

BIMM 143

Introduction to Bioinformatics

Barry Grant
UC San Diego

<http://thegrantlab.org/bimm143>

HELLO
my name is

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[SignUp](#)

Location:
Muir #3266

Introduce Yourself!

Your preferred name,
Place you identify with,
Major area of study/research,
Favorite joke (optional)!

Today's Menu

Course Logistics

Website, screencasts, survey, ethics, assessment and grading.

Learning Objectives

What you need to learn to succeed in this course.

Course Structure

Major lecture topics and specific learning goals.

Introduction to Bioinformatics

Introducing the *what, why and how* of bioinformatics?

Bioinformatics Database

Hands-on exploration of several major databases and their associated tools.

<http://thegrantlab.org/bimm143/>

The screenshot shows a web browser window with the URL bioboot.github.io/bimm143_F18/ in the address bar. The main content area displays the following information:

UC San Diego

BIMM 143

A hands-on introduction to the computer-based analysis of genomic and biomolecular data from the Division of Biological Sciences, UCSD.

Course Director
Prof. Barry J. Grant (Email: bjgrant@ucsd.edu)

Instructional Assistant
Chao Shi (Email: bioshichao@gmail.com)

Course Syllabus
[Fall 2018 \(PDF\)](#)

Overview

Bioinformatics - the application of computational and analytical methods to biological problems - is a rapidly maturing field that is driving the collection, analysis, and interpretation of the avalanche of data in modern life sciences and medical research.

This upper division 4-unit course is designed for biology majors and provides an introduction to the principles and practical approaches of bioinformatics as applied to genes and proteins.

Navigation links on the left side include: Overview, Lectures, Computer Setup, Learning Goals, Assignments & Grading, Ethics Code, and social media icons for Twitter, GitHub, Email, and RSS.

<http://thegrantlab.org/bimm143/>

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On the left sidebar, the following menu items are listed:

- Overview
- Lectures
- Computer Setup
- Learning Goals
- Assignments & Grading
- Ethics Code

Below the sidebar are social media icons for Twitter, GitHub, Email, and RSS feed.

What essential concepts and skills should YOU attain from this course?

The screenshot shows a web browser window with the URL bioboot.github.io/bimm143_W18/goals/ in the address bar. The page content is as follows:

UCSanDiego

BIMM 143

A hands-on introduction to the computer-based analysis of genomic and biomolecular data from the Division of Biological Sciences, UCSD.

Learning Goals (highlighted with a red box)

Specific Learning Goals

At the end of this course students will:

- Understand the increasing necessity for computation in modern life sciences research.
- Be able to use and evaluate online bioinformatics resources including major biomolecular and genomic databases, search and analysis tools, genome browsers, structure viewers, and select quality control and analysis tools to solve problems in the biological sciences.
- Be able to use the R environment to analyze bioinformatics data at scale.
- Understand the process by which genomes are currently sequenced and the bioinformatics processing and analysis required for their interpretation.
- Be familiar with the research objectives of the bioinformatics related sub-disciplines of Genomics, Transcriptomics and Structural bioinformatics.

In short, students will develop a solid foundational knowledge of bioinformatics and be able to evaluate new biomolecular and genomic information using existing bioinformatic tools and resources.

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In short, you will develop a solid foundational knowledge of **bioinformatics** and be able to evaluate new biomolecular and genomic information using **existing bioinformatic tools and resources.**

Specific Learning Goals....

What I want you to know by course end!

The screenshot shows a web browser window with the URL bioboot.github.io/bimm143_W18/goals/. The page content is as follows:

Specific Learning Goals

Teaching toward the specific learning goals below is expected to occupy 60%-70% of class time. The remaining course content is at the discretion of the instructor with student body input. This includes student selected topics for peer presentation, as well as one student selected guest lecture from an industry based genomic scientist.

All students who receive a passing grade should be able to:

	Lecture(s):
1 Appreciate and describe in general terms the role of computation in hypothesis-driven discovery processes within the life sciences.	1, 2, 20
2 Be able to query, search, compare and contrast the data contained in major bioinformatics databases and describe how these databases intersect (GenBank, GENE, UniProt, PFAM, OMIM, PDB, UCSC, ENSEMBLE).	2, 12, 13
3 Describe how nucleotide and protein sequence and structure data are represented (FASTA, FASTQ, GenBank, UniProt, PDB).	3, 10
4 Be able to describe how dynamic programming works for pairwise sequence alignment and appreciate the differences between global and local alignment along with their major application areas.	4, 5
5 Calculate the alignment score between two nucleotide or protein sequences using a provided scoring matrix and be able to perform BLAST, PSI-BLAST, HMMER and protein structure based database	5, 10

The left sidebar of the website includes the following navigation links:

- UC San Diego
- BIMM 143
- Overview
- Lectures
- Computer Setup
- Learning Goals** (highlighted with a red box)
- Assignments & Grading
- Ethics Code

Course Structure

Derived from specific learning goals

The screenshot shows a web browser window with the URL bioboot.github.io/bimm143_S18/lectures/. The page title is "Lectures". The main content area contains a table titled "Topics for Spring 2018" with two rows of data. The first row corresponds to Lecture 1 on Tu, 04/03, with the topic "Welcome to Bioinformatics" and a detailed description of the course introduction, learning goals, and expectations. The second row corresponds to Lecture 2 on Th, 04/05, with the topic "Sequence alignment fundamentals, algorithms and applications" and a detailed description of homology, sequence similarity, local and global alignment, classic Needleman-Wunsch, Smith-Waterman, and BLAST heuristic approaches, and hands-on experience with dot plots, Needleman-Wunsch, and BLAST algorithms. The left sidebar of the website includes the UC San Diego logo, the course title "BIMM 143", a description of the course as a hands-on introduction to bioinformatics, and navigation links for "Overview", "Lectures" (which is highlighted with a red box), "Computer Setup", "Learning Goals", "Assignments & Grading", and "Ethics Code".

#	Date	Topics for Spring 2018
1	Tu, 04/03	Welcome to Bioinformatics Course introduction, Learning goals & expectations, Biology is an information science, History of Bioinformatics, Types of data, Application areas and introduction to upcoming course segments, Hands on with major Bioinformatics databases and key online NCBI and EBI resources
2	Th, 04/05	Sequence alignment fundamentals, algorithms and applications Homology, Sequence similarity, Local and global alignment, classic Needleman-Wunsch, Smith-Waterman and BLAST heuristic approaches, Hands on with dot plots, Needleman-Wunsch and BLAST algorithms highlighting their utility and limitations

Course Structure

Derived from specific learning goals

The screenshot shows a web browser window with the URL bioboot.github.io/bimm143_S18/lectures/. The page title is "Lectures". A text block states: "All Lectures are Tu/Th 9:00-12:00 pm in Warren Lecture Hall 2015 (WLH 2015) ([Map](#)). Clicking on the class topics below will take you to corresponding lecture notes, homework assignments, pre-class video screen-casts and required reading material." Below this is a table titled "Topics for Spring 2018". The first row, which is highlighted with a red box around the title, contains the following information:

#	Date	Topics for Spring 2018
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		Advanced sequence alignment and database searching

The sidebar on the left includes links for "Overview", "Lectures" (which is highlighted with a red box), "Computer Setup", "Learning Goals", "Assignments & Grading", and "Ethics Code". The main content area features a large blue circular graphic with the text "UCSanDiego" overlaid.

Class Details

Goals, Class material, Screencasts & Homework

The screenshot shows a web browser window with the following details:

- Title Bar:** Shows the URL `blobstore.github.io/bimm143_W16/lectures/01` and browser controls.
- Header:** BIMM 143, Home, Gmail, Goal, Bitbucket, GitHub, News, Discuss, EGNN-213, BIMM-143, GDocs.
- Left Sidebar (UC San Diego BIMM 143):**
 - UCSanDiego** logo.
 - BIMM 143** title.
 - A hands-on introduction to the computer-based analysis of genomic and biomolecular data from the Division of Biological Sciences, UCSD.
 - Navigation links: Overview, Lectures, Computer Setup, Learning Goals, Assignments & Grading, Ethics Code.
- Content Area (Lecture 1):**

1: Welcome to Foundations of Bioinformatics

Topics:
Course introduction, Learning goals & expectations, Biology is an information science, History of Bioinformatics, Types of data, Application areas and introduction to upcoming course segments, Student 30-second introductions, Student computer setup.

Goals:

 - Understand course scope, expectations, logistics and [ethics code](#).
 - Understand the increasing necessity for computation in modern life sciences research.
 - Get introduced to how bioinformatics is practiced.
 - Complete the [pre-course questionnaire](#).
 - Setup your [laptop computer](#) for this course.

Material:

 - Pre class screen casts (also see below):
 - SC1: [Welcome to BIMM-143](#),
 - SC2: [What is Bioinformatics?](#) and
 - SC3: [How do we do Bioinformatics?](#).
 - Lecture Slides: Large PDF, Small PDF
 - [Handout: Class Syllabus](#)
 - [Computer Setup Instructions](#)

Homework

Goals, Class material, Screencasts & Homework

The screenshot shows a web browser window with the URL blobbo洽github.io/bimmm143_W16/lectures/M1. The page content includes:

- UCSanDiego** logo
- BIMM 143** title
- A hands-on introduction to the computer-based analysis of genomic and biomolecular data from the Division of Biological Sciences, UCSD.
- Overview**, **Lectures**, **Computer Setup**, **Learning Goals**, **Assignments & Grading**, and **Ethics Code** navigation links.
- Homework:**
 - [Questions](#)
 - Readings:**
 - [PDF1: What is bioinformatics? An introduction and overview](#)
 - [PDF2: Advancements and Challenges in Computational Biology](#)
 - [Other: For Big-Data Scientists, 'Janitor Work' Is Key Hurdle to Insights](#) New York Times, 2014.
- Screen Casts:**
 - Welcome to "Foundations of Bioinformatics" (BGGN-213)** video player showing a man speaking in front of a molecular model. The video is at 2:05 / 4:06 and has CC and YouTube options.
- 1 Welcome to BIMM-143: Course introduction and logistics.**

Homework

Goals, Class material, Screencasts & Homework

The screenshot shows a web browser window with the URL blobbo洽github.io/bimml43_W16/lectures/M1. The page content includes:

- Homework:**
 - Questions [\[link\]](#) (highlighted with a red box)
 - Readings:
 - PDF1: [What is bioinformatics? An introduction and overview](#) [link]
 - PDF2: [Advancements and Challenges in Computational Biology](#) [link]
 - Other: [For Big-Data Scientists, 'Janitor Work' Is Key Hurdle to Insights](#) [link] New York Times, 2014.
- Screen Casts:**
 - [Welcome to "Foundations of Bioinformatics" \(BGGN-213\)](#) (video thumbnail showing a man speaking in front of a molecular model, timestamp 2:05 / 4:05, YouTube link)

On the left side of the browser window, the UC San Diego logo and BIMM 143 course information are visible:

UCSanDiego
BIMM 143
A hands-on introduction to the computer-based analysis of genomic and biomolecular data from the Division of Biological Sciences, UCSD [link].

Navigation links on the left include: Overview, Lectures, Computer Setup, Learning Goals, Assignments & Grading, and Ethics Code.

Homework

Goals, Class material, Screencasts & **Homework**

The screenshot shows a Google Forms survey titled "BIMM143 Lecture 1 Homework (W18)". The survey begins with a question asking for an email address. Below that is a multiple-choice question about operating systems used for bioinformatics tool development. A second question about protein sequence databases is partially visible at the bottom.

BIMM143 Lecture 1 Homework (W18)

Please answer the following questions

* Required

Email address *

Your email

Which of the following operating systems is most frequently used for bioinformatics tool development 1 point

- Windows
- iOS
- Unix
- Perl

Which of the following databases contains primarily protein sequences 1 point

- GenBank

Homework

Goals, Class material, Screencasts & **Homework**

docs.google.com/forms/d/e/1FAIpQLSeqDGQCYYIWKovPsc3Unk4SsgAEdTHRJp... BIMM 143 Home Gmail Goal Bitbucket GitHub News Discuss EGNN-213 BIMM-143 GDocs

BIMM143 Lecture 1 Homework (W19)

Please answer the following questions

* Required

Homework is due before the next weeks class!

