

Program/ Curriculum Innovation

Biomedical Engineering Development: Contributing to Quantitative Physiology, Precision Medicine, and Quality Healthcare Delivery

Dhanjoo Ghista

University 2020 Foundation, San Jose, California, USA

Email: d.ghista@gmail.com

Website: <https://sites.google.com/site/dhanjooghista/home>

ABSTRACT

This article comprises the following Items:

Item 1. Biomedical Engineering (BE, ME & PhD) Programs

Biomedical Engineering is the application of engineering disciplines' formulations (of theories and designs) to biology, physiology and medicine, to improve medical monitoring, diagnosis, and therapy.

Item 2. Quantitative Physiology Program, jointly with College of Medicine

Quantitative Physiology Program can help to develop more precise medical diagnostics. This program involves formulation of Human Physiology courses from physics and engineering perspectives. It comprises two parts: Part I. Fundamental Physiological Processes: Physics and Engineering Modelling, and Part II. Physiological Systems Functions: Physics and Engineering Modelling.

Item 3. Precision Quantitative Medicine Program, jointly with College of Medicine

The Precision Quantitative Medicine Program is based on my Biomedical Engineering developments in (i) Physiology, Medicine, Orthopaedics and Surgery, (ii) Sports Biomechanics and Medicine, and (iii) Mind-Body Medicine in Psychiatry. This Program can be offered as an MD-PhD (Biomedical Engineering) Program, jointly between the Biomedical Engineering Department and the College of Medicine.

Item 4. MD-PhD (Biomedical Engineering) Program, jointly with College of Medicine

This Program is intended for medical students interested in combining medical practice with competency in biomedical engineering, to implement BME technologies in clinical research and applications in clinical care in hospitals. The program emphasizes computational medicine and computational surgery.

Item 5. Hospital and Healthcare Management (MBA and MD-MBA) Program, jointly with College of Business and College of Medicine

The Hospital and Healthcare (HOHM) Program is designed to provide the relevant multidisciplinary knowledgebase in business administration, clinical and hospital engineering, economic and financial management, related to cost-effective operation of hospitals and healthcare delivery (as represented by the three pillars of HOHM depicted below), to healthcare and hospital administrators.

Together, these developments constitute a novel model of Biomedical Engineering, contributing to Quantitative Physiology, Precision Quantitative Medicine, and Quality Healthcare Delivery.

Item 6. In Conclusion

Biomedical Engineering drives modern healthcare through its integration with medicine. By enabling advanced measurement, targeted therapies, and data-driven treatments, the field has fundamentally transformed how we understand human physiology and deliver quality patient care.

KEYWORDS: Biomedical engineering; Curriculum development; Quantitative physiology; Precision medicine; MD-PhD program; Healthcare management.

Item I. Biomedical Engineering (BE, ME & PhD) Programs Clinical Internship

Biomedical Engineering is the application of engineering disciplines' formulations (of theories and designs) to biology, physiology and medicine, to improve medical monitoring, diagnosis, and therapy.

Biomedical engineering bridges engineering and medical disciplines to provide an overall enhancement of health care. Today, Biomedical Engineering has advanced incredibly, and is poised to provide new insights in medicine and healthcare, through: 1. Quantitative analysis of mechanisms and functions of Physiological systems (such as cardiovascular and musculoskeletal systems), 2. Cellular and Molecular Engineering, 3. Computerized processing and diagnostic pattern recognition of medical signals and images, 4. Design of prosthetic devices and implanted systems, 5. Regenerative Tissue engineering, 6. Pharmaceutical Engineering, 7. Rehabilitation systems, prosthetic and orthotic devices.

Biomedical Engineering Courses:

1. Quantitative Physiology I (Cells and Molecules), Quantitative Physiology II (Organ Systems).
2. Biomaterials, Cellular and Tissue Biomechanics, Biofluid Mechanics, Biotransport processes, Musculoskeletal Biomechanics.
3. Cellular and Molecular Engineering, Pharmaceutical Engineering: Drug designing, producing and delivery Systems.
4. Bioelectrical Processes, Physiological Control Systems, Tissue Engineering and Regenerative Medicine.
5. Physiological Signals and Processing, Medical Image Processing and Pattern Recognition, Medical Instrumentation.
6. Orthopaedic Biomechanics, Cardiovascular System Engineering, Pulmonary System Engineering, Renal System Engineering, Neurological System Engineering.

