Pacific Journal of Medical and Health Sciences
ISSN: 2456-7450 | Vol.4, No.1, 2022, pp-01-09

Original Concept

New Era of Integrated Biomedical Engineering and Medicine: STEM Model of Medicine (STEM^2) Part 2. Gateway to new format of Medical Colleges

Dhanjoo Ghista

University 2020 Foundation, San Jose, California, USA

*Corresponding author Email: d.ghista@gmail.com

Website: www.dhanjooghista.com

ABSTRACT

We are now in an era of integrated Biomedical Engineering and Medicine. This paper is about the new format of Medical Colleges (or Medical Schools) in which all subjects from anatomy and physiology to medicine and surgery would be structured by STEM. Together, this formatting of subjects can transform medicine into a STEM format of Medicine or STEM^2, which can be incorporated into both education and healthcare delivery.

KEYWORDS: STEM format of Medicine, Anatomical Engineering, Physiological Engineering, Medical Engineering, Surgical Engineering

Section I. New Era of Medicine and Medical Colleges

We are now entering a new era of Medicine and Medical Colleges, as the most significant developments are taking place at the interface of medicine with biomedical engineering, towards the development of life-changing scientific and technological formulation of medical and surgical procedures. So, in this paper we have formatted a novel STEM Model of Medicine, involving biomedical engineering formulations of anatomy and physiology, medicine, and surgery.

In all fields of science and engineering, Colleges offer bachelor's degree as well as higher master's and PhD degrees. In the same way, new era Medial Colleges will offer the basic medical MBBS (or MD degree in US) as well as MD-PhD (Biomedical Engineering) and MD-PhD (Medical & Surgical Engineering) degree programs

For the MD-PhD (Biomedical Engineering) Program, we have outlined computational courses in (i) Quantitative Physiology, (ii) Organ Systems Medical Engineering, (iii) Orthopedic and Spinal Surgical Engineering, (iv) Mind-Body Psychosomatic Medicine, (v) Sports Biomechanics and Medicine, (vi) Surgical Engineering, preoperatively designed to be patient-specific.

Next, we have structured a novel MD-PhD (Medical & Surgical Engineering) Program to be offered in the Medical College, involving computational courses in (i) Physiological Engineering, towards quantifying physiological systems and processes, (ii) Medical Engineering, towards precision medicine, and (iii) Surgical Engineering, towards patient-customized surgery for obtaining optimal outcomes. This would be the first such medical program worldwide.

Both these dual degree Programs can educate a new batch of scientific and technological medical doctors, who are learned in biomedical engineering formulations of physiological systems, medical diagnostics, and surgical procedures, and are hence also able to implement them in clinical care.

Section II. Dual Degree MD-PhD Programs

In Section II, we have outlined the steps involved in offering Dual-degree Education Programs.

In (i) MD-PhD (Biomedical Engineering), and in (ii) MD-PhD (Medical & Surgical Engineering). These steps involve completing (i) Master's degree in Biomedical Engineering, and (ii) the basic Medical MBBS degree (or MD degree in US). Then for the Dual degree programs, in the first two years, the students can take the above mentioned advanced prescribed courses. Thereafter, the students can work on their PhD thesis.

Section III. Conclusion

In this way, this paper is setting the stage for a new era of integrated medicine, based on the STEM format of Medicine (or $STEM^2$), resulting in the formulation of new types of computationally based disciplines of Anatomical Engineering, Physiological Engineering, Medical Engineering, and Surgical Engineering. We have elaborately described these disciplines.

While this article is breaking new grounds in terms of new academic programs and disciplines, we have also provided many related References of my journal papers and elaborate book chapters, to substantiate and provide examples of the new academic programs and academic disciplines outlined in this paper. This will enable offering of courses for MD-PhD (Biomedical Engineering) and MD-PhD (Medical & Surgical Engineering) programs.

§New era Medical College: STEM model of Medicine

Now we are entering a new era of Medicine, with the most significant developments taking place at the interface of medicine with biomedical engineering, towards the development of life- changing, technological medical procedures and patient-specific surgical procedures. We have developed the guidelines to develop new era medical college, offering STEM based medical education (MD-PhD) programs, contributing to precision medicine and surgery, and hence to enhanced quality of healthcare delivery. Medicine constitutes the "science and engineering of the human body". So, in today's era of advanced science and technology, let us also apply it to our human body, to (i) make precision medical diagnostic systems and appliances, and (ii) design accurate patient-specific surgical procedures and prostheses.

Section I. Background and Raison D'être for a new approach to Medicine, as the most complex of all professional disciplines:

We have been applying advanced Structural Engineering methods to design and construct complex structures that we see around us. Now, Architecture has advanced to architectural design of cities and townships. The Human Body is much more complex than these structures. Besides, it is an active structure that is continually maintained in physiological homeostasis and restructured at the cellular level by molecular biological processes. In fact, the human body is the most complex mini-city architecturally, having the most complicated infrastructure needed to maintain millions of cellular entities living within it.

