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The Relevance of Biological Sciences in the 21st Century

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Introduction

Biological Sciences, as the name implies, is a group of sciences, rather than a single science. All bioscientists are concerned in one way or the other with living creatures - plants, animals and microorganisms. The importance of the application of biological knowledge is better assessed by the various problems of modern civilization that have been solved. Examples of these problems are:

- pollution of air, water or soil.
- Disposal of waste.
- Effects of over-population and crowding.
- Use of drugs.
- Aging of the population.
- Descent into the depths of the sea.
- Ascent to the highest mountains and even into outer space.

Biology can also be appreciated by the advances in the improvement of food supply and elimination of hereditary diseases. It can therefore be said that the relevance of the Biological Sciences, long before and even now in the 21st century, goes beyond taking specimens of plants and animals into the laboratory and looking at them to describe what is seen. It is of great interest at this point of our discussion to take a brief look at the types of biology and the range of careers available to those trained in bioscience. First and foremost, let us start with the History of Biological Sciences.

History of Biological Sciences

Biology can be traced to have its origin in ancient Greeks and Romans. Aristotle classified plants and animals in the 4th Century B.C., while his pupil, Theophrastus, wrote the first botany book. Hippocrates in the turn of the century laïd the foundations of the medical science-an applied biological science. However, the shine was taken off the science of biology over a thousand years in Europe where it all began, the records of which are kept alive by Arab and Jewish Scholars.

Biology, however, awakened after the great renaissance, the beginning of which was very slow with few names like Vesalius, the father of anatomy; William Harrey, the discoverer of circulation of the blood; Robert Hook, who introduced the concept of "cells " as units of biological structure; and Anton van Leeuwenhoek, who devised the first microscope. The study of Biochemistry was made popular in the eighteenth century with names like Priestley, Laviosier and Laplace entering into prints as discoverers of important biochemical mechanisms. The great Swedish

naturalist, Carl von Linne, commonly known by the Latin form of his name, Carolus Linnaeus, devised the scientific method of classifying and naming plants and animals, which is in use to this day.

The 19th Century saw the revolutionization of biology as new ideas came to the fore. All living organisms are made up of cells, theorized two Germans, Schleiden and Schwann, while Liebig from the same country discovered plants' ability to synthesize organic compounds from carbon dioxide of the atmosphere and nitrogen from the soil.

Louis Pasteur, a native of France and a pioneer in microbiology, proved that life begets life, that is, all life comes from life. This, and the works of the bacteriologist Robert Koch, opened the way for many advances in the treatment of disease including aseptic surgery.

Advances in bioscience in the 19th Century were at a climax in the impact-oriented publication in 1859 of Charles Darwin's *The Origin of Species*, spelling out the gradual changes of species of plants and animals due to natural selection.

Developments in Biological Sciences in the last century are mainly associated with the gene theory, which was formulated by Thomax Hunt Morgan. Another important biological milestone in the mid-1900s was the elucidation of the structure of genes-the deoxyribonucleic acid (DNA) by two biochemists, Watson and Crick. The impact of the discovery was great as it gave biologist altogether too much potential power to produce whole new species (e.g. anthrax), on which the destruction or otherwise of the planet earth could depend.

Biological Careers (Pure and Applied)

The biological science as a group is so large and diverse that there are several different ways of classifying the numerous types of careers available for study at the University level. They can be grouped according to:

- Subject matter - whether plant, animal or microorganisms.
- Object of attention - whether whole organism, organs, organelles, cell or sub-cellular.
- personal interest - research, teaching or practical such as in health, industrial or allied application.

Growth and changes in the biosciences occur at such a speed that is difficult to keep up with, bringing the statement of one of the great physicists of the early 20th century, the late Frederic Joliot Curie, to mind. He prophesied that while the first half of the 20th Century belonged to the Physicists, the second half and beyond belonged to the Biologist. Recent developments in the biological sciences seem to bear out this saying considering the various fields of bioscience that have given birth to newer types of careers.