We can catalogue these courses into the following five domains:

1. Quantitative Human Physiology: Physics and Engineering formulations of Physiological Systems functions and dysfunctions, enable us to clearly understand the physiological system functional mechanisms, monitoring systems, and diagnostics. For example, in 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 analyse the resting potential of axon membrane, the action potential from stimulus, and propagation of the action potential in a nerve axon. In Cardiovascular Physiology, we can develop a novel cardiac contractility index, in terms of the maximum rate of change of LV systolic wall stress normalized to intra-LV pressure, which can be determined noninvasively in terms of myocardium volume and maximum outflow rate^{1,2}.
2. Organ Systems Function: Biomedical Engineering formulation of Organ Systems, such as the Heart, Lungs and Kidneys, involving (i) analyses of their function, (ii) detection of abnormal function by formulation of indices (such as left ventricle contractility index to assess heart dysfunction due to cardiomyopathy), and (iii) design of systems and devices to compensate for dysfunction (as for example, ventricular assist device to assist the weakened-contractile left ventricle in providing adequate cardiac output).
3. Medical Diagnostic Apps: Over the years, there has been significant number of works and publications on medical signal and image processing methods and techniques for making medical diagnosis. We now need to convert them into devices that can automate accurate medical diagnostics. Medical Diagnostic

Apps combine these signal and image processing software into smart apps by using machine learning computer-generated artificial intelligence technique, for automatically classifying patterns in data to crowdsource and build on the best medical knowledge from thousands of physicians across many countries. Our goal is to provide timely and affordable specialist advice to general practitioners serving millions of people worldwide, in the "safety net" hospitals and clinics. Learning of these Medical Apps as part of medical education can help improve the training and performance of primary care physicians.

4. Customized Surgical Systems and Procedures: This category includes (i) Presurgical Patient-specific Surgical Design, and (ii) Creating 3D Surgical Models from Patient Scans.

For obtaining more reliable surgical outcomes, it is necessary to pre-surgically design patient-specific procedures. For example, in order to obtain the best outcome from coronary bypass surgery on a patient, we need to determine the optimal configuration of distal anastomosis of graft and occluded artery, to obtain the ideal blood flow distribution in this anastomotic space which will promote long-term patency of the surgical procedure.

Then for Surgical Precision, surgeons can learn how to (i) guide surgical instruments to the exact place, and (ii) move organs out of the way without causing damage.

5. Customized Precision 3-d printed Limb Prostheses, Human tissues and Organ Replacements: The medical industry is now utilizing the rapidly advancing 3D printing technology for human health benefit in a big way. We can now print anything from 3d printed customized prosthetic limbs to heart valves and dentures, to human organs and human tissues with blood vessels. For a 3D printer to work, we have to feed it instructions in the form of a 3D model, which is a 2-d computer-aided design file designed by using special 3D production software, to create an accurate 3D representation of an object's surface area. The 3D medical printers for artificial tissue use biodegradable materials along with hydrogels comprising of real human cells, which gives the tissue both strength and structure.

This program can be supported by my Textbooks:

1. Cardiac Perfusion and Pumping (World Scientific, 2006): Physiomics of Coronary Perfusion and Cardiac Pumping; Quantification of Cardiac Perfusion and Function Using Nuclear Cardiac Imaging; Perfusion Depiction by SPECT Imaging, Computation of Blood Flow Pressure and Velocity Patterns Within

Myocardial Regions; Left Ventricular (LV) Pressure Increase Mechanism During Isovolumic Contraction, and Determination of the Equivalent LV Myocardial Fibers Orientation; New Clinically Relevant Left Ventricular Contractility Index (based on Normalized Wall Stress); Augmented Myocardial Perfusion by Coronary Bypass Surgical Procedure: Emphasizing Flow and Shear Stress Analysis at Proximal and Distal Anastomotic sites.

