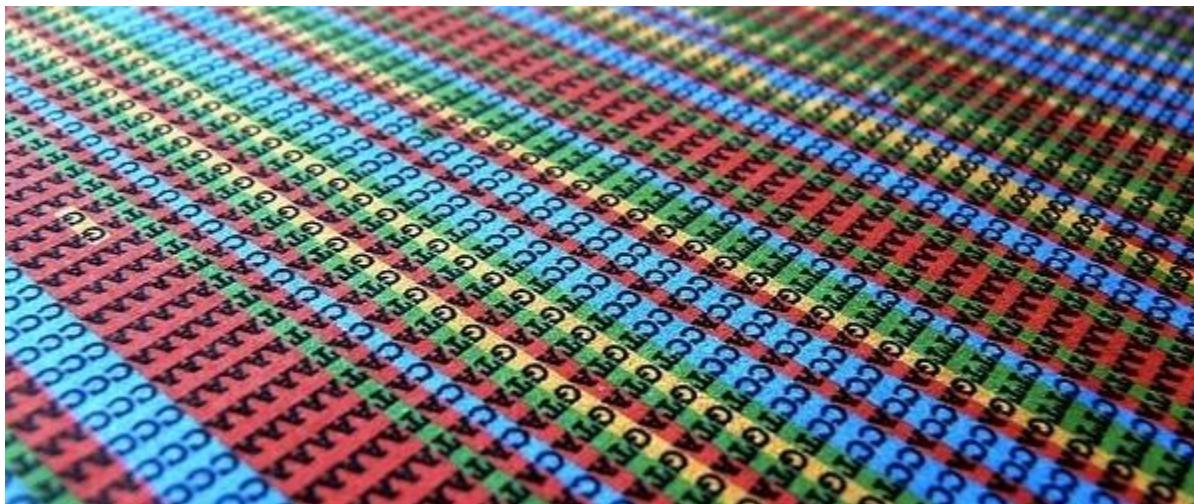
Material: <http://galaxyproject.github.io/training-material/topics/sequence-analysis/>



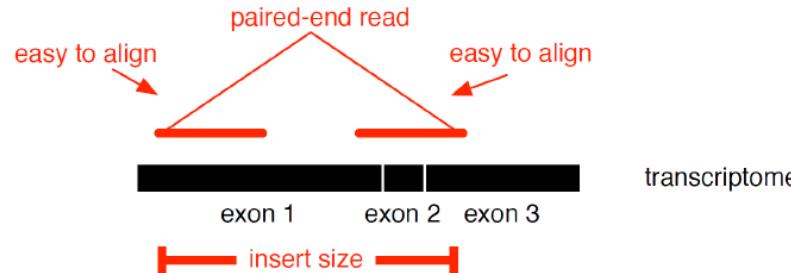
Hands-on part 3

14:30 – 15:15

“Application of different read mapping approaches for genomic alignment”

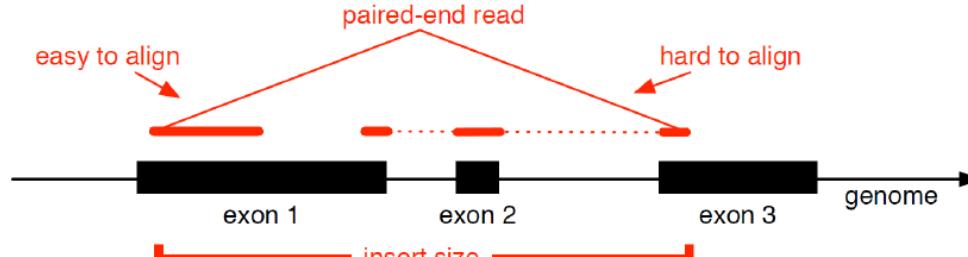


Transcriptome alignment



- reliable gene models required
- no detection of novel genes

Genome alignment (splice-aware read alignment)

