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INCORPORATION OF NATURE'S DESIGN AND DEVELOPMENT IN HIGHER SCIENCE EDUCATION CURRICULUM DESIGN AND RESEARCH PRACTICE

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Abstract. The incorporation of nature's design and development in the higher science education system and research practice is emphasized to foster improved awareness of foundational skills in molecular biology among learners. Multiple perspectives through the prism of global interest in molecular biology will have a huge ripple effect throughout the world of science while protecting the environment and preserving the ecosystem. Steps in the right and exciting directions could enhance the ability to carry out solution-focused and productive research activities on various topics in this interdisciplinary area and eventually result in new cost-effective technologies, technology commercialization, and practical applications. It is clear that in the long run, the benefits of research practice will have a significant positive impact on society.

Keywords: Molecular biology; Nature's design; Higher education; Research practice

1. Introduction

We are naturally curious to know how an enormous variety of life forms such as animals and plants around us function and the origin of life on earth. The human body is one of the most complex living biological multifunctional molecular machines ever designed, and non-linear learning with concept mapping is one of the primary processes that affect the learning outcome in individuals. Cultivating the discipline of scientific inquiry is necessary to sustain the interest and curiosity of the learners in the subject. The applications of molecular biology include research, diagnosis, paternity testing, pedigree verification, forensic analysis, gene therapy, drug design, and genotyping (Malacinski & Pratt 2006; Mader 2001; Audesirk & Byers 2008; Karp 2006; Lodish, Berk, Mtsuadaira et al. 2004). The research output produced in molecular biology, genetic engineering, and biotechnology innovation is already widely recognized by the global research community. Currently, there is a paradigm shift in the methods to investigate the real world around us following scientific modeling principles. The teaching of the fundamental principles of human organ systems such as circulatory, respiratory, nervous, digestive, muscular, and skeletal systems and their comparison with the design and development of artificial engineering systems and modern technological advances helps us to understand the big picture and broader perspective. This different perspective could have a powerful effect on learners' mindsets and productivity. Teaching simple biological aspects through illustrative examples rather than far more biologically complex 3D structures and functions would make higher education more useful. The higher education transformation involving the introduction of a crash course in basic biomimicry brings awareness; however, the real challenge lies in the context of research of new methods and materials. It is essential to expedite the process of research in molecular biology, considering the specific challenges in the field. It is possible to foster breakthrough research outcomes through collaborative, interdisciplinary research efforts to create a vibrant innovation ecosystem. There are at least 21 official journals and more than 374 journals in the journal rankings in the field of molecular biology that reflect extensive research activity[1)].

The purpose of the brief discussion is to motivate the students to think about and learn about natural phenomena, processes, and systems in daily life and apply scientific principles in creative problem-solving. The far-reaching functional implications of the discoveries as a result of research in molecular biology or synthetic biology would help in understanding the universe and designing molecular motors or advanced functional systems, leading to sustainable solutions and care about science and the environment (Nelson & Cox 2012; Mathews, Van Holde & Ahern 2000; Shi 2006; Devlin 2006; Heymann 2014). The development of design thinking involving the three Ps, perception, possibility, and practicality in the learners would help in understanding the intricate mechanism of function of biological systems, designing a logical pattern of structure, the design of engineering systems, and comparing with working artificial systems. The design process steps include the definition of the problem, investigation, research, idea generation, solution development, prototype construction, testing, evaluating and presenting the solution, and finally, technology transfer. It is essential to engage like-minded people in sharing molecular biology-related information on online platforms like LinkedIn or ResearchGate in the current context. This is crucial for the success of the occupation and improves teaching or enhances innovation prospects.

The constructivist approach to learning combines prior knowledge, experiences, and creativity to foster learning and has long-term implications for contemporary classroom practice. This model emphasizes problem-solving and understanding while teaching biological systems and their comparison with functional scientific systems. A cursory glance at research reports and constructive discussions on particular biomimicry studies reveals that many researchers are attempting to imitate many expressions of nature with action planning. Interestingly, these investigations paved the way for fulfilling tangible goals such as tailor-made design, pre-determined properties, thoughtful products, and functional systems. In a sense, it is a bridge between natural and artificial systems as these synthesized products, processes, and systems can be used as biomimetics to understand the natural dynamics with minimal external interference. Strengthening the understanding of basic biomimicry concepts at an early stage in student life is essential in extending the learner's interest in future research activities and developing a systematic problem-solving approach in their everyday lives. Especially the subtler, more profound lessons from nature will lead to more questions about a healthier ecosystem and re-examining, re-discovering, re-educating, and re-connecting universities with the universe in a rational perspective at the head of the 21st century. This relationship and these nature-inspired models inspire close links with nature-related phenomena and participatory approaches involving group discussions and practice sessions. It is possible to regenerate interest and re-ignite the passion for basic and applied research. The reader is introduced to a typical chain of biomimicry examples, stretching their imaginations with threads of many colors in the next section.