Which of the following operating systems is most frequently used for bioinformatics tool development 1 point

- Windows
- iOS
- Unix
- Perl

Which of the following databases contains primarily protein sequences 1 point

- GenBank

Side Note: **Why stick with this course?**

Provides a hands-on practical introduction to major bioinformatics concepts and resources.

Covers modern hot topics and the intimate coupling of informatics with biology - highlighting the impact of computing advances and 'big data' on biology!

Designed for biology majors with no programming experience or high level math skills.

Provides a hook for increasing computational and data science competencies in the biosciences - valuable high demand translational skills!

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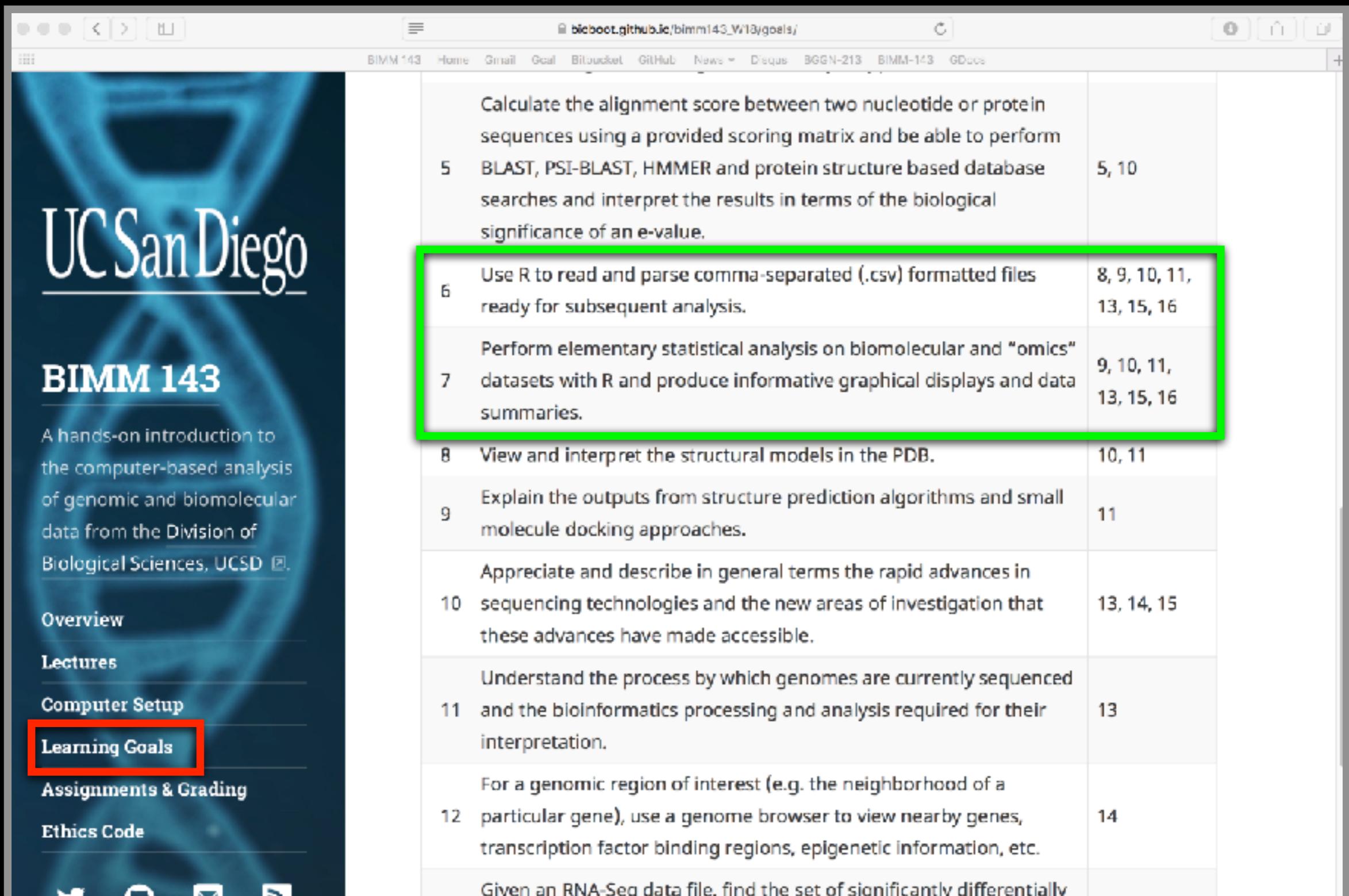
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BIMM-143 Learning Goals....

Data science R based learning goals



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[Overview](#)

[Lectures](#)

[Computer Setup](#)

Learning Goals

[Assignments & Grading](#)

[Ethics Code](#)

Given an RNA-Seq data file, find the set of significantly differentially expressed genes.

Calculate the alignment score between two nucleotide or protein sequences using a provided scoring matrix and be able to perform BLAST, PSI-BLAST, HMMER and protein structure based database searches and interpret the results in terms of the biological significance of an e-value.

5, 10

6 Use R to read and parse comma-separated (.csv) formatted files ready for subsequent analysis. 8, 9, 10, 11, 13, 15, 16

7 Perform elementary statistical analysis on biomolecular and "omics" datasets with R and produce informative graphical displays and data summaries. 9, 10, 11, 13, 15, 16

8 View and interpret the structural models in the PDB. 10, 11

9 Explain the outputs from structure prediction algorithms and small molecule docking approaches. 11

10 Appreciate and describe in general terms the rapid advances in sequencing technologies and the new areas of investigation that these advances have made accessible. 13, 14, 15

11 Understand the process by which genomes are currently sequenced and the bioinformatics processing and analysis required for their interpretation. 13

12 For a genomic region of interest (e.g. the neighborhood of a particular gene), use a genome browser to view nearby genes, transcription factor binding regions, epigenetic information, etc. 14

BIMM-143 Learning Goals....

Delve deeper into “real-world” bioinformatics

UC San Diego

BIMM 143

A hands-on introduction to the computer-based analysis of genomic and biomolecular data from the Division of Biological Sciences, UCSD.

[Overview](#)

[Lectures](#)

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Learning Goal	Description	Page Number
9	Explain the outputs from structure prediction algorithms and small molecule docking approaches.	11
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11	Understand the process by which genomes are currently sequenced and the bioinformatics processing and analysis required for their interpretation.	13
12	For a genomic region of interest (e.g. the neighborhood of a particular gene), use a genome browser to view nearby genes, transcription factor binding regions, epigenetic information, etc.	14
13	Given an RNA-Seq data file, find the set of significantly differentially expressed genes and use online tools to interpret gene lists and annotate potential gene functions.	15, 16
14	Perform a GO analysis to identify the pathways relevant to a set of genes (e.g. identified by transcriptomic study or a proteomic experiment).	16
15	Use the KEGG pathway database to look up interaction pathways.	17
16	Use graph theory to represent biological data networks.	17, 18
17	Understand the challenges in integrating and interpreting large heterogeneous high throughput data sets into their functional	19

These support a major learning objective

At the end of this course students will:

- Understand the increasing necessity for computation in modern life sciences research.
- Be able to use and evaluate online bioinformatics resources and analysis tools to solve problems in the biological sciences.
- Be able to use the R environment to analyze bioinformatics data at scale.
- Be familiar with the research objectives of the bioinformatics related sub-disciplines of Genome informatics, Transcriptomics and Structural informatics.

Why use R?

Productivity

Flexibility

Designed for data analysis

IEEE 2016 Top Programming Languages

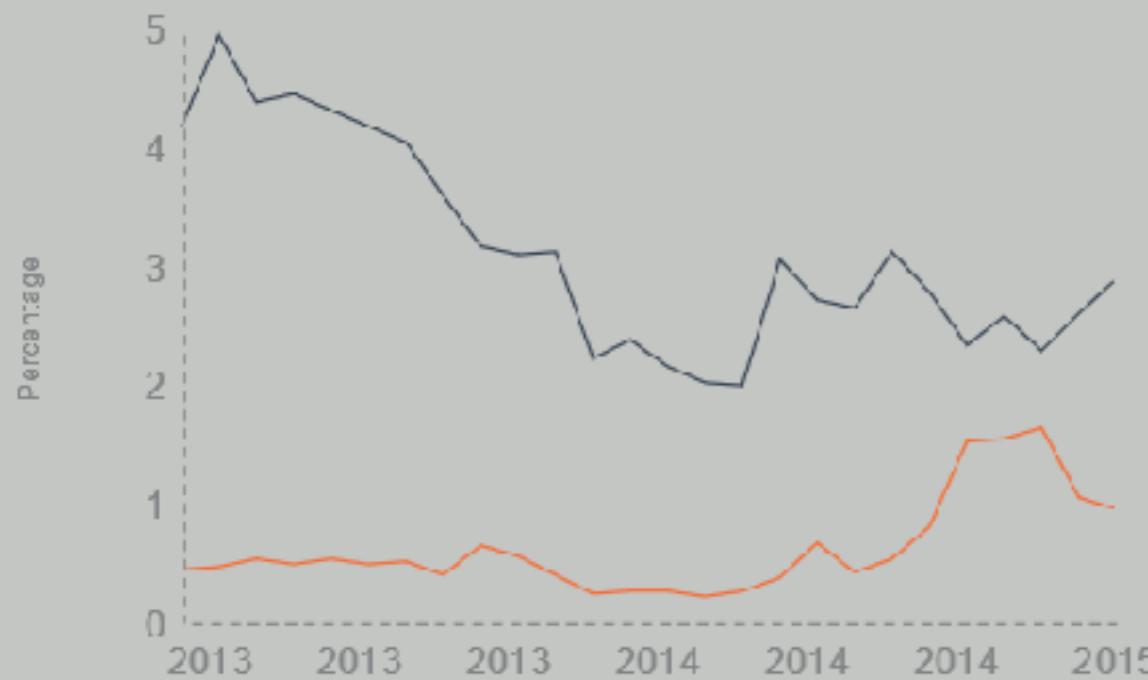
Language Rank	Types	Spectrum Ranking
1. C		100.0
2. Java		98.1
3. Python		98.0
4. C++		95.9
5. R		87.9
6. C#		86.7
7. PHP		82.8
8. JavaScript		82.2
9. Ruby		74.5
10. Go		71.9

<http://spectrum.ieee.org/computing/software/the-2016-top-programming-languages>

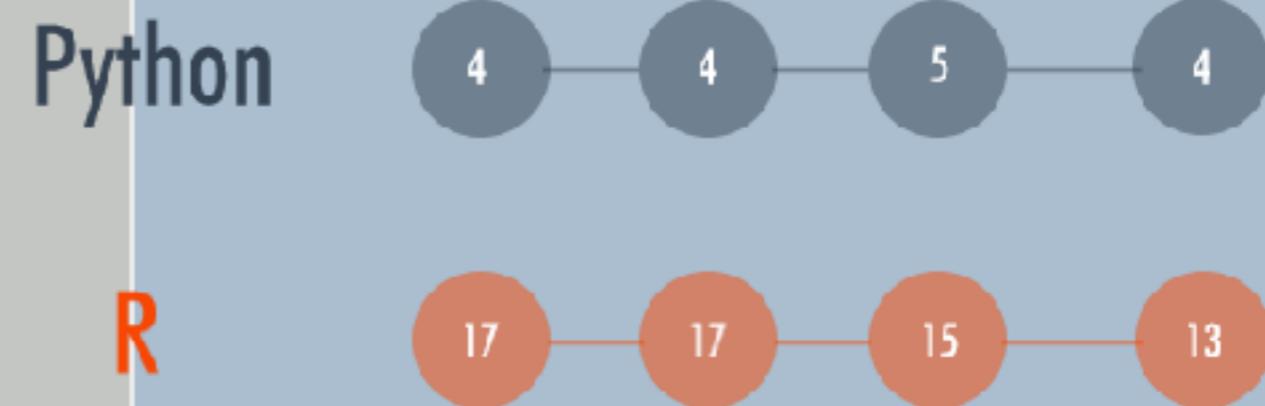
R and Python: The Numbers

Popularity Rankings

R and Python's popularity between 2013 and February 2015 (Tiobe Index)



Redmonk ranking, comparing the relative performance of programming languages on GitHub and Stack Overflow (September 2012 and January 2013, 2014, 2015)



Jobs And Salary?