Hence it is necessary to employ even more advanced methods to (i) analyze and diagnose what is physiologically happening inside the body, (ii) provide preventive care to maintain homeostasis, by mind-body medicine methods, (iii) repair physiological dysfunction, by medications, (iv) repair organ systems dysfunction and failed orthopedic structures, by customized surgery, and (v) build customized prostheses and organ replacements, by 3d printing.

This then calls for a new format of Medical College to educate scientific and technologically competent doctors, to develop and practice precision medicine and surgery. In this modern medical school, we can have new education programs and courses, incorporating STEM formulated biomedical sciences, medicine, and surgery. We are hence proposing to closely involve Biomedical Engineering Departments with Medical Colleges, to (i) make medicine more precise in its diagnostics, (ii) design customized surgical procedures, (iii) improve the patency of implants and prostheses, and (iv) design an efficient health informatics-based healthcare delivery system. We can even have the Biomedical Engineering Departments to be located within the Medical Schools, which would make it more convenient to offer MD-PhD (Biomedical Engineering) Program and MD-PhD (Medical & Surgical Engineering) Program.

I.1STEM Model of Medicine: Biomedical Engineering formulation of Anatomy, Physiology, Medicine, and Surgery:

Through biomedical engineering analysis of anatomical structures, physiological and organ systems, medical tests data, and surgical procedures, we have developed new insights in:

1. **Intrinsic Anatomy,** in how anatomical structures are intrinsically optimally designed for their functional performance, as for example the intrinsic hyperboloid shape of the spinal vertebral body (as a light-weight, high-strength structure), and the ellipsoidal shape of the left ventricle that enables it to contract efficiently.[12-14,27,32,33]
2. **Physiological Engineering,** in quantifying physiological systems and developing indices for their functions and dysfunctions, leading to precision medical diagnostics, such as analyzing how the contraction of the left ventricle (LV) causes its twisting and development of vortices in intra-LV flow, for promoting adequate output into the aorta.[8,17,20,21,27,35,36,45]

3. **Precision Medicine,** by developing biomedical engineering formulation of medical diagnostic and assessment methods and indices, including new concepts of non-dimensional indices in medical assessment, such as cardiac contractility index for risk of heart failure and diabetic index for diabetes diagnosis. [9,10,15,16,17,19,21,24,26,44]

4. **Computational Surgery,** involving customized biomedical engineering analysis of surgical procedures (such as of coronary bypass surgery), and design of prosthetic devices (such as the vertebral body cage for fractured vertebral body, to preserve its intrinsic hyperboloid shape). [22,23,25.28,32,41,42]

Together, they can provide a more rigorous and precision formulation of medicine, which can be incorporated into the courses of the medical curriculum, and then also in clinical care.

I.2. MD-PhD (Biomedical Engineering) Program: involving biomedical engineering formulation of medical and surgical systems

Herein, we are describing Programs in (i) Quantitative Physiology, (ii) Organ Systems Medical Engineering, (iii) Orthopedic and Spinal Surgical Engineering, (iv) Sports Biomechanics and Medicine,(v) Mind-Body Psychosomatic Medicine, (vi) Non-dimensional Physiological Indices in Medical Assessment, and (vii) Patient-specific Surgical procedures. These programs can be offered in the MD-PhD (Biomedical Engineering) Program.

1. Quantitative Physiology

Physics formulations of Physiological Systems functions and dysfunctions can enable us to clearly understand the physiological systems' functional mechanisms, and then apply them in developing medical diagnostic and monitoring systems. For example, for Cardiovascular Physiology, we can study viscous laminar flow in a tube, and how blood pressure is measured using the sphygmomanometer. The study of Electrical field can enable us to determine the electrical field in a cell membrane and the potential difference across the membrane. Then for Neurophysiology, the physics formulation of the concepts of electrical potential, current, resistance and capacitance can be applied to neurobiology phenomenon of nerve conduction, by enabling us to analyze the resting potential of axon membrane, the action potential from stimulus, and propagation of the action potential in a nerve axon. [43,46-49]

2. Organ Systems Medical Engineering

Cardiovascular Medical Engineering: Left Ventricular Wall Stress and Contractility Index, Vector Cardiogram and ECG Signal Processing; Coronary Blood flow and Myocardial Perfusion, Myocardial Infarct detection and Heart Failure; Intra-Ventricular Blood Flow and Candidacy for bypass surgery; Left Ventricular shape based Contractility index; Pulse wave velocity and Detection of Arteriosclerosis, Aortic Pressure Profile and Aortic stiffness determination; Coronary Bypass Surgery design for maximal patency; Prosthetic Aortic and Mitral Valve designs. [8,25,26,27,29,39-42,44-45]

Respiratory-Pulmonary Medical Engineering: Lung Ventilation modeling for lung disease detection, Lung Ventilatory Index; Lung Gas Transfer performance analysis, Determination of O_2 and CO_2 diffusion coefficients, Non-dimensional Gas-transfer index; Indicators for extubation of Mechanically ventilated COPD patients. [15,30,37,38]

Diabetic Medical Engineering: Glucose-Insulin Regulatory Control systems; Oral Glucose Tolerance Test modeling and model parameters determination; Non-dimensional indices for glucose and insulin responses, Non-dimensional Diabetic Index for Diabetes detection; Automated insulin infusion regulatory system, for lowering blood glucose after a meal. [7,31,35,38]