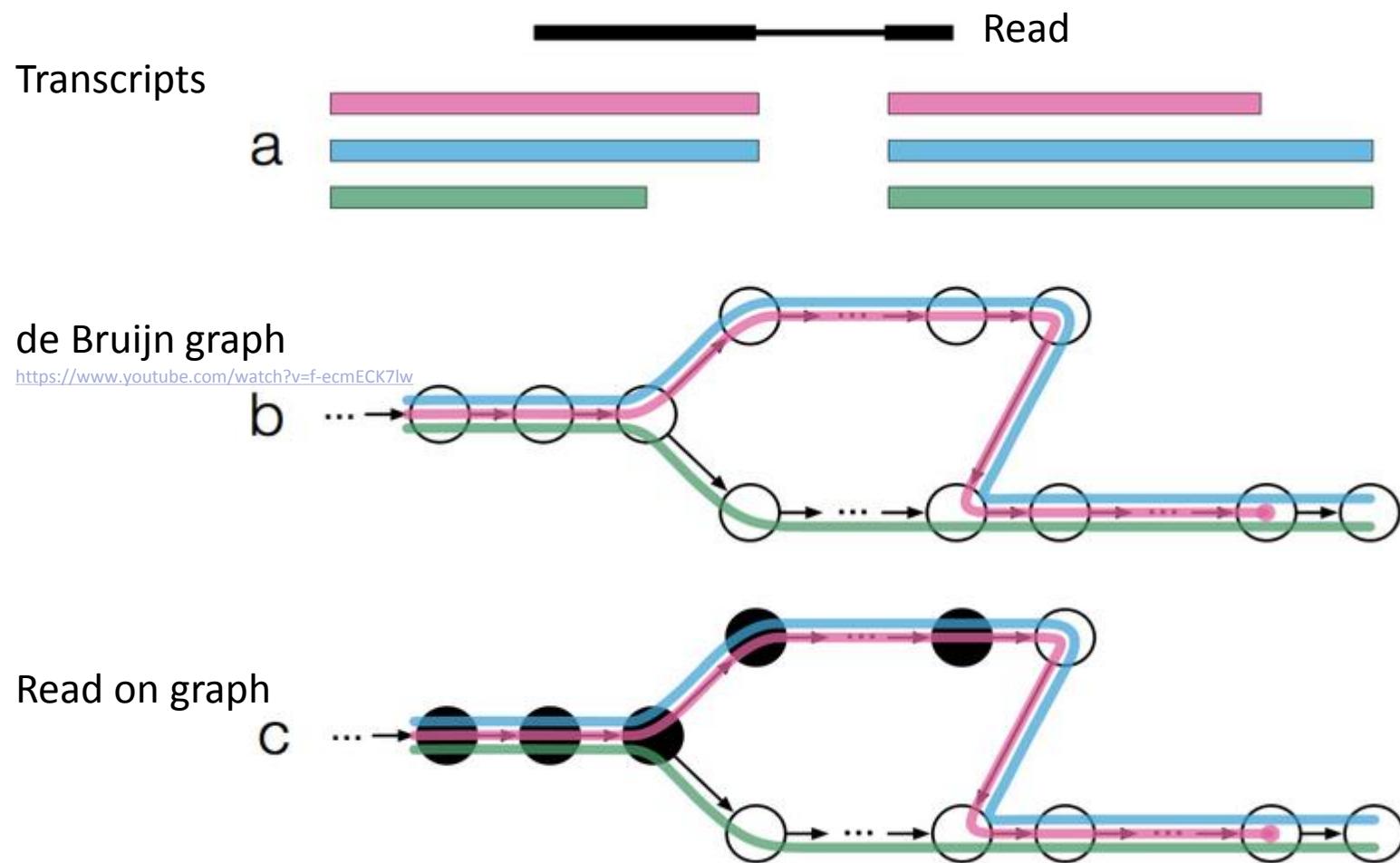


- + detection of novel genes and isoforms

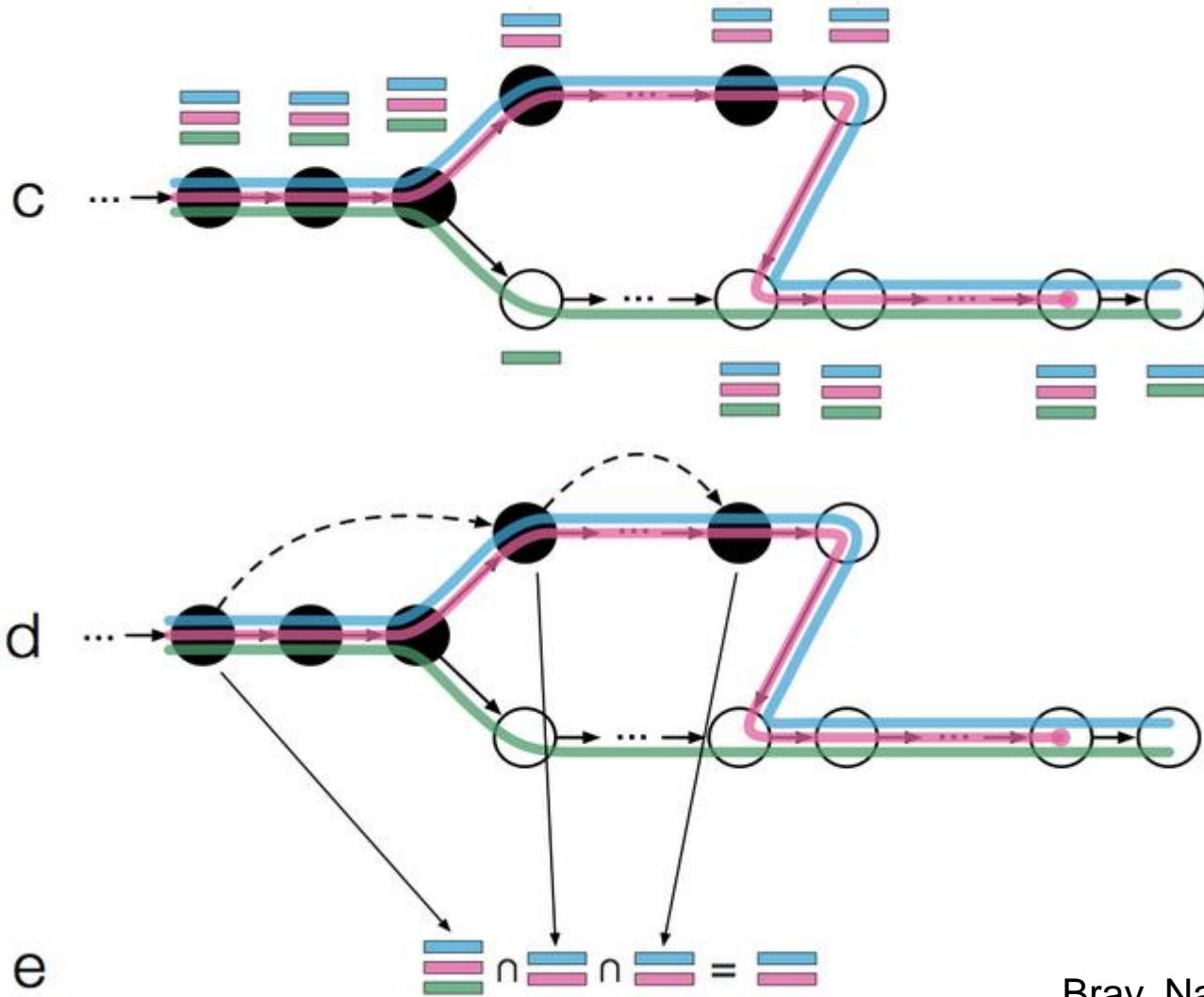
Turro, EMBO, 2012

For clinical usage combination of different algorithms possible:

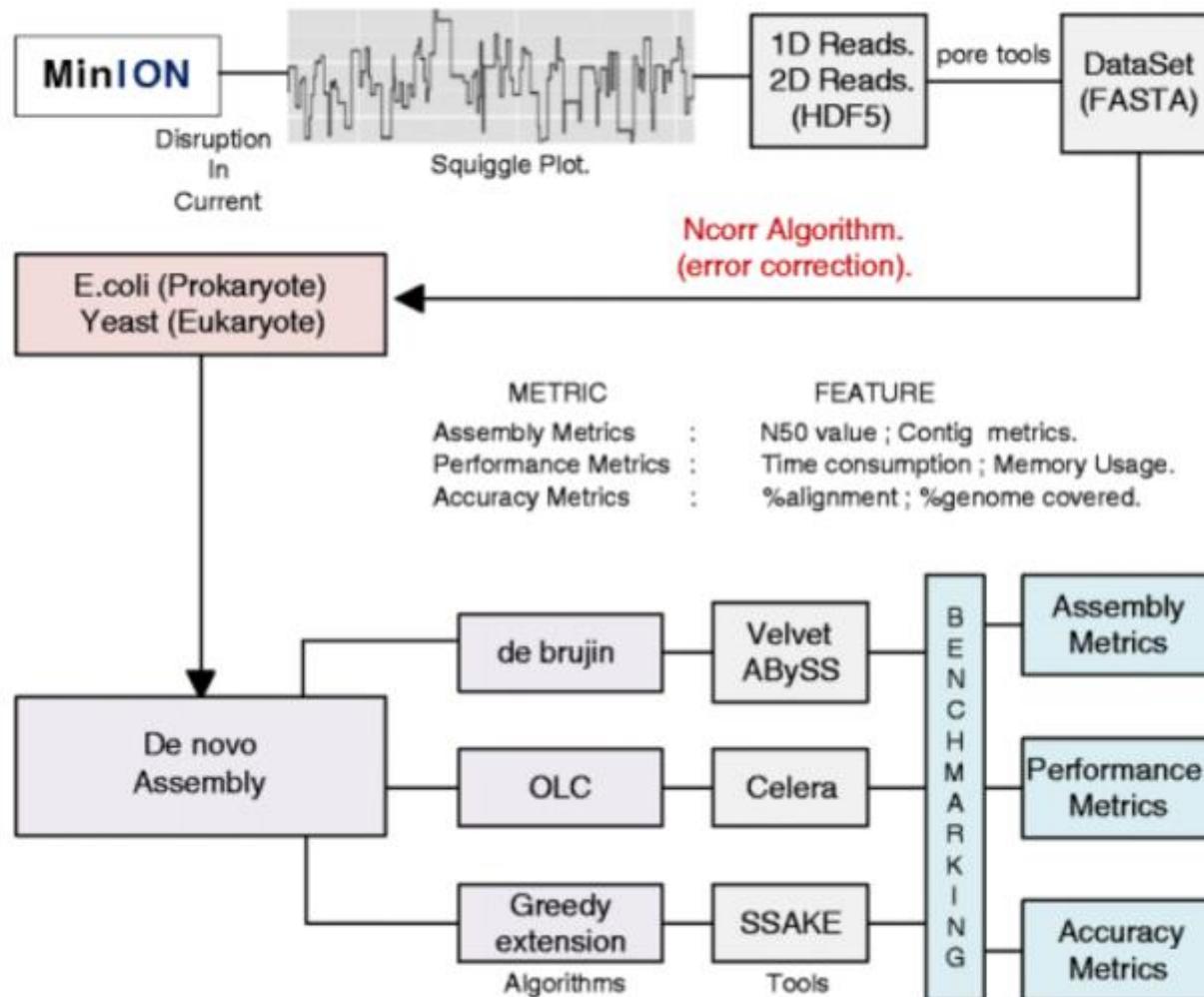
Genomic alignment - pseudoalignment



Genomic alignment - pseudoalignment

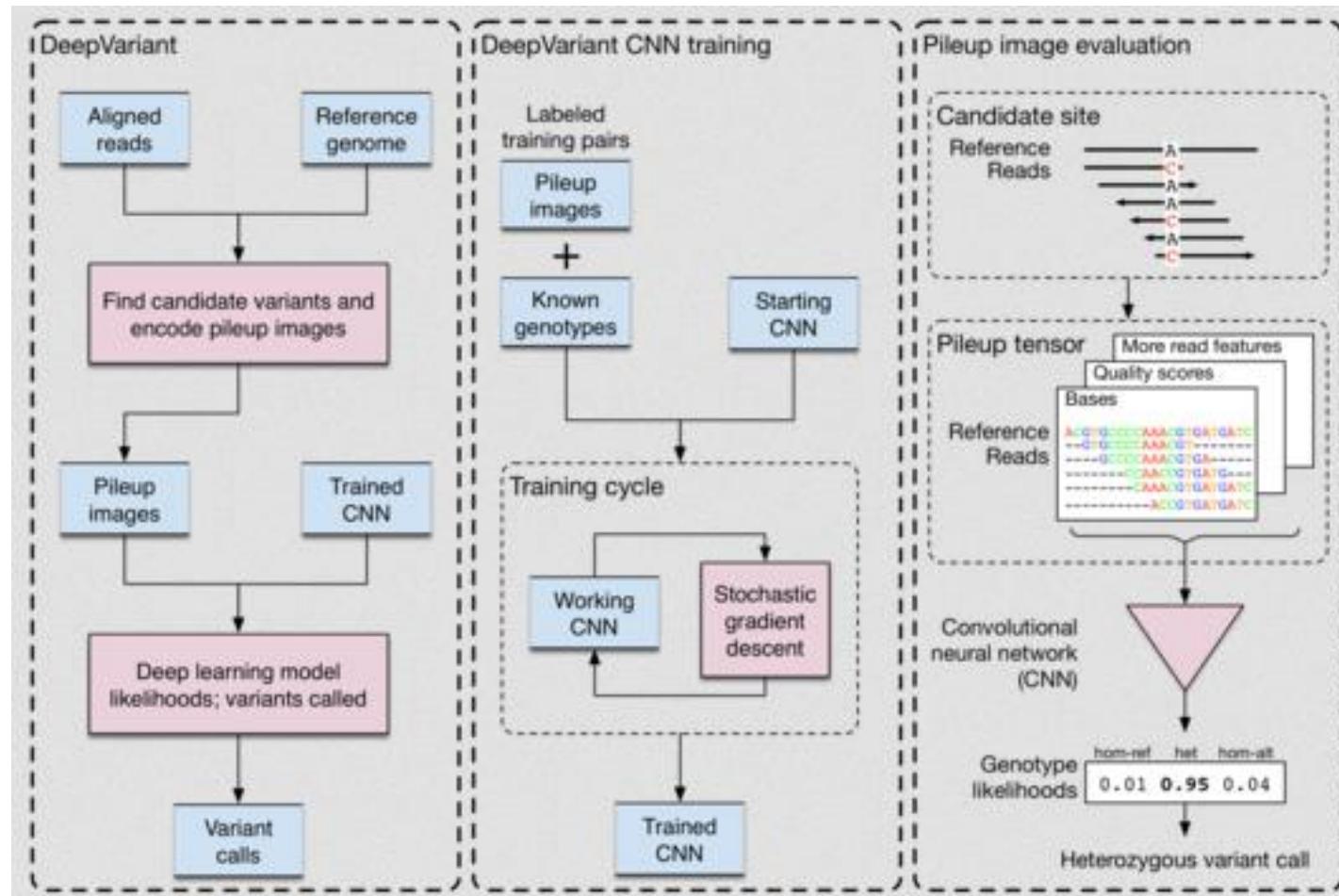


Bray, Nat Biotech, 2016



Cherkuri, BMC Genomics, 2016

Genomic alignment – deep neural network

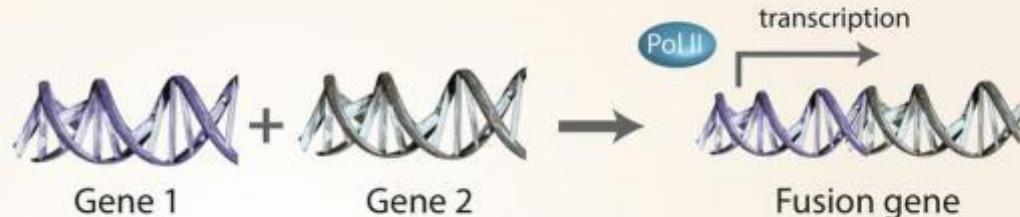


<https://github.com/google/deepvariant>



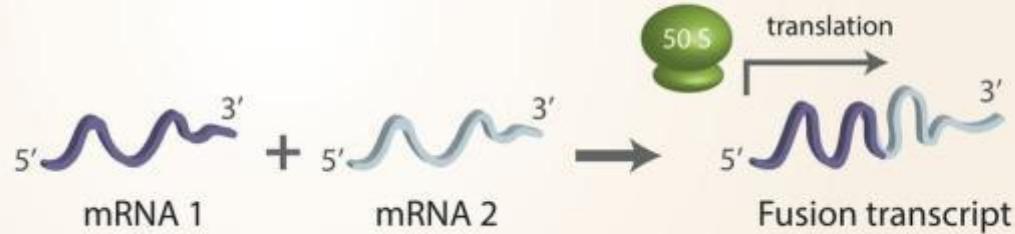
A Fusion by structural rearrangements

Translocations, inversions,
deletions and insertions



B Fusion by transcription or splicing

Transcription read-through,
mRNA *trans*-splicing or
cis-splicing



Natasha, *Nucl. Acids Res.*, 2016

“ Gene fusions are associated with oncogenic properties, and often act as driver mutations in a wide array of cancer types.”

- Deregulating one of the involved genes
- Forming a fusion protein with oncogenic functionality
- Inducing a loss of function

Yoshihara, *Oncogene*, 2015

Visualization of .bam files



<http://software.broadinstitute.org/software/igv/>



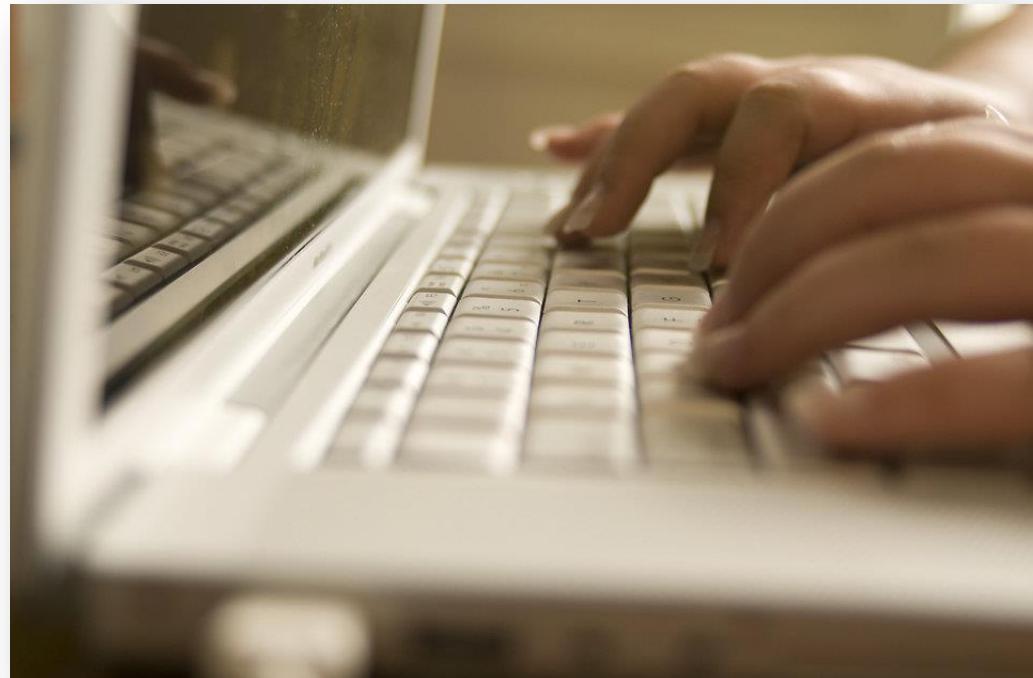
<https://ics.hutton.ac.uk/tablet/>

Hands-on part 3

14:30 – 15:15

“Application of different read mapping approaches for genomic alignment”

Material: <http://galaxyproject.github.io/training-material/topics/sequence-analysis/>



Time for a break ...