2014 Dice Tech Salary Survey:
Average Salary For High Paying Skills and Experience



\$ 115,531



\$ 94,139

[http://www.kdnuggets.com/2015/05/r-vs-python-data-science.html?
utm_medium=email&utm_source=flipboard](http://www.kdnuggets.com/2015/05/r-vs-python-data-science.html?utm_medium=email&utm_source=flipboard)

- R is the “lingua franca” of data science in industry and academia.
- Large user and developer community.
 - As of Aug 14th 2018 there are 12,907 add on **R packages** on **CRAN** and 1,560 on **Bioconductor** - more on these later!
- Virtually every statistical technique is either already built into R, or available as a free package.
- Unparalleled exploratory data analysis environment.

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Course Structure

Major lecture topics and specific learning goals.

Introduction to Bioinformatics

Introducing the *what, why and how* of bioinformatics?

Computer Setup

Ensuring your laptop is all set for future sections of this course.

OUTLINE

Overview of bioinformatics

- The what, why and how of bioinformatics?
- Major bioinformatics research areas.
- Skepticism and common problems with bioinformatics.

Online databases and associated tools

- Primary, secondary and composite databases.
 - Nucleotide sequence databases (GenBank & RefSeq).
 - Protein sequence database (UniProt).
 - Composite databases (PFAM & OMIM).

Database usage vignette

- How-to productively navigate major databases.

Q. What is Bioinformatics?

“Bioinformatics is the application of computers to the collection, archiving, organization, and analysis of biological data.”

... Bioinformatics is a hybrid of biology and computer science

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- ... Bioinformatics is a hybrid of biology and computer science
- ... **Bioinformatics is computer aided biology!**

Q. What is Bioinformatics?

“Bioinformatics is the application of computers to the collection, archiving, organization, and analysis of biological data.”

- ... Bioinformatics is a hybrid of biology and computer science
- ... **Bioinformatics is computer aided biology!**

Computer based management and analysis of biological and biomedical data with useful applications in many disciplines, particularly genomics, proteomics, metabolomics, etc...

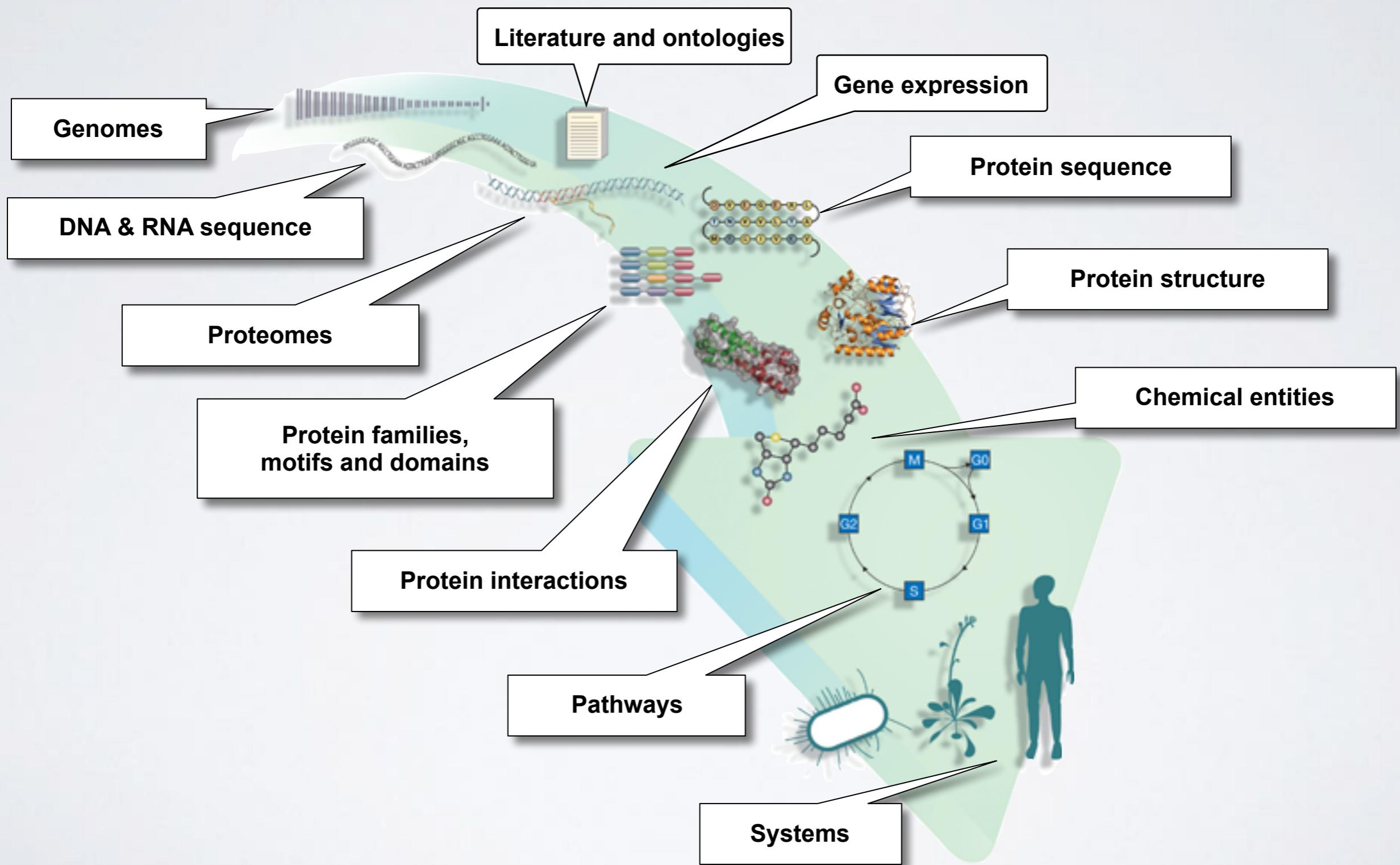
MORE DEFINITIONS

- ▶ “Bioinformatics is conceptualizing biology in terms of **macromolecules** and then applying “**informatics**” techniques (derived from disciplines such as applied maths, computer science, and statistics) to **understand** and **organize** the information associated with these molecules, on a **large-scale**.
Luscombe NM, et al. Methods Inf Med. 2001;40:346.
- ▶ “Bioinformatics is research, development, or application of **computational approaches** for expanding the use of **biological, medical, behavioral or health data**, including those to **acquire, store, organize and analyze** such data.”
National Institutes of Health (NIH) (<http://tinyurl.com/l3gxr6b>)

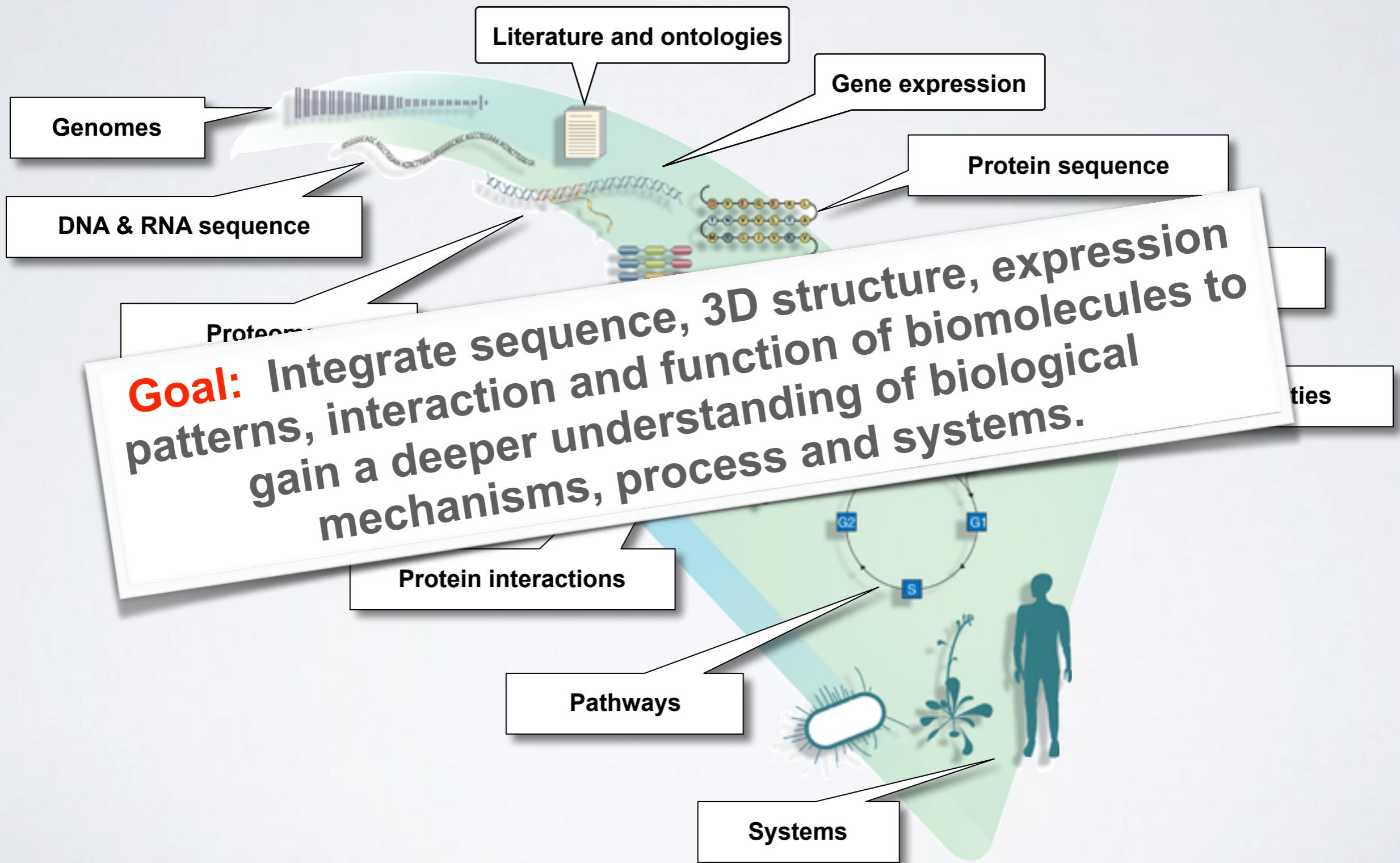
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National Institutes of Health (NIH) (<http://tinyurl.com/l3gxr6b>)
- Key Point:** Bioinformatics is Computer Aided Biology*