2. Aspects and Impacts

The molecular biology field is related to several disciplines of life science and biology and involves the techniques of biochemistry, genetics, and chemistry. Molecular genetics, bioinformatics, molecular medicine, and computational biology are considered sub-fields of molecular biology. There are several career opportunities in molecular biology, medical microbiology, biotechnology, and genetic engineering. The invention of the airplane inspired by vultures, 'Flex-foot' inspired by the hind leg of a cheetah, and solar cell inspired by a leaf are typical examples of biomimicry. Biomimicry is becoming more widespread using nature's designs, processes, and strategies to create systems, and methods that solve human problems. Nature has solved many engineering problems related to useful products, industrial processes, and valuable ecosystems. The abstract design and solid construction of new biological systems and devices to mimic entities such as enzymes, proteins, and cells are essential, contributing to advances in synthetic biology. Our younger generation needs to understand the intricacies of research in molecular biology and feel confident about research work later in their careers. It is necessary to give them a taste of design and allow them to participate in the broader design aspects to understand nature, apply the principles of the biomedical sciences to human needs, or create a complete range of value-packed products. The structural analysis of biological samples using mass spectrometry, X-ray crystallography, and nuclear magnetic resonance provides mechanistic and functional insights. Other molecular biology techniques such as centrifugation, gel electrophoresis, microscopy, DNA fingerprinting, polymerase chain reaction, hybridization, and blotting methods provide useful information about the genesis and function of biological systems, processes, and products (Andreoli, Benjamin, Griggs et al. 2010; Facui and Braunwald 2011; Saltzman 2001; Popescu 2011; Jones 2010). Decoding the secrets of nature would help to develop advanced coding systems or functional models for various applications. The awareness of the multiple aspects of natural systems could eventually lead to the development of superconducting electronics, synthetic blood, artificial leaf, or human body spare parts. The current topics of research emerge from the areas of bio-inspired design, gene expression, genetically modified organisms/foods, biomimetics, bioinformatics, medical imaging, edible vaccines, tissue engineering, eco-friendly materials, high throughput technology, and nanobiotechnology (Hung 2010; Walsh 2007; Crommelien, Sindelar & Meibohm 2008; Fazel-Rezai 2011; Webster 1988). A research journey within molecular biology changes the perspectives and makes the research scholars more conscious and responsible as human beings and provides a touch of accomplishment to the explorer's sense of exploration. The specific challenges of molecular biology include measures of reliability and efficiency, an advanced understanding of fundamental mechanisms and properties, better characterization processes, and develop computation-specific research protocols. However, different parameters such as temperature, pressure, and so on certainly alter the kinetics of the reaction with a profound influence on the properties of the finished products. The best teaching and research contributions in particular areas of study ranging from pure biology to biotechnology will make a meaningful impact on society. During the last decade, significant advances have been made in the development of biomaterials for medical applications (Setlow 2006; Hill 2003; Palacios & Newton 2005; Smith, Richards & Newton 2004). In addition to some basic molecular biology, hot topics such as genetic engineering, gene therapy, genome editing, RNA interference (RNAi), drug delivery, DNA synthesis, DNA sequence, stem cell research, monoclonal antibodies, cancer cell research, primary cells, and transfected cell lines, cytokines and growth factors, and microfluidic methods for molecular biology should be incorporated into the syllabus.

Biomimicry is a method for creating solutions to human challenges by emulating designs and ideas found in nature. The typical examples of biomimicry in the design include gecko climbing feet, kingfisher-inspired bullet trains, baobab tree-inspired treehouses, armadillo backpacks, inch worms-inspired tree-climbing robots, survivor-locating spiders, tentacle-inspired prosthetic arm, wind turbines modeled after humpback whales, antimicrobial film mimicking sharkskin, cephalopod camouflage, spider web glass, firefly lightbulbs, and ventilation systems inspired by termites. The mosquitos painlessly, and unnoticeably suck human blood, and this has inspired scientists to create a similarly-designed harpoon-like hypodermic needle that is equally painless that has been implemented in small biomedical devices such as blood-glucose monitors for diabetic patients. Translating the design of the flippers of a humpback whale into wind turbines will allow us to harvest more wind energy. In the transportation sector, mimicking the sharp and streamlined beak of the kingfisher, the fast-moving trains have increased their speed by 10% and reduced electricity consumption by 15%. The mechanical ventilation design inspired by the termite mounds saves the buildings from purchasing air-conditioning systems and the electricity bill that accompanies them. The study of the echolocation of bats has led to the design of canes for the visually impaired. Similarly, spider-web silk mimicry has led to bullet-proof vests (Kevlar, parachutes). Mimicry of a lotus leaf in its super-hydrophobicity property has led to the discovery of self-cleaning surfaces (e.g., tiles) and clothes. It is this nature-inspired model that will help regenerate an interest in further scientific and technological research activities. The future should hold many new and innovative techniques that will become more and more effective, specific, and reliable. New methods may move out of the research level to practical applications.

