Theme 6. Basic Science Research

Basic science research is a systematic study directed towards greater knowledge or understanding of the fundamental aspects of phenomena. Basic science research lays the foundation for advancement in knowledge that leads applications of sciences to problem-solving, occasionally as a result of unexpected discoveries. Pure basic sciences may also focus on refuting or supporting theories that explain how this world operates, what makes things happen, etc. It is the source of most new scientific ideas and ways of thinking about the world. Basic science research generates new ideas, principles and theories, which may not be immediately utilised but instead, form the basis to modern progress and development of different fields.

Most scientific progresses made so far are the results of findings obtained through basic or curiosity driven research. Today's computers, for example, could not exist without the pure research in mathematics conducted over a century ago, for which there was no known practical application at that time. Pure research rarely helps practitioners directly with their everyday concerns. Nevertheless, it stimulates new ways of thinking about deviances that have the potential to revolutionise and dramatically improve how practitioners deal with problems. A new idea or fundamental knowledge is not generated through pure basic science research alone but new knowledge could be built through it.

Sub-Theme 6.1. Biosciences Research

Rationale

The alarming rate of human population growth that has put greater pressure on the environment, and the parallel need for new knowledge, are increasing. To meet the increasing human needs for new knowledge, conducting cutting-edge basic bioscience research is of paramount importance. Cutting edge basic bioscience research advances scientific knowledge

that can be applied for advancement in agriculture, health, industry, natural resources conservation, and other sectors.

Aim

The main aim of this sub-theme is to explore, generate, and document knowledge on biodiversity resources, bio-fuels, and industrial materials from novel biological sources.

Description

The sub-theme deals with the study of organisms from molecular and cellular levels up to the whole organism, population, and ecosystem. Research under this sub-theme also focuses on systematics, diversity, physiology, ecology and genetics of plants, animals, microbes, and tools and technologies underpinning biological research.

Potential Collaborators

National and overseas universities, the Federal Ministry of Science and Technology, Ethiopian Environmental Protection Agency, and Ethiopian Standards and Quality Authority.

Expected Output

- Explored and documented microbial, plant and animal biodiversity resources of Ethiopia, particularly in the eastern part of the country
- Broadened and advanced biological knowledge, skills, and innovation that maximize the impact of bioscience
- Enhanced national and international research partnerships in bioscience research
- Improved awareness on biological resources and sustainable utilisation

Research Areas

6.1.1. Microbiological research

This research area encompasses biodiversity of bacteria, fungi, algae, protozoa, and other simple eukaryotic organisms and their fundamental life processes. It also addresses evolutionary and genomic microbiology through genomic analyses and metagenomic investigations of microbial populations. Biodegradation of environmental or anthropogenic chemicals, geo-microbiology and environmental microbiology that are related with interactions among microorganisms are also focus areas.

6.1.2. Zoological research

This research area encompasses species composition of animals, distribution and diversity, morphological and anatomical variations among animal species, biology of animal species, epidemiology of parasites and their association, testing and documenting efficacy of medicines, damages caused by animal pests, population ecology of animals, and population dynamics of economically and medically important animal species.

6.1.3. Botanical research

This research area focuses on plant systematics and documentation of plant biodiversity and utilisation by indigenous people. It deals also with plant physiology to understand the principles behind plant growth and development, reproduction, etc. Elucidation of biochemical and physiological responses of plants to various environmental conditions will also be treated under this research area. Plant ecology, under which plants interact with biotic and abiotic factors, is also the focus of this research area.

6.1.4. Genetics research

This research area studies the effect of genes on the phenotype and gene mapping on chromosomes. It also deals with molecular genetics concerning how alternative forms of genes differ at the molecular level and how one form of gene mutates into another alternative form

as well as how it results in different expressed traits. The research also deals with population genetics, focusing on the patterns of transmission of complex traits whose expression depends on multiple genes as well as environmental factors.

6.1.5. Biotechnology and molecular biology research

This research area focuses on characterisation of high value added metabolomics and their effects on biological systems. In addition to this, emphasis will be given to screening of biomass for future bio-energy needs of the country. This research area also encompasses plant and animal biotechnology, medical biotechnology with emphasis on stem cell research, fermentation technology, bioremediation, enzyme engineering, recombinant DNA technology, genomics, proteomics, and tissue culture.

Beneficiary

Agricultural sectors, food processing industries, pharmaceutical industries, Federal Ministry of Health, Universities, research institutions, and the wider community

Sub-Theme 6.2. Chemical Science Research

Rationale

Research in chemical sciences seeks solutions to major challenges facing society. The outcome of research in this arena would contribute to creating and securing supplies of energy and food, improving and maintaining accessible health, and developing and ensuring sustainable management of water and air quality. It also helps to solve unknown challenges lying ahead. Many of the life-improving breakthroughs of the last century in areas such as health and medicine, food and agriculture, energy and the environment have been heavily dependent on advances in chemical knowledge. In fact, it was the application of molecular science that resulted in the silicon chip and unlocked the secret of the genetic code. New developments in nanotechnology and materials have chemistry at their core. Thus, basic research in chemistry

holds the key to tackling many of the challenges we face as a society and is the breeding ground of the knowledge-based industries of the future.