SYSTEMS BIOLOGY
BIOINFORMATICS
ROSTOCK

15:15 – 15:45

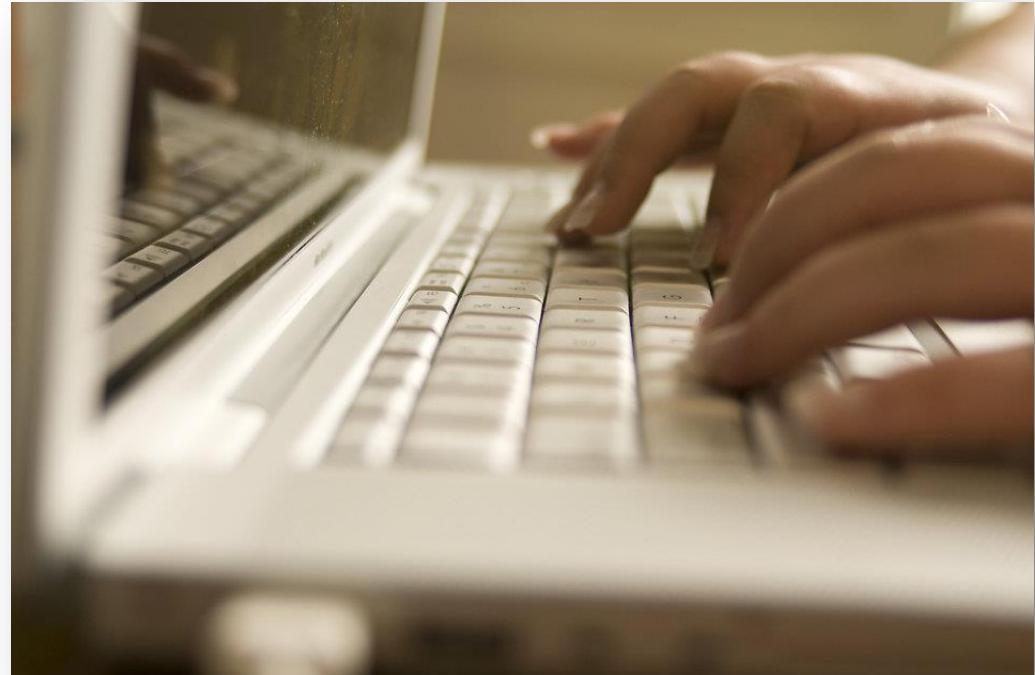


Hands-on part 4

15:45 – 16:30

“Quantification and DE analysis of RNA-Seq alignments”

Material: Part of <https://galaxyproject.github.io/training-material/topics/transcriptomics/tutorials/ref-based/tutorial.html#analysis-of-the-differential-gene-expression>



- Read counts
 - Count the reads per feature
 - relatively easy: count the number of reads per gene, exon, ...
 - How to handle multi-mapping reads (i.e. reads with multiple alignments)?
- Normalization - aims to make expression levels comparable across:
 - Features (genes, transcripts, isoforms, ...)
 - RNA libraries (samples)
 - Batch (different technologies, vendors, locations)
- Normalization methods:
 - **TPM (featureCounts, htseqCount, Kallisto)**
 - **RPKM / FPKM (Cufflinks /Cuffdiff)** (Mortazavi, Nat Meth, 2008)
 - **TMM (edgeR)** (Robinson & Oshlack, Genome Biol, 2010)
 - **DESeq2 (DESeq2)** (Love et al., Genome Biol, 2014)





TPM normalization

- Transcripts Per Million (TPM) is a normalization method for RNA-seq, should be read as "for every 1,000,000 RNA molecules in the RNA-seq sample, x came from this gene/transcript."
 1. For each transcript in the gene model, the number (raw count) of reads mapped is divided by the transcript's length, giving a normalized transcript-level expression.
 2. The sum of ALL normalized transcript expression values is divided by 1,000,000, to create a scaling factor.
 3. Each transcript's normalized expression is divided by the scaling factor, which results in the TPM value.
 4. Gene-level TPM's are calculated by summing up the transcript-level TPM for each gene.
- In this scaling, the sum of all TPMs (transcript-level or gene-level) should always equal 1,000,000.
- For a given sample, TPM values will linearly scale with FPKM values for genes or transcripts, but FPKM will not add up to 1,000,000
(http://www.arrayserver.com/wiki/index.php?title=TPM_and_FPKM)
- Differences with and without normalization and differences among them stated at <https://www.youtube.com/watch?v=TTUrtCY2k-w>

Get your data set!