Renal Medical Engineering: Kidney Functional analysis, Countercurrent mechanisms and modeling of urine concentration, osmolality in the descending and ascending limbs of the Loop of Henle; Compartmental model of renal clearance kinetics; Physiological measurement of the Glomerular Filtration Rate (GFR), relationship between blood creatinine levels and the renal clearance rate, Renal clearance convolution analysis; Renography modeling and determination of normalized urine flow rate index to differentiate between obstructed and normal kidneys. [36]

3. Orthopedic and Spinal Surgical Engineering

Orthopedic Biomechanics and Surgery: Osteoporosis Index for osteoporosis detection; Structural analysis of plate-reinforced fractured bone and Optimal design of fixation plate; Osteosynthesis using hemihelical plates for fixation of oblique bone fractures, Finite Element analysis and design of Bone-Plate assemblies and Helical Fixation plate. [10,11,18,23]

Spinal Biomechanics and Surgery: Biomechanical Simulation of Scoliotic Spinal deformity and Correction, Pre-surgical Finite-element Simulation of Scoliosis Correction, Back Pain biomechanics and treatment; Structural analysis of the Spinal Vertebral body as an intrinsically optimal lightweight and high-strength structure, Fractured Vertebral body fixation techniques (anterior and posterior fixations) and design of a vertebral body cage to preserve the hyperboloid shape of the vertebral body; Structural analysis of Intervertebral Disc as an intrinsically optimal minimally deformed structure under spinal loading, Denucleated Disc model analysis and solution for disc herniation. [1-6,12,13,32,33]

4. Sports Biomechanics and Medicine

This Program involves: Optimal Walking Modality based on modeling the leg as a Simple-compound pendulum, Optimal Jogging Mode based on Double-compound model of the lower limb; Analysis of Spinning Ball Trajectories of Soccer kicks and Basketball throws, Analysis of high jump and pole vault, Analysis of tennis serves and cricket bowling, Analysis of Ice Hockey Slap shots and Field Hockey Drag flick; Cardiac Fitness Index based on Treadmill test, Evaluation of Hip Joint based on Differential equation model of the Swinging Leg motion, to determine the hip joint damping and stiffness parameters.[34]

5. Mind-Body Psychosomatic Medicine

This Program will involve stimulation of Cakras and Endocrine Glands, causing release of hormones affecting the Organs, resulting in: Mind-body rejuvenation, by boosting cognitive function, increasing gray matter density in the hippocampus, lowering blood pressure and boosting the immune system, reducing depression and easing stress; Triggering of neurohormonal mechanisms that bring about health benefits, as evidenced by increased parasympathetic and reduced sympathetic nerve activity and increased overall HRV, reducing stress and anxiety; Enhanced release of melatonin, which has anti-inflammatory, immune-stimulating, anti-oxidant and regeneration-enhancing properties.

6. Non-dimensional Physiological Indices in Medical Assessment

This is our new Concept of Non-dimensional Physiological Indices (NDPIs) or Physiological Numbers (PHYNs) for analyzing Physiological Systems and Medical Tests' Data. We have developed some unique NDPIs, such as: Sports Fitness index, Cardiac contractility index, Lung ventilation Index to detect lung disorders, Diabetes diagnosis index from oral-glucose-tolerance test, Arterial stiffness or arteriosclerosis index, Mitral Valve Elasticity Index from heart sound and echocardiography data, Bone osteoporosis index, Hospital Departments' performance-cost indices, and optimizing budget allocation for maximizing patient care with cost-effective hospital operation.[9,21,38]

7. Surgical Engineering, preoperatively designed to be patient-specific

For optimal outcome, surgical procedures can be pre-surgical designed for patients. We have applied this concept to many surgical procedures, ranging from (i) coronary bypass surgery to (ii) fractured vertebral body fixation by means of a fixator designed to simulate the cortical vertebral body's hyperboloid shape. The coronary bypass grafting (CABG) surgical procedure constitutes an effective remedy for high-risk coronary CAD patients. However, its complications and patency are known to be intertwined with the hemodynamics and vascular mechanics of bypass-grafted arterial vessels at the anastomotic sites. In particular, the hemodynamic analysis of CABG blood flow at distal anastomotic sites (which are prone to disturbed flow patterns) is important, to develop anastomoses designs that can enhance the CABG patency. So pre-surgical computational modeling is employed to study how the distal anastomotic geometry can affect the blood flow patterns and the hemodynamic parameters influencing CABG patency. In this way, the optimal anastomotic geometry is designed for a patient.[22,25,42]

I.3 What is needed for Medicine, towards precision (vs. empirical) medicine for the best treatment outcomes:

It is our objective to (i) make medicine more precise in its diagnosis, (ii) improve the outcomes of medical and surgical procedures, and (iii) enhance the patency of medical implants and prostheses.

For this purpose, we need to make Medical Sciences more quantitative, so that they can be translated into more reliable medical and surgical procedures. Now, medical sciences, such as anatomy, physiology, biochemistry, microbiology, molecular biology, pharmacology are undergoing transformation into more scientific and mathematically oriented disciplines. For example, physiology can be taught as physiological physics, anatomy can be taught as anatomical engineering, biology subjects can be taught as systems biology and mathematical biology.