If we examine the concept of biological models, scientifically, we can gain insight into the functioning of natural systems, and that will allow us to construct a variety of models based on different parameters, ranging from theoretical models to practical ones. Recently, biological research has focussed on *in-silico* models (performed on a computer or via computer simulation), in addition to conventional *in-vitro* and *in-vivo* models. The design of structural and functional models of complex metalloenzymes, and analyzing the genetic and environmental influences on diseases are made possible by the recent advancements in characterization techniques. However, at a practical level, the current methods of characterization based on a specific analysis of different samples remain the most useful. A long-term approach from concept to commercialization journey involves different phases from bio-inspired ideas for nature-inspired solutions to the marketplace. This exploration is necessary for tackling social and environmental problems in creative ways.

In nature, octopus and cuttlefish can instantaneously change their skin color & pattern to disappear into the environment-swiftly and reversibly morph their skin into a textured 3D surface, giving a rough outline that can lock hundreds of tiny structures into an upright position, giving themselves a particular texture. In an attempt to prepare this concealing material (camouflaging skin) for texture morphing, engineering researchers have invented synthetic camouflaging skin with programmable 3D texture morphing. Engineers are attempting to mimic slug mucus because it has the sticking power of superglue, and the preparation of surgical superglue could revolutionize the way surgical wounds are closed. The direct air-capture machines using carbon capture technology, self-cooling buildings, prosthetics and factory robots, greenhouses in the desert, a bionic leaf that creates hydrogen fuel from sunlight, and making more efficient, greener wind turbines could change the way we live. The reality is that products, processes, and systems are on a spectrum from impure to pure-grade products, less efficient to more efficient processes, and monofunctional to multifunctional systems. The bottom line is that biomimicry is transforming how we live.

3. Biomimicry of Structural Colors

In recent years, researchers inspired by the pattern of colors in nature and studied the physical principles behind them elaborately. The interaction of sunlight on the micro and nanostructure of living beings produces various optical phenomena in biological systems. This phenomenon is now being applied to produce different color patterns by engineering the surface's structure without coloring pigments. Colors change by the synergistic effect of optical phenomena, and the surface structure of the component has many advantages compared to colors obtained by using pigments. The color pattern generated by the specific structure has a long life and a more extended scale. They are also eco-friendly because they are not produced through a chemical process (Dumanlia & Savin 2016). Further, it is possible to make it economical by using cost-effective processes and inexpensive materials. In this direction, two types, namely top-down and bottom-up approaches, are used for engineering the structure on the surface. Top-down techniques such as photolithography (Pimpin & Srituravanich 2012), nanoimprint lithography (Balla, Spearing & Monk 2008), and electron-beam lithography is used to fabricate nanostructure surface. Layer-by-layer deposition technique and self-assembly (Lee, Shim, Hwang et al. 2013) have been used and found attractive from a cost and quality point of view.

4. Self-healing Materials

Researchers are working on biological to technical material systems as part of interdisciplinary research projects to develop self-healing materials. Cracks developed in cured concrete are one of the longstanding problems in the construction sector. The microcracks that developed during the construction process led to a leakage problem and eventually corrode the concrete's steel reinforcements, ultimately causing collapse. Civil engineers and scientists were inspired by the human body wound healing mechanism and developed self-healing concrete technology. The self-healing concrete material developed in such a way that microcapsules filled with healing agents in concrete. When microcracks tips rupture the microcapsules, shells release the healing agent. The released healing agent reacts with the catalyst, and the compound helps in sealing the crack (Al-Ansari, Abu-Taqa, Hassan et al. 2017).

5. Biomimicry in Robots

In recent years bioinspired mechanisms and materials are used in advanced robots. The snakes can make their bodies twist, turn and bend in many ways, making them enter the smallest holes, swim underwater, get wrapped around trees, and crawl over surfaces where most other living beings could not because of their flexible skeleton. It is inspired to develop such mechanisms for robots having such advanced features. The bioinspired mechanisms such as lizard feet, climbing with adhesion, and the exclusive gripper is developed using a combination of livers, transmission elements, and motors for robots. Also, certain smart bioinspired materials are developed and used in the robots to perform the intended function due to external stimulation. Today, drones with flaps inspired by birds designed to look like real birds are used for many applications. It stops like real birds flying in the air flight paths, and they are used in agricultural farms, the waste management sectors, and landfilling.