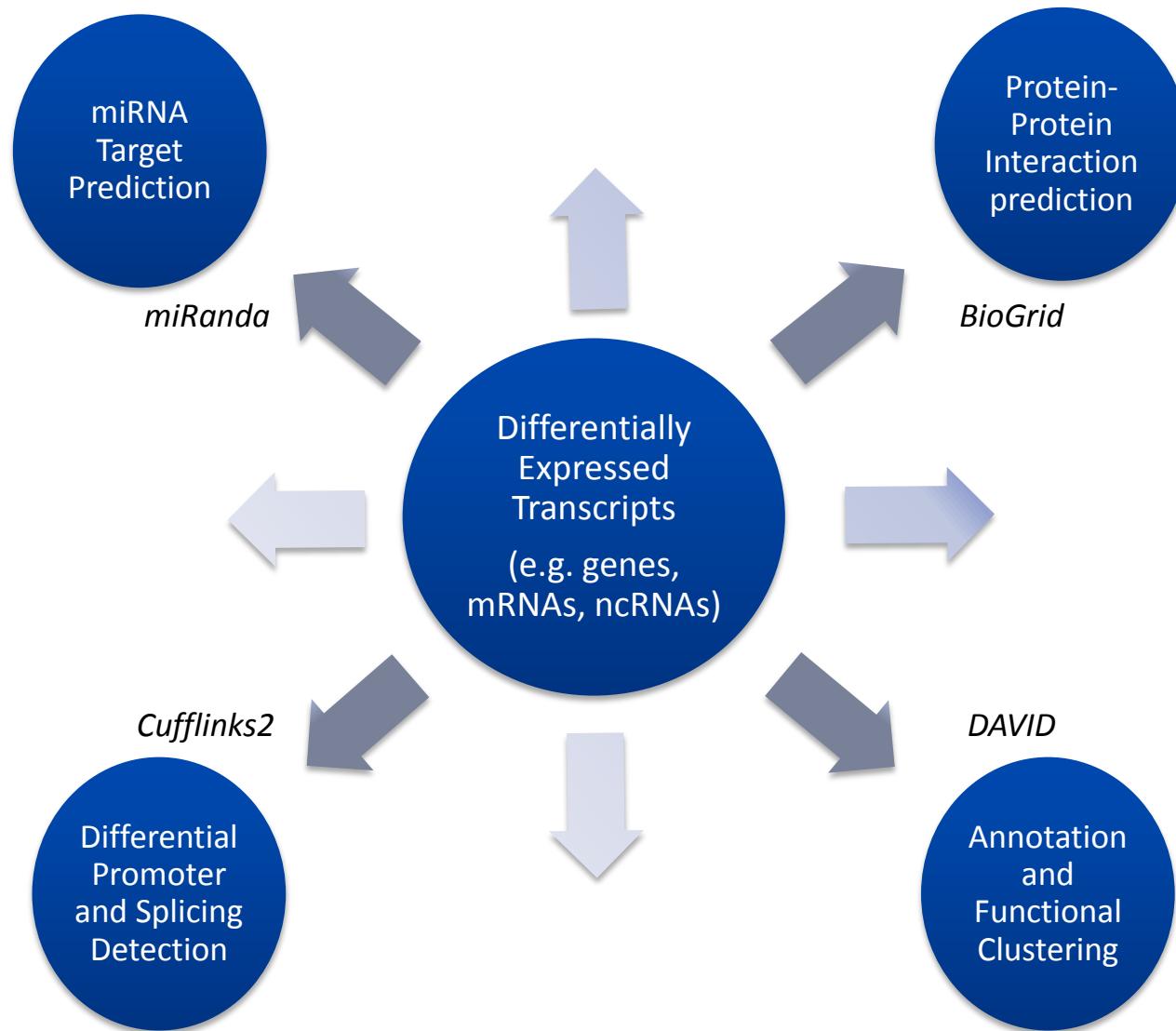
gene_exp - Microsoft Excel

A1 fx test_id

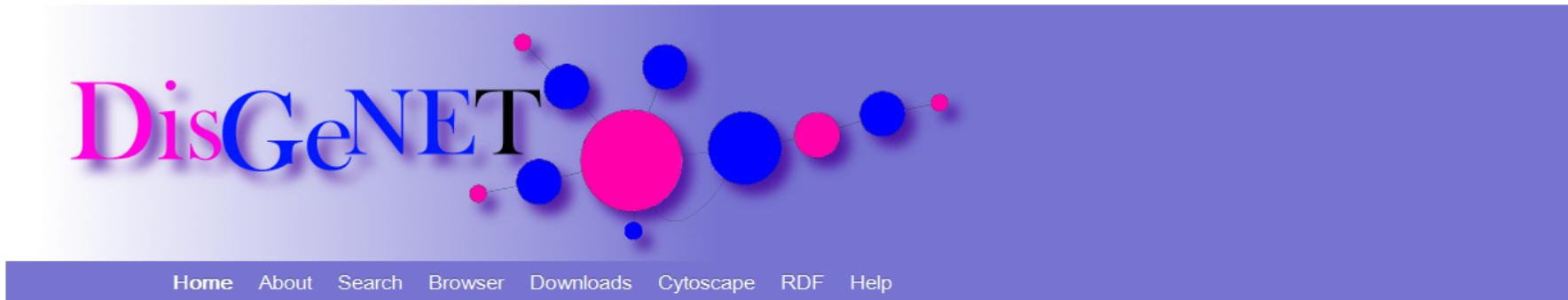
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	test_id	gene_id	gene	locus	sample_1	sample_2	status	value_1	value_2	log2(fold_ch)	test_stat	p_value	q_value	significant						
2	ADAMTS4	ADAMTS4	ADAMTS4	chr1:1611595	patient	control	OK	118.001	48.454	-128.411	-43.619	5,00E-05	0.0140016	yes						
3	AOC3	AOC3	AOC3	chr17:410032	patient	control	OK	11.335	457.446	-130.911	-43.654	5,00E-05	0.0140016	yes						
4	APOD	APOD	APOD	chr3:1952955	patient	control	OK	207.113	540.507	13.839	471.016	5,00E-05	0.0140016	yes						
5	ARHGAP40	ARHGAP40	ARHGAP40	chr20:372305	patient	control	OK	643.756	188.355	154.887	530.044	5,00E-05	0.0140016	yes						
6	ARHGEF19	ARHGEF19	ARHGEF19	chr1:1652459	patient	control	OK	357.156	112.397	-166.795	-60.984	5,00E-05	0.0140016	yes						
7	ARRDC1	ARRDC1	ARRDC1	chr9:1405000	patient	control	OK	699.613	139.438	0.994996	340.275	0.0003	0.0493798	yes						
8	ATL1	ATL1	ATL1	chr14:509997	patient	control	OK	76.407	249.703	-161.349	-441.121	5,00E-05	0.0140016	yes						
9	ATP6V0D2	ATP6V0D2	ATP6V0D2	chr8:8711113	patient	control	OK	141.496	602.768	-123.109	-398.314	0.0002	0.0383333	yes						
10	BCAT1	BCAT1	BCAT1	chr12:249625	patient	control	OK	191.027	586.341	-170.397	-622.628	5,00E-05	0.0140016	yes						
11	BMP2	BMP2	BMP2	chr20:674874	patient	control	OK	961.681	336.814	-151.361	-466.973	5,00E-05	0.0140016	yes						
12	BPIFB1	BPIFB1	BPIFB1	chr20:318705	patient	control	OK	36.651	761.925	10.558	395.806	0.00015								
13	C9orf152	C9orf152	C9orf152	chr9:1129618	patient	control	OK	126.281	293.493	121.669	444.641									
14	CCL5	CCL5	CCL5	chr17:341984	patient	control	OK	263.041	571.128	111.852										
15	CD109	CD109	CD109	chr6:7440362	patient	control	OK	245.725	920.931											
16	CEMIP	CEMIP	CEMIP	chr15:810717	patient	control	OK	838.152												
17	CHI3L1	CHI3L1	CHI3L1	chr1:203148C	patient	control	OK													
18	CITED4	CITED4	CITED4	chr1:4132672	patient	control	OK													
19	CNN1	CNN1	CNN1	chr19:116495	patient	control														
20	COL10A1	COL10A1	COL10A1	chr6:1164215	patient	control														
21	CRYAB	CRYAB	CRYAB	chr11:1164215	patient	control														
22	CYP4B1	CYP4B1	CYP4B1	chr1:1164215	patient	control														
23	CYP4X1	CYP4X1	CYP4X1	chr1:1164215	patient	control														
24	DEGS2	DEGS2	DEGS2	chr1:1164215	patient	control														
25	DKK3	DKK3	DKK3	chr1:1164215	patient	control														
26	EDIL3	EDIL3	EDIL3	chr1:1164215	patient	control														
27	EDNRA	EDNRA	EDNRA	chr1:1164215	patient	control														
28	ELL2	ELL2	ELL2	chr1:1164215	patient	control														
29	ERBB2	ERBB2	ERBB2	chr1:1164215	patient	control														
30	ERMN	ERMN	ERMN	chr1:1164215	patient	control														
31	FBXL16	FBXL16	FBXL16	chr1:1164215	patient	control														
32	FGRF2	FGRF2	FGRF2	chr10:123237	patient	control														
33	FXYD6	FXYD6	FXYD6	chr11:11769C	patient	control														
34	GALNT15	GALNT15	GALNT15	chr3:1621618	patient	control														
35	GALNT5	GALNT5	GALNT5	chr2:1581143	patient	control														
36	GFPT2	GFPT2	GFPT2	chr5:1797276	patient	control														
37	GJB2	GJB2	GJB2	chr13:207616	patient	control														
38	GOLIM4	GOLIM4	GOLIM4	chr3:1677276	patient	control														
39	GPR68	GPR68	GPR68	chr14:916988	patient	control														
40	GRAMD2	GRAMD2	GRAMD2	chr15:732521	patient	control														

https://usegalaxy.eu/u/mwolfien/h/galaxy-training-rostock-quantification

Interconnection of RNA-Seq data



- DisGeNET (<http://www.disgenet.org/>)



One of the most challenging problems in biomedical research is to understand the underlying mechanisms of complex diseases. Great effort has been spent on finding the genes associated to diseases (Botstein and Risch, 2003; Kann, 2009). However, more and more evidences indicate that most human diseases cannot be attributed to a single gene but arise due to complex interactions among multiple genetic variants and environmental risk factors (Hirschhorn and Daly, 2005). Several databases have been developed storing associations between genes and diseases such as CTD™ (Davis, et al., 2014), OMIM® (Hamosh, et al., 2005) and the NHGRI-EBI GWAS catalog (Welter, et al., 2014). Each of these databases focuses on different aspects of the phenotype-genotype relationship, and due to the nature of the database curation process, they are not complete. Hence, integration of different databases with information extracted from the literature is needed to allow a comprehensive view of the state of the art knowledge within this research field. With this need in mind, we have created DisGeNET.

DisGeNET is a discovery platform integrating information on gene-disease associations (GDAs) from several public data sources and the literature (Píñero, et al., 2015). The current version contains (DisGeNET v4.0) contains 429,036 associations, between 17,381 genes and 15,093 diseases, disorders and clinical or abnormal human phenotypes, and 72,870 variant-disease associations (VDAs), between 46,589 SNPs and 6,356 phenotypes. Given the large number of GDAs compiled in DisGeNET, we have also developed a score in order to rank the associations supporting evidence. Importantly, useful tools have also been created to explore and analyze the data contained in DisGeNET. DisGeNET can be queried through Search and Browse functionalities available from this web interface, or by a plugin created for Cytoscape to query a network representation of the data. Moreover, DisGeNET data can be queried by downloading the SQLite database to your local machine. Furthermore, an RDF (Resource Description Framework) representation of DisGeNET database is also available. It can be queried using an endpoint and a Faceted Browser. Follow the [link](#) for more information.