Aim

The main aim of this sub-theme is to understand matter, create new forms of matter, and translate its new discoveries into useful products, as well as provide enabling technologies for other disciplines such as biology, medicine, and material science.

Description

This sub-theme involves research in all areas of chemical sciences such as analytical, environmental, inorganic, organic, physical, biological and medicinal chemistry in both experimental and theoretical modalities.

Potential Collaborators

Universities, industries, environmental offices, non-governmental organisations, Ministry of Science and Technology, schools, national and international chemical societies etc.

Expected Output

- Novel materials with wide applications
- Enhanced knowledge on chemical sciences
- New chemical methods
- Advanced chemical instruments
- Improved health protection and care
- Reduced energy demand for domestic purposes
- Reduced depletion of natural resources
- Effectively managed water resources

Research Areas

6.2.1. Analytical chemistry

Research in this area encompasses surface chemistry and interfaces, separation and characterisation of molecules of biological importance, sensors, ion transport within electroactive polymers, high-resolution mass spectrometry of polymers and bio-molecules, fate and transport of pollutants in the environment, modelling, toxicology, electro-analytical measurements, spectroscopy, chromatography, chemometrics, green chemistry, and atmospheric/ aquatic/terrestrial chemistry.

6.2.2. Inorganic chemistry

This research areas cover the spectrum from physical-inorganic to synthetic-inorganic, coordination, organometallic, bioinorganic and biomimetic chemistry, homogeneous catalysis and reaction mechanisms, structure determination, solid state and surface chemistry, crystallography, magnetochemistry, spectroscopy and sensor design and nuclear chemistry that address problems in modern medicine and biology, energy storage and consumption, materials synthesis, photo- and electro-chemical homogeneous and heterogeneous catalysis, and surface chemistry.

6.2.3. Organic chemistry

This research area encompasses physical organic, organic synthesis and asymmetric catalysis, drug discovery, protein and nucleic acid chemistry, bioorganic chemistry, photochemistry, molecular biochemistry, molecular recognition and architecture. Molecular biochemistry, enzymology, and catalysis by proteins are also included under this research area. The topic emphasizes the synthesis of complex natural and unnatural molecules of biological significance with emphasis on the development of new synthetic methodologies. Isolation of bioactive natural products and synthesis aimed at drug discovery and development and medicinal chemistry are other important areas of the research. Newer areas of research are related to utilisation of parallel and combinatorial synthesis methods in complex molecule synthesis.

6.2.4. Physical chemistry

This research area focuses on understanding the physical basis of chemical phenomena. The research includes spectroscopy and microscopy employed to reveal reactions and interactions crucial in biology, materials science, solar energy conversion, and gas phase dynamics; theoretical and computational methods development to discover mechanisms of protein folding and function or to develop new drugs; and quantum and statistical mechanics application to model electron and energy transfer, biochemical reactions, aerosol chemistry, and gas adsorption in porous materials.

Beneficiary

The scientific community, chemical and agrochemical industries, pharmaceuticals, educational institutions.

Sub-theme 6.3. Biophysics and Computational Physics

Rationale

Developments in experimental spectroscopy have, for the first time, revealed quantum effects, in biological system. Quantum mechanics has already proved its remarkable power in understanding the complex micro-phenomena at low temperature, in the fields of physics and chemistry. The current and the most relevant question being asked is how to apply quantum mechanics to events under warm and wet conditions such as in biological systems. Recent evidence of quantum tunnelling, quantum coherence and entanglement in processes such as DNA mutation and photosynthesis show that quantum phenomena indeed play a vital role in biological processes. This motivates to explore the question of how and in what ways quantum mechanics is driving some of the most elegant and inexplicable processes of life. The answers, if and when found, will have great impacts on medical and health sciences.

A quantitative analysis of the bioprocesses requires an improved version of computational techniques. The huge increase in the power of computers in recent years has made an impact on the role of computational physics. In many cases, the entire problems can now be solved

computationally without the need for any experimental inputs. Computer graphics and visualisation now play an important role in the scientific process as they can provide a greater understanding of physical processes. Advances in microelectronics, numerical analysis and computer science have greatly enhanced the importance of computational physics and its applications.

Aim

The aim of this sub-theme is to investigate the life-processes in plants and animals at the micro level and explore the possibility of extending the concepts to the field of medical and other sciences.

