

Review

BIOINFORMATICS RESOURCE DEVELOPMENT IN PAKISTAN: A REVIEW

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Summary: The article describes the perspective of Bioinformatics, its importance and the measures of implementation in Pakistan and in other developing countries. The article is expected to help in projecting new research ideas embodied in the ongoing research effort being made in this field in Pakistani institutions. The issues and constraints in the development of Bioinformatics are addressed with some suggestions and recommendations. The areas in which jobs can be created for Bioinformaticians and how the required human resource can be produced are also dealt with here. It is an effort to foresee Bioinformatics in Pakistan by integrating the potential areas and the steps taken by HEC (Higher Education Commission) of Pakistan to promote its infrastructure in the country. It is expected that some of the perspectives discussed in this article will raise new questions and will become a basis for new discussions.

Keywords: Pakistan, Bioinformatics, biology, genomics, proteomics.

Introduction

Bioinformatics lies at the interface of biology, computer science and mathematics. The ultimate goal of the field is to enable the discovery of new biological insights as well as to create a global perspective from which unifying principles in biology could be discerned. The advent of sequencing technologies and the human genome project sparked the creation of a data-rich enterprise in biology [1]. Continuing input from computational and molecular biology research has together transformed Bioinformatics into an applied field with great promise. It is high time for us to carefully analyse how far a developing country like ours can reap the benefits of a Biotech-IT nexus in the form of Bioinformatics. Before we consider the current state and future applications of Bioinformatics in Pakistan, it would highly informative to have a look at the global Bioinformatics scenario. The

research report “Bioinformatics Market Update (2006)” recently published by Research and Consultancy Outsourcing Service (RNCOS) provides an updated and detailed overview of the Bioinformatics industry worldwide [2].

Genomics and proteomics are providing an ever-stronger baseline for application development in healthcare industry. Development of applications based on genomics and proteomics has mainly contributed in boosting the growth of bioinformatics tools over the past few years. A greater number of R&D centres across the world are seeking a common platform for transfer of data, information and knowledge to enable an informatics-based decision support system. Over the past few years, bioinformatics has gained acceptance among a number of markets especially in pharmaceutical industry and in industrial and agricultural biotechnology. Major players in the bioinformatics industry include

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Accelrys, Compugen, Celera Genomics, IBM Life Sciences Solutions, Incyte Genomics and LION Bioscience AG. With current revenues at around \$840 million, the bioinformatics market is expected to become even more dominant in the future and increase to around \$1.82 billion by 2007 [2]. The growth rate is expected to stabilize at 17 percent per annum until 2007 [2]. Currently, the largest markets for Bioinformatics include USA, Europe and Japan. The total European Bioinformatics market is set to expand from nearly \$310 million in 2004 to \$720 million by 2011. In the neighbouring India, there is a \$300 billion pharmaceutical industry and a very fast-growing supporting biotech industry. It is a \$300 billion industry, spending \$30-40 billion a year in R&D.

Bioinformatics is being practiced worldwide by academic groups, companies, national and international research consortia. Currently, bioinformatics is focusing worldwide on prediction of the functions of newly identified genes, finding the repetitive sequences, regulatory elements, restriction analysis, primer designing, extraction of protein sequence from nucleotide sequence to predict the structure, estimation of the evolutionary distance for phylogeny reconstruction, determination of the active sites of enzymes, identification of mutations, characterization of SNPs (haplotype analysis), 2D gel studies, modeling and simulation, finding protein interactions and visualization assays (Fig. 1). Most significant applications of bioinformatics are in the research institutions where scientists are working on a wide range of topics ranging from protein chemistry to siRNA and functional genomics (Table 1).

Given the current state of biotechnology and molecular biology research in Pakistan, it appears that bioinformatics expertise is mainly required in limited areas. While on the one side a lot of effort is still required to strengthen the basic research infrastructure at universities and

research institutions, on the other side we need to take initiatives in promoting modern sciences and integrating them into the already developing basic sciences.

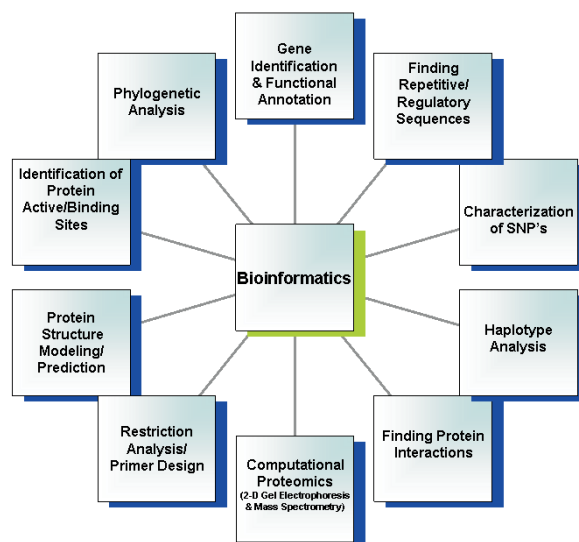


Fig. 1. Major application areas of bioinformatics.

Major Problems in the Development of Bioinformatics in Pakistan

The field of bioinformatics is so new that one cannot fulfil the manpower demands to cope with the problem of increasing data. Not only the size of sequence data is rapidly increasing but also the number of characterized genes and protein structures from many organisms doubles every two years. The first requirement is that all these data need to be stored. The second requirement is the need for radically new methods for analyzing these huge databases. Thirdly, powerful hardware is required to carry out the task of analyzing these databases. The speed with which bioinformatics is growing globally, the academia is unable to produce the necessary trained bioinformaticians. The genome sequencing projects are creating incredible amounts of sequential data. Whoever will get this information under control first will win. Not only in Pakistan but also in the other developing countries, there is considerable need at the moment in the scientific community for people

who may fill the gap in this field. Without bioinformatics, new research in most fields of medicine and biology would stagnate or at best remain handicapped. Unfortunately, there is dearth of investigators in Pakistan who are able to meet the challenges posed by new developments in biology in particular and in science in general. There is very little participation by our scientists in the process of developing genome resources and fighting disease. This is largely due to a low rate of absorption of new technology because of lack of financial resources and absence of the crucial network that is necessary to meet these demands.

How to improve Bioinformatics in Pakistan?

In order to meet the demands of bioinformatics research and identification of trained manpower in Pakistan, several lines of actions would be fruitful. There is always room at the top for people who are very good at what they do. To increase the number of resource people, there can be a transition into bio-informatics of experts from other fields. Those scientists having expertise in the areas of microbiology, cell biology, molecular biology, environmental biology, medicine, mathematics and computer sciences may interact and join hands for solving given biological problems. One important step aimed at improving bioinformatics research in Pakistan is development of Bioinformatics Support Centers in universities and institutions with active life science research. Top ranking universities and research centres across the world have already developed such support centers over the past few years [3]. Here the bioinformatics research and technology development are strongly connected with life sciences research. This has empowered their molecular biology and biotechnology research to contribute towards national progress. There is also a huge gap between creation of databases and establishing ways for the best usage of these. Interaction between different databases is problematic,

which remains an unsolved problem. To get rid of it, research institutions should focus on IT technologies for developing process efficiencies and increased throughput. IT professionals may play a significant role in electronic data capture, data mining, data warehousing, data visualization and designing the customized software. There is a great need of computer tools in the areas such as molecular modeling, microarray gene expression, gene identification and prediction, evolutionary comparison, functional assays, identification of drugs and drug targets, visualization tools and protein studies. Biologists may get into bioinformatics by picking up programming, while others may enter via the reverse route. The required programming skills include HTML, Perl, JAVA and C++. Also, familiarity with a variety of operating systems (especially UNIX) and relational database skills (SQL, Oracle) are very much sought after. There is also a huge demand for people who can communicate with both biologists and computer scientists. To meet this challenge, short bioinformatics courses should be initiated along with improvement in school education. Another area of bioinformatics that needs to be expanded is determination of relationship between structure and sequence. Entry into this area requires learning structural biology and modelling, mathematical optimization, computer graphics theory and linear algebra. There is also dire need of interaction between industry and scientific research in Pakistan. Increase in the demand and growth of bioinformatics industry has been noticed only in those regions where there is a strong supporting biotech industry. Biotech industry, in turn, gets its strength from highly established research infrastructure, having potential of active research as well as its conversion to publicly embraced technologies. Such a scenario is currently a far cry from reality in Pakistan. However, we have seen a significant increase in academic research potential over the past few years in Pakistan. We expect this trend to continue with the hope that the government

would pay even greater attention to human resource development and incentives for scientists engaged in productive research than has been possible in the past.

Bioinformatics jobs in Pakistan

Pakistan offers unique genetic resources in human population, crops and other species. In several areas such as development of crop varieties, Pakistan offers genuine promise. In other words, service provision in bioinformatics is possible. Although the research and development capabilities in Pakistan are limited, the bioinformatics graduates can be absorbed in prestigious universities, agri-biotech and pharmaceutical companies (Fig. 2). Teaching programs geared towards training individuals at the graduate/undergraduate levels and arousing interest in the subject are imperative. The government needs to provide a network of communication among the existing scientists, academic institutions and research organizations. Effective communication and collaboration amongst all sectors is crucial for the success of bioinformatics and would push technology transfers from research to industry.

Many types of bioinformatics jobs are available currently for computational specialists involving the design and implementation of programs and systems for the storage, management and analysis of vast amount of DNA sequence data. As the field of bioinformatics matures, there will be a great need for people having in-depth knowledge of biological processes in order to determine the novel targets. Other areas, which can be considered for job creation, are described below.

Role of industries in job creation

The field of Bioinformatics is multi-disciplinary. With informatics providing enormous computing powers to the bioscience processes,

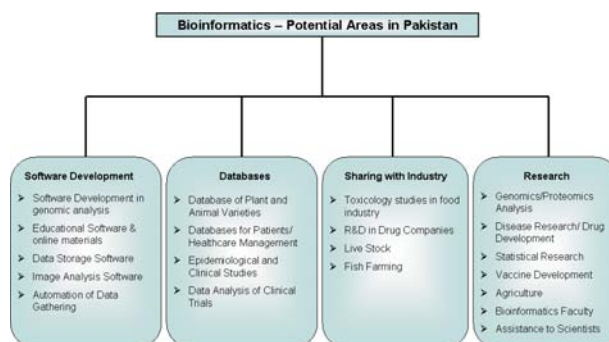


Fig. 2. The potential job areas in Pakistan.

bioscience firms are readily allowing the expansion in their IT infrastructure for R & D operations [4]. Biotechnology is used across a wide range of applications including health care, agriculture, environmental protection, industrial applications and crime investigation [5]. However, globally the focus of biotechnology is on health care. The industry has continued to be a highly R & D incentive with R & D expenses exceeding 50% of revenues [6]. The significant industrial demand for bioinformatics professionals is perhaps more pronounced among biotechnology and pharmaceutical companies in Pakistan than in other areas. The official web site for the list of companies registered with the Board of Investment is available at www.pakboi.govt.pk/pak/list.asp [7].

Database development

Databases can be developed using a number of different methods including simple file directories, object-oriented database software and relational database software [8]. Relational databases provide effective means of storing and retrieving large quantities of data via indexes, normalization, referential integrity, triggers, and transactions. Notable relational database software that is freely available and quite popular in bioinformatics is MySQL [9]. In relational databases, data are represented as entities, attributes and relationships between the entities. This type of representation is called Entity-Relationship (ER) and database schemas are

described using ER diagrams. SQL has a reasonably intuitive and simple syntax that requires no programming skills and is suited for biologists to learn. In most databases, access to the data is provided via database access software and graphical user interface (GUI) that allow searching and browsing of the data. Efforts are required for development of database interfaces, developing software that will connect to individual databases directly, or developing a data warehouse of many different data types or database in one site. Projects such as myGRID [10] are implementing these ideas for biological databases, but are not widely used.

Clinical management

The fields at the periphery of bioinformatics such as laboratory information management systems (LIMS), medical informatics and clinical trials management [11] should not be neglected by Pakistan. Major objectives of LIMS include, shortening the turnaround time of lab tests, improving the access to the results database, improving the productivity, improving the accuracy of results, counting and monitoring the resource utilization, and exchanging the data and information both with analytical equipment and mainframes. The problems in these areas in Pakistan and the developing countries are regulatory uncertainties, involvement of multiple agencies for approval of biotech products, lack of extensive documentation of patient records and low level of patient literacy. Knowledge of good clinical practices and establishment of ethics committees in health care facilities will be an important stepping-stone for solving these problems.

Research tools designing

In Pakistan, the development of new crop varieties and vaccines is admirable. There is a good trend of research in areas of molecular biology, particularly for identification of diseased

loci responsible for the hereditary disorders, drug targeting, agriculture and live stocks (Table 1). The conventional research occurring in the world would fail without bioinformatics and molecular biology. By implementing bioinformatics research, new tools of data analysis would be developed to help scientists gain insight into many of the new areas in an efficient way. Awareness of the existing tools is necessary to get information about the solved issues and deriving novel ideas for the development of new tools. Useful web links of bioinformatics tools can be accessed through [12].

Pharmaceutical areas

In the advanced countries, the biggest job sector for Bioinformaticians is the pharmaceutical industry. Research in the fields of drug designing [13], finding targets of drug [14] and identification of new therapeutic tools is vital. Other related areas include Pharmacogenomics and Cheminformatics to broaden the number of jobs.

Pharmacogenetics draws on the study of human variations (predominantly SNPs), to reduce the drug side effects in a genetically heterogeneous patient population [15,16]. Pharmacogenetics on the one hand will reduce the market of a drug by reducing the target population, while on the other hand it will increase the drug revenues by rescuing several drugs from clinical trials. Also the prospects of personalized medicine will tremendously increase research in pharmaceutical industry. At the same time, it will require physicians to obtain genetic data from their patients (clinical management).

Cheminformatics deals with the chemical and biological data integration, structure comparison and compound acquisition and chemical data mining assays. It is actually a generic term that encompasses the design, creation, organization, management, retrieval,

analysis, dissemination, visualization and use of chemical information [17].

Universities and Research Institutions: Role in Bioinformatics

The major role that universities and other R&D institutions can play in the field of bioinformatics is training of researchers in the areas described in the above mentioned sections. There is need of strong collaboration at institutional level by developing a platform for integration of a wide range of services and tools in order to make these easily available, in

particular to the biological research community. Developing interoperability standards and deciding how to judge a good piece of open-source software are some of the open challenges. To facilitate and enhance the biological research by Bioinformatics solutions, it is necessary to get a thorough knowledge of bioinformatics tools and gain insight of the quality research occurring by the local research groups. A look at the projects funded by HEC (Table 1) reveals that active research is being conducted in several areas of life sciences in Pakistan, providing a basic representational framework leading to the unification of Bioinformatics as a primary candidate.

Table 1. Major funded ongoing research projects at various Pakistani institutions.

Title of the Project	Institution Conducting Research
Identification of genes involved in hereditary hearing impairment	Quaid-i-Azam University, Islamabad
Screening for vision and hearing impairment in rural Sindh and Balochistan	University of the Punjab, Lahore
Identification, characterization of drug resistant <i>E.coli</i> and its treatment: A perspective of novel antibacterial agents	University of the Punjab, Lahore
Isolation, purification and characterization of protease inhibitors from plants	Centre for Advance Studies in Biotechnology, University of Sindh
Genetic and molecular basis of recessive deafness	University of the Punjab, Lahore
Production and characterization of engineered proteins containing non-natural amino acids; potential tools for specific drug targeting	University of Karachi
Characterization of loci responsible for inherited eye anomalies in families of Pakistan	COMSATS Institute of Information Technology
Prevalence of bovine tuberculosis in human, animal population and animal food products	University of Veterinary and Animal Sciences
Atherosclerosis an inflammatory disease: Roles for cyclooxygenase-2	University of Karachi
Botanical, chemical and pharmacological studies of important medicinal plants by establishment of medicinal plant farm.	Kohat University of Science and Technology
Process development for the production of enzyme invertase by <i>Saccharomyces cerevisiae</i>	Govt. College University, Lahore
Vanadium complexes as Insulin Mimetic Agents: Coordination chemistry, characterization and biological studies of vanadium (IV) and vanadium (V) complexes of various ligands containing carboxylate group	Quaid-i-Azam University, Islamabad
Extraction, Isolation and Investigation of some indigenous Natural Products for their Anti-leishmanial activities	Gomal University, D.I. Khan
Isolation, structural elucidation and bioassay of the constitutions of oconitum violaceum jack	Gomal University, D.I. Khan
Synthesis and biological screening of combinatorial libraries of small drug-like molecules to establish compounds activity relation and drug development	Quaid-i-Azam University, Islamabad
Synthesis and biological studies of some anti-narcotic drugs	University of Karachi
Isolation of structural elucidation and biological activity of some medicinal plants of Pakistan and Iran	University of Veterinary and Animal Sciences
Synthetic manipulations of bioactive amino sugars for the development of new antiosteoarthritis, antiviral and antitumor agents—a new approach in drug designing and SAR studies	University of Karachi
Development of new antiviral and anticancer steroids by combinatorial synthesis and high-throughput biological screening—a new approach to drug discovery	University of Karachi
Peptidyl antibiotics: structure-function relationship of the antimicrobial peptides and	University of Karachi

- bacteriocins/antibiotics from indigenous *Enterococci*
- Effect of cloves, bay leaves and turmeric on blood glucose and lipid profile in diabetic individuals. NWFP Agriculture University, Peshawar
- Photodynamic Diagnosis System: A new method for the early recognition of bladder tumor Liaqat University of Medical and Health Sciences, Jamshoro, Sindh
- Finite element modeling of blood flow: relevance to atherosclerosis Mehran University of Eng. & Technology, Jamshoro
- Studies on the effects of alcohol and antidepressant on tryptophan metabolism and disposition in stressed and unstressed conditions. University of Karachi
- Studies on the effect of Vitamin C supplementation on lead levels of blood, hair and urine in adults The Aga Khan University, Karachi
- Phytochemical investigations on the genus *Abutilon* with emphasis on the isolation of some hypoglycaemic factors University of Karachi
- Identification and characterization of drug resistant *E.coli*, and its treatment: A perspective of novel antibacterial agents University of Punjab, Lahore
- Determination of essential and trace elements in biological samples of human subjects with various physiological disorders University of Sindh, Jamshoro
- Synthesis of metal-based sulphonamide-derived novel antibacterial, antifungal and antiviral compounds. Bahauddin Zakaria University, Multan
- Synthesis of some natural and unnatural isocoumarins and related compounds in search of potential chemotherapeutic agents University of Karachi
- A histological study of human olfactory mucosa National University of Science and Technology, Rawalpindi
- University of Karachi
- Studies of nano-enzymatic glycation in Pakistani subjects suffering from diabetes and cataract: a proteomic approach. University of Karachi
- Suppression and treatment of Tardive dyskinesia: Neurochemical and pharmacological studies on a rat model. University of Karachi
- Effect of Papranolol on the morphology of rat testis National University of Science & Technology
- Preparation and evaluation of sustained released analgesic drugs University of Peshawar, Peshawar
- Vaccine Development against Hepatitis-C virus (Type 3a) The Aga Khan University
- Atherosclerosis-an inflammatory disease: role for Cyclooxygenase-2 The Aga Khan University
- Activities of plasma membrane and vacuolar H⁺-ATPase and accumulation of antioxidants as markers of salt tolerance in a potential oil seed crop canola University of Agriculture, Faisalabad
- Phenolic allelochemical of sunflower as natural herbicide for weed management in wheat University of the Punjab, Lahore
- Physiological basis of drought and high temperature tolerance in wheat Quaid-i-Azam University
- Utilization of Plant growth promoting and nodule producing Bacteria in control of root knot nematode and root infecting fungi University of Karachi
- Socioeconomic improvement of Cholistan desert dwellers through exploitable genetics improvement Islamia University Bahawalpur
- Biochemical characterization of in vitro salt tolerant cell lines and regenerated plants of potato and subsequent establishment under ex-vitro University of the Punjab, Lahore
- Plant biodiversity conservation and its sustainable use of Kirther Range University of Karachi
- A survey of germplasm resources and phytosociology, ecotype variations in morphological, anatomical, biochemical characterization and phytoremediation potential of two aromatic grasses with special reference to southern Punjab Islamia University, Bahawalpur
- Generation of salt resistant tomato by using HAL II genes and molecular analysis of transgenic Quaid-i-Azam University
- Dendrochronological potential of pine trees species of Pakistan Federal Urdu University of Arts, Sciences and Technology, Karachi
- University of Agriculture, Faisalabad
- Identification of biochemical indicators for salt tolerance and their genetic basis in potential oilseed crops, canola and sunflower University of Karachi
- Salt-induced oxidative stress, consequences and management University of Karachi
- Impact of agronomic practices on water use efficiency of rainfed wheat NWFP Agricultural University, Peshawar
- Reconstruction of chromosomal inheritance in pedigree of Pakistani wheat cultivars Kohat University of Science & Technology
- Micropropagation and cultivation of some economically important plants of Balochistan Balochistan University of Information Technology and Management Sciences

Floristic phyto-geographic and ethno-botanical studies of vascular biodiversity in Swat, Kohistan (upper Swat), Hindukush range, Swat	University of Peshawar
Studies on biology, ecology and physiology of wild oat (<i>Avena fatua</i> L.)	NWFP Agriculture University, Peshawar
Studies on epidemiology & biology of virus & viroid diseases of Citrus & their control through integrated approaches	NWFP Agriculture University, Peshawar
Efficacy of water users organizations and water management in agriculture (a study of water crisis and irrigation system in Pakistan)	Quaid-i-Azam University
Farmers' capacity building through information technology in Shaikhupura.	University of the Punjab, Lahore
Integrated management of aphid in canola in D.I.Khan	Gomal University, D.I.Khan
Preparation and characterization of complexes of some of biological active chelating agents	University of Peshawar, Peshawar
Use of allelopathy for reducing herbicide imports.	University of Agriculture, Faisalabad
Systematic study of the berry bugs (Heteroptera: Pentatomidae: Pentatominae: Halyini) of Sindh	University of Sindh
Identification, tissue-specific expression and immunolocalization of stress proteins (dehydrins) under high temperature stress	University of Agriculture, Faisalabad
Pathobiology of Shisham (<i>Delbergia sissoo</i>) dieback	Quaid-i-Azam University, Islamabad
Physiological basis of drought and high temperature tolerance in wheat (<i>Triticum aestivum</i> L.)	Quaid-i-Azam University, Islamabad
Medicinal and pesticidal agents based on targeted species	University of Karachi, Karachi
Mass rearing of Coccinellid predators on different insect pests	Sindh Agriculture University, Tandojam
Biochemical characterization of in vitro salt-tolerant cell lines and regenerated plants of potato (<i>Solanum tuberosum</i>) and subsequent establishment under ex-vitro conditions	University of the Punjab, Lahore
Diagnostic and research centre for mango orchards	Bahauddin Zakariya University, Multan
Bionomic systematics & predatory efficacy of Phytoseiid and stigmatiid against harmful mites and small insects.	University of Agriculture, Faisalabad
Bioecology and systematics of acridoid grasshoppers (Orthoptera) with special emphasis on <i>Heiroglyphus nigrorepletus</i> from AJ&K.	University of Azad Jammu & Kashmir, Muzaffarabad, Azad Kashmir
Plant biodiversity, conservation and its sustainable use of Kirthar range.	University of Karachi, Karachi
Studies on low productivity of mango orchards: causes & possible remedies.	Bahauddin Zakariya University, Multan
Phenolic allelochemicals of sunflower as natural herbicides for weed management in wheat.	University of the Punjab, Lahore
Response of rice based cropping system to soil and root dip Zn application under integrated fertilization.	Gomal University, D.I. Khan
Multiplication of <i>Chrysoperla carnea</i> as a biocontrol agent in integrated pest management.	University of Agriculture, Faisalabad
Sustainable use of plant wealth of Chitral and preparation of red data list.	University of Karachi, Karachi
Integrated Pest Management (IPM) of Asian Ambrosia beetle - a vector of a killer disease of mango in Sindh	Sindh Agriculture University, Tandojam
Biosystematics of dragonflies (Odonata) of Pakistan	University of Arid Agriculture, Murree Road, Rawalpindi
Effect of neem products on some economically important insect pests of cotton, gram and muskmelon and their natural enemies.	Gomal University, D.I. Khan
Utilization of plant growth promoting and nodule forming rhizobacteria in the integrated control of root infecting fungi of sunflower and soybean.	University of Agriculture, Faisalabad
Inducing salt tolerance in cereals through bacterial ACC-deaminase biotechnology	University of Agriculture, Faisalabad
Conservation and cultivation of two aromatic grasses—Vetiver & Cymbopogon—with special reference to southern Punjab.	Islamia University, Bahawalpur
Micropropagation and cultivation of some economically important plants of Balochistan	University of Balochistan, Quetta.
Impact of agronomic practices on water use efficiency of rainfed wheat	NWFP Agricultural University
Potential species identification and evaluation as efficient resource capture and utilization for forage in remote sector of NWFP	NWFP Agricultural University, Peshawar
Enhancement of performance of direct seeded rice by seed priming	University of Agriculture, Faisalabad
Analytical characterization of some non-conventional oil seed crops of Pakistan for promoting their conservation, utilization and potential oil production	University of Agriculture, Faisalabad
Salt-induced oxidative stress, consequences and management	University of Karachi
Cross adaptation and <i>in vitro</i> development of salt tolerant somaclones of rice	NWFP Agricultural University, Peshawar

Evaluation and control of post harvest losses in colocasia	NWFP Agricultural University, Peshawar
Development of induced breeding larval and fry rearing techniques for Indus River Palla, <i>Tenulosa ilisha</i> Hamilton	University of Sindh
Aqua fed formulation and assessment for Marketing	University Karachi, Karachi
Some studies to improve meat and milk production to sheep in and around Multan by gonadotrophin supplementation	B.Z. University
Serodiagnosis tests for infectious diseases of the poultry	University of Karachi, Karachi
Rapid diagnosis and immunoprophylaxis of acute viral diseases in Canines Lahore	University of Veterinary and Animal Sciences,
Screening nematode populations of sheep and goats for development of anthelmintic resistance against commonly used anthelmintics on Government livestock farms of NWFP and Punjab	University of Agriculture, Faisalabad
Some studies to improve meat and milk production of sheep in and around Multan by gonadotrophin supplementation	Bahauddin Zakariya University, Multan
Selection and characterization of starter culture for fermented milk products	University of Arid Agriculture, Murree Road, Rawalpindi
Serodiagnostic tests for infectious diseases of the poultry	University of Karachi, Karachi

Ongoing Efforts

Bioinformatics cannot be disregarded by any country intending to remain up-to-date in the biomedical, biotechnological and agricultural sectors. Challenges in the education and training in bioinformatics are readily apparent. This field is becoming increasingly interdisciplinary/multidisciplinary, as emerging technologies are constantly adding to the amount of information that faculty and students across disciplines can gather, analyze, manipulate, and present. A few universities, both in public and private sectors, are currently running undergraduate programs in Bioinformatics. In terms of content and faculty, these programs have an acceptable level of competence. Nevertheless, it is a very challenging task to produce undergraduates in bioinformatics possessing multidisciplinary skills, readily applicable knowledge and research potential. It is equally demanding on the student's part as well, given the limitation of available resources. Besides focusing of the interest on diverse courses in biological and computer sciences, the real strength of academic programs in bioinformatics lies in the degree of integration and cross-disciplinary communication skills. Computations pertaining to biological information are complicated and require an organized effort by the instructors and the students.

The efforts at the Government level are also admirable. Pakistan Education and Research Network (PERN) [18] through its nodes at the Centre of Biotechnology, University of Peshawar [19], the university of Karachi [20] and the Centre of Excellence in Molecular Biology (CEMB), University of the Punjab [21], are actively collaborating to build a Bioinformatics and computational resource in collaboration with the Asia Pacific Bioinformatics Networks (APBioNet) [22]. Part of this effort includes the successful establishment of an official Bio-Mirrors node at CEMB and the University of Peshawar. Bio-Mirrors is an APAN-APBioNet joint project that was started in 1998. PERN and HEC have closely worked with the University of Peshawar to establish a pilot project called "bioinformatics@PERN" with the S* Alliance (Life Science Informatics Alliance) team the secretariat of which is based in Singapore. The bioinformatics@PERN features the use of Bio-Moodle, which is a deployment of the online education open source software called Moodle [23] for bioinformatics. This course had observers from Japan, Korea and Thailand. At the moment, there are three educational institutions offering a four year (8 semesters) BS Bioinformatics programme in Pakistan. These are COMSATS (Committee on Science and Technology for the Sustainable Development in the South) Institute of Information

Technology, Islamabad [24], Mohammad Ali Jinnah University, Islamabad [25] and International Islamic University, Islamabad [26]. Recently, COMSATS acquired the membership of EMBnet (European Molecular Biology Network) and represents as the national node of Bioinformatics in Pakistan. It has established a powerful web server for the fast usage and efficient access of Bioinformatics tools. The Higher Education Commission of Pakistan (HEC) [27] is playing an admirable role by recruiting highly qualified professionals (under foreign faculty hiring program) for improving the research infrastructure of public sector Pakistani institutions. Training workshops are jointly conducted occasionally by COMSTECH (Organization of Islamic Conference Standing Committee on Scientific and Technical Cooperation, Pakistan) [28] and HEC in the areas of Bioinformatics and life sciences, in which foreign scientists and resource persons are invited to deliver lectures.

HEJ (Hussain Ebrahim Jamal) Research Institute of Chemistry, Karachi [29] is a prominent institute in Pakistan with emphasis on the chemical and biochemical sciences and mobilizing resource for the development in these fields. Major areas to focus include natural product chemistry, protein chemistry, pharmacology of herbal medicines and plant biotechnology. The Panjwani Centre for Molecular Medicine and Drug Research (PCMD) [30] like HEJ is also affiliated with the Department of Chemistry, Karachi University. The main research areas in PCMD are the emerging fields of molecular medicine and drug development. The efforts in the centre are mainly focus on developing greater and more comprehensive understanding of the pattern and causes of common diseases of Pakistan in order to develop effective diagnostic tools and affordable treatments. The faculty members of both institutes are involved in drug discovery, screening of natural compounds, discovery of

new therapeutics using a combination of *in silico* and medicinal chemistry methods, molecular modeling, computational chemistry, computer-aided drug design, bioinformatics related to drug design, virtual screening (docking, scoring, 3D-QSAR; CoMFA, COMSIA), virtual combinatorial library design, molecular dynamics simulations and ab initio calculations, and study of enzyme inhibitors. In short, both HEJ and PCMD are potential foci of expertise to develop drug discovery research in Pakistan. Information about the research groups at HEJ and PCMD can be obtained from [29] and [30], respectively. In short, Pakistan is on the way towards a global Bioinformatics market.

Emerging Fields in Bioinformatics

Nutritional informatics

Nutritional genomics is a field that is growing very fast. It deals with multiple issues. What should be a balanced diet for patients? Selection of particular type of diet according to genetic makeup is an increasing problem. About 15% of folks are born with a form of liver enzyme that causes their HDL, or good cholesterol level to go down in response to dietary fat [31]. In most cases, the HDL level goes up, counterbalancing some of the bad effects of dietary fat on LDL (the dangerous cholesterol). Indeed there is a great need to begin tests for a limited number of gene-nutrient interactions and a database development covering these issues.

Functional Genomics

The field of functional genomics is advancing rapidly. Developments in this field will have a profound influence in the wet as well as dry labs. One application of such technology is the development of microarray chip or the gene chip [32]. In this system a small volume of sample is enough to analyse hundreds of tests, and several hundred samples can be analyzed in

a very short time using a signal compact instrument. With the unravelling of the human genome, it is possible to examine DNA for defects that may have adverse effect, using DNA chip technology [33]. The interplay between the advances in bioinformatics and functional genomics defines an interesting positive feedback between these two areas (Fig. 3). The more logical and broader understanding of functional genomics will generate ultimately, an integrated realm that cannot be comprehensively understood without bioinformatics.

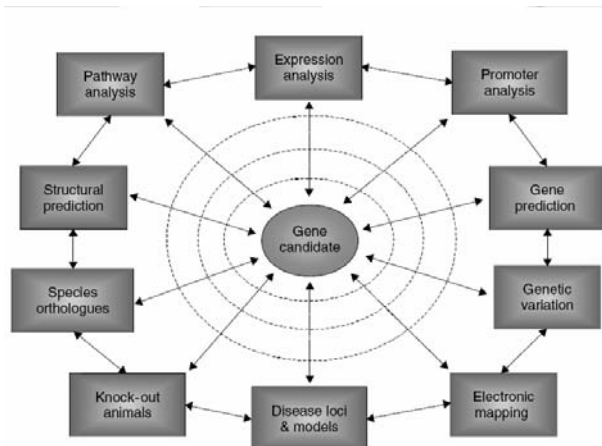


Fig. 3. Scheme for functional analysis of gene using functional genomics approaches: Bioinformatics as the general area involving the application of informatics to biology (dotted circles).

Computational System Biology

Classical system analysis in engineering treats a system as a black box whose inner structure and behaviour can be analyzed and modelled by varying internal or external condition, and studying the effect of the variation on the external observables [34]. The result is an understanding of the inner makeup and working mechanisms of the system [35]. System biology is the application of this theory to biology [36]. The observables are measurements of what the organism is doing, ranging from phenotypic description to detailed metabolic profiling. Some

areas that require more work include creating coherent validated data sets, developing common formats for pathway data and creating ontologies to define complex interactions, curation, and linkages with text-mining tools. The System Biology Work-bench project [37] aims to develop an open-source software framework for sharing information between different types of pathway models. Other issues are that biological systems are underdefined (not enough measurements are available to characterize the system) and samples are not taken often enough to capture time changes in a system that may occur at vastly different time scales in different networks such as signalling and regulatory networks [38, 39].

Semantic Web

Semantic web is a model to create a universal mechanism for information exchange [40]. This model will enable the development of searching tools that know what type of information can be obtained from which documents and understand how the information in each document relates to another. It will allow IT professionals to generate reason and logic and to make decisions automatically based on the constraints. Bioinformatics could benefit enormously from successful implementation of this model and could play a leading role in realizing it.

Nanotechnology

Research in nanotechnology and electron microscopy is allowing researchers to select specific areas of cells and tissues and to image spatiotemporal distributions of signalling receptors, gene expression, and proteins [41]. Laser capture microdissection allows the selection of specific tissue types for detailed analysis [42]. The emerging bioinformatics may help in new understanding of cell dynamics through this technology.

In Pakistan, the pace of development in this area is exponentially growing in the recent years. The research institutions like Ghulam Ishaq Khan Institute, NWFP, Pakistan, have extensively initiated research in nano-composites, nano-magnetics, nano-polymers and the techniques involved in the synthesis and characterization of nano-materials thus produced [43]. Other institutions include, PINSTECH (Carbon based Nanotechnology, Quantum Dot based Laser Diodes) [44], Physics departments of COMSATS and Quaid-I-Azam University, PCSIR [45] and National Centre for Nanotechnology, PIEAS [46]. Government of Pakistan has established recently a National Commission on Nano-Science and Technology (NCNST) to help the local research institutions and universities in labs development and to support the existing nanotechnology projects being carried out in Pakistan. NCNST had already held three conferences on Nanotechnology in the last year to develop the community in Pakistan for possible interactions and enhancing the scope in this field.

Concluding Remarks

The ongoing efforts in Bioinformatics networking, computational and database resources as well as in educational programme are bound to kickstart the expansion of the advanced internet applications in various disciplines and will facilitate the connection to plug Pakistani research institutions and universities into the pulse of world class research. It is the need of hour to keep attracting students in this industry by expanding awareness and by setting up additional teaching institutions in the educational sector of Pakistan. Moreover, collaboration between local and foreign universities is a vital need. Also, the important question to remember is: What will be the future of increasing Bioinformaticians? One fear is that there will be fewer jobs than the Bioinformaticians in the country. However, the

situation is not too alarming at the moment. We need to initiate fruitful efforts to multiply the jobs for gaining our share of the global Bioinformatics business.

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