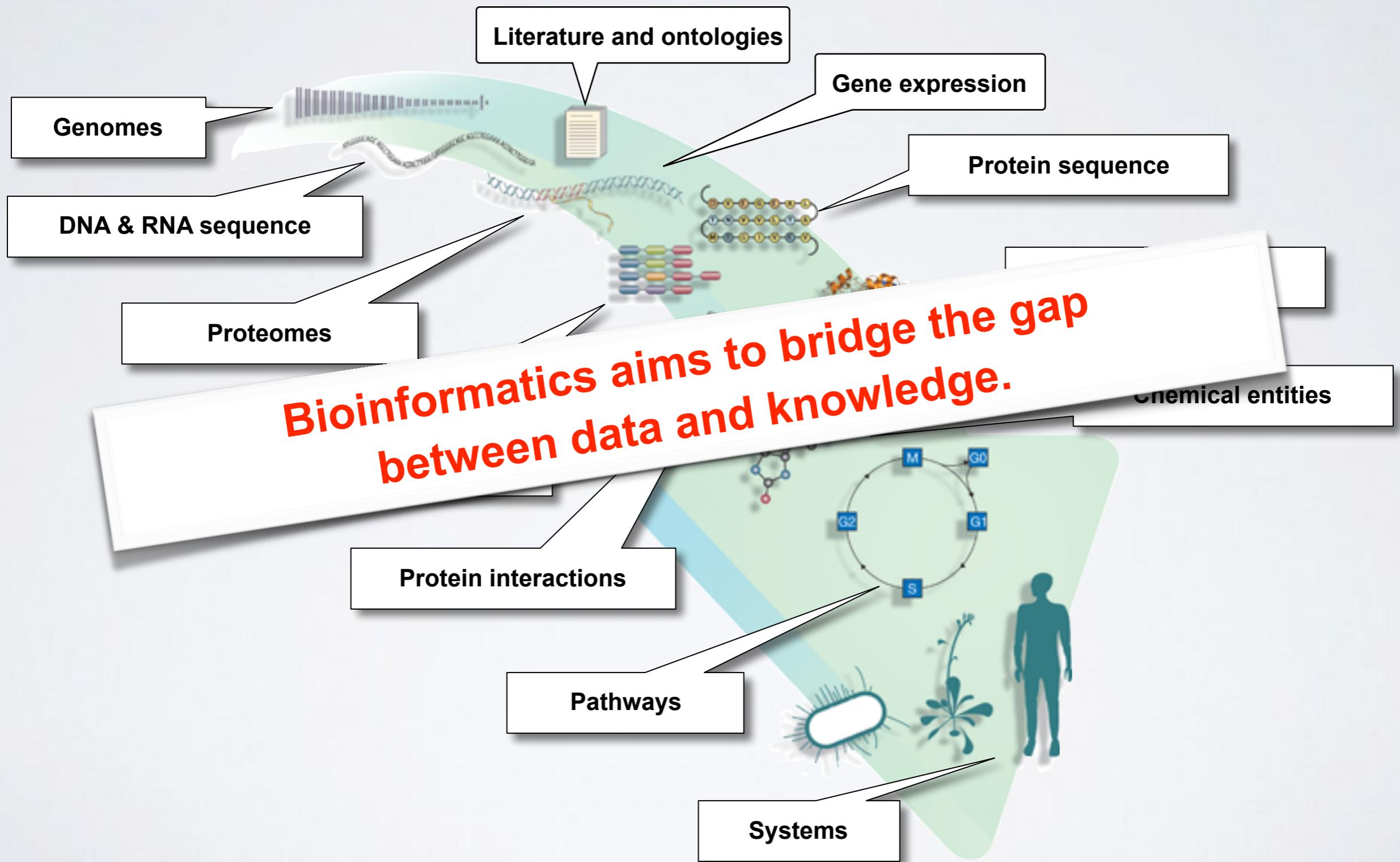
Major types of Bioinformatics Data



Major types of Bioinformatics Data



Major types of Bioinformatics Data



BIOINFORMATICS RESEARCH AREAS

Include but are not limited to:

- Organization, classification, dissemination and analysis of biological and biomedical data (particularly '-omics' data).
- Biological sequence analysis and phylogenetics.
- Genome organization and evolution.
- Regulation of gene expression and epigenetics.
- Biological pathways and networks in healthy & disease states.
- Protein structure prediction from sequence.
- Modeling and prediction of the biophysical properties of biomolecules for binding prediction and drug design.
- Design of biomolecular structure and function.

With applications to Biology, Medicine, Agriculture and Industry

Where did bioinformatics come from?

Bioinformatics arose as molecular biology began to be transformed by the emergence of molecular sequence and structural data

Recap: The key dogmas of molecular biology

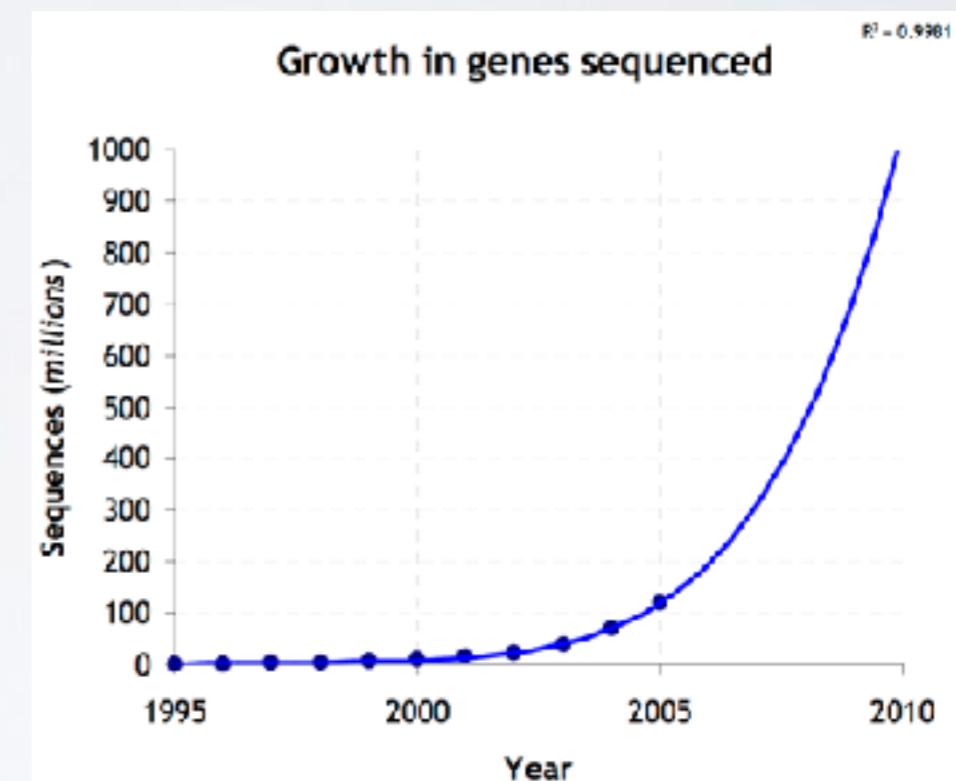
- *DNA sequence determines protein sequence.*
- *Protein sequence determines protein structure.*
- *Protein structure determines protein function.*
- *Regulatory mechanisms (e.g. gene expression) determine the amount of a particular function in space and time.*

Bioinformatics is now essential for the archiving, organization and analysis of data related to all these processes.

Why do we need Bioinformatics?

Bioinformatics is necessitated by the rapidly expanding quantities and complexity of biomolecular data

- Bioinformatics provides methods for the efficient:
 - ▶ **storage**
 - ▶ **annotation**
 - ▶ **search and retrieval**
 - ▶ **data integration**
 - ▶ **data mining and analysis**

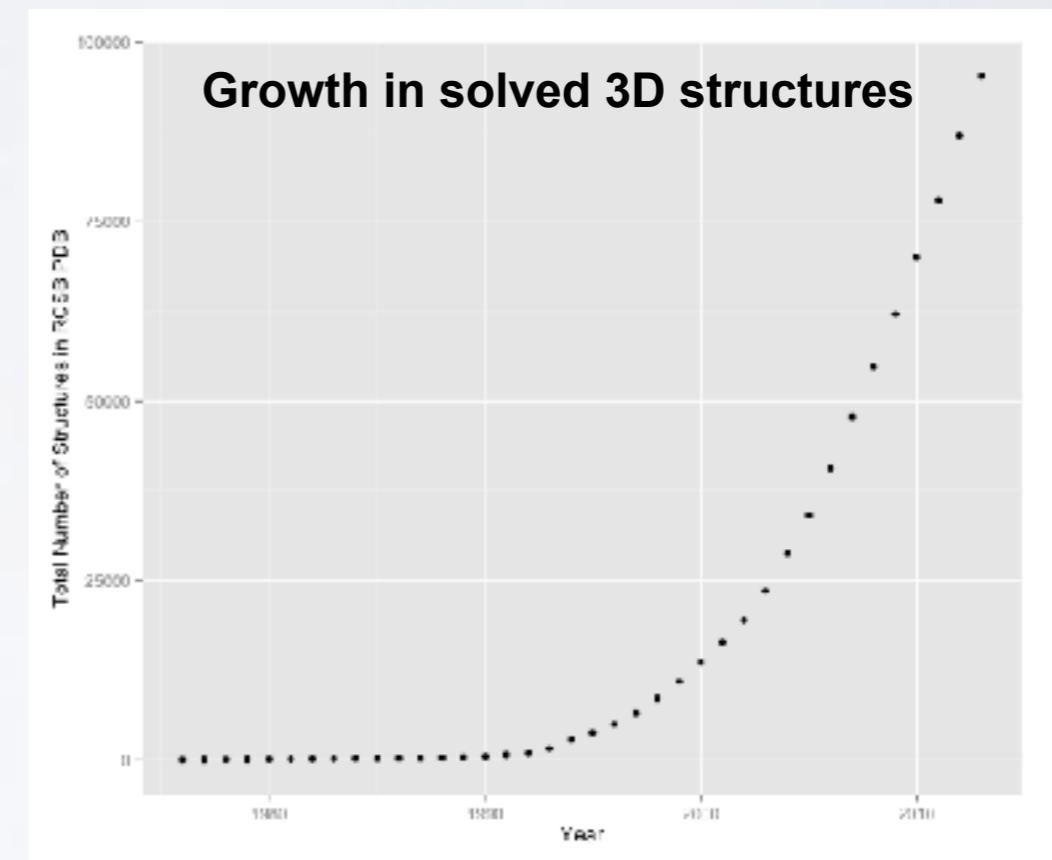


E.G. data from sequencing, structural genomics, proteomics, new high throughput assays, etc...

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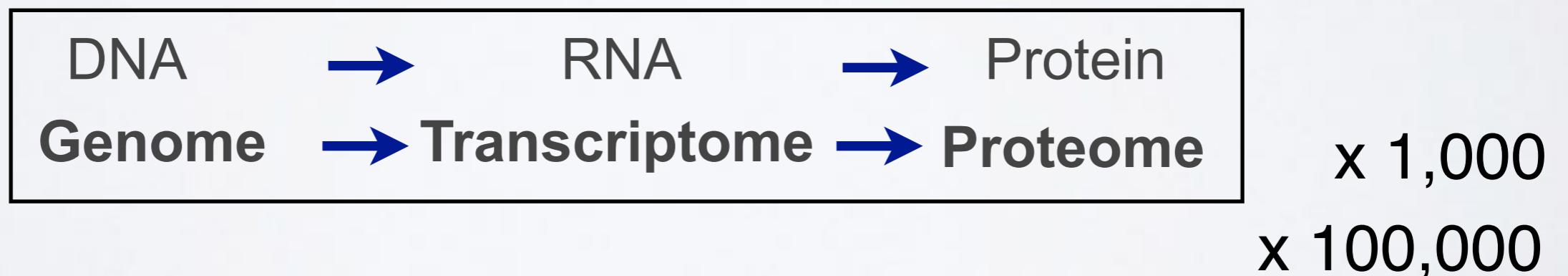
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How do we do Bioinformatics?

- A “*bioinformatics approach*” involves the application of **computer algorithms**, **computer models** and **computer databases** with the broad goal of understanding the action of both individual genes, transcripts, proteins and large collections of these entities.



How do we *actually* do Bioinformatics?

Pre-packaged tools and databases

- Many online
- Most are free to use
- Time consuming methods require downloading...

Advanced tool application & development

- Mostly on a UNIX environment
- Knowledge of programming languages frequently required
(*e.g.* R, Python, Perl, C, Java, Fortran)
- May require specialized high performance computing...

How do we *actually* do Bioinformatics?