1. **Microbiology:** Microbiology is the study of small organisms that cannot be seen without the aid of a microscope. Microorganisms include bacteria, fungi, viruses, algae, yeasts, rickettsiae, protozoa, etc. Products of microorganisms are not always harmful, as many tend to believe. There are numerous useful substances such as vitamins and antibiotics produced by microorganisms. As

noted below in the discussions of genetics and biotechnology, the quantity and variety of such useful products of microbiological origin can be greatly increased in the laboratory by manipulations, which include insertion of genes regulating specific chemical reaction with the microorganism's cell. Practitioners of microbiology have been responsible for the development of vaccines, antisera, and toxoids against a wide variety of diseases in man and animals. These include smallpox, typhoid fever, yellow fever, whooping cough, measles, influenza and polio. The production, preservation and improvement of most of our processed food and beverage products such as cheese, vinegar, wines, pickles, bread, olive and cabbage products, meats, vegetables and fish, are examples of the contributions of microbiologists to global self-sufficiency in food production and preservation. The manufacture and use of the kitchen wonder, microwave oven, has popularized the use of preserved food for both human and domestic animal consumption.

So important is this branch of biology that the American Society of Microbiology says that "microbiology is important from the core of the earth to the far reaches of outer space". Little wonder therefore that it boasts of some of the most illustrious names in the history of science like Louis Pasteur, Robert Koch, Sir Alexander Fleming and Jonas Salk. Also, a third of all the Nobel Prize Awards in physiology and medicine during the last century have been bestowed on microbiologists. Microbiological research is so varied in their practical application that some biologists have complained that the subject's value as a basic science has not been properly appreciated.

Within the Nigerian University System, the study of animal diseases is very common. According to the World Health Organization, about 150 animal diseases are important in human medicine. These diseases called zoonoses include brucellosis, and bovine tuberculosis. In Africa today, hundreds of microbiologists are researching into just a single cattle disease - trypanosomiasis, caused by a microbiological organism called trypanosomes. This same organism is incriminated to be responsible for the human sleeping sickness that has virtually rendered uninhabitable large areas of the African Continent.

So diverse is the subject that trained Microbiologists can gain employment to teach and to do research in colleges and universities and professional schools, including those of medicine, dentistry, public health, nursing, pharmacy, veterinary medicine and agriculture. Main employers include private research foundations, government research laboratories, service agencies, public health facilities, hospitals and agricultural research and experimental stations. Others are food, chemical, pharmaceutical, wood products, paper, textiles, optical equipment and leather industries.

2. **Systematic Biology:** Sometimes referred to as simply systematics or biosystematics, Systematic biology is described as the study of the different kinds of organisms which exist, as well as the kinds, which existed in the past that are now extinct. It therefore includes the description and classification of organisms alongside the relationship between them (called taxonomy), as well as the changes that have occurred in them during the past generations, called evolution. Biosystematics enjoy orderliness and independence, using the tools supplied by other disciplines to achieve their goals. It must be stressed here that the glamour, importance and monetary promises of certain fields

of experimental biology including the much talked-about biotechnology and some of the biomedical sciences may have overshadowed or taken the shine off systematic biology. This is dangerous to the advancement of pure biology. We must recall the enormous contributions made by systematists to the quality of life which we enjoy since systematics interacts with and overlaps other biological disciplines, particularly ecology and genetics. Without the foundation of basic knowledge provided by systematic biologists, the great advances in health sciences and medicine would have been immensely more difficult if not impossible. Lukewarm concern to the study of biosystematics has caused the world a lot of problems in the study of introduced pests. These are introduced into novel areas without adequate study of relationship between the native and the exotic species. The numbers of such accidental or careless releases of unwanted species are astonishing. Reports have it that these releases account for more than 100 million fishes, half a million birds and 100,000 mammals! I am therefore using this medium/forum to advocate for increased and sustained drive to admit graduate students into this area of study in our universities due to its importance. Systematics finds employment as teachers in secondary schools, colleges, universities and agricultural colleges. Museums, botanical gardens, arboretums, zoos, aquariums, private research foundations and various local, state and federal agencies employ this category of biologists.