In other words, we need to incorporate the full scope of STEM subjects into Medicine, into both medical sciences and clinical sciences.

Modern Medical Curriculum, to educate scientific and technological doctors to offer the best healthcare to their patients:

Many medical schools in US have started to develop a new medical curriculum, for the next generation of primary care physicians, medical and surgical specialists. This curriculum provides an education that integrates formal classroom-based medical science knowledge with patient-centered and disease-focused medical education. Essentially, the new curriculum features foundational medical sciences courses integrated with early engagement with patients and clinical training, involving teaching medical students about the health care system, and how to integrate use of technology into the practice of medicine. The four inter-woven pillars of this new medical curriculum are Health Systems Sciences, Medical Sciences, Healthcare Informatics, and Clinical Sciences. The shift in this new curriculum is to make students more informed about healthcare delivery system.

However, this modern curriculum does not contribute to precision medicine. In fact, in this modern medical curriculum, there remains the need for (i) engineering-physics-mathematics incorporation into medical sciences, and (ii) biomedical engineering incorporation into clinical sciences, in order to cultivate knowledge for more quantitative medical and clinical sciences leading to more precise medical and surgical procedures — which is where medicine is headed in the 21st century.

For this purpose, we are proposing the following MD-PhD (Medical & Surgical Engineering) Program, to be offered in the Medical College (or Medical School in US and UK), in collaboration with the Biomedical Engineering Department.

I.4.MD-PhD (Medical & Surgical Engineering) Program (to be offered in the Medical College (or Medical School in US and UK) :

With the help of the Biomedical Engineering Department, this novel program will consist of the above-described Courses in:

1. Physiological Engineering (described in Section I.1):

Quantifying physiological systems by physics and engineering formatting, and developing indices for their functions and dysfunctions, leading to precision medical diagnostics, such as analyzing how the contraction of the left ventricle (LV) causes its twisting and development of vortices in intra-LV flow, for promoting ejection fraction. [9,17,20,21,27,35,36,38,39,45]

2. Medical Engineering (described in Section I.2):

Cardiovascular Medical Engineering; Renal Medical Engineering; Pulmonary Medical Engineering; Glucose-Insulin Regulatory Diabetic Engineering. [7, 8, 16, 19,20,27,28,29,30,31,36,37]

3. Surgical Engineering (described in Section I.2):

Cardiac Surgical Engineering (in coronary stenting and bypass surgery); Orthopedic and Spinal Surgical Engineering (of bone fracture fixation, joint replacement, and spinal fracture fixation); Computerized surgical simulation to analyze and plan patient-specific surgical procedures for obtaining optimal outcomes. [1-6,10,18,22,23,25,41,42]

This MD-PhD (Medical & Surgical Engineering) would be the first such program worldwide. In fact, both these dual-degree programs would educate a new batch of scientific and technological medical doctors, who are learned in biomedical engineering formulations of medical systems and surgical procedures, and are able to implement them in clinical care.

I.5Textbooks to offer these Courses:

My recent book scan serve as textbooks for many of these courses.

1. Applied Biomedical Engineering (CRC Press, Taylor and Francis, 2009):This book uses a problem-based approach to (i) quantify cardiovascular, respiratory, glucose-insulin regulatory systems, and formulate diagnostic and interventional procedures, (ii) analyze orthopedic and spinal structures and design surgical procedures for fractured structures, and (iii) analyze sports and athletic events, and develop fitness measures.

[https://drive.google.com/open?id=0BzOPlHbjWLYta3djeFV0MkRaMXc]

2. Biomedical Science, Engineering and Technology (InTech Publishers, 2012):

Biomedical Science, Engineering and Technology, by Dhanjoo N. Ghista

Chapter 1: Biomedical Engineering Professional Trail from Anatomy and Physiology to Medicine and Into Hospital Administration: Towards Higher-Order of Translational Medicine and Patient Care.

Chapter '35. Physiological Nondimensional Indices in Medical Assessment: For Quantifying Physiological Systems and Analysing Medical Tests Data

3. Cardiology Science and Technology (CRC Press, Taylor and Francis, 2016)

Section 1: Left Ventricular Wall Stress; Left Ventricular Contractility measures; Mechanics of LV Pressure Increase during LV Isovolumic Contraction Phase due to Activation of Myocardial Fibers; Myocardial Infarct induced Left Ventricular Shape Remodeling, and Surgical Ventricular Restoration to restore cardiac contractility, Vector Cardiogram theory and clinical Applications.

Section II: ECG Signal Analysis to detect cardiac arrhythmias, Intra-LV Blood Flow Analysis, and Coronary bypass surgery candidacy; Arterial Pulse wave propagation analysis of pulse wave velocity; Cardiac Perfusion analysis and Computation of Intra-myocardial Blood Flow patterns; Simulation of Blood Flow in Patient-Specific Coronary Arteries: Coronary Bypass surgical graft design for enhancing its patency.

[https://drive.google.com/open?id=0BzOPlHbjWLYtR0ZieEFQNTNmVGM].