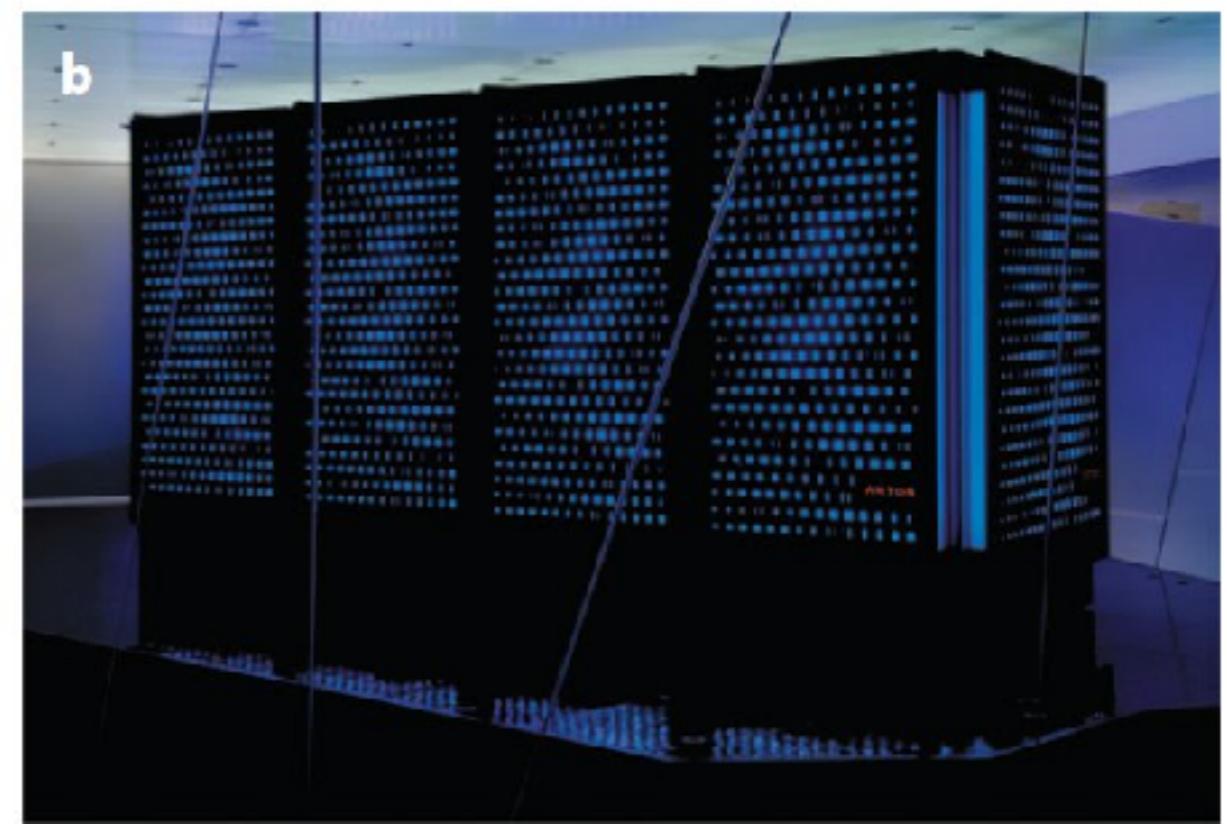
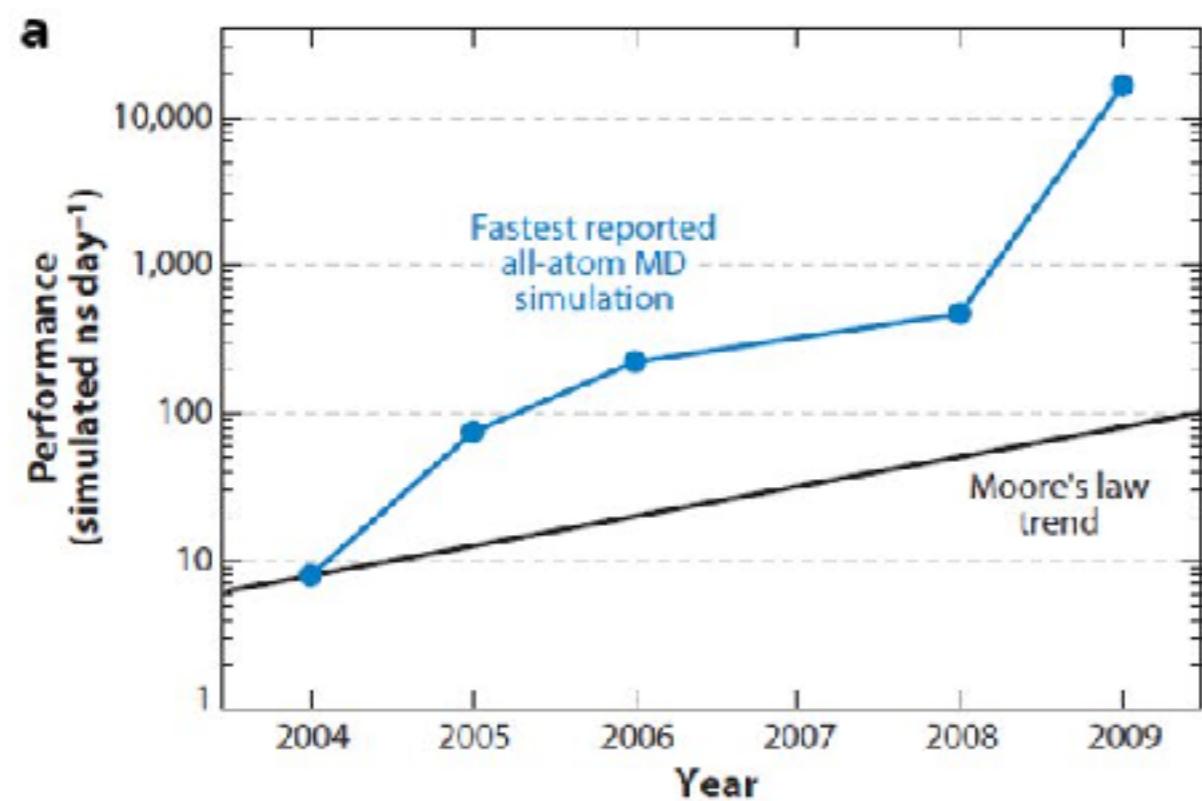
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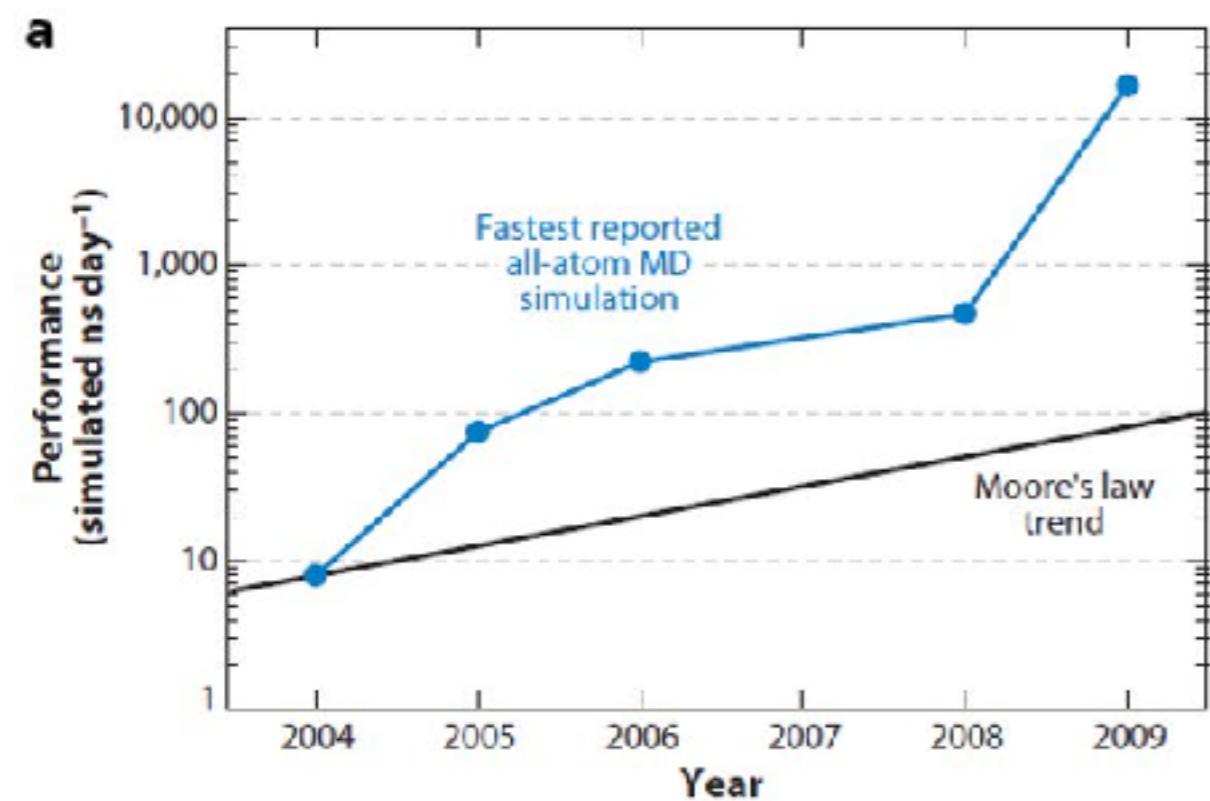
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(e.g. R, Python, Perl, C, Java, Fortran)
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SIDE-NOTE: SUPERCOMPUTERS ANDGPUS



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HOW COMPUTERS HAVE CHANGED

DATE	COST	SPEED	MEMORY	SIZE
1967	\$10M	0.1 MHz	1 MB	WALL
2013	\$14,000	1 GHz	10 GB	LAPTOP
CHANGE	10,000	10,000	10,000	10,000

If cars were like computers then a new Vehc
would cost \$3, would have a top speed of
1,000,000 Km/hr, would carry 50,000
adults and would park in a shadow.



Skepticism & Bioinformatics

We have to approach computational results the same way we do wet-lab results:

- Do they make sense?
- Is it what we expected?
- Do we have adequate controls, and how did they come out?
- Modeling is modeling, but biology is different...

What does this model actually contribute?

- Avoid the miss-use of ‘black boxes’

Skepticism & Bioinformatics

Gunnar von Heijne in “*Sequence Analysis in Molecular Biology; Treasure Trove or Trivial Pursuit*” states:

→ “Think about what you’re doing; use your knowledge of the molecular system involved to guide both your interpretation of results and your direction of inquiry; use as much information as possible; and do not blindly accept everything the computer offers you”.

Key-Point: Avoid the miss-use of ‘black boxes’!

Common problems with Bioinformatics

Confusing multitude of tools available

- ▶ Each with many options and settable parameters

Most tools and databases are written by and for nerds

- ▶ Same is true of documentation - if any exists!

Most are developed independently

Notable exceptions are found at the:

- **EBI** (European Bioinformatics Institute) and
- **NCBI** (National Center for Biotechnology Information)

General Parameters

Max target sequences	500
Select the maximum number of aligned sequences to display	
Short queries	<input checked="" type="checkbox"/> Automatically adjust parameters for short input sequences
Expect threshold	10
Word size	3
Max matches in a query range	0

Scoring Parameters

Matrix	BLOSUM62
Gap Costs	Existence: 11 Extension: 1
Compositional adjustments	Conditional compositional sco

Filters and Masking

Filter	<input type="checkbox"/> Low complexity regions
Mask	<input type="checkbox"/> Mask for lookup table only <input type="checkbox"/> Mask lower case letters

PSI/PHI/DELTA BLAST

Upload PSSM Optional	Choose File no file selected
PSI-BLAST Threshold	0.005
Pseudocount	0

Even Blast has many settable parameters

STEP 3 - Set your PROGRAM FASTA

MATRIX	GAP OPEN	GAP EXTEND	KTUP	EXPECTATION UPPER VALUE	EXPECTATION LOWER VALUE
BLOSUM50	-10	-2	2	10	0 (default)
DNA STRAND	HISTOGRAM	FILTER		STATISTICAL ESTIMATES	
N/A	no	none		Regress	
SCORES	ALIGNMENTS	SEQUENCE RANGE	DATABASE RANGE		MULTI HSPs
50	50	START-END	START-END		no
SCORE FORMAT					
Default					