DisGeNET database has been cited by several papers. Some of them can be reviewed [here](#).

The DisGeNET database is made available under the [Open Database License](#). Any rights in individual contents of the database are licensed under the [Database Contents License](#).

Tweets by @DisGeNET

 DisGeNET
@DisGeNET

Check out the new publication describing the DisGeNET platform in NAR database issue nar.oxfordjournals.org/con



Linking and integrating data

- David (<https://david.ncifcrf.gov/list.jsp>)

Gene Name Batch Viewer
DAVID Bioinformatics Resources 6.8, NIAID/NIH

Home Start Analysis Shortcut to DAVID Tools Technical Center Downloads & APIs Term of Service Why DAVID? About Us

*** Welcome to DAVID 6.8 with updated Knowledgebase ([more info](#)). ***
*** If you are looking for [DAVID 6.7](#), please visit our [development site](#). ***

Upload List Background

Upload Gene List

[Demolist 1](#) [Demolist 2](#)
[Upload Help](#)

Step 1: Enter Gene List

A: Paste a list

```
ERBB3  
ERBB4  
ERC1  
ERC2  
ERC2-IT1
```

Or

B: Choose From a File

No file selected.
 Multi-List File [?](#)

Step 2: Select Identifier

OFFICIAL_GENE_SYMBOL

Step 3: List Type

Gene List
Background

Step 4: Submit List

Gene Name Batch Viewer

Submit your gene list to start !

Tell us how you like the tool
Read technical notes of the tool
Contact us for questions

What does this tool do?

- Quickly translate given gene IDs to corresponding gene names in a batch way
- Provide links for each genes to DAVID Gene Report for in-depth information
- Search functionally related genes within user's input gene list or genome

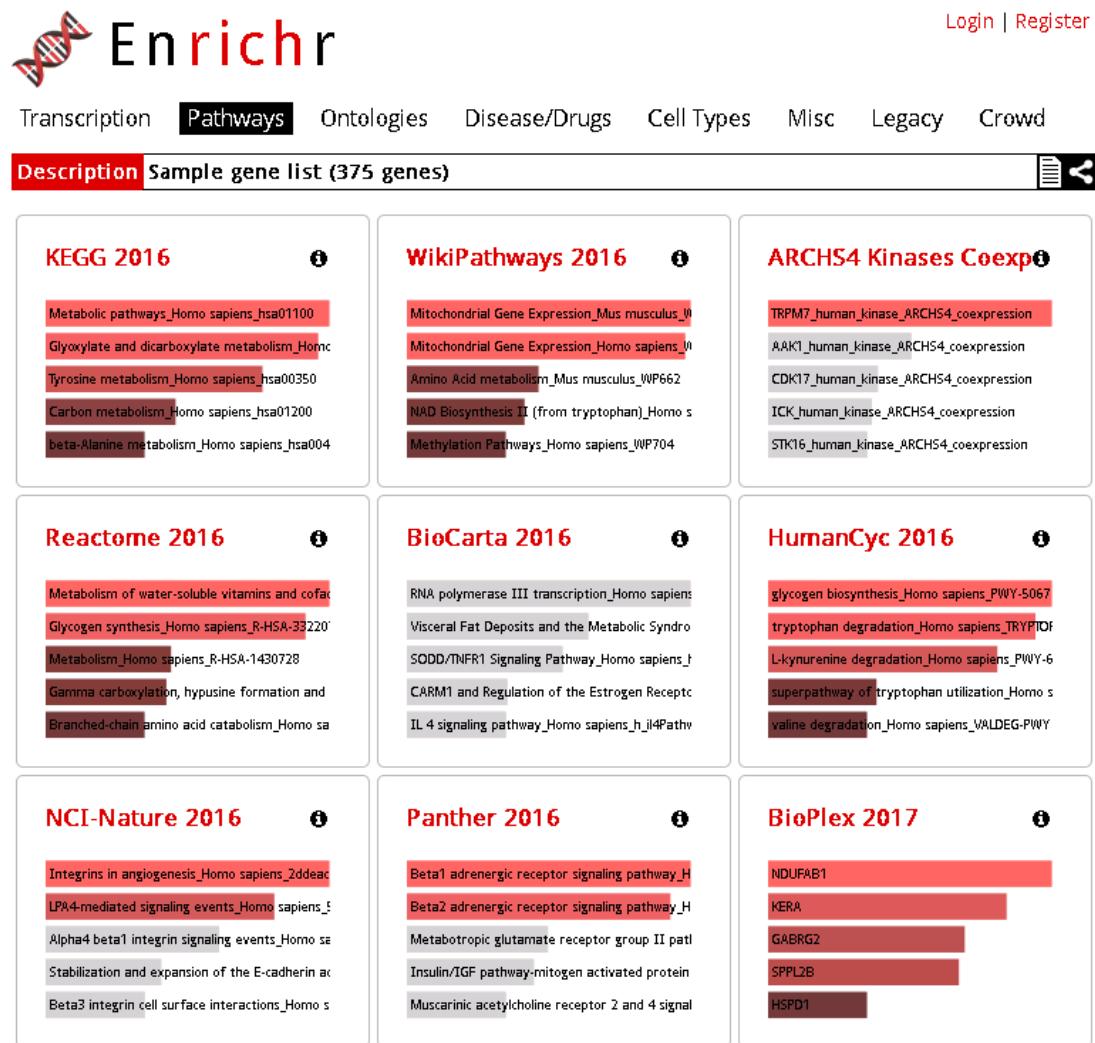
Key Concepts of "Search Related Genes"

Any given gene is associating with a set of annotation terms. If genes share similar set of those terms (annotation profile), they are most likely involved in similar biological mechanisms. The algorithm adopts kappa statistics to quantitatively measure the degree of the agreement how genes share the ~75,000 annotation terms collected by DAVID knowledgebase. For any given gene(s), the tool instantly searches and lists the related genes passed kappa similarity measurement threshold. The searching scope could be within user's input gene list, selected genome or all genomes (~1.2 million genes) as user's choice.

Find Related Genes Tool is very different and complementary to the common gene clustering methods, such as homologous genes based on sequence similarity; protein families based on one common biological activity. The approach provides researchers a new way to group those functional related genes by measuring the similarity of their global annotation profile, which facilitates new understanding of the biological network. [More](#)



- Enrichr (<http://amp.pharm.mssm.edu/Enrichr/>)

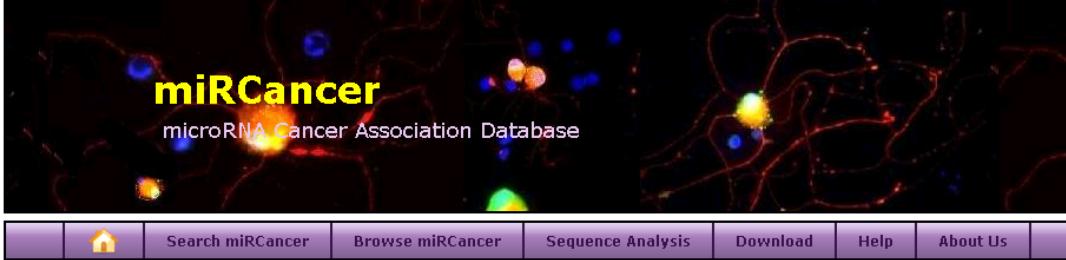


The screenshot shows the Enrichr homepage with a navigation bar at the top. Below the navigation, there are nine boxes representing different databases:

- KEGG 2016**: Metabolic pathways_Homo sapiens_hsa01100, Glyoxylate and dicarboxylate metabolism_Homo sapiens, Tyrosine metabolism_Homo sapiens_hsa00350, Carbon metabolism_Homo sapiens_hsa01200, beta-Alanine metabolism_Homo sapiens_hsa004
- WikiPathways 2016**: Mitochondrial Gene Expression_Mus musculus_WP662, Mitochondrial Gene Expression_Homo sapiens_WP662, Amino Acid metabolism_Mus musculus_WP662, NAD Biosynthesis II (from tryptophan)_Homo sapiens_WP704, Methylation Pathways_Homo sapiens_WP704
- ARCHS4 Kinases Coexp**: TRPM7_human_kinase_ARCHS4_coexpression, AAK1_human_kinase_ARCHS4_coexpression, CDK17_human_kinase_ARCHS4_coexpression, ICK_human_kinase_ARCHS4_coexpression, STK16_human_kinase_ARCHS4_coexpression
- Reactome 2016**: Metabolism of water-soluble vitamins and cofactors_Homo sapiens, Glycogen synthesis_Homo sapiens_R-HSA-33220, Metabolism_Homo sapiens_R-HSA-1430728, Gamma carboxylation, hypusine formation and Branched-chain amino acid catabolism_Homo sapiens
- BioCarta 2016**: RNA polymerase III transcription_Homo sapiens, Visceral Fat Deposits and the Metabolic Syndrome_Homo sapiens, SODD/TNFR1 Signaling Pathway_Homo sapiens, CARM1 and Regulation of the Estrogen Receptor_Homo sapiens, IL 4 signaling pathway_Homo sapiens_h_jl4Pathway
- HumanCyc 2016**: glycogen biosynthesis_Homo sapiens_PWY-5067, tryptophan degradation_Homo sapiens_TRYPTO9F, L-kynurenine degradation_Homo sapiens_PWY-6, superpathway of tryptophan utilization_Homo sapiens, valine degradation_Homo sapiens_VALDEG-PWY
- NCI-Nature 2016**: Integrins in angiogenesis_Homo sapiens_2ddeac, LPA4-mediated signaling events_Homo sapiens_5, Alpha4beta1 integrin signaling events_Homo sapiens, Stabilization and expansion of the E-cadherin network_Homo sapiens, Beta3 integrin cell surface interactions_Homo sapiens
- Panther 2016**: Beta1 adrenergic receptor signaling pathway_Homo sapiens, Beta2 adrenergic receptor signaling pathway_Homo sapiens, Metabotropic glutamate receptor group II pathway_Homo sapiens, Insulin/IGF pathway-mitogen activated protein kinase_Homo sapiens, Muscarinic acetylcholine receptor 2 and 4 signaling pathway_Homo sapiens
- BioPlex 2017**: NDUFAB1, KERA, GABRG2, SPPL2B, HSPD1



- miRCancer db - Find up regulated miRNAs (<http://mircancer.ecu.edu/index.jsp>)



The screenshot shows the miRCancer db homepage. At the top, there's a banner with the text "miRCancer microRNA Cancer Association Database" and a background image of a cell with red and blue staining. Below the banner is a purple navigation bar with links: Home, Search miRCancer, Browse miRCancer, Sequence Analysis, Download, Help, and About Us.

Search
Search for miRNA and cancer associations
miRNA name: Example: mir-145, hsa-mir-21, let-7
 Or And
cancer name:
Search

miRCancer : microRNA Cancer Association Database
 miRCancer provides comprehensive collection of microRNA (miRNA) expression profiles in various human cancers which are automatically extracted from published literatures in PubMed. It utilizes text mining techniques for information collection. Manual revision is applied after auto-extraction to provide 100% precision.
User can search the database by miRNA and/or cancer names in the [miRCancer Search](#) page. Our website also provides two [sequence analysis](#) tools: clustering and chi-square analysis which can perform analysis on all or selected pool of miRNA sequences.

Reference
If you make use of the information presented here, please cite the following references:
miRCancer: a microRNA-cancer association database constructed by text mining on literature
Boya Xie; Qin Ding; Hongjin Han; Di Wu
Bioinformatics, Vol. 29, Issue 5, pp.638-644, 2013
Text Mining on Big and Complex Biomedical Literature, Big Data Analytics in Bioinformatics and Healthcare, IGI Global, 2014.
Boya Xie; Qin Ding; Di Wu
MIRSAT & MIRCDB: An Integrated microRNA Sequence Analysis Tool and a Cancer-associated microRNA Database
Boya Xie; Robert Hochberg; Qin Ding; Di Wu
International Conference on Bioinformatics and Computational Biology, Honolulu, Hawaii, 2010, pp. 159-164.

Mailing List
To get announcements about miRCancer database update, new available functionality and more, please [subscribe](#) to our mailing list.

Links



- TriplexRNA database (<https://www.sbi.uni-rostock.de/triplexrna/>)



What is the TriplexRNA database?

Description

The triplexRNA database contains predicted RNA triplexes composed of two cooperatively acting microRNAs (miRNAs) and their mutual target mRNAs. The phenomenon of miRNAs that cooperatively repress target gene transcription is illustrated below and elucidated in detail in our article Schmitz et al. (2014).

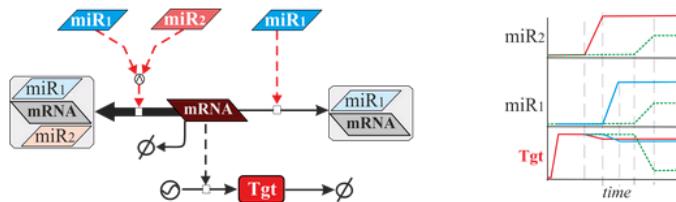


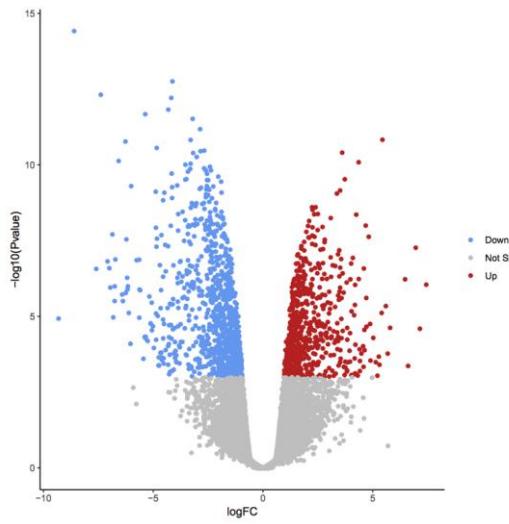
Figure 1 General principle of cooperative target regulations by pairs of miRNAs

The illustration on the left shows how a target mRNA can be repressed by either a single miRNA or by a pair of cooperating miRNAs. While in the first case miRNA and target form a duplex structure, the second case leads to the formation of a RNA triplex. On the right side we illustrated the repressive effect on the target that is induced either by a single miRNA (red and blue lines) or by two cooperating miRNAs (green dashed line). Even if the expression of the cooperating miRNAs is only mildly up-regulated an enhanced repressive effect can be observed as compared to the cases where single miRNAs are highly up-regulated.