Description

This sub-theme focuses on mutation, mutation and quantum tunnelling, enzyme action, quantum nano structure (casimir effect), mathematical modelling, microtubules, quantum network in biology, photosynthesis, quantum computing, and quantum information. It also includes the societal and development impact of quantum biological research outputs. The simultaneous applications of computational physics further compliment and augment the process of research activities and output in the above fields.

Potential Collaborators

Universities, research institutions, Ministry of Science and Technology, pharmaceutics industries etc.

Expected Output

- Better understood molecular systems governing life processes
- Improved technologies to measure quantum systems and quantum effects
- New type of quantum biosensors to understand and manipulate enzymes and other biomolecules.
- Photosynthesis-based technologies for energy collection**.**

- Optimum industrial solutions in quality and process control
- Synthesis of quantitative information generation
- Computational understanding of gene expression data
- Development of software tools to assist in drug discovery process

Research Areas

6.3.1. Quantum Biology

This research area focuses on quantum tunnelling to explain the phenomenon of mutation. It also deals with the mechanism of enhanced catalytic rates in enzymes that can be explained by quantum tunnelling. Nano-machines, which can be approached by quantum limit, quantum electro dynamical effects such as the casimir effect, and physics of certain enzymes that crawl along DNA and considered as molecular motors, will be investigated. Moreover, the concepts of microtubules inside cells that permit long-range quantum coherence, enable quantum information processing to take place at the sub-cellular level, theoretical and experimental basis of photosynthesis, which may lead to the development of artificial photo-systems, will be studied from the physics point of view. The research area also deals with quantum computing and quantum information through quantum coherence and sustenance in the biological system that would help in efficient modelling of the quantum system for energy transfer.

6.3.2. Computational Physics

This area of research encompasses the science of using computers to assist in the solution of physical problems and to further physics research. Large scale quantum mechanical calculations in nuclear, atomic, molecular, and condensed matter physics can be performed. Similar calculations can be done in such fields as hydrodynamics, astrophysics, plasma physics, meteorology and geophysics. Simulation and modelling of complex physical systems such as those that occur in condensed matter physics, medical physics, and industrial applications are quite possible. One can also focus on experimental data processing, image processing, and

data mining/analysis. Development of an efficient software tool to analyse gene expression data can lead to the discovery of a gene responsible for a disease process. This research can accelerate a drug discovery processes.

Beneficiary

Researchers, research institutions, national and overseas universities, and the wider citizen

Sub-theme 6.4. Mathematical Research

Rationale

The need of mathematics is strongly increasing in areas of natural sciences, education, technology, finance, economics and medicine. Nowadays mathematics is categorised in to pure mathematics and applied mathematics. Applied mathematics is more interdisciplinary than pure mathematics. However, the two sub-disciplines are interconnected in such a way that pure mathematics enriches and develops applied mathematics under some constraints. On the other hand, some new technologies may be in need of new and highly advanced mathematical concepts to be formulated for addressing the real problems of technologies. This can be addressed by conducting research at a high level pure mathematics. Hence, the two sub-disciplines complementary roles in serving the advancement of other sciences.

Aim

The main aim of this sub-theme is to explore, introduce, and transfer new computational mathematics knowledge, and to formulate and develop mathematical theories in different streams.

Description

This sub-theme encompasses analysis, ordinary and partial differential equations, optimisation, control theory, algebra, operational research, dynamical systems, etc, which have their own applications in real world problems and sciences such as engineering, agriculture, economics,

medicine, finance, etc. In addition to its role in developing new mathematical theories, the sub-theme deals with relevant applications and models.

Potential Collaborators

Schools, universities, MOE, industries and NGOs involved in promoting mathematics education

Expected Output

- New mathematical methods and theories
- Transformative mathematical knowledge
- Applicable mathematics

Research Areas

6.4.1. Computational mathematics theories and applications

The focus of this research area is integrated modeling, formulation, analysis and numerical algorithms for solving mathematical and computational real world problems. This includes ordinary differential equation (ODE), partial differential equation (PDE), integro-differential equations and stochastic methods, modeling and numerical simulation, computational and mathematical biosciences, and computational algebra. The research area also encompasses studies related to computational methods in solving problems through linear algebra, analysis, ordinary and partial differential equations, asymptotic analysis, elements of harmonic analysis, numerical analysis, optimisation and nonlinear equations.

6.4.2. Transformative new mathematical knowledge and applications

This research area covers a wide range of pure and applied mathematics. It focuses on identifying new mathematical research results in pure as well as applied areas such as analysis, optimisation, operational research, mathematical control theory, numerical analysis, ordinary and partial differential equations, bio-mathematical models, algebra, etc in which an extension,

formulation and developing new theories in connection with agricultural economics, engineering, physics, finance etc. will be conducted.

Beneficiary

Public institutions, industries, scientific community, policy makers, and the wider community