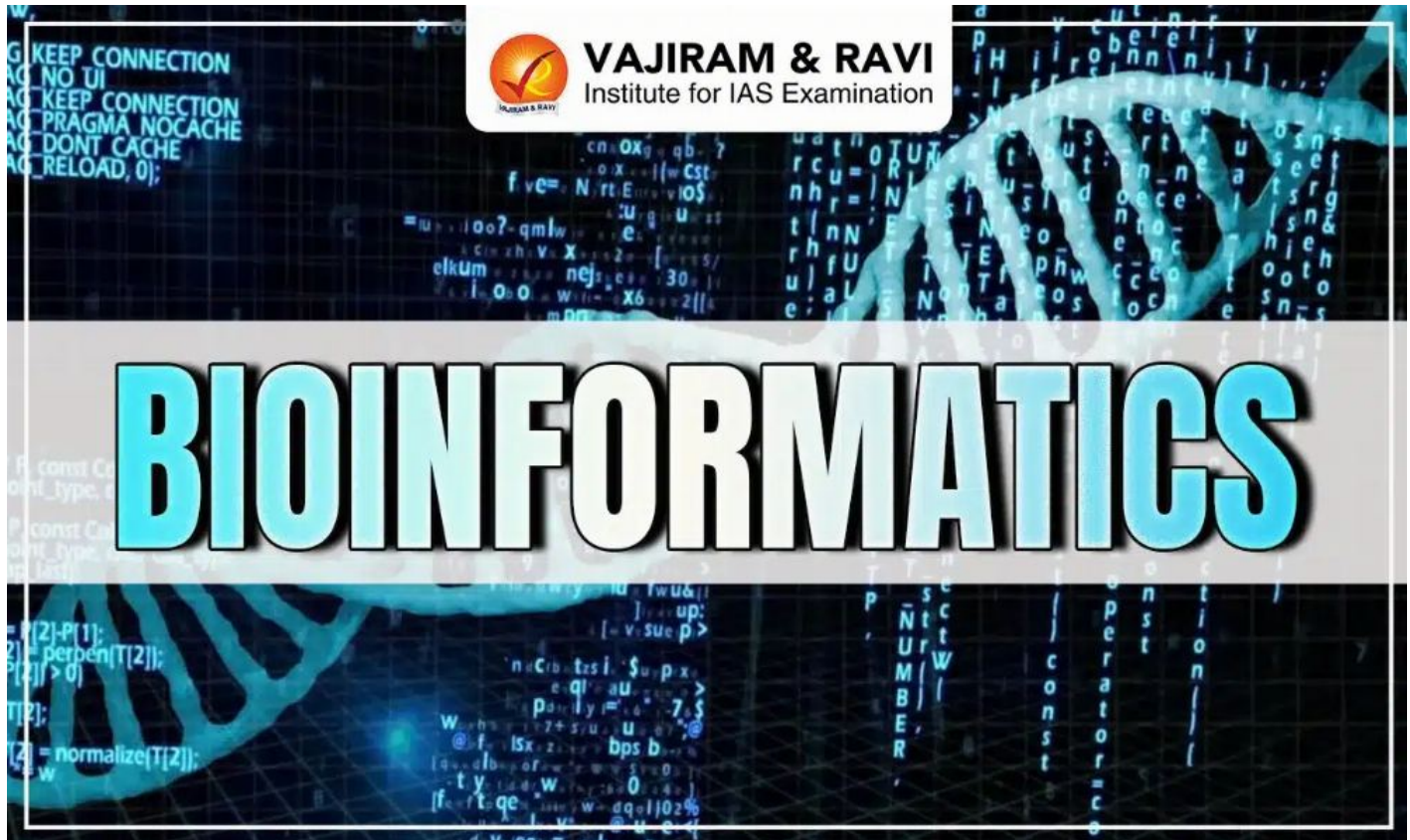


Bioinformatics, Definition, Applications, Challenges, UPSC Notes

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Bioinformatics is a hybrid science that combines biological data with techniques for information storage, distribution, and analysis to support a wide range of scientific research, including biomedicine. Bioinformatics is fed by high-throughput data-generating experiments, including genomic sequence determinations and measurements of gene expression patterns.

The main objective of bioinformatics is to **develop efficient algorithms for mapping and analysing** sequences and pattern recognition analysis and interpretation of biological data using computer-based software and tools.

Bioinformatics Working

Bioinformatics creates strategies and **computer programmes** to comprehend biological data. Following are the **working steps** of the Bioinformatics process:

- **Probing a Large Sequence Database:** Data banks are used to store and organize biological data for Protein structure prediction, sequence alignment, gene and various protein-protein interaction prediction, and genome-wide association studies.

- **Mapping and Analysing:** Collect DNA and **RNA** sequences **to map DNA and protein sequences**, match various DNA and protein sequences to compare them, and build and examine 3D models of protein structures are typical bioinformatics tasks.
 - **For example- Fast Adaptive Shrinkage Threshold Algorithm (FASTA) in Bioinformatics.**
 - FASTA is a text-based peptide and nucleotide sequence representation system.
 - The tools aid in DNA alignment sequencing and protein sequencing.
- **Information-Retrieval:** Information-retrieval algorithms that can deal with the vast amounts of data in the archives.
 - For example: the **Basic Local Alignment Search Tool (BLAST)** uses conservation patterns in related sequences and combines the high speed of BLAST with very high sensitivity to find related sequences.

Application of Bioinformatics

Bioinformatics seeks to discover practical insights and applications such as biological data visualisation, genome informatics, biomedicine phylogenetic analysis, etc.