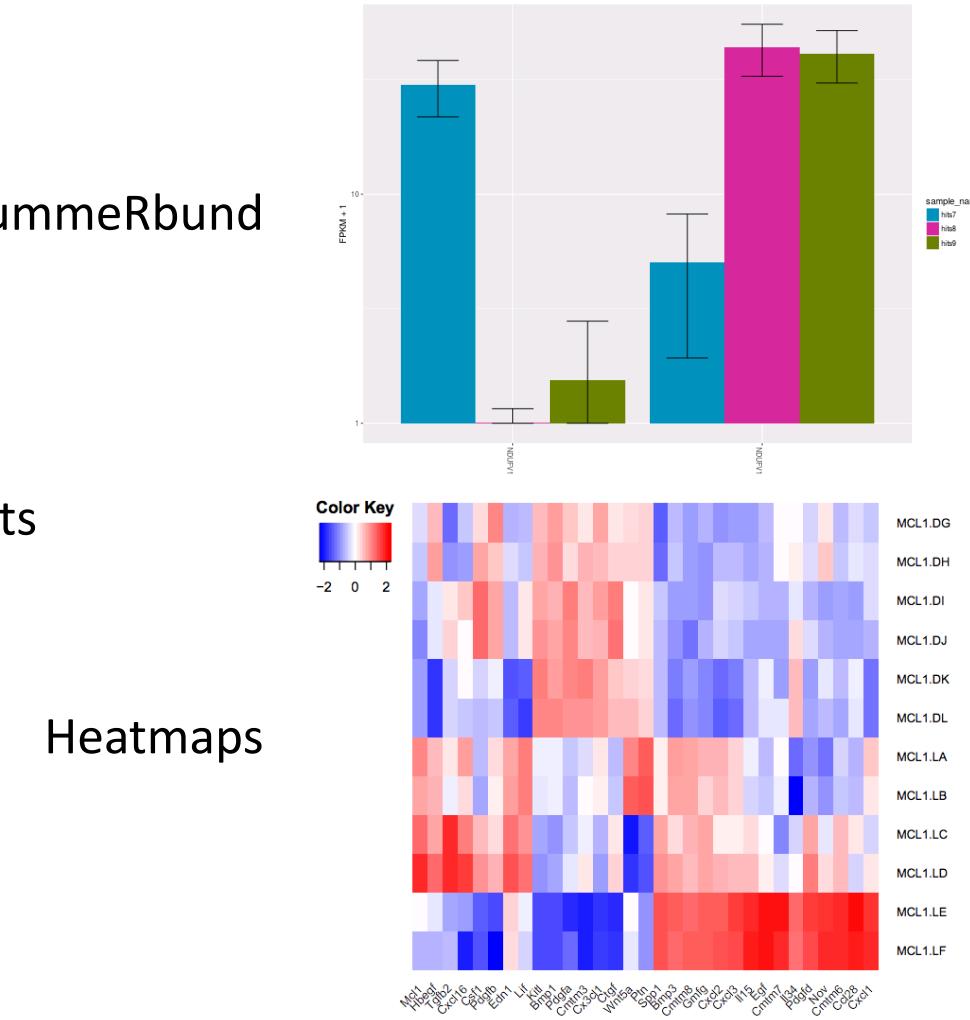
The following information about predicted RNA triplexes can be retrieved from the TriplexRNA database: triplex free energies, experimental evidences, secondary simulations of target gene repression and more...



- Available at: <https://galaxyproject.github.io/training-material/topics/transcriptomics/>



Volcano plots

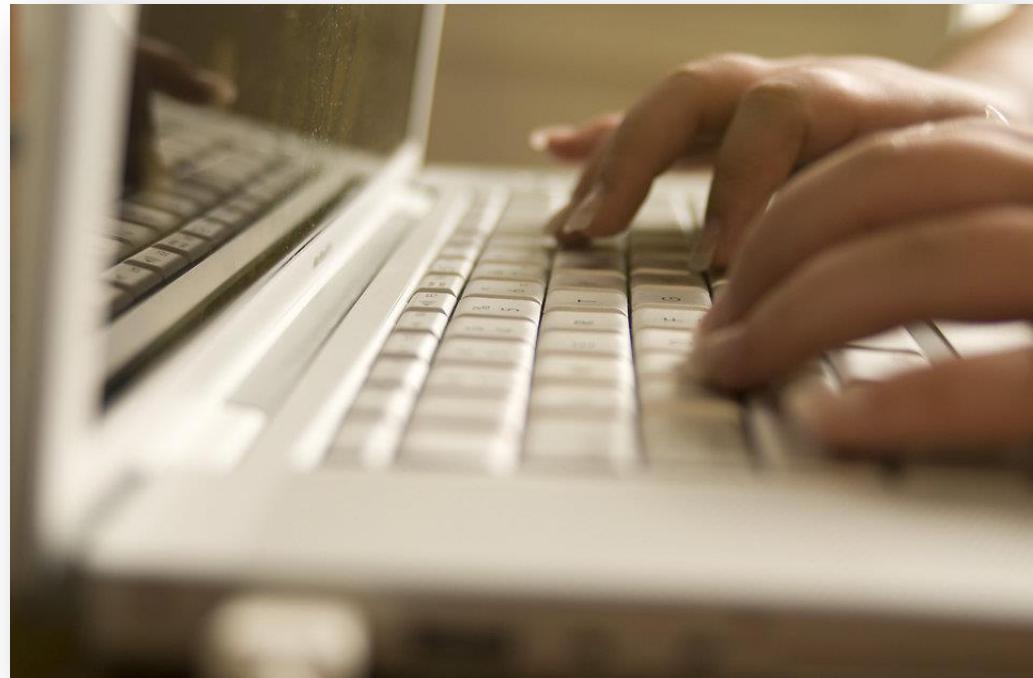


Heatmaps

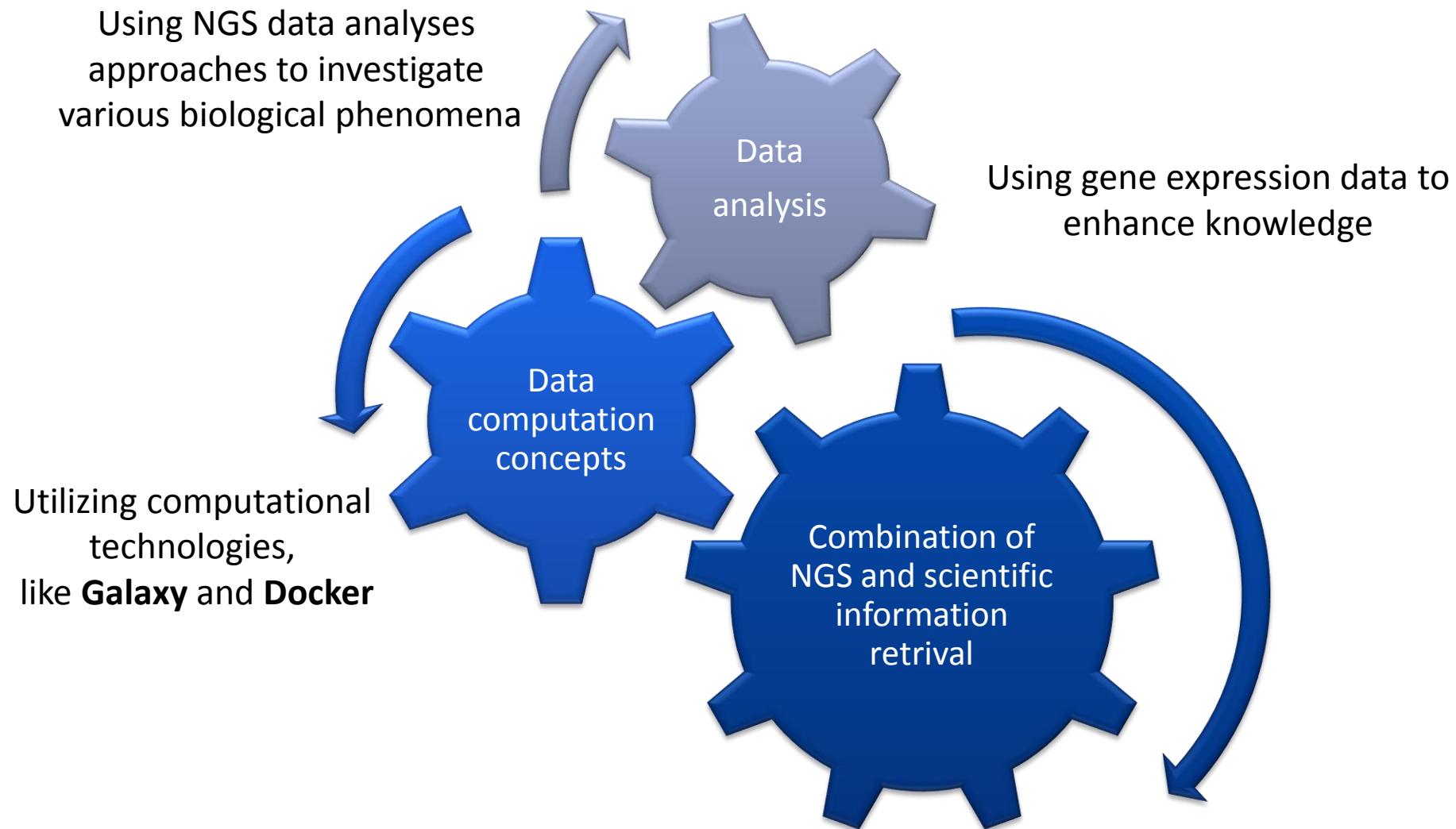
Hands-on part 6

16:30 – 17:15

“Galaxy modular workflow generator”



What did we learn so far?



Acknowledgements



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