2. Applied Biomedical Engineering (CRC Press, Taylor and Francis, 2009): Uses a problem-based approach to quantify physiological processes, formulate diagnostic and interventional procedures, develop orthopaedic surgical procedures; Features: Incorporates material from solid mechanics, fluid mechanics, dynamics and vibrations, control systems, and mathematical Modelling; Provides biomechanical guidelines for internal fixation of bone and spinal fractures as well as the treatment of herniated discs; Presents the mechanics of heart function, heart structures, non-invasive determination of aortic pressure, and characterization of left-ventricular afterload; Discusses detection of infarcted myocardial segments; Assesses the constitutive properties and degeneration of heart valves; Covers the modelling of lung ventilation, its application to lung disease diagnosis, lung gas-transfer mechanism, and indices to assess its performance; Examines how human anatomical structures and physiological processes are designed for optimal functionality.
3. Biomedical Science, Engineering and Technology (InTech Publishers, 2012): Cohesively integrates biomedical science (disease pathways, models and treatment mechanisms), biomaterials and implants, biomedical engineering, biotechnology, physiological engineering, and hospital management science and technology. Together, these topics are providing a pathway for incorporation of STEM into medical knowhow, procedures and devices, towards a higher order of translational medicine applied in tertiary patient care.
4. Cardiology Science and Technology (CRC Press, Taylor and Francis, 2016):

Book Contents

Section 1: Left Ventricular Wall Stress, Contractility and Vector Cardiogram, with Applications in Cardiology: Left ventricular Wall Stress Compendium; Assessment of Cardiac Function in Filling and Systolic Ejection Phases; Novel Cardiac Contractility Index $d\sigma^*/dt$ (max); Cardiomyopathy effect on Left ventricle (Shape, Wall stress and Contractility) and Improvement after Surgical

Ventricular Restoration; Cardiac Contractility Measures for Left Ventricular Systolic Functional Assessment in Normal and Diseased Hearts; Analysis for Left Ventricular Pressure Increase during LV Isovolumic Contraction Phase, due to Activation of the Myocardial Fibers; Computation of LV Myocardial Wall Stresses, Myocardial Fiber Stresses and Orientation; Myocardial Infarct Induced Left Ventricular Shape Remodelling, and Surgical Ventricular Restoration to restore LV Shape and Cardiac Contractility; Vector Cardiogram Theory and Clinical Application.

Section II: ECG Signal Analysis and Cardiac Pumping (Intra-Ventricular, Aortic and Coronary Flow), with Applications in Cardiology and Cardiac Surgery: ECG and Heart Rate Variability Signal Processing and Analysis to detect Cardiac Arrhythmias; Left Ventricular Blood Pump Analysis and Outcome: Intra-LV Flow and Pressure Distributions to determine Candidacy for Coronary Bypass Surgery; Cardiac Perfusion Analysis and Quantification by Nuclear Cardiac Imaging and Computation of Intra-Myocardial Blood Flow Velocity and Pressure Patterns; Determination of Arterial Pulse Wave Propagation Velocity and Arterial Properties; Blood Flow in Patient-Specific Coronary Arteries: Causes of Atheromas at Arterial Curvatures and Bifurcations based on Hemodynamic Parameters; Intra-Left Ventricular Diastolic and Systolic Flow Distributions, based on Colour Doppler Echo Velocity Flow Mapping of Normal subjects and Heart Failure Patients; Coronary Blood Flow Analysis and Coronary Artery Bypass Graft Flow and Design; Coupled Sequential Anastomotic Bypass Graft (SABG) Design.

5. Computational and Mathematical Methods in Cardiovascular Physiology (World Scientific, 2018): This book has literally 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.

So how is this mathematically and computationally configured landscape going to impact cardiology and even cardiac surgery? We are now entering a new era of mathematical formulations of anatomy and physiology, leading to technological formulations of medical and surgical procedures towards more precision medicine and surgery. This will even entail reformatting of (i) the medical MD curriculum and courses, so as to educate and train a new generation of

physicians who are conversant with medical technologies for applying into clinical care, as well as (ii) structuring of MD-PhD (Computational Medicine and Surgery) Program, to train competent medical and surgical specialists in precision medical care and patient-specific surgical care.