3. **Entomology:** Entomology is the study of insects. Whereas, the Jurassic period of some 150 million years ago is referred to as the Age of Reptiles because of the abundance of reptiles at that time, the present age should likewise be referred to as the "Age of Insects", since the class Insecta of the phylum Arthropoda boasts of more than 75% of all the species of animals in the world today. To man, many insect pests are spreading disease or competing for food or destroying desirable plants, while others are useful in pollinating trees, crops and other plants or providing food for us or even helping to destroy pest species. Whichever way you look at them, insects affect the life of every person. The work of entomologists overlap with those of many other biologists. This is mainly because description and classification of insect forms, which have been on for more than a century are far from completed. According to Entomological Society of America, only about 10% of all insect species are known. The training therefore of insect biosystematists is a must for our universities since identification and classification of insects are fundamental to all other research in entomology. I hereby advocate for Faculty Fellowships for M. Sc. and Ph.D. in Insect Systematics.

The insect physiologists is another entomologist whose study of the intimate nature of the physiological and biochemical reactions taking place within insect cells provides abundant useful and interesting materials presently being used in human medicine. Insect control techniques concerned with reducing the damage done to crops, forests, food in storage and other interests of mankind, is the exclusive reserve of the economic entomologist. These control measures include the use of poisonous chemicals, use of biopesticides, use of insect attractants, Sterile Insect Technique (SIT), etc.

The insect biological control specialist is essentially involved in the study of other insects or other forms of life, which prey upon or destroy the insects regarded as pests; as well as the study

of insect diseases originating from bacteria, viruses or fungi. Personnel involved in the biocontrol must work closely with the microbiologist, virologist, mycologist, ecologist and wildlife biologist. Some of these collaborations are for the purpose of maintaining the fragile balance of nature. One of the most interesting examples of the biological warfare is against mosquitoes. Dumping of large number of *Hydra* species (tiny freshwater relations of jelly fish) into mosquito-infested water is expected to reduce mosquito population drastically. *Hydra* is known heavy feeders of mosquito larvae and of course they do not chemically contaminate the water.

It would be difficult to mention a field of biology offering a greater variety of employment opportunities than entomology. Colleges, universities and professional schools employ entomologists to teach the subject to their students. Industries employing entomologists include producers and processors of food, insect control chemical industries and lumber and pulp industries. Government also employs entomologists in research laboratories in biological survey work.

4. **Marine and Aquatic Biology:** Biologists that concern themselves with plants or animals that live in watery environment, could be called marine biologists, if the interest is in the classification, mode of life, function or adaptations of organisms inhabiting the sea; or an aquatic biologist, if the interest is in studies of the freshwater environment. The marine or aquatic biologist's interest may be limited to a specialized study area like the physiology of fishes, systematics of marine algae, structure, embryology or ecology of any group of species.

The increase in worldwide consumption of fish is for human food, commercial livestock feeds and fertilizers demand. There is a great strain on the sea due to improved efficiency of fishing techniques and increased fishermen. It is advocated that aquaculture, which is the aquatic equivalent to agriculture should be studied and practiced by more trained personnel so that humankind can realize the full potentialities of aquatic organisms. Aquaculture has been in practice for centuries in China, and among the species of aquatic and marine animals widely cultivated in modern aquaculture business are salmon, trout, edible catfish, oysters and shrimps. Note that the full potentialities of aquaculture cannot be realized without the contributions to knowledge, which only the biologists can supply.

Marine and aquatic biology offers a seemingly unending variety of occupations, and with advances in technology, the list of possible careers expands. Outdoor and indoor work opportunities include:

- Monitoring salmon/fish migration for the country or particular State Fishery Board.
- Inspection of fish handling aboard a processing vessel.
- Analyzing water samples for culture of shellfish.
- Managing fish hatcheries.
- Surveying fish population.
- Supervising a fish farm.
- Investigating effects of volcano, earth movements or oil spills on rivers and lakes.
- Preparation of environmental impacts statements.
- Stream managements for a private club.

- Surveying the endemicity of water-transmitted diseases among coastal fishing human population.

Apart from the several aquatic and marine biologists employed in the teaching and research institutions, many governmental agencies in water-related ministries employ those trained in fisheries, while international agencies, such as Food and Agriculture Organization of the United Nations, also employ marine biologists.