4.Computational and Mathematical Methods in Cardiovascular Physiology (World Scientific, 2018):

This book has transformed Cardiovascular Physiology into a STEM discipline, involving (i) quantitative formulations of heart anatomy and physiology, (ii) technologies for imaging the heart and blood vessels, (iii) fluid mechanics and computational analysis of blood flow in the heart, aorta, and coronary arteries, (iv) design of heart valves, percutaneous valve stents, and ventricular assist devices.

[https://www.worldscientific.com/worldscibooks/10.1142/10996]

5. Biomedical Engineering Modeling of Pancreatic, Respiratory, and Renal Systems, and Medical Assessments, to be published by Elsevier.

I.5. New Era Colleges of Medicine:

In Section I.2, we have outlined the MD-PhD (Biomedical Engineering) Program, and in Section 1.4, we have described the MD-PhD (Medical & Surgical Engineering) Program. Together these two programs can help to develop a new era Medical Colleges.

Section II. STEM Model of Medicine: Medical College and Biomedical Engineering Department to jointly offer (i) MD-PhD (Biomedical Engineering) Program, and (ii) MD-PhD (Medical & Surgical Engineering) Program

In the Part 1 paper, we have we have outlined the constituents of new era Biomedical Engineering Departments. In this paper Section I, we have described the make-up of a new era Medical College. So now let us bring them together to outline the steps for offering these dual degree MD-PhD (Biomedical Engineering) and MD-PhD (Medical & Surgical Engineering) Programs in a Medical College. For that purpose, ideally new era medical colleges can have biomedical engineering departments within them. In this way, it would make it more convenient for biomedical engineering students to be educated and prepared to enter the medical college to do MD-PhD (Biomedical Engineering) degree or MD-PhD (Medical & Surgical Engineering) degree.

Step 1. Biomedical Engineering Bachelor's Degree

The first two years will comprise of Core Curriculum courses, in Humanities and Social sciences, Chemistry and Biology, Physics and Mathematics, Computer Science and Information Technology.

In year Three, we can offer basic Engineering courses, in Mechanical Engineering (solid and fluid mechanics), Chemical engineering and Transport processes, Electrical Engineering and Electronic Engineering, Computer Engineering and Artificial Intelligence.

In year Four, we can offer fundamental Biomedical Engineering courses, in Biomechanical Engineering, Bioelectrical Engineering, Biochemical Engineering, Signal and Image Processing, Medical Instrumentation.

Step 2:At this stage, we will divide the graduated students into two batches: (i) Admitted to School of Medicine, to do MBBS (or MD in US), followed by MD-PhD (Biomedical Engineering) degree; (ii) Admitted to doing a Master's degree in Biomedical Engineering, followed by PhD in Biomedical Engineering or MD-PhD (Medical & Surgical Engineering),.

Master's Degree in Biomedical Engineering

This will be a 2-year program, during which time the students will take master's degree courses in Physiological Engineering, Organ Systems Engineering, Medical Signal & Image Processing, Medical Instrumentation& Medical Apps, Medical Engineering, as described in Section I.2 or in more detail in Part I.

Then, after passing the PhD qualifying exam, the master's degree graduates can complete the PhD degree in Biomedical Engineering.

Step 3. Complete the 4-year Basic Medical Degree:

For that purpose, Biomedical Engineering bachelor's, master's and doctoral graduates can be admitted to the Medical School, and complete the basic MBBS (or MD) Degree in four years.

Step 4. Do either MD-PhD (Biomedical Engineering) or MD-PhD (Medical & Surgical Engineering):

In years 5 and 6 (after entering the Medical College), the MBBS (or MD) students can take the above-prescribed courses in

(i) Section I.2, for MD-PhD (Biomedical Engineering) degree

(ii) Section I.4, for MD-PhD (Medical and Surgical Engineering) degree.

Thereafter, the students will do PhD Thesis, while also doing internship in the hospital.

Section III. Conclusion

This paper is setting the stage for a new era of medicine, medical education, and medical colleges, based on the coalition of medicine and biomedical engineering, resulting in the engineering of the human body function, and formulation of these new disciplines:

1. Anatomical Engineering: Anatomical structures can be modeled as intrinsically optimally designed for their function, as for example (i) The hyperboloid shaped spinal vertebral body whose generators enable it to efficiently bear compression, bending, and torsional loadings, and (ii) The helically wound fibers of the left ventricle, which can enable it twist and hence contract very efficiently. [12-14,27,32,33]

2. Physiological Engineering: Physiological systems can be engineering model led to illustrate their intricate function, as for example:(i) How the blood flow in the left ventricle (LV) develops vortices in response to the contractile twisting of the ellipsoidal-shaped LV, to enable efficient blood flow out of the LV into the aorta, (ii) How the countercurrent multiplier mechanism in the kidney's loop-of-Henle creates osmotic gradient for active transport of Na+ from the tubular fluid, diffusion of H_2O from the tubular lumen into the interstitium, resulting in the production of concentrated urine in the distal tubule and collecting duct. [9,17,19,21,27,35,36,38]

