Biology: Historical and Developmental Trends

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Abstract

The history of biology at its earliest periods cannot be described without mentioning the roles played by Aristotle, Hippocrates, Galen and, Theophrastus in ancient Greco-Roman world, and Leonardo da Vinci in Italy among others, who did studies that helped ignite and consequently shape the early periods of the study of biology as a field of natural science.

This underwent progress in growth, developments of new and advanced tools, and methods in its study. It enhanced emergence of the era of seeking to understand life much better from the cellular and sub-cellular levels. Biology has grown over the scores of decades from mare study of organisms in their gross structure and functions. This was accompanied with correlating them with functions that are observed into seeking to understand these organisms at deeper perspectives from their molecules and ultra-structures, such as through emerged fields like molecular biology, metabolomics and synthetic biology and cell biology) features. It has opened up deeper insights to support better understanding of life features. The resultant effects have been emergence of new fields under biology, using advanced techniques to study life. These has supported biological investigations with improved drugs, varieties of crops and animals, industrial bio-products like enzymes, hormones, bio-polymers that are more environmentally friendly and more robust ways to study our ecosystem and tackle emerging environmental problems.

In this review we present its historical overview, developments are presented to provide an overview for trends in biology over the ages.

Introduction

It is difficult to pinpoint the precise moment when the first notions of Biology as a formal field of study began, but several schools of thought in biology have attributed this to the Aristotle's era of study which dates back to a period between 384-322 BC. Aristotle's studies encompassed the entire world of living things as many of his descriptions and classifications remain sound today, although he was not a physician, it exerted profound influence on medicine as well for the next 2000 years biology is a science that studies life from the most microscopic beings to the macroscopic flora and fauna life forms of living things. In recent developments, biological scientists have acquired knowledge and skills to deep-sequence, read, analyze and annotate genes and genomes of living things; and moved beyond this into editing existing genomes and stitching pieced of DNAs into an assembly to create new strains of species and chassis design-build-test synthetic cells [1].

The discovery of the electron in 1897 marked the beginning of a major turning point in the history of science. This now enables efficient and robust use of increasing large volume of data for inquiry, insights, elucidations, discoveries and wide range applications that supports healthcare (for therapeutic discoveries and innovative life support systems), industry, agriculture (to increase yields and in disease controls), environmental management (bio-remediation, eco-friendly environment and protection of rare species) and space explorations. The life sciences have been in a midst of historical period analogous to the 20th century in the physical sciences. This has been harnessed through development of electron microscope in scientific discoveries. Biology, physics and chemistry use matter (of small sizes) within life organizational frames, such as molecules, micro-organelles and other forms of very minute cell and tissue inclusions to study and tackle issues that help promote life on earth.

Modern biology has witnessed the entry of systems biology and synthetic biology into the framework of biology is contributing to science of human and animal health care, and environmental management. They have brought in synergized collaborative inputs of fundamental biology, bioinformatics, computer science, chemistry, physics and engineering-tackling life related tasks through developed robust predictive indices [2].

Systems biology takes into account the interactions of key molecular elements such as DNA, RNA (ribonucleic acid), proteins and cells with respect to one another and (complimentarily) integrated with knowledge and insights from computer science, as the introduction of high-throughput molecular biology techniques contributed to system biology such as linked genetic diversity and biological mechanisms.

Synthetic biology is an emerging field of biology. It uses data generated from investigations in biological experiments, more-so from molecular biology and biotechnology based research data, to design synthetic cells and associated circuits to perform the role of cells that can now synthesize bio-molecules like enzymes, hormones, key proteins that support metabolic events in the human body for improved health and in bio-manufacturing processes that make better and more environmentally friendly bio-products like bio-fuels.