Related tools with different terminology

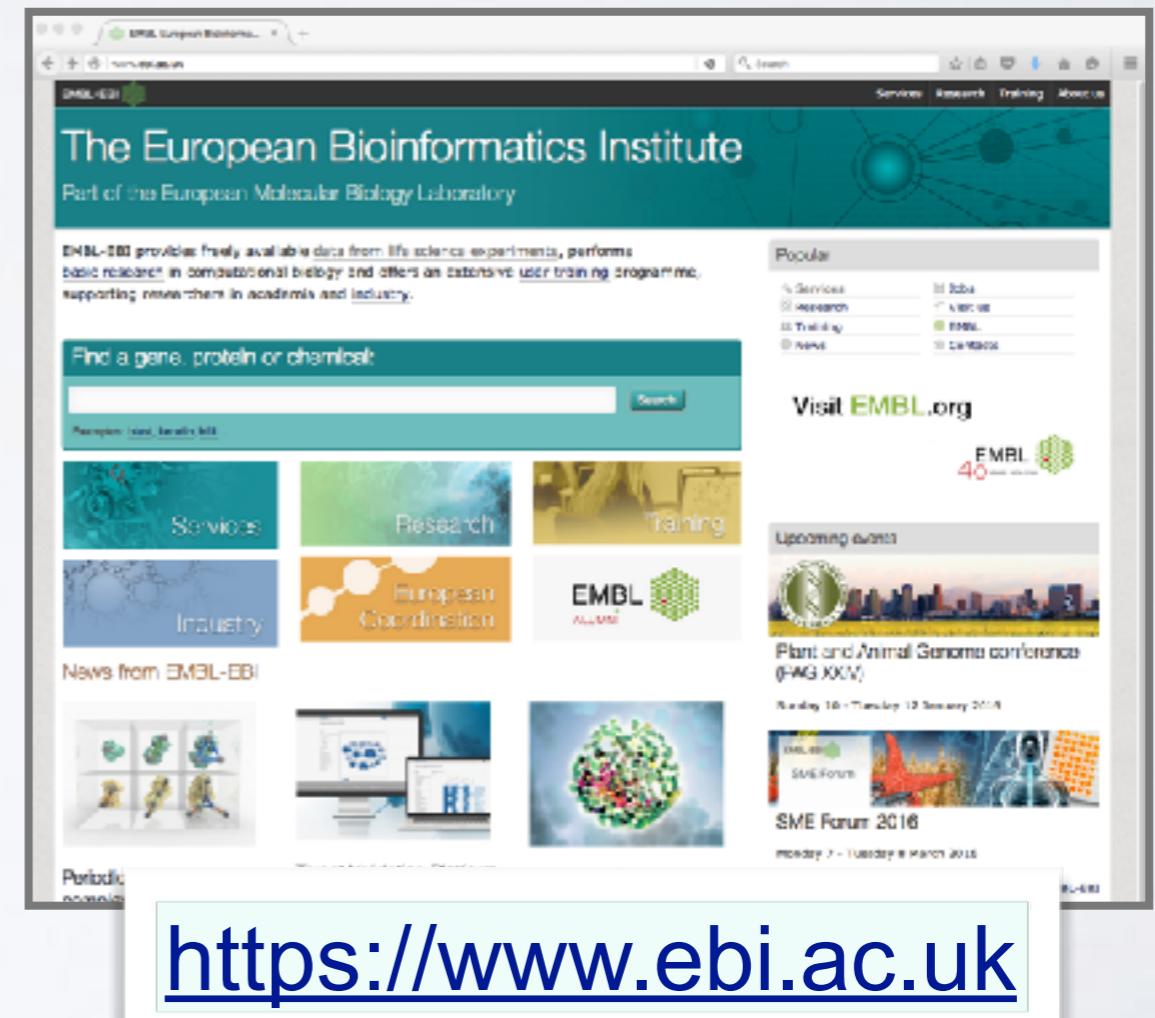
Key Online Bioinformatics Resources: NCBI & EBI

The NCBI and EBI are invaluable, publicly available resources for biomedical research



The screenshot shows the NCBI homepage with a blue header "National Center for Biotechnology Information". Below it is a navigation bar with links for "NCBI Resources", "How To", "Sign in to NCBI", "All Databases", and a search bar. The main content area includes a "Welcome to NCBI" section, a "Get Started" section with links for tools, downloads, how-to guides, and submissions, and a "3D Structures" section featuring a 3D molecular model. On the left is a sidebar with links for various NCBI databases and services.

<http://www.ncbi.nlm.nih.gov>



The screenshot shows the EBI homepage with a green header "The European Bioinformatics Institute, Part of the European Molecular Biology Laboratory". Below it is a navigation bar with links for "Services", "Research", "Training", and "About us". The main content area includes a "Find a gene, protein or chemical" search bar, sections for "Services", "Research", "Training", "Industry", "European Coordination", and "News from EMBL-EBI". There are also sections for "Upcoming events" (Plant and Animal Genome conference) and "SME Forum 2016".

<https://www.ebi.ac.uk>

National Center for Biotechnology Information (NCBI)

- Created in 1988 as a part of the National Library of Medicine (NLM) at the National Institutes of Health
- NCBI's mission includes:
 - ▶ Establish **public databases**
 - ▶ Develop **software tools**
 - ▶ **Education** on and dissemination of biomedical information
- We will cover a number of core NCBI databases and software tools in the lecture



<http://www.ncbi.nlm.nih.gov>

National Center for Biotechnology Information

NCBI Resources How To Sign in to NCBI

All Databases Search

NCBI Home Resource List (A-Z) All Resources Chemicals & Bioassays Data & Software DNA & RNA Domains & Structures Genes & Expression Genetics & Medicine Genomes & Maps Homology Literature Proteins Sequence Analysis Taxonomy Training & Tutorials Variation

Welcome to NCBI

The National Center for Biotechnology Information advances science and health by providing access to biomedical and genomic information.

[About the NCBI](#) | [Mission](#) | [Organization](#) | [Research](#) | [RSS Feeds](#)

Get Started

- [Tools](#): Analyze data using NCBI software
- [Downloads](#): Get NCBI data or software
- [How-To's](#): Learn how to accomplish specific tasks at NCBI
- [Submissions](#): Submit data to GenBank or other NCBI databases

3D Structures

Explore three-dimensional structures of proteins, DNA, and RNA molecules. Examine sequence-structure relationships, active sites, molecular interactions, biological activities of bound chemicals, and associated biosystems.

Popular Resources

PubMed
Bookshelf
PubMed Central
PubMed Health
BLAST
Nucleotide
Genome
SNP
Gene
Protein
PubChem

NCBI Announcements

New version of Genome Workbench available 06 Sep

An integrated, downloadable applicati

<http://www.ncbi.nlm.nih.gov>

National Center for Biotechnology Information

NCBI Resources How To Sign in to NCBI

All Databases Search

NCBI Home Resource List (A-Z) All Resources Chemicals & Bioassays Data & Software DNA & RNA Domains & Structures Genes & Expression Genetics & Medicine Genomes & Maps Homology Literature Proteins Sequence Analysis Taxonomy Training & Tutorials Variation

Welcome to NCBI

The National Center for Biotechnology Information provides access to unique information, tools and resources in the fields of medicine, health and biology.

About the NCBI | Mission | Our History

Get Started

- Tools: Analyze data using NCBI's bioinformatics tools
- Downloads: Get NCBI data files and software
- How-To's: Learn how to access and use NCBI resources
- Submissions: Submit data to NCBI's databases

3D Structures

Explore three-dimensional structures of proteins, DNA, and RNA molecules. Examine sequence-structure relationships, active sites, molecular interactions, biological activities of bound chemicals and associated biosystems.

Popular Resources

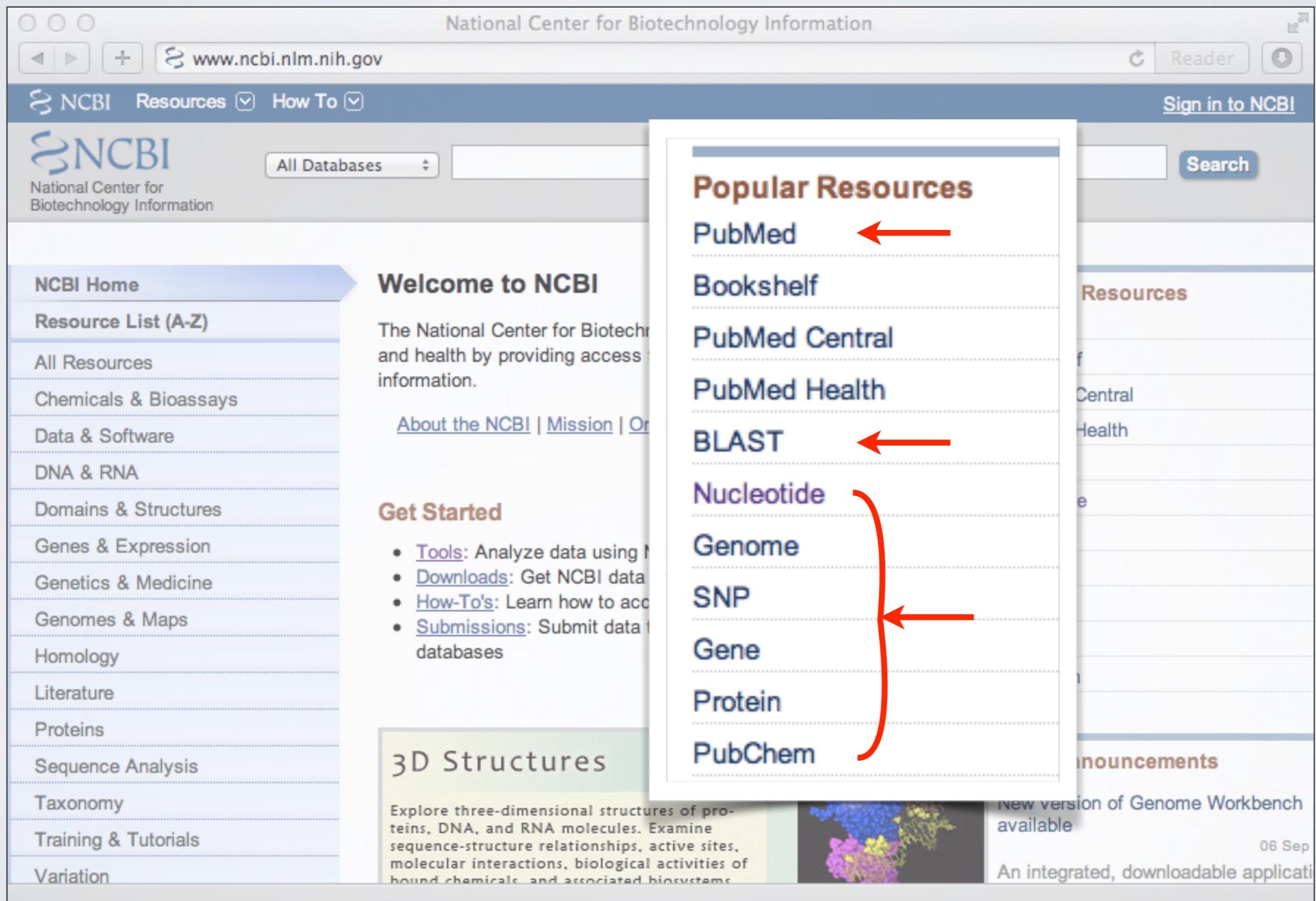
PubMed Bookshelf PubMed Central PubMed Health BLAST Nucleotide Genome SNP Gene Protein PubChem

Resources

Central Health

Announcements

New version of Genome Workbench available 06 Sep An integrated, downloadable application



<http://www.ncbi.nlm.nih.gov>

National Center for Biotechnology Information

NCBI Resources How To Sign in to NCBI

All Databases Search

NCBI Home Resource List (A-Z)

Welcome to NCBI
The National Center for Biotechnology Information advances science

Popular Resources PubMed

Notable NCBI databases include:
GenBank, **RefSeq**, **PubMed**, **dbSNP**

and the search tools **ENTREZ** and **BLAST**

Homology Literature Proteins Sequence Analysis Taxonomy Training & Tutorials Variation

databases

3D Structures
Explore three-dimensional structures of proteins, DNA, and RNA molecules. Examine sequence-structure relationships, active sites, molecular interactions, biological activities of bound chemicals and associated biosystems

Protein PubChem

NCBI Announcements
New version of Genome Workbench available 06 Sep
An integrated, downloadable applicati