5. **Specialties in Plant (Botanical) Science:** There are many varieties of botanists. Plant systematists or taxonomists as mentioned previously described, classify and study the evolutionary interrelationships of the endless variety of members of the plant kingdom. Plant morphologists' sole interest is on the form and structure of plants, while plant ecologists are fascinated by their environmental relationships. Plant physiologists are primarily concerned with the normal functioning and behaviour of plants and energy absorption mechanisms. The highly important problems of plant disease engage the undivided attention of the phytopathologist (or plant pathologist). Whereas botanists interested in specialized groups of plants such as the mosses and liverworts are called bryologists, those interested in trees are called dendrologists. Many plant scientists use their training in practical applications of their skills in becoming foresters, horticulturists, agricultural scientists, etc.

6. **Wildlife Biology:** The extinction of biological species began with that of dinosaurs over a period of a million years - a very impressive event in geological history. But more impressive is the present situation where it is estimated that man's activities have destroyed more than 200 species of birds and mammals within the past two or three centuries. Many more species are so drastically reduced in numbers that they may be doomed in spite of efforts to save them. Concern on the rate of disappearing biological entities by biologists worldwide gave birth to a new world - Biodiversity in 1980. Decrease in global biodiversity and its management promise to be one of the central focuses of the 21st Century bioscience.

Wildlife biology basically deals with the principles of ecology in the natural environment. This aspect of biology is being threatened by a technology, which includes even the potentiality of destroying all life. The present increase in the rate of human population growth renders ineffective all other efforts at preservation of earth's natural environment. This is the reason for the high demand for wildlife biologists/ecologists whose main function is the management of game, fish, fowl, fur-bearing animals or any type of wildlife. This biologist is interested in the habitats of all these animals and usually helps in the preservation or restoration of streams, lakes, or marshes. Therefore, a wildlife biologist should be a lover of nature as the work takes him/her into remote areas, often under rugged and difficult field conditions. Their research is often related to taxonomy, physiology, genetics and many other fields as applied to wild animals, fish or birds. Although wildlife biologists engage in research, teaching in all levels of formal education is their basic function.

7. **Genetics** - Genetics is the science of heredity and involves observation of the superficial appearance of an animal or plant as related to its parents or its offspring, the inheritance of biochemical characteristics and the intimate nature of the structures of the cells, particularly those of the sex cells that transmit hereditary traits. The works of trained geneticists vary from the solution to highly abstract and theoretical problems involving modeling and computer simulation to the application of genetic principles to economically important subjects. The geneticists can work on any species of plant, animal or microorganisms. An age-long geneticist tool is the lowly fruitfly, *Drosophila* species (Diptera), which has contributed more than any other animal to knowledge of the cellular structures known as chromosomes and genes involved in heredity. The counterpart of *Drosophila* is the corn *Zea mays* in the kingdom Plantae. Genetics has benefited mankind particularly in the area of agriculture. The great hybrid corn industry, which has enhanced yields, owes its success to the study of the corn plant. The popular "green revolution" of the last century was built around advancement in the genetics of crops especially rice, the staple food of million of people in the Far East. There is no doubt that further advances in this area will lessen our dependence on organic fertilizers, particularly in the semi-arid zone of sub-Saharan Africa. Since genetically improved crops are imbued with resistance to pests and adverse conditions in addition to high yield and improved quality, Nigeria, with its 120 million people, facing rapid encroachment of the desert and diminishing arable land, will definitely gain from genetic research focused on improved agricultural practices.

Genetically improved arable agriculture can be supported by selective breeding of superior strains of livestock through the practical application of genetics. It is on record worldwide that geneticists (and other biologists) virtually eliminated the parasitic screwworm fly, ***Cochliomyia (Callitroga) hominivorax*** (Diptera: Calliphoridae) whose larvae feed upon the living tissues of cattle, in Florida, United states. This involved the release of large numbers of male screwworm flies, which had been rendered sterile by radiation in a technique called the Sterile Insect Technique (SIT). Other disease-carrying insects such as tsetse flies have been controlled this way with considerable success. Concerns employing geneticists include pharmaceutical manufacturers, farms and departments of Agriculture, Fish and Wildlife Service, Institutes of Health, Colleges of Agriculture, University Departments of Biology, Botany, Zoology, Microbiology and Genetics.