3. Medical Engineering: This can comprise of (i) Cardiovascular Medical Engineering, e.g., Left ventricular normalized wall-stress based contractility index for detecting heart failure;(ii) Pulmonary Medical Engineering, e.g., Non-dimensional Gas-transfer index, involving diffusion coefficients of O_2 and CO_2, to assess the gas-transfer capacity of the lung-capillary system; (iii) Diabetic Medical Engineering, e.g., Oral Glucose Tolerance Test modeling and data simulation to determine the model parameters, for diabetes detection; (iv) Renal Medical Engineering, involving formulation of hemodialysis and peritoneal dialysis for kidney failure. [8,15,16,19,20,21,24,26,27,29,30,31,36,37,45]

4. Surgical Engineering: This can comprise of (i) Biomechanical simulation of Scoliosis Surgical Correction, (ii) Patient-specific Coronary Bypass Surgery, involving pre-surgical analysis of optimal configuration of anastomosis of the graft and occluded coronary artery, to promote long-term patency of the surgical procedure, and (iii) Fractured Vertebral body fixation technique, and design of a vertebral body cage to preserve the intrinsic hyperboloid shape of the fractured vertebral body. [1-6,10,18,22,23,25.41,42]

These new disciplines can now form part of medical education in medical schools, by which we will have an advanced STEM format of Medicine in Medical Colleges, and correspondingly an advanced healthcare delivery system.

CONFLICTS OF INTEREST: None

FINANCIAL SUPPORT: None

Section IV. References (of my related Journal Papers and Book Chapters)

1. Biomechanical Analysis and Simulation of Scoliosis Surgical Correction, by G.R. Viviani, D.N. Ghista, P.J. Lozada, K. Subbairaj' and G. Barnes. Special issue of ***Clinical Orthopaedics and Related Research, featuring "Advances in Canada"***, Vol. 208, July1986.

2. Biomechanical Basis of Optimal Scollosis Surgical Correction, by D.N.Ghista, G.R. Viviani, K. Subbaraj, P.J. Lozada, T.M. Srinivasan and G. Barnes. ***Journal of Biomechanics,*** Vol. 2 1, No. 2,1988.

3. Presurgical Finite-element Simulation of Scoliosis Correction, by K.Subbaraj, D.N.Ghista and G.R.Viviani. ***Journal of Biomedical Engineering***,Vol.1,9-18, 1989.

4. Clinical Biomechanics of Spinal Fixation: Anterior, Posterior Fixations", by S.M. Rezaian and D.N. Ghista. ***Engineering in Medicine and Biology,*** Vol. 13, No. 4, Aug/Sept1994.

5. Spinal Biomechanics of Function and Low-Back Pain", by D.N.Ghista and A. Shirazi-Adl. ***Reviews in Neurology,*** (editors: R. Borgohain & S. Mohandas), ***Indian Academy of Neurology,*** 1997.

6. Biomechanics of Back Pain Prevention and Treatment: Postural Energization of Spinal Structures, and Percutaneous Discectomy, by D.N. Ghista, J. Mazumdar, S. Subbaraj, and S.M. Rezaian. ***Engineering in Medicine & Biology,*** May issue, 1998.

7. Glucose Tolerance Test Modeling & Patient-Simulation for Diagnosis, by Sarma Dittakavi & Dhanjoo N. Ghista. ***Journal of Mechanics in Medicine& Biology,*** Vol. 1, No.2,Oct.2001.

8. Determination of Aortic Pressure-time Profile, Along with Aortic Stiffness and Peripheral Resistance, by Liang Zhong, Dhanjoo N. Ghista, Eddie Y-K. Ng, Lim Soo Teik and Chua Siang Jin. ***Journal of Mechanics in Medicine & Biology*** 2004,4(4):499-509.

9. Physiological Systems' Numbers in Medical Diagnosis and Hospital Cost- effective Operation, by Dhanjoo N. Ghista. ***Journal of Mechanics in Medicine & Biology*** 2005, vol 4, No.4.

10. Design of Fracture Fixation Plate for Necessary and Sufficient Bone Stress Shielding, by K. Rama Krishna, I. Sridhar, S. Sivashanker, K. S. Khong and D.N. Ghista. ***The Japan Society of Mechanical Engineers*** Series C, Vol 47(4), pp 1086-1094. 2005.

11. Stress Analysis of Normal and Osteoarthritic Femur Using Finite Element Analysis", by A.H. Elkholy, D.N.Ghista, F.S. D'Souza and M.S. Kutty. ***International Journal of Computer Applications in Technology,*** 2005, 22(4): 205-211.

12. Human Lumbar Vertebral Body as an Intrinsic Functionally-optimal Structure, by D.N. Ghista, S.C. Fan, K. Ramakrishna, I. Sridhar. ***International Journal of Design and Nature,*** 2006, 1(1): 34-47.

13. The Optimal Structural design of the human Spinal Intervertebral disc", by D.N.Ghista, S.C. Fan, I. Sridhar, K. Ramakrishna. ***International Journal of Design and Nature,*** 2006, 1(2).

14. LV shape-based contractility indices, by Liang Zhong, Dhanjoo N. Ghista, Eddie Y-K. Ng, Lim Soo Teik and Chua Siang Jin, CN Lee. ***Journal of Biomechanics,*** 2006, 39:2397-2409.