Biology has received impact from the emergence of bioinformatics and metabolomics. Bioinformatics is a field that generates and uses big data to analyze complexs concepts and issues of problems to life in human health, and life. For instance, bioinformatics based tools that are run with developed bioinformatics software like BLAST, SIFT, and Polyphen, which has greatly aided in discovering biomarkers for diseases like cancer, neurodegenerative diseases, and for drug discoveries. Also of note is that in bioinformatics we look at how we can efficiently store, annotate, search and compare information from Biological measurements and observations. The transformation of biology has involved the fusion of molecular principles and concepts with those of other disciplines that includes physics, structural chemistry and computational biology. This has enabled developments that produced human genome sequencing, emergence of synthetic biology, systems biology and epigenetics. Kay (2000) remarked that for those who haven't noticed, genetics make ample use of communication concepts and imagery; genes are information, with DNA as a language, genome an encyclopedia, and organisms are genetic communication systems [3]. This brings to fore, how molecular biology and molecular genetics are transforming biology, enlightening biologists and bio-related scientists, making significant inputs that are contributing to tackling problems in human health, agriculture, veterinary animal life and in our ecosystem as now done through molecular ecology, an entry to support environmental management and ecosystem sustenance.

We have witnessed the introduction of computational biology which uses biological data to develop algorithms or models and unravels the relationship between them, which systems biology engages to tackle problems for translational benefit. These models can describe what biological tasks are carried out by particular nucleic acid or peptide sequences, and how changes in cell organization influence cell behavior.

Over the scores of decades, the scope of biology has emerged with a broader, deeper and more intricate framework that has gone beyond descriptive studies, though this is still necessary in some aspects of knowledge.

Biology has developed from being a descriptive science, progressing through introduction of cellular and molecular level studies to make us understand living things and the environment better. Then further into combing molecular data with deep learning attributes digging deeper into obtaining big dada, retrospectively mining past data and combining with present day data in big sizes, building algorithms that are obtained from trained data sets and seeking to solve problems and challenges previously unknown to us. Aristotle is regarded as a key figure in earliest development of Biology [4].

Objectives of this review are to:

- Discuss trends briefly from its history onto present day developments in biology.
- Provide applications from emerging fields of biology.
- Connect the synergy between biology and other fields in the physical sciences, agriculture, medicine and environmental science.

Literature Review

Contributions from specific fields of biology (plant and animal biology) to developmental trends

- Typical contributions from plants and animals genetics.
- Typical contributions from bioinformatics and computational biology.
- Typical contributions from synthetic biology.
- Typical contributions from metabolomics.
- Typical contributions from plant and animal ecology, conservation and environmental biology.

Contributions from specific fields of biology (plant and animal biology) to developmental trends

Typical contributions from plant and animal genetics: A study has generated the first genomic atlas for global wheat improvement. November 2020. The study engaged sequences of genomes of 15 wheat varieties around the world. One of its benefits was that the size and complexity of the wheat genome coupled to lack of genome assembly data for multiple wheat lines, has made it difficult to be probed and used to improve wheat production and quality as it has been achieved for several other crops. This study is one of the proofs of the benefits that come from synergistic use and applications of molecular biology, molecular genetics, and bioinformatics to support agricultural productions.

Contributions from bioinformatics and computational biology: The foundations of bioinformatics were laid in the early 1960's with the application of computational methods to protein sequence analysis (notably *de novo* sequence assembly, biological sequence databases and substitution models), coupled with increasing amount of bioinformatics tools. Big data in biological research have implications on the predictive power and reproducibility of products from bioinformatics. A school of thought in the sciences has defined bioinformatics as application of tools of computation of biological data in an interdisciplinary approach that harnesses knowledge and devices from computer science, physics, mathematics, biology (and chemistry). Bioinformatics has been beneficial to modern day biology and invariably in fields in which biological principles are applied such as agriculture, industrial bio-molecule based productions, medicine and the environment. Desany and Zhang in a review described bioinformatics is bridging the gap between biological knowledge of characterized and sequenced genes and genomes and clinical therapy through development of new and novel drugs designed against specific molecular targets, by identifying genes that have properties similar known targets in a novel conceptual bioinformatics based approach [5].

The human genome project generated large pool of data from the sequencing of each of the 23 pairs of chromosomes of normal humans. To meet the demands and tasks of fine, in-depth, fast analysis of these sequences, use of molecular biology paved way for bioinformatics tools to be engaged. Bioinformatics tools and knowledge enabled us to now manage the huge amount of biological data generated from various genome scale sequencing projects around the world involving diverse selections of genes, molecules, strains and of to integrate large and disparate datasets, between different biological states that these data represents.

In specific application usage and contributions to better life, Bhuvaneshwar and Gusev remarked that translational bioinformatics plays a critical role in biomarker discovery helping the bridge gap between bench research and bedside clinical applications [6]. This has been supported by entry of newer cheaper cost, and faster molecular profiling technologies. They added that it has supported better characterization of patients' health condition, prediction of treatment responses, monitor disease outcomes, and support early detection, intervention and prevention.

Computational biology flows with use of developed algorithms such as those involving machine learning principles which are helping to uplift our ability to analyze, synchronize and interpret big data and data swamps. This has supported statistical analysis that obviously cannot handle the level of huge data generated by genomic sequences and protein analysis. Typical examples for those from next generation deep sequences for human, animals and plant genomes under different health conditions, The Cancer Genome Atlas (TCGA) which began in 2006 is designed to be specific for genes identified to be associated with tumours, has molecularly characterized over 20,000 primary cancer and matched normal samples spanning 33 cancer types from analysis of over 11,000 tumours. It has generated over 2.4 petabytes of genomic, epigenomic, transcriptomic and proteomic data has made impacts on diagnoses, treatment and prevention of cancer and its Pan-cancer atlas provides a uniquely comprehensive, in-depth and interconnected understanding of how, where, and why tumours arise in humans in pursuit of precision medicine. A feature in working principle of computational algorithms is the ability of designed programs to identify vital patterns in large data compendia using either supervised or unsupervised machine learning algorithms, train the data and develop algorithms of application based uses in therapeutics, diagnosis and management of diseases in plants, animals and humans [7].

In a rigorous systemic review with meta-analysis of abstracts published in MEDLINE and Abstracts of NIH funded project grants to determine the growth and spread of computational approaches across various sub-fields in biomedicine during the past 50 years, which explored three bioinformatics concepts of computation, the internet and databases, between 2000 and 2003 alone, computational biology showed 3-fold increase while bioinformatics showed 15 fold increase, and identified the main areas of use in bioinformatics to be protein, gene and nucleic acid databases. Key in its uses are studies geared towards discovering target molecules for new drugs and vaccines, improving enzymes by bio-engineering, understanding basis for points of synthetic bio-engineering of gene and protein sequences in re-modeling, for medicines, enzymes, bio-molecules of use in chemical industries with attributes of environmental friendliness and cost effectiveness in addition to efficacy [8].

Taken together, the principles and tools of bioinformatics and computational biology have presented a clear scenario of how bioinformatics and computational biology-driven methods, emerging in fields of study in biology, which are used for key experiments, have resulted in significant speed of processing big biological and clinical data and economy of mapping of vaccine targets. Better knowledge on concepts are emerging from new fields within Biology involving neuro-imaging, use of molecular microarray datasets, molecular neuroscience engaging single cell biology nucleic acid (mRNA and DNA) analysis using omics and multi-omics spatially resolved single cell technologies to create brain and tissue genomics maps. These are helping us to better understand pathogenesis and pathophysiology of mental and other neurodegenerative disorders. Data and development of neurodegenerative drugs on clinical trial trials, for which some have progressed to higher stages of clinical trials, are good proofs of the benefits from Bioinformatics in combination with genomic analyses in applications that support agriculture, medicine and bio-Industries with awareness for greenness and quality of our ecosystem (through industrial/green biotechnology). For instance, use of neural-enriched extracellular vesicles provide MicroRNA (miRNA) fingerprints with unequivocal signatures of neuro-degeneration aimed to identify Amyotrophic Lateral Sclerosis/Motor Neuron Disease (ALS/MND) in patients and assist in early diagnosis of Alzheimer's Disease (AD), Parkinson's Disease (PD) and ALS/MND ALS/MND where biomarkers useful for diagnosis, prognosis and analysis of drug efficacy [9].

Contributions from plant and animal synthetic biology: History of synthetic biology has been traced to the beginning of the current millennium and has been viewed as an bridge connecting progress made in recombinant DNA technology of the 1970's to improve process of genetic engineering using and pooled assembly of the fields of biological, chemical and electrical engineering, bioinformatics, computational biology, and the basics of the biological and physical sciences. The use of these multi-fields in synthetic biology has supported biotechnology and bio-manufacturing of more environmentally friendly bio-products that are energy efficient and cost efficient as well, The products include drugs, chemicals, enzymes, hormones, bio-fuels, and now venturing to use them to develop better and more environmentally friendly polymers of use in fabrics, plastics, nylon and related polymer productions [10].

Scale-up from research products to industrial scale productions requires optimized bio-process and biochemical engineering process lines and optimized microbial fermentations processes. The key arms of synthetic biology include pathway engineering, metabolic engineering, protein engineering, DNA technology, computer aided bio-molecule designs and re-modelling, systems biology and cell-analysis.

For instance, discovery and use of combinatorial biosynthesis techniques in synthetic biology approach to bio-engineering of micro-organisms to produce proteins and glycolipids. This serves as vital sources of chemical scaffolds for drug development in animal and crop protection.

Engineering mammalian cells for human therapy in the discovery of a path to administration of cellular therapeutics in format like direct infusion of cell suspensions, engraftment of structured tissues and implantation of cells encased in bio-materials; adoptive transfer of autologous T-cells.

Synthetic biology technique enabled development of tumour targeting Chimeric Antigen Receptors (CARs) in a form 'O' genetically modified cell therapy approved for human use by the United States Food and Drug Administration (FDA) in August 2017.

Introduction of this new line of cell therapeutics development of bio-engineered cell-based therapeutics for stem- cell therapy by Hematopoetic Stem-Cell Transplantation (HSCT) for treatment of conditions like multiple myeloma and leukemia aided by development of advanced tools for bio-engineering of genes, particularly CRISPRi/Cas9 techniques to modify genes of host cells into new strains housing traits of value to cellular therapeutics.

Typical products from synthetic biology in synergy with tools of bioinformatics, computational biology and molecular biology are: Production of enzymes like Sitgalipin (with brand name Januvia), used together with diet and exercises to uplift level of controls on blood sugar in adults with type 2 diabetes mellitus); and Diamines (significant ones have meet needs to decongest as nasal cavity and anti-sneeze ailments, in addition to being components of polymers like nylon based products) [11].

This product has enjoyed inputs from key processes in Synthetic Biology such as design and development of Synthetic cells, bio-engineering of genes and genomes, pathway engineering, metabolic engineering and key methods of design-build-test chassis developments of bio-engineering (Figure 1).
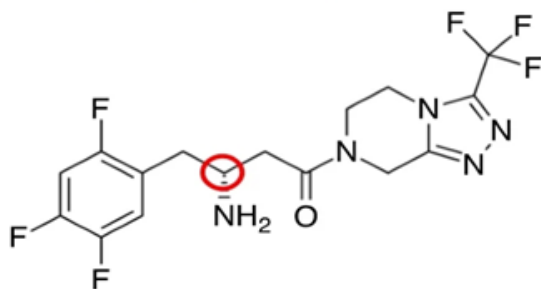
Figure 1. Shows the molecular based chemical structure for Sitgalpin with an enzymatically produced stereo-centre in red color.

The invention of Bio-isobutanol ("iBut16") a product from synthetic biology and biotechnology methods, an approved certified advanced bio-fuel which is added up to 16% v/v in gasoline brands. This is geared towards supporting use of fuel additives used over the years for the problem associated with bio-fouling of gasoline during storage caused by bacteria and fungi that form bio-film at a fuel-water interface to produce organic acids and sulfides. Synthetic biology is helping to develop methods for bio-refining of fuels have now prompted use of micro-organisms now being highly considered for consolidation for 2nd generation bio-refining.

Contributions from metabolomics in plant and animal biology: Metabolomics is a technique for investigations in systems biology. It is useful in the study the complexities of chemical processes involving intermediates and products of metabolism within the cell, tissue or organism. Escudero et al. defined metabolomics as the study of metabolites (carbohydrates, lipids, amino acids and organic acids) present in a biological sample [12]. It has been applied in several fields such as nutrition through biological food systems, in ophthalmology through investigations that unveil disease metabolism and pathogenesis to identification of bio-markers, applied for Rhizosphere health sustainability in plant and crop protection and changes in root exudates that were due to presence of fungus, nematode or both, used to screen of cellular activities in biological systems from set of identified metabolites in cells and tissues of plants and animals. Other areas include plant responses to genetic and environmental perturbations, diagnostic and prediction tool for genes functions and regulatory properties of metabolic networks.

The tools engaged by metabolomics includes chromatography to separate molecules, the sensitive spectroscopy to identify bio-molecules, Nuclear Magnetic Resonance (NMR) which is largely quantitative and compliments spectroscopy measurements, among others. Manchester and Anand added that metabolomics as a technique in molecular biology based analysis of applications in several fields of life sciences combines high-throughput analytical chemistry and multi-variate data analysis to offer a window on metabolic mechanisms due to the fact that they intimately utilize and often re-wire host metabolism [13].

Some evolving contributions from plant and animal ecology, conservation and environmental biology: The fields of ecology and conservation have evolved rapidly over the past century, adding that their analysis illuminates the boom-and-burst of ecological hypotheses and theories, the adoption of statistical genetic and social science approaches, and the domination of others that have emerged in recent decades such as climate change, invasive species, ecosystem services, meta-analysis. Just like its parent body Biology, Ecology has metamorphosed from a largely descriptive field focused on natural history and observational studies to a more data-driven, multidisciplinary field focused on applied environmental issues.

Biology plays a critical role in support of sustenance of our environment in various ways from use of genetics to support effects of environmental radiations and pollution on quality of life through monitoring of chromosomal shapes, the numbers and nucleotide sequences on selected genes or genome, to use of certain organisms like phyto-planktons, zooplanktons and other microbes to serve as pollution indicators in aquatic and terrestrial water bodies. Now this is emerging with new concepts accompanied with design and building of gene edited cell factories and now with forays into synthetic cells that can synthesize bio-plastics that degrade faster in the environment on being dumped [14].

Then is a field of ecology which has overlaps with environmental biology where Biologist explore, monitor and study various natural ecological problems facing life on earth such as global warming, greenhouse effect, climate change and depletion of the ozone layer, with lots of biology core studies and collaborative studies with Chemists, Astronomers, Climatologists and Physicist, to make the world a safer place to live in and sustain life on earth. Ecology has been supported with molecular approaches to facilitate studies on predicting parasites and microbial transmission, their population dynamics and growth patterns and simulating studies, now building algorithms to support monitoring of environmental issues for improved preventive measures against various pathogens.

Discussion

In a study by Anderson et al. using large full-text culturomic analysis of ecology and conservation journals, covering 80 years, 52 journals and half a billion words, it was observed that many common terms today, including climate change, phylogenetics, and biodiversity were coined only in recent decades [15]. Ecology and conservation have broadened from local field studies to include global issues, and increasingly feature advanced statistical modeling. The focus on genetics in ecology-related research increased markedly over the past several decades, as phylogenetics remained a top referenced genetics term. As such, a strong interest in genetic variation and diversity began to emerge in the ecology.

Entomology studies insects and their relationship with humans, animals, plants and the environment. Knowledge of the Biology of insects is vital to understanding the diseases that they carry and spread. Insects have become models for life processes, such as *Drosophilia* used in genetic studies due to its short generation time, small size and ease of being by scientists [16].

Emerging technologies with potential to make significant impact on entomology are High-Throughput DNA Sequencing (HTDS) generating huge data DNA sequences-information that can be referenced between tissue and whole organismal levels, and spatial repellents. The last few decades we witnessed increased use of high-resolution remote sensing to study small organisms such as insects at various resolutions. Such usage has enabled mapping environmental variables to specific insect populations, their destructive feeding patterns for crop damaging ecological behaviors. There are emerging interesting areas in forensic and economic entomology. The study of insects serve as basis for development of in biological and chemical pest control, food and fiber production and storage systems, pharmaceutical entomology, and biological diversity [17].

Fisheries have been moving towards achieving environmental integrity and sustainability, with the contributions of fisheries and aquaculture to global food security linked to increased fish consumption. Based on premise that aquatic food systems are a powerful solution to food insecurity and quest for sustainability of our environment, blue transformation has been an in-thing in fisheries. Climate and environmentally friendly policies and practices, as well as technological innovations, are critical building blocks for Blue transformation. Blue transformation is a strategy that aims to enhance the role of aquatic food systems in feeding the world's growing population. Some ocean creatures are a challenge to study because they live in places that are difficult to get to or because they have complex life cycles. This has warranted using unique tools such as drones (both aerial and sail), satellite tags, remote and automated underwater vehicles, acoustics, genetics and research ships in new

technologies to gather and analyze ecosystems and marine life. Researchers now use remotely sensed data captured by drones to investigate essential habitat and to determine the distribution and abundance of species in habitats. Smart tags systems coupled to remote sensing systems enable scientists to explore and obtain information about other features of internal physiological processes such as digestion [18].

Genetic tools such as mitochondrial, SSRs, ISSRs and SNPs have helped to do fingerprinting studies, paternity testing and population genetic studies. Aquaculture is a critical component of global food security and selective breeding has offered substantial opportunities to enhance production efficiency in seafood supply and study related diseases. Recent research advances in genetics and omics are being engaged to enhance aquaculture breeding.

One other area of research has involved assessing genetic diversity of founder stocks to facilitate forming a base population with large genetic variability that ensures long term response to selection and to assist in identification and recruitment of genetically diverse stocks for selective breeding programs as earlier demonstrated by Guo [19]. Genetic selection as highlighted here has supported improved productivity, growth, survival and quality of several aquaculture species in a breeding revolution.

Furthermore, Palaiokostas et al. stepped into an emerging area of aquaculture research involving genomic prediction of breeding values through genomic section of for traits that are difficult to measure such as meat quality and disease resistance [20]. Also, genomic studies have provided a framework informing us on concepts on working fish immune systems, related proteins and cells through cellular and molecular tools. The application of wonder tools of synthetic biology such as TALEN (Transcription-activation-like effector nucleases) and CRISPR (clustered regularly interspaced short palindronic repeats) systems based gene editing tools has yielded positive results in fish quality and enhanced features. A typical study engaged CRISPR-Cas9 and TALEN to do gene editing and transfers which helped shorten maturation time for Spurgeon species of fish.

Conclusion

Biology has grown over the scores of decades from its approximate period of start-up or awareness in history of over a century ago, centering mostly on structural and descriptive attributes of living things onto present era Biology. Present era Biology utilizes discoveries from use of microscope, contents of atoms from physical and mathematical/statistical sciences, molecular biology with DNA/gene as inclusive core components, alongside collaborations with physical sciences, computer science and engineering, to explore deeper into nature, life forms, intricacies, solve life problems, open up more useful knowledge based attributes and better elucidate metabolic pathways and processes with translatable benefits. Biology is still growing and has not reached the apex because emerging challenges and changes in structure of challenges from our natural environment tend to always propel need or zeal to discover, formulate, test and design new paths of studying rare phenomena in biology.

Acknowledgement

Conflict of Interest

We declare no conflict of interest.

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