- **Biological Data Visualisation:** It involves the application of graphics and data representation and incorporates sequences, genomes, alignments, phylogenies, macromolecular structures, microscopy, and other imaging information.
- **Genome informatics:** It is the application of bioinformatics tools to process the outputs of genome-wide assays and technologies, facilitating the interpretation of data and linking them to function to analyse biomolecules.
 - For example - **Human Genome Project**
 - **Genomics** is a field of science that deals with the structure, function, evolution, mapping, and modification of genomes.
- **Transcript prediction** Prediction of transcripts (both coding and non-coding) is important to understanding the identity of unannotated genes/transcripts. Several tools can do this.
 - **For example** - Cufflinks, cuffmerge, and cuffcompare are part of a suite that helps in the identification of transcripts.
- **Phylogenetic analysis:** Phylogenetic analysis is done to determine the evolutionary relationship of an organism with others. It indicates how close that organism is related to others on an evolutionary scale.
 - For example- **Evolutionary biology**
- **Biomedicine:** Precise study of DNA sequence enabled by bioinformatics paved the way for biological research of data analysis. Hence advances in reading DNA sequences led to the development of **personalised medicines, drug delivery, and gene therapy.**
 - **Examples-** Therapy to cure sickle cell anaemia and cystic fibrosis.
- **Structural Biology:** Boost of structural biology with the help of new computational methods.
 - **3-D models of eukaryotic protein** interaction developed by the University of Washington with the help of **evolutionary computer-based techniques** such as Artificial Intelligence to discover **metabolic activities** in our biological bodies.
 - This led to the **discovery of new drug targets** concerning different cellular processes.

- **Medicine and vaccination Preparation:** The study of **genome sequencing** (arrangement of DNA, RNA, and protein in the pathogens) using bioinformatics tools helps develop vaccines and medications.
 - **Example - recent fast-mutating covid19 virus.**
- **Diagnosis:** Bioinformatics is used for transcriptome analysis where mRNA expression levels can be determined.
 - **For example- Polymerase Chain Reaction (PCR)**
- **Tackling Antibiotic resistance:** The discovery of the pathogenicity island with the use of bioinformatics could provide useful markers for detecting pathogenic strains and help to establish controls to prevent the spread of infection inwards.
- **Climate change Studies:** Study the genomes of microbes that use carbon dioxide as their sole carbon source.
 - The Department of Energy, USA, has launched a program to decrease atmospheric carbon dioxide levels.
- **Farming:** Many bioinformatics tools are being used to study **plant genomes to increase the** yield of crops. Moreover, research-backed bioinformatics is also in progress to produce crop varieties capable of tolerating reduced water conditions.

Bioinformatics Sector in India

India is one of the world's top biotech destinations. Many pharmaceutical, information technology, and biotechnology companies have entered the bioinformatics sector due to increasing volumes of genomic data and an increasing number of participants contracting work to Indian companies.

Opportunity and Development

- **Bioinformatics Divisions:** Many Indian companies such as Tata Consultancy Services Infosys, and WIPRO have already established bioinformatics divisions due to **strong IT infrastructure**.
- **Biotechnology Information System Network (BTISnet):** The Department of Bio-Technology, the regulatory body for bioinformatics, established the BTISnet in 1987.
 - **BTISnet** covers several interdisciplinary areas of biotechnology.
- **National Infrastructure Facility for Bioinformatics:** DBT granted revenue and resources for the facilitation bioinformatics ecosystem in India.
- **Bioinformatics Policy of India (2004):** It aims to develop human resources through a schooling program for scientists, research fellows, and scholars pursuing their careers in bioinformatics.
- **Knowledge sharing:** DBT has created a system to facilitate the sharing of bioinformatics knowledge among **SAARC** members.
- **Reduce the cost of drug development:** It reduces the time and costs of developing medicine because of its facilitation with filtering data.
 - It is expected to cut the annual cost of developing a new drug by 33% and the time it takes to discover a new drug by 30%.
- **Capitalising emerging markets:** According to Bioinformatics Market Report Forecasts over the period 2021 to 2026, the global bioinformatics market is predicted to increase at a compound annual rate of

19.36%, from US\$ 10.729 billion in 2019 to US\$ 37.029 billion in 2026.

Challenges of Bioinformatics

There are a slew of roadblocks impeding the growth of computational biology in India and the issues that need to be resolved are as follows:

- **Due to a lack of interest and awareness**, India's software industry does not contribute much to bioinformatics. As a result, there is no efficient database integration, making it difficult to query multiple databases at once.
- **The inability to maintain quality checks and gain** rapid approval for products has resulted in a lack of public-private **relationships and a lack of angel funding**.
- **The lack of a bridge between IT leaders and biologists** is a major barrier to optimal bioinformatics exploration for solving life sciences issues.
- **Data translation:** Biological data is available as a variety of web services all over the world, the disparate data formats present a technical barrier to full utilisation.
 - **For example, Bio Java converts documents into XML formats.**
- **Small share:** Bioinformatics contributes to the smallest part of the biotechnology industry in India. Despite the rapid growth of biotechnology in India, the country only has a 3% share in worldwide biotech industries.

Bioinformatics UPSC PYQs

Question 1: In the context of the developments in Bioinformatics, the term 'transcriptome', sometimes seen in the news, refers to **(UPSC Prelims 2016)**

1. a range of enzymes used in genome editing
2. the full range of mRNA molecules expressed by an organism
3. the description of the mechanism of gene expression
4. a mechanism of genetic mutation taking place in cells

Answer: (b)

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