15. Lung Ventilation Modelling and assessment, by D.N.Ghista, K.M. Loh. ***Human Respiration: Anatomy & Physiology, Mathematical Modelling and Applications,*** ed by Vladimir Kulish, WIT Press,2006.

16. Lung Gas Composition and Transfer Analysis: O_2 and Co_2 Diffusion Coefficients and Metabolic rates, by D.N.Ghista, K.M. Loh and D. Ng. **Human Respiration: Anatomy & Physiology, Mathematical Modelling and Applications,** ed by Vladimir Kulish, WIT Press,2006.

17. Validation of a novel noninvasive cardiac index of left ventricular contractility in patients, by Zhong L , Tan RS, Ghista DN, Ng E. Y-K, Chua LP, Kassab GS. ***Am.J Physiol*** Heart Circ Physiol 2007,292:H2764-2772.

18. Analysis of the helical plate for bone fracture Fixation", by Kotlanka Rama Krishna, Idapalapati Sridhar , Dhanjoo N. Ghista. ; in ***INJURY : International Journal of the Care of the Injured,*** 2008;39(12):1421-1436.

19. Mechanism of Left Ventricular Pressure increase during Isovolumic contraction, and determination of its Equivalent myocardial fibers orientation, by Ghista, DN, Liu Li, Chua LP, Zhong L, Tan RS, Tan YS. ***J of Mechs Med Biol,*** 2009, 9 (2),177– 198.

20. Cardiac Contractility measures of Left Ventricular systolic functional assessment of normal and diseased hearts, by Dhanjoo N. Ghista, Liang Zhong , Thu-ThaoLe, and Ru-San Tan. ***J of Mechs Med Biol,*** Vol 9, No 4,2009.

21. Nondimensional Physiological Indices for Medical assessment, by Dhanjoo N. Ghista. ***J of Mechanics in Medicine and Biology,*** Vol 9, No 4, 2009.

22. A Novel Coronary Artery Bypass Graft Design of Sequential Anastomoses, by Foad Kabinejadian, Leok Poh Chua, Dhanjoo N. Ghista, Meena Sankaranarayanan, Yong Seng Tan. ***Annals of Biomedical Engineering*** 2010; 38:3135-3150.

23. Optimal Design of Customised Hip Prosthesis Using Fibre Reinforced Composites", by I. Sridhar, P.P. Adie and D.N. Ghista. ***J Materials and Design,*** 31, 2767-2775, 2010.

24. An integrated diabetic index using heart rate variability signal features for diagnosis of diabetes, U. Rajendra Acharya, Oliver Faust, S. Vinitha Sree, Dhanjoo N Ghista, Sumeet Dua, Paul Joseph, V. I. Thajudin Ahamed, Nittiagandhi Janarthanan, Toshiyo Tamura. ***Computer Methods in Biomechanics and Biomedical Engineering,*** vol.16, no. 2, pp.222-234, 2013.

25. Coronary Artery Bypass Grafting Anastomoses' Hemodynamics and Designs: A Biomedical Engineering Review, Dhanjoo N Ghista and Foad Kabinejadian. ***BioMedical Engineering Online,*** 2013.

26. Automated Detection and Localization of Myocardial Infarction Using Electrocardiogram: A Comparative Study of Different Leads, U Rajendra Acharya, Hamido Fujita, Vidya Sudarshan, Oh Shu Lih, Muhammad Adam, Joel EW Koh, Jen Hong Tan, Dhanjoo N Ghista, Roshan Joy Martis, Chua K Chua, Chua KoK Poo, Tan Ru San. ***Knowledge-Based Systems,*** 99, 2016, 146-156.

27. Computerizing the anatomically smart Left Ventricle: How its shape-factor based index relates to its contractile performance—depicting new quantitative trends in medicine, by Dhanjoo Ghista. ***Pacific Journal of Medical and Health Sciences,*** August 2021.

28. Physiologically personalized coronary blood flow model to improve the estimation of noninvasive fractional flow reserve", by Xiujian Liu, Chuangye Xu, Simin Rao, Ye Zhang, Dhanjoo Ghista, Zhifan Gao, Guang Yang. ***Medical Physics,*** November 2021.

29. Left Ventricular Contractility Indices, by Dhanjoo N. Ghista and Liang Zhong. ***Chapter 3, Applied Biomedical Engineering Mechanics,*** by Dhanjoo Ghista, CRC Press, Taylor and Francis, 2008.

30. Lung Ventilation Modeling for Lung Disease Diagnosis, by Dhanjoo N. Ghista and Meena Sankaranarayanan. ***Chapter 5, Applied Biomedical Engineering Mechanics,*** by Dhanjoo Ghista, CRC Press, Taylor and Francis, 2008.

31. Modeling of OGTT Blood Glucose and Insulin Responses and Diagnostic Indices, by Dhanjoo N. Ghista, Kah Meng Loh, and Meena Sankaranarayanan. ***Chapter 10, Applied Biomedical Engineering Mechanics,*** by Dhanjoo Ghista, CRC Press, Taylor and Francis, 2008.