8. **Biotechnology:** This is universally characterized as "wonder world" which has revolutionized the ways we live, work and play. Its rapid development is based on the cracking of the genetic code stemming from the discoveries of the structures of genes -deoxyribonucleic acid (DNA) - in the 1950s by Watson and Crick. Described in comparison with "the discovery of fire, invention of the printing press and the splitting of the atom" by the U.S. News and World Report, March 28, 1983, the future promise of biotechnology can scarcely be imagined. Worthy of note here is the first pharmaceutical product of biotechnological research - human insulin. This biotech revolution using "gene splicing" techniques and appropriate fragments of human DNA ended the era of classifying diabetes as a fatal disease.

Recent technical advances in the manipulation and analysis of DNA and RNA have initiated a revolutionary change in our understanding of gene structure and function. Recombinant DNA technology has permitted great advances in biomedical research. These advances have a dramatic influence on fields as diverse as medicine, neurobiology, plant and animal biology, as well as agricultural science (including pest control and disease management). Recombinant DNA cloning involves the formation of new hereditary genetic material by insertion of foreign DNA into an appropriate cloning vector. Cloning allows the incorporation of genetic material into a host organism in which it does not naturally occur, but in which it is capable of continued replication. DNA cloning presently holds the greatest hope for the vaccine development of many deadly diseases and holds promise to be a useful tool in the treatment of single disorders, prevention of multifactorial diseases, supply of small molecules such as insulin in diabetic patients, cancer therapies, management of infectious diseases and immunization as in HIV/AIDS.

The use of recombinant DNA techniques by biotechnologists does not stop at drug manufacturing. Perhaps even more important in the long run are projects in agriculture. These include development of:

a. Food crops that resist the assaults of insects.
b. Food crops that will grow in soils and climates that cannot now produce food, and
c. Food crops such as peas and beans that manufacture some of their fertilizer.

The technology of cell fusion, which deals with whole biological systems have been used by this group of biologists to form special form of new cells, which are superparamagnetic in nature. When the dynabeads are coated with specific antibodies (via a hybridoma biotechnology), a *hybridoma* is formed. This biotechnological process has revolutionized the diagnosis of many kinds of diseases, disorders and cancer. Notable among this, is the discovery of the human immunodeficiency virus (HIV) by biologists (Montagner and Gallo in 1983 in USA and France), after the recognition of AIDS in 1981. Polymerase chain reaction (PCR), enzyme immunoassay (EIA) and immunochemical staining represent the most important advances in DNA technology in the past three decades. Thus, the advent of hybridoma technology provided a new dimension in biomedical research. Used in biomagnetic separations, it is simple, rapid and reliable. This has largely come about with the advent of monoclonal antibodies and their particular specificity for defined antigen epitopes. The problems of disease discovery, monitoring of disease prognosis, progression and drug efficacy, as well as susceptibility and resistance, has been solved by the inputs of this branch of biology.

Other biotechnology dividends include the test tube breeding of farm animals and human test tube babies with embryo transfer, in a process called genetic engineering. Genetic engineering is presently producing super cows with milk production capacity three times higher than the common cows as well as production of superior meat animals with a shorter time.

9. **Molecular Biology:** This is the study of the physical life of living organisms from the molecular level of cells. It utilizes a systematic application of biological systems to systematic knowledge and action, usually of industrial process, but applicable to any recurrent activity. Hence,

molecular biology utilizes great advances in biotechnology and genetics. Outstanding advances in molecular biology are the gene therapy and HIV/AIDS.

- ***Gene Therapy:*** Gene therapy is an outstanding advance in molecular biology, which involves the medical use of genes in curing in-born errors responsible for rare incurable diseases such as the extremely rare but incurable severe combined immunodeficiency (SCID) resulting from adenosine deaminase (ADA) deficiency. Patients with ADA deficiency do not develop an immune system so cannot fight infections; they need constant protection from pathogens. The modern era of gene therapy began 18 years ago with the approval of the first human gene therapy protocol by the Food and drug Administration (FDA) of the USA. It was not until September 14th 1990, when Professor W. French Anderson and Colleagues of the National Institute of Health (NIA) USA, marked the beginning of the first gene therapy with a 4 year old Ashanti Raj who was born with an autosomal recessive form of SCID resulting from adenosine deaminase deficiency. This was followed by the work of Professor Bob Williamson of St Mary's Hospital Medical School, London; two children suffering from ADA deficiency were given a working copy of the ADA gene, which were inserted into their gene through some of their white blood cells. Five years on, the children are living comparatively normal lives. Dr Alain Fischer and his colleagues have also described a successful gene therapy against SCID with 10 months on normal immune system. Promising results of gene therapy have also been reported in haemophilia B.