This book is providing a gateway for this new emerging scenario of (i) science and engineering based medical educational curriculum, and (ii) technologically oriented medical and surgical procedures. As such, this book can be usefully employed as a textbook for courses in (i) cardiovascular physiology in both the schools of engineering and medicine of universities, as well as (ii) cardiovascular engineering in biomedical engineering departments world-wide.

6. Biomedical Engineering of Pancreatic, Pulmonary, and Renal Regulatory Systems, and Applications to Medicine (Elsevier Publisher, 2023).

Book Contents

Section I. Pancreatic and Glucose-Insulin Regulatory System Engineering and Medical Assessment

- Chapter 1. Pancreatic Regulatory Physiology and Medical Assessment
- Chapter 2. Glucose-Insulin Regulatory Kinetics
- Chapter 3. Automated Insulin Infusion Regulatory System
- Chapter 4. Using Diabetes Technology to Maximize Diabetes Management

Section II. Respiratory and Pulmonary System Engineering and Medical Assessment

- Chapter 5. Physiologic and Medical Assessments of Respiratory Mechanics and Ventilation
- Chapter 6. Lung Ventilation Modelling and Medical Assessment
- Chapter 7. Respiratory Control Mechanism-Modelling
- Chapter 8. Lung Alveoli and Pulmonary Capillary Gas Transfer Analysis

Section III. Renal System Engineering and Medical Assessment

- Chapter 9. Renal Physiology Theory and Functional Assessment
- Chapter 10. Determining Kidney Obstructions by Renogram Data Modelling
- Chapter 11. Artificial Kidney Function and Dialysis

Physiology: Mechanisms and Analysis of Haemodialysis and Peritoneal Dialysis

- Chapter 12. Renal Physiology Modelling, Part 1: Acid Base Balance, Part 2: Body Fluid Balance

This book addresses the need for biomedical engineering to provide physiological analysis of organ systems and their medical applications to help enable quantitative formulation of physiological systems and defining their functions and dysfunctions, leading to precision diagnostics of diabetes, lung diseases, and kidney failure, often in the form of non-dimensional indices. The book chapters also deal with treatment systems, namely automated insulin infusion systems, haemodialysis, and peritoneal dialysis. The book is formulated to solve many physiological, bioengineering, and medical problems.

Item 2. Quantitative Physiology Program (Jointly with the College of Medicine)

This Quantitative Physiology Program can help to develop more precise medical diagnostics. This program involves formulation of Human Physiology courses from physics and engineering perspectives. It comprises two parts: Part I. Fundamental Physiological Processes: Physics and Engineering Modelling, and Part II. Physiological Systems Functions: Physics and Engineering Modelling.

In the College of Medicine, this Program can be offered as a Physiology course in the Biomedical Engineering Department, as well as contribute to Master's and PhD program in Physiology.

I can also help to set up a new STEM College of Medicine, in which there would be a Biomedical Engineering Foundation course in semester 1 of Year 1. Then in semester 2 of Year 1, this Program can be offered as a Quantitative Physiology course.

Curriculum

Part 1: Fundamental Physiological Processes: Physics and Engineering Modelling

- Unit 1: Cell Structure and Biochemical Reactions: Cell Structure, Cell Chemicals, Reaction Equations
- Unit 2: Cellular Homeostasis and Membrane Potential: Membrane: composition, Equilibrium Potential, Cell Model and Membrane potential.
- Unit 3: Action Potential: Na^+/K^+ Action Potential, Ca^{2+} Contribution, Hodgkin-Huxley Model.
- Unit 4: Cellular Transport and Communication: Passive and Active Transport, Cellular Communications, Electrical and Chemical Synapses, Action Potential Propagation.

- Unit 5: Tissue Mechanics: Stress-Strain relationships and Constitutive properties; Coupled Cell-Tissue, Fluid-Tissue and Blood Vessel-Tissue Models.

Part II: Physiological Systems Functions: Physics and Engineering Modelling

Unit 1: Cardiovascular System:

1. Bioelectrical Process in the Heart: Electrical activity is initiated in the SA node, and the impulse spreads via specialized pathways to myocardial contractile cells in the ventricles, causing ventricular contractility; this bioelectrical activity is characterized by ECG, and its signal processing