32. Human Lumbar Vertebral Body: Analysis of Its Functionally Optimal Structure, by Dhanjoo N. Ghista, Sridhar Idapalapati, and Ramakrishna Kotlanka. ***Chapter 12, Applied Biomedical Engineering Mechanics,*** by Dhanjoo Ghista, CRC Press, Taylor and Francis, 2008.

33. Human Spinal Intervertebral Disc: Optimal Structural Design Characteristics, by Dhanjoo N. Ghista, Sridhar Idapalapati, and Ramakrishna Kotlanka. ***Chapter 13, Applied Biomedical Engineering Mechanics,*** by Dhanjoo Ghista, CRC Press, Taylor and Francis, 2008.

34. Biomechanics of Fitness Index: Optimal Walking and Jogging Modes, and Hip Joint Assessment, by Dhanjoo N. Ghista, Jor Huat Ong, and Geok Hian Lim. ***Chapter 14, Applied Biomedical Engineering Mechanics,*** by Dhanjoo Ghista, CRC Press, Taylor and Francis, 2008.

35. Biomedical Engineering Professional Trail from Anatomy and Physiology to Medicine and Into Hospital Administration: Towards Higher-Order of Translational Medicine and Patient Care, by Dhanjoo Ghista, ***Chapter 1, Biomedical Science, Engineering and Technology,*** by Dhanjoo N. Ghista, InTechOpen, 2012.

36. –Renal Physiological Engineering Optimization Aspects, by David Chee-Eng Ng and Dhanjoo N. Ghista. ***Chapter 33, Biomedical Science, Engineering and Technology,*** by Dhanjoo N. Ghista, InTechOpen, 2012.

37. Lung Ventilation Modeling for Assessment of Lung Status: Detection of Lung Disease and Indication for Extubation of Mechanically-Ventilated COPD Patients, by Dhanjoo N. Ghista, Kah Meng Koh, Rohit Pasam and Yi Su. ***Chapter***

34, Biomedical Science, Engineering and Technology, by Dhanjoo N. Ghista, InTechOpen, 2012.

38'. Physiological Nondimensional Indices in Medical Assessment: For Quantifying Physiological Systems and Analysing Medical Tests Data, by Dhanjoo N. Ghista. ***Chapter 35, Biomedical Science, Engineering and Technology,*** by Dhanjoo N. Ghista, InTechOpen, 2012.

39. Novel Cardiac Contractility Index and Ventricular-Arterial Matching Index to Serve as Markers of Heart Failure, by Liang Zhong, Dhanjoo N. Ghista, Ghassan S. Kassab, and Ru San Tan. ***Chapter 3, Cardiology Science and Technology,*** by Dhanjoo N. Ghista, CRC Press, Taylor and Francis, 2016.

40. Cardiomyopathy Effect on Left Ventricle Function (Shape, Wall Stress, and Contractility) and Improvement after Surgical Ventricular Restoration, by Dhanjoo N. Ghista, Yi Su, Liang Zhong, Ru San Tan, and Ghassan S. Kassab. ***Chapter 4, Cardiology Science and Technology,*** by Dhanjoo N. Ghista, CRC Press, Taylor and Francis, 2016.

41. Left Ventricular Blood Pump Analysis of Intra-LV Flow Velocity and Pressure, for Coronary Bypass Surgery Candidacy, by Dhanjoo N. Ghista, Foad Kabinejadian, K. Subbaraj, and Ernie Fallen. ***Chapter 10, Cardiology Science and Technology,*** by Dhanjoo N. Ghista, CRC Press, Taylor and Francis, 2016.

42. Coronary Blood Flow Analysis and Coronary Bypass Graft Flow and Design Foad Kabinejadian, Yunlong Huo, Dhanjoo N. Ghista, and Ghassan S. Kassab. ***Chapter 15, Cardiology Science and Technology,*** by Dhanjoo N. Ghista, CRC Press, Taylor and Francis, 2016.

43. Physics, by Joseph Kane and Morton Sternheim, John Wiley & Sons.

44. A Hybrid Approach for Cardiac Blood Flow Vortex Ring Identification based on Optical Flow and Lagrangian Averaged Vorticity Deviation", by Ke Yang, Shiqian Wu, Oluwarotimi W. Samuel, Hui Zhang, Dhanjoo N. Ghista, Di Yang, Kelvin K.L. Wong, ***Frontiers in Physiology, section Computational Physiology and Medicine,*** August 2021.

45. Physiologically personalized coronary blood flow model to improve the estimation of noninvasive fractional flow reserve", by Xiujian Liu, Chuangye Xu, Simin Rao, Heye Zhang, Dhanjoo Ghista, Zhifan Gao, Guang Yang, ***Medical Physics,*** Vol 49, Issue 1, Jan 2022.

46. A Text-Book of Physics (with sections on Applications of Physics to Physiology and Medicine, by Robert Alfred Lehfeldt, Biblio Life, 2015.

47. Physics of the Human Body, by Irving Herman, Springer, 2007.

48. Intermediate Physics for Medicine and Biology, by Russell Hobbie and Bradley Roth, Springer, 2007.

49. Physiology, Biophysics and Biomedical Engineering, by Andrew Wood, CRC Press, Taylor and Francis, 2012.