6. Bioinspired Self-cleaning Surfaces

The application of self-cleaning is extensive and varies from window glass to solar cell panels. The self-cleaning property of the surface is due to the superhydrophobic and superhydrophilic phenomena of the surface. Further, anisotropic wetting, low drag, antifouling, slippery surfaces, and photocatalytic oxidation activities play an important role in the self-cleaning effect. Figure 1 shows the self-cleaning surfaces inspired by a few biological topics (Nishimoto & Bhushan 2012).

7. Conclusions

The peculiar features of products, processes, and systems found in nature have been drawing the attention of many scientists, engineers, and technocrats all over the globe for centuries. The molecular level of understanding of the biological phenomena and multidisciplinary approach has enormous research growth prospects and would eventually lead to exciting breakthroughs that contribute to global technological development (Chen, Klotz & Ross 2016). The construction of structural and functional models of complex biomolecules, mimicking biochemical processes in nature, and the production of eco-friendly materials play a pivotal role in understanding their formation, actions, and regulations. The capabilities of molecular biology and synthetic chemistry combined with the recent progress in the understanding of natural photosynthetic systems promise artificial photosystems on a large scale. Mimicking the seashell structure could lead to more durable buildings. The photosynthesis process can be simulated to create more efficient energy conversion systems. We can also mimic ecosystems and their mode of function to create novel systems to perform specific tasks. Advances in molecular biology and computational informatics will be vital to the realization of the appropriate use of personalized medicines. The exciting developments in liquid biopsy and immunotherapy drugs would help in the early detection and effective treatment of different types of cancer. Creating the nexus between research and practice, enhancing tertiary science education research, and connecting research productivity to classroom and laboratory learning and development would result in a paradigm shift and help to create a sustainable design for human challenges leading to sustainable solutions. A delicate balance of nurturing an intense passion for interdisciplinary molecular biology and its dynamic possibilities and the larger picture of research practice will unfold the enormous potential of practical applications.

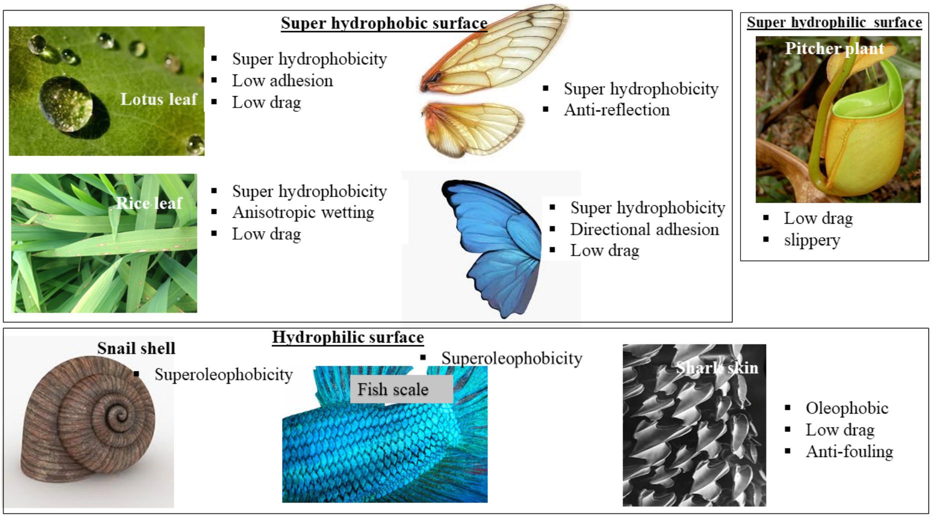

Figure 1. A few inspired biological examples for self-cleaning surfaces

It is a way of trying to engage people and educate them about scientific mimicry, a trend that has long-term implications for rebuilding enduring higher education institutions. There is a widespread perception that the research in biomimicry is quite complex, time-consuming to prepare molecular models, hard to micro-monitor the processes, and challenging to quantify. However, the above qualitative analyses provide a clear message that there are enough scientific reserves to mount a successful research outcome using solution-focused thinking within a goal-focused context and an increase in goal-directed activities supported by academicians, serious think tanks, and proper research infrastructure. Choosing a different course of research activities in solving technical issues will redirect research by altering problem perceptions. It is essential to create a local, national, and global infrastructure to solve a variety of issues in health, agriculture, and education. These facilities will help us revisit research with innovative practices and higher-order thought processes in a scientific context, and eventually, reach into every field of human endeavor. Further study of termite mounds could inspire innovations leading to better human-dwelling design. The detailed investigation of different systems present in the human body could lead to the design of electronically operated artificial body parts. Extending research into the functions of a variety of biological systems could lead to solutions to several engineering problems and a glowing picture of our future.

NOTES

1. https://www.scimagojr.com/journalrank.php?area=1300

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