Molecular biology have earlier identified factor IX, a blood clotting protein. Today, factor IX packaged gene in a definitive adeno-associated virus (AAV) was used to insert gene into patients who suffered abnormal blood clotting because they lacked factor IX.

Doctored gene has also scored some clinical victory over cancer. With the might of molecular biology it has been identified that most cancers have a signature flow, a mutation in a tumor suppressing protein called p53. The protein, when normal, prevents unchecked cell growth. Now by stitching a cell-killing gene into a common virus they could selectively destroy cells that express mutant copies of p53.

Gene therapy promises to be a useful tool in the treatment of single-gene disorders such as cystic fibrosis, prevention of multifactorial diseases such as coronary heart disease, supply of small molecules such as insulin dependent diabetes, cancer therapies, management of infectious diseases and immunization as in HIV/AIDS. It holds potential for parental intervention to prevent severe and irreversible damage to foetus and gene transfer to prevent or treat neurological disease. With the rapidly growing biotechnology, it is obvious that soon gene enhancement may lead to gene intervention, to increase a child's intelligence quotient (IQ).

Presently germline genetic intervention is being advocated which would lead to prevention of disease or disabilities in one generation and subsequent generations, since uterus gene therapy is too late for some disease. The startling rapidity with which gene therapy has developed stems from three factors:

1. a much improved understanding of the molecular basis of many diseases.
2. an improved understanding of cell structure and functions.

For instance, the initial problems of gene therapy were:

- new genes should first be gotten into stem cells, which are progenitor of the immune system.
- stem cells that are not dividing, will not accept new genes.
- if the cells are allowed to divide, they would accept the genes, but the cells would mature and would not be stem cells anymore. Along with numerous technical achievements, molecular biology has helped in overcoming these obstacles.

3. development of techniques to isolate genes of interest and to study and change them outside the body.

Unlike conventional treatments, which attempt to deal with the consequences of a defect, gene therapy aims to correct the effect itself. With the explosion of the number of concerns entering this field, there is bound to be a scramble for geneticists, molecular biologists, biomedical personnel, etc. Indeed, the 21st century is going to be the era of the biotechnologists!

- ***The Acquired Immunodeficiency Syndrome (AIDS)***: Today it is commonplace, when citing the triumph made in molecular biology to quote advances made towards the knowledge and control of the human immunodeficiency virus (HIV), the causative agent of AIDS; the world's most dreaded disease. By pointing to the many drug failures, the driving force rate of virus transmission, and the difficulties of developing an effective vaccine, good credit can be given to the advances made in molecular biology. Progress made against HIV exemplifies the potency of molecular medicine-based on viral dynamics, pathogenesis, and development of protein-targeted drugs. Perhaps the best strategy for AIDS protection would involve the transfer of elements (genes) that would protect cells from infection by HIV. Such protection might be provided by synthesis of peptides that block HIV entry at the level of the cell surface receptor for HIV. Evidence of this already exists in retroviral *env* proteins of avian or murine leukemia virus.

This is strong evidence that the prospects are bright for rational treatment of many other complex disorders once we understand their genetic origins and pathophysiological mechanisms. Meanwhile extensive spread of HIV has been traced to the year 1959 in Central Africa. . The virus has been confirmed in over 70% of all countries and in all continents of the world. Sub-Saharan Africa has the highest burden with Nigeria on the lead. Molecular biology has also elucidated the two major types of the pathogen-HIV-1 and HIV-2. HIV-1. The dominant type worldwide has also been noted to have about 14 different genetic types (subtypes) with notable biological and epidemiological significance. It is true that basic science research of medicinal chemistry informed by structural biology, generated success crop production against several diseases. They were however, more invasive, tedious and slow, compared to molecular diagnosis which is highly efficient, sensitive and specific along convenience for mass evaluation of population sample for monitoring of crop-yield, diseases and pests.