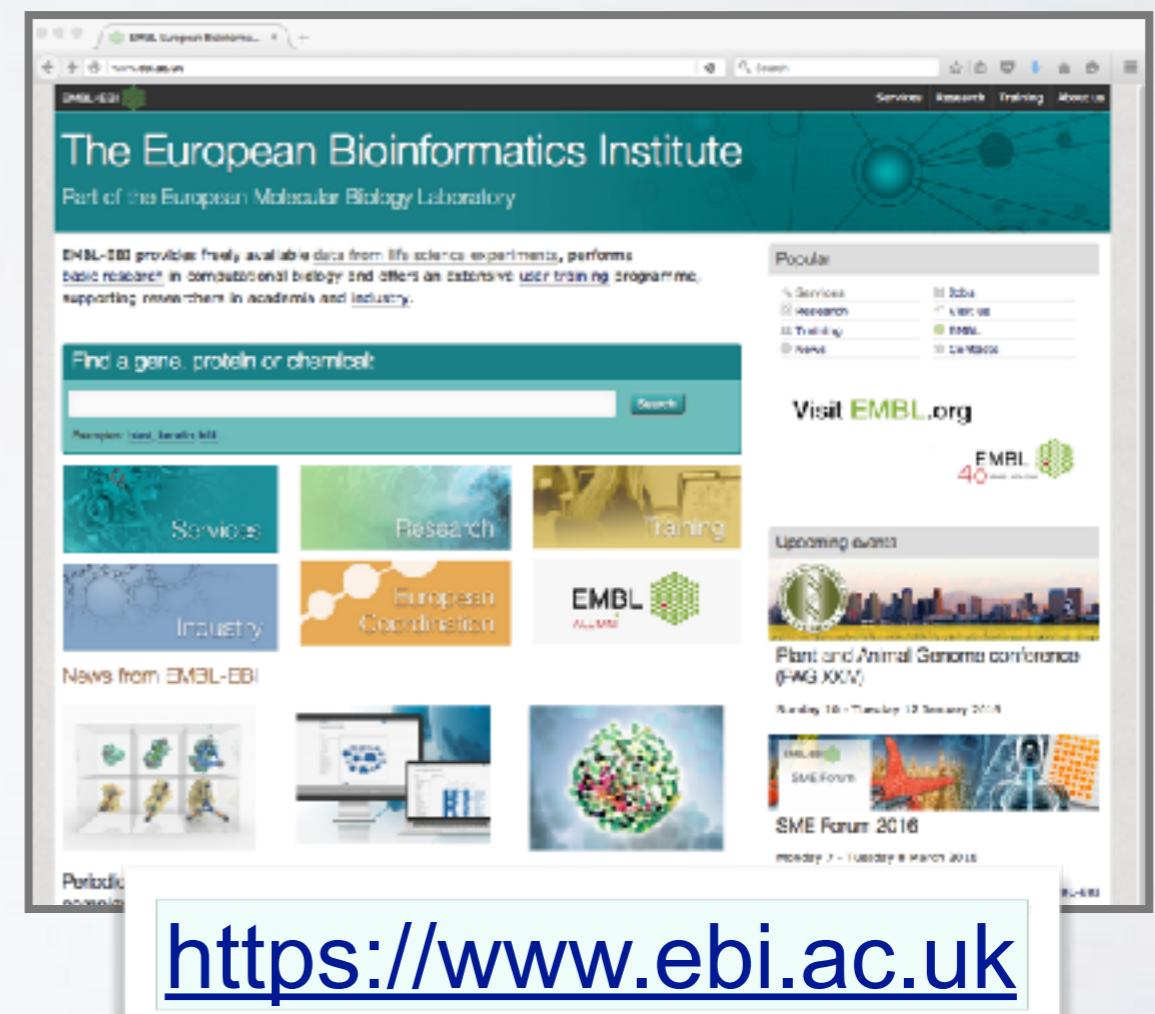
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<http://www.ncbi.nlm.nih.gov>



The screenshot shows the EBI homepage with a green header "The European Bioinformatics Institute, Part of the European Molecular Biology Laboratory". Below it is a navigation bar with links for "Services", "Research", "Training", and "About". The main content area includes a search bar for "Find a gene, protein or chemical", sections for "Services", "Research", "Training", "Industry", "European Coordination", and "News from EMBL-EBI". A "Visit EMBL.org" section features the EMBL 40th anniversary logo. A "Upcoming events" section lists the "Plant and Animal Genome conference (PAG XXV)" (Monday 10 - Tuesday 11 January 2016) and the "SME Forum 2016" (Monday 7 - Tuesday 8 March 2016).

<https://www.ebi.ac.uk>

European Bioinformatics Institute (EBI)

- Created in 1997 as a part of the European Molecular Biology Laboratory (EMBL)
- EBI's mission includes:
 - ▶ providing freely available **data and bioinformatics services**
 - ▶ and providing advanced **bioinformatics training**
- We will briefly cover several EBI databases and tools that have advantages over those offered at NCBI



The EBI maintains a number of high quality curated **secondary databases** and associated tools

The screenshot shows the homepage of the EMBL European Bioinformatics Institute (EBI) at www.ebi.ac.uk. The page features a dark blue header with the EMBL-EBI logo, a search bar, and navigation links for Services, Research, Training, and About us. The main content area has a teal background with the text: "The European Bioinformatics Institute Part of the European Molecular Biology Laboratory". It describes EMBL-EBI's mission to provide freely available data from life science experiments, perform basic research in computational biology, and offer user training. A "Find a gene, protein or chemical:" search bar is present. Below it, there are five main service categories: Services (highlighted with a red box), Research, Training, Industry, and European Coordination. To the right, there are sections for Popular links (Services, Research, Training, News, Jobs, Visit us, EMBL, Contacts), a "Visit EMBL.org" link with the EMBL 40th anniversary logo, and an "Upcoming events" section for the Plant and Animal Genome conference (PAG XXIV).

EMBL European Bioinforma... [+/-](#)

www.ebi.ac.uk [Search](#) [Services](#) [Research](#) [Training](#) [About us](#)

The European Bioinformatics Institute

Part of the European Molecular Biology Laboratory

EMBL-EBI provides freely available data from life science experiments, performs basic research in computational biology and offers an extensive user training programme, supporting researchers in academia and industry.

Find a gene, protein or chemical:

Examples: blast, keratin, bfl1...

Search

Services

Research

Training

Industry

European Coordination

EMBL ALUMNI

Popular

Services

Research

Training

News

Jobs

Visit us

EMBL

Contacts

Visit EMBL.org

EMBL 40 YEARS 1974-2014

Upcoming events

Plant and Animal Genome conference (PAG XXIV)

Sunday 10 - Tuesday 12 January 2016

The EBI maintains a number of high quality curated **secondary databases** and associated tools

The screenshot shows the EMBL-EBI Services website at www.ebi.ac.uk/services. The page features a navigation bar with links for Services, Research, Training, and About us. Below the navigation is a banner with a molecular structure background. The main content area is titled "Bioinformatics services" and includes a section about maintaining comprehensive molecular databases. It lists nine categories: DNA & RNA, Gene expression, Proteins, Structures, Systems, Chemical biology, Ontologies, Literature, and Cross domain. To the right, there's a "Popular" sidebar with links to Ensembl, UniProt, PDBc, ArrayExpress, CHEMBL, BLAST, Europe PMC, Reactome, Train online, and Support. There are also sections for "Service news" featuring a butterfly image and "Training".

Services < EMBL-EBI

www.ebi.ac.uk/services

Search

Services | Research | Training | About us

Services

Overview A to Z Data submission Support

Bioinformatics services

We maintain the world's most comprehensive range of **freely available** and up-to-date **molecular databases**. Developed in collaboration with our colleagues worldwide, our services let you share data, perform complex queries and analyse the results in different ways. You can work locally by downloading our data and software, or use our [web services](#) to access our resources programmatically. You can read more about our services in the journal *Nucleic Acids Research*.

DNA & RNA
genes, genomes & variation

Gene expression
RNA, protein & metabolite expression

Proteins
sequences, families & motifs

Structures
Molecular & cellular structures

Systems
reactions, interactions & pathways

Chemical biology
chemogenomics & metabolomics

Ontologies
taxonomies & controlled vocabularies

Literature
Scientific publications & patents

Cross domain
cross-domain tools & resources

Popular

- Ensembl
- UniProt
- PDBc
- ArrayExpress
- CHEMBL
- BLAST
- Europe PMC
- Reactome
- Train online
- Support

Service news

Training

The EBI maintains a number of high quality curated **secondary databases** and associated tools

The screenshot shows the EBI Services website at www.ebi.ac.uk/services. The page features a navigation bar with links for Services, Research, Training, and About us. Below the navigation is a 'Popular' sidebar containing links to Ensembl, UniProt, PDBe, ArrayExpress, and ChEMBL, with the Ensembl link highlighted by a red box. The main content area displays nine service categories in a grid:

- DNA & RNA**: genes, genomes & variation
- Gene expression**: RNA, protein & metabolite expression
- Proteins**: sequences, families & motifs (highlighted with a red box)
- Structures**: Molecular & cellular structures
- Systems**: reactions, interactions & pathways
- Chemical biology**: chemogenomics & metabolomics
- Ontologies**: taxonomies & controlled vocabularies
- Literature**: Scientific publications & patents
- Cross domain**: cross-domain tools & resources

A large banner at the bottom right features a woman working on a computer with the word "Training" overlaid.

<https://www.ebi.ac.uk>

The EBI makes available a wider variety of **online tools** than NCBI

Proteins

Popular services

 UniProt	UniProt: The Universal Protein Resource The gold-standard, comprehensive resource for protein sequence and functional annotation data.
 InterPro	A database for the classification of proteins into families, domains and conserved sites.
 PRIDE	PRIDE: The Proteomics Identifications Database An archive of protein expression data determined by mass spectrometry.
 Pfam	A database of hidden Markov models and alignments to describe conserved protein families and domains.
 Clustal Omega	Multiple sequence alignment of DNA or protein sequences. Clustal Omega replaces the older ClustalW alignment tools.
 HMMER	Fast sensitive protein homology searches using profile hidden Markov models (HMMs). Variety of different search methods for querying against both sequence and HMM target databases.
 InterProScan 5	InterProScan 5 searches sequences against InterPro's predictive protein signatures. Please note that InterProScan 4.8 has been retired.

Quick links

- o Popular services in this category
- o All services in this category
- o Project websites in this category

The EBI also provides a growing selection of **online tutorials** on EBI databases and tools

The screenshot shows the homepage of the EMBL European Bioinformatics Institute (EBI) at www.ebi.ac.uk. The page features a dark blue header with the EMBL-EBI logo, a search bar, and navigation links for Services, Research, Training, and About us. The main title "The European Bioinformatics Institute" is prominently displayed, along with the subtitle "Part of the European Molecular Biology Laboratory". A teal banner below the title contains a brief description of EMBL-EBI's mission: "EMBL-EBI provides freely available data from life science experiments, performs basic research in computational biology and offers an extensive user training programme, supporting researchers in academia and industry." To the right, there is a "Popular" sidebar with links to Services, Research, Training, News, Jobs, Visit us, EMBL, and Contacts. Below the banner is a search bar with the placeholder "Find a gene, protein or chemical:" and a "Search" button. The main content area includes several colored boxes: a teal "Services" box, a green "Research" box, a yellow "Training" box (which is highlighted with a red border), a blue "Industry" box, and an orange "European Coordination" box. At the bottom left, there is a "News from EMBL-EBI" section with three small thumbnail images. On the right side, there is a "Visit EMBL.org" section featuring the EMBL 40th anniversary logo and a "Upcoming events" section for the "Plant and Animal Genome conference (PAG XXIV)".

EMBL European Bioinformatic... [www.ebi.ac.uk](#)

EMBL-EBI

The European Bioinformatics Institute

Part of the European Molecular Biology Laboratory

EMBL-EBI provides freely available data from life science experiments, performs basic research in computational biology and offers an extensive user training programme, supporting researchers in academia and industry.

Find a gene, protein or chemical:

Search

Examples: blast, keratin, bfl1...

Services

Research

Training

Industry

European Coordination

EMBL ALUMNI

Popular

- Services
- Research
- Training
- News
- Jobs
- Visit us
- EMBL
- Contacts

Visit EMBL.org

EMBL 40 YEARS 1974-2014

Upcoming events

Plant and Animal Genome conference (PAG XXIV)

Sunday 10 - Tuesday 12 January 2016

The EBI also provides a growing selection of **online tutorials** on EBI databases and tools

The screenshot shows a web browser displaying the EBI Training online course page. The URL in the address bar is www.ebi.ac.uk/training/online/course/using-sequence-similarity-searching-tools-embl-ebi. The page title is "Using sequence similarity searching tools at EMBL-EBI: webinar". The main content area features a video player showing a thumbnail of the webinar presentation. The thumbnail has a blue header with the text "Using sequence similarity search tools at EMBL-EBI" and "Finding homologous sequences with BLAST, FASTA, PSI-Search etc.". Below the header is a photo of a man (Andrew Cowley) and his contact information: andrew.cowley@ebi.ac.uk and support@ebi.ac.uk. The video player shows a progress bar at 0:03 / 37:42. To the left of the video player is a sidebar titled "Course content" with a link to the same webinar page. Below the sidebar is a "Print Course" button. To the right of the video player is a "Popular" sidebar with links to "Train online", "Find us", and "Funding". Another sidebar titled "Find us at..." lists various EBI events and activities.

Using sequence similarity searching tools at EMBL-EBI: webinar

Using sequence similarity searching tools at EMBL-EBI: webinar

Using sequence similarity search tools at EMBL-EBI

Finding homologous sequences with BLAST, FASTA, PSI-Search etc.

Andrew Cowley
andrew.cowley@ebi.ac.uk
support@ebi.ac.uk

0:03 / 37:42

Popular

Train online

Find us

Funding

Find us at...

Open days and career days

Conference exhibitions

EMBL courses and events

Genome campus events

Science for schools

This webinar focuses on how to use tools like **BLAST** and **PSI-Search** to find homologous sequences in EMBL-EBI databases, including tips on which tool and database to use, input formats, how to change parameters and how to interpret the results pages.

The EBI also provides a growing selection of **online tutorials** on EBI databases and tools

A screenshot of a web browser displaying the 'Train online | EBI Train online' website. The address bar shows the URL www.ebi.ac.uk/training/online/. The page header includes the EMBL-EBI logo and links for 'Find', 'Help', and 'Feedback'. A red 'Beta' badge is visible in the top right corner. The main navigation menu at the top includes 'Databases', 'Tools', 'Research', 'Training', 'Industry', 'About Us', and 'Help'. A secondary navigation bar on the left labeled 'Navigation' contains a link to 'Train online Home'. The main content area features a large heading 'Train online'.

Notable EBI databases include:
[ENA](#), [UniProt](#), [Ensembl](#)

and the tools [FASTA](#), [BLAST](#), [InterProScan](#),
[MUSCLE](#), [DALI](#), [HMMER](#)

Find a course

Browse by subject



[Genes and Genomes](#)



[Gene Expression](#)



[Interactions, Pathways, and Networks](#)

Next Class...

**MAJOR BIOINFORMATICS
DATABASES AND ASSOCIATED
ONLINE TOOLS**

Bioinformatics Databases

AATDB, AceDb, ACUTS, ADB, AFDB, AGIS, AMSdb, ARR, AsDb, BBDB, BCGD, Beanref, BiolImage, BioMagResBank, BIOMDB, BLOCKS, BovGBASE, BOVMAP, BSORF, BTKbase, CANSITE, CarbBank, CARBHYD, CATH, CAZY, CCDC, CD4OLbase, CGAP, ChickGBASE, Colibri, COPE, CottonDB, CSNDB, CUTG, CyanoBase, dbCFC, dbEST, dbSTS, DDBJ, DGP, DictyDb, Picty_cDB, DIP, DOGS, DOMO, DPD, DPInteract, ECDC, ECGC, EC02DBASE, EcoCyc, EcoGene, EMBL, EMD db, ENZYME, EPD, EpoDB, ESTHER, FlyBase, FlyView, GCRDB, GDB, GENATLAS, Genbank, GeneCards, Genlilesne, GenLink, GENOTK, GenProtEC, GIFTS, GPCRDB, GRAP, GRBase, gRNAsdb, GRR, GSDB, HAEMB, HAMSTERS, HEART-2DPAGE, HEXAdb, HGMD, HIDB, HIDC, HIVdb, HotMolecBase, HOVERGEN, HPDB, HSC-2DPAGE, ICN, ICTVDB, IL2RGbase, IMGT, Kabat, KDNA, KEGG, KloTho, LGIC, MAD, MaizeDb, MDB, Medline, Mendel, MEROPS, MGDB, MGI, MHCPEP5 Micado, MitoDat, MITOMAP, MJDB, MmtDB, Mol-R-Us, MPDB, MRR, MutBase, MycDB, NDB, NRSub, O-lycBase, OMIA, OMIM, OPD, ORDB, OWL, PAHdb, PatBase, PDB, PDD, Pfam, PhosphoBase, PigBASE, PIR, PKR, PMD, PPDB, PRESAGE, PRINTS, ProDom, Prolysis, PROSITE, PROTOMAP, RatMAP, RDP, REBASE, RGP, SBASE, SCOP, SeqAnaiRef, SGD, SGP, SheepMap, Soybase, SPAD, SRNA db, SRPDB, STACK, StyGene, Sub2D, SubtiList, SWISS-2DPAGE, SWISS-3DIMAGE, SWISS-MODEL Repository, SWISS-PROT, TeIDB, TGN, tmRDB, TOPS, TRANSFAC, TRR, UniGene, URNADB, V BASE, VDRR, VectorDB, WDCM, WIT, WormPep, etc ..!!!!

Bioinformatics Databases

AATDB, AceDb, ACUTS, ADB, AFDB, AGIS, AMSdb, ARR, AsDb, BBDB, RCCP, Beanref, CANSITE, CarbBank, CARBHYD, CATH, CAZy, ChickGBASE, Colibri, COPE, CottonDB, dbSTS, DDBJ, DGP, DictyDb, ECGC, EC02DBASE, FlyBase, GDB, HEPDB, KEGG, MHCDB, MycoDB, PDBe, PDB, Pfam, PhosphoBase, PigBASE, PIR, PKR, PMD, PPDB, PRESAGE, PRINTS, ProDom, Prolysis, PROSITE, PROTOMAP, RatMAP, RDP, REBASE, RGP, SBASE, SCOP, SeqAnaiRef, SGD, SGP, SheepMap, Soybase, SPAD, SRNA db, SRPDB, STACK, StyGene, Sub2D, SubtiList, SWISS-2DPAGE, SWISS-3DIMAGE, SWISS-MODEL Repository, SWISS-PROT, TelDB, TGN, tmRDB, TOPS, TRANSFAC, TRR, UniGene, URNADB, V BASE, VDRR, VectorDB, WDCM, WIT, WormPep, etc ..!!!!

There are lots of Bioinformatics Databases

For a annotated listing of major bioinformatics databases please see the online handout

< Major Databases.pdf >

Side-note: Databases come in all shapes and sizes



Databases can be of variable quality and often there are multiple databases with overlapping content.

Primary, secondary & composite databases

Bioinformatics databases can be usefully classified into *primary*, *secondary* and *composite* according to their data source.

- **Primary databases** (or archival databases) consist of data derived experimentally.
 - **GenBank**: NCBI's primary nucleotide sequence database.
 - **PDB**: Protein X-ray crystal and NMR structures.
- **Secondary databases** (or derived databases) contain information derived from a primary database.
 - **RefSeq**: non redundant set of curated reference sequences primarily from GenBank
 - **PFAM**: protein sequence families primarily from UniProt and PDB
- **Composite databases** (or *metadatabases*) join a variety of different primary and secondary database sources.
 - **OMIM**: catalog of human genes, genetic disorders and related literature
 - **GENE**: molecular data and literature related to genes with extensive links to other databases.

Today's Menu

Course Logistics

Website, screencasts, survey, ethics, assessment and grading.

Learning Objectives

What you need to learn to succeed in this course.

Course Structure

Major lecture topics and specific learning goals.

Introduction to Bioinformatics

Introducing the *what, why and how* of bioinformatics?

Bioinformatics Database

Hands-on exploration of several major databases and their associated tools.

Your Turn!

https://bioboot.github.io/bimm143_F18/lectures/#1

BIMM 143
A hands-on introduction to the computer-based analysis of genomic and biomolecular data from the Division of Biological Sciences, UCSD.

Overview

Lectures

Computer Setup

Learning Goals

Assignments & Grading

Ethics Code

1: Welcome to Foundations of Bioinformatics

Topics:
Course introduction, Learning goals & expectations, Biology is an information science, History of Bioinformatics, Types of data, Application areas and introduction to upcoming course segments, Student 30-second introductions, Student computer setup.

Goals:

- Understand course scope, expectations, logistics and [ethics code](#).
- Understand the increasing necessity for computation in modern life sciences research.
- Get introduced to how bioinformatics is practiced.
- Complete the [pre-course questionnaire](#).
- Setup your [laptop computer](#) for this course.

Material:

- Lecture Slides: [Large PDF](#), [Small PDF](#),
- Lab: [Hands-on section worksheet](#)
- Feedback: [Muddy Point Assessment](#)
- Handout: [Class Syllabus](#)
- Computer [Setup Instructions](#).

BIMM-143: INTRODUCTION TO BIOINFORMATICS (Lecture 1)

Bioinformatics Databases and Key Online Resources

https://bioboot.github.io/bimm143_W18/lectures/#1

Dr. Barry Grant

Jan 2018

Overview: The purpose of this lab session is to introduce a range of bioinformatics databases and associated services available on the Web whilst investigating the molecular basis of a common human disease.

Sections 1 and 2 deal with querying and searching GenBank, GENE and OMIM databases at NCBI. Sections 3 and 4 provide exposure to EBI resources for comparing proteins and visualizing protein structures. Finally, section 5 provides an opportunity to explore these and other databases further with additional examples.

Side-note: The Web is a dynamic environment, where information is constantly added and removed. Servers "go down", links change without warning, etc. This can lead to "broken" links and results not being returned from services. Don't give up - give it a second go and try a search engine using terms related to the page you are trying to access.

Section 1

The following transcript was found to be abundant in a human patient's blood sample.

```
>example1
ATGGTGCATCTGACTCCGTGGAGAAGTCTGCCGTTACTGCCCTGTGGGCAAGGTGAACGTGGATGAAG
TTGGTGGTGAGGCCCTGGCAGGCTGCTGGTGGTCTACCCCTGGACCCAGAGGTTCTTGAGTCCTTGG
GGATCTGTCCACTCCTGATGCAGTTATGGGCAACCCCTAACGGTGAAGGCTCATGGCAAGAAAGTGCCTCGGT
GCCTTAGTGTGGCTGGCTCACCTGGACAACCTCAAGGGCACCTTGCCACACTGAGTGAGCTGCACT
GTGACAAGCTGCACGTGGATCCTGAGAACTTCAGGCTCCTGGCAACGTGCTGGTCTGTGTGCTGGCCA
TCACCTGGCAAAGAATTCACCCCACCAGTGCAGGCTGCCTATCAGAAAAGTGGTGGCTGGTGTGGCTAAT
GCCCTGGCCCACAAGTATCACTAAGCTCGCTTCTGCTGTCCAATTT
```

The only information you are given is the above sequence so you must begin your investigation with a sequence search - for this example we will use NCBI's **BLAST** service at: <http://blast.ncbi.nlm.nih.gov/>

Note that there are several different "basic BLAST" programs available at NCBI (including nucleotide BLAST, protein BLAST, and BLASTx).

YOUR TURN!

- There are five major hands-on sections including:

1. BLAST, GenBank and OMIM @ NCBI	[~35 mins]
2. GENE database @ NCBI	[~15 mins]
— BREAK —	
3. UniProt & Muscle @ EBI	[~25 mins]
4. PFAM, PDB & NGL	[~30 mins]
— BREAK —	
5. Extension exercises	[~30 mins]

- ▶ Please do answer the last review question (**Q19**).
- ▶ We encourage discussion and exploration!

YOUR TURN!

- There are five major hands-on sections including:

	End times:
1. BLAST, GenBank and OMIM @ NCBI	[10:35 am]
2. GENE database @ NCBI	[10:55 am]
— BREAK —	— 11:05 am —
3. UniProt & Muscle @ EBI	[11:30 am]
4. PFAM, PDB & NGL	[12:00 pm]
— BREAK —	— 12:10 am —
5. Extension exercises	[12:40 pm]

- ▶ Please do answer the last review question (**Q19**).
- ▶ We encourage discussion and exploration!

SUMMARY

- Bioinformatics is computer aided biology.
- Bioinformatics deals with the collection, archiving, organization, and interpretation of a wide range of biological data.
- There are a large number of primary, secondary and tertiary bioinformatics databases.
- The NCBI and EBI are major online bioinformatics service providers.
- Introduced Gene, UniProt, PDB databases as well as a number of ‘boutique’ databases including PFAM and OMIM.

HOMEWORK

https://bioboot.github.io/bimm143_F18/lectures/#1

- Complete the **initial course questionnaire**:
- Check out the “**Background Reading**” material online:
- Complete the **lecture 1 homework questions**:

THANK YOU