Rewards of a Biologist

An ideal career in our present day should be able to provide a lot of things such as:

- Sufficient income for one and one's family.
- Good living standard comparable with others of similar education and experience.
- Reasonable opportunity for advancement.
- Recognition by society as one engaged in useful work.
- A feeling of self-esteem and deep personal satisfaction; and
- Sufficient challenge to allow/promote development of one's capabilities to the fullest.

As a biologist, myself, it is prediction that most bioscientists feel that biology offers a great deal of the above provisions. The rewards of a biologist can be classified into tangible and intangible ones.

Tangible Rewards: These include working conditions and salaries. Most biologists work in laboratories and/or classrooms and these places are (ideally) comfortable, clean well lighted and adequately equipped. The biologist's working places like field, experimental stations and research stations usually boast of office space, library facilities which are supplied at the expense of the employer. In these places, there is usually stimulating interactions among fellow scientists, technicians, assistants and students. Special safety and security is provided for those involved in handling of hazardous materials.

Presently in Nigeria, bioscientists are fairly well paid. The median salary of biologists with doctorate degrees or equivalent involved in university lecturing is about half a million Naira annually. Total annual take-home could be high when allowances like excess workload, leave grants, travel allowance, etc, are considered. I consider it worthwhile to emphasize the following concerning the salaries of bioscientists in this country:

a. Salaries paid to biologists are in the middle-income brackets and are adequate for a reasonable standard of living.
b. Biologists' salaries compare well with those of other scientists and are higher than those of some non-science academic disciplines.
c. Merit is rewarded by advancement and salary increases.
d. It is financially rewarding to obtain the highest degree possible.
e. If your primary aim/goal is to get (stinking) rich, do not enter the profession of biology, as most biologists do not make as much money as the most successful physicians, lawyers, or businessmen.

***Intangible Rewards*:** The deepest satisfaction of the average biologist about his career comes from things that money cannot buy.

a. For the biology teacher, the thrill of watching young people with keen minds react to the excitement of science is impossible to describe. Delight and wonderment showed by students, and satisfaction displayed by teachers in observing comprehension and enthusiasm in the faces of their wards are the rewards of teaching.

b. Students could be so influenced by the biology teacher that he/she chooses bioscience as a career and thus extending the teacher's influence to yet another generation.

c. Deep satisfaction in the soul of the biologist in doing a daily work that is gratifying and pleasurable and not "just a job" to keep body and soul together. Biologists believe that their work/efforts are worthwhile and that they can leave the world a little better than they found it. This may explain why so many biologists continue studying, thinking and working after retirement.

Conclusions

Pioneers of the Nigerian educational history; as you now retire into a more active sphere of decision making in Nigerian nation, I wish to encourage you to continue with the ominous task of nation building which you have been involved in during your days of active service. I challenge you with a renewed interest in the potentials of bioscience. Using the AIDS pandemic and its challenges, there is no doubt that a safe and effective vaccine - probably the single most important long-term goal of current research efforts, would be found by the manipulations of bioscience. Biological science is recreating nature; its bombs (we should be aware) may drop more silently, but it will kill more profusely. I stand assured that all of us are already policy makers in the various sciences. Your continued support for biosciences will spell a new Nigeria free of diseases, great in agricultural products and modern warfare, which are the strength of every nation.

I will like to conclude by saying that 21st century bioscience promises to fine-tune domestic biodiversity in the proliferation of advanced breeding lines of food plants and animals whose genome are created by laboratory manipulations, perhaps including genetic diversity impossible through natural processes. In fact, I foresee that the importance of this new science of biodiversity that touches all areas of our lives will be harvested in ways such as:

- Ecosystem services through soft coastal engineering against sea level rise from global warming.
- Improved medical services through the harvesting of rainforest plant products for production of new drugs, to combat existing and new diseases.
- Biotechnological impacts through the production of metal digesting bacteria with potential to clean contamination and extract valuable metals.

Whichever way you approach it, the role of biological sciences in the next 100 years will enhance the living standards of the human race. It, therefore, must be pursued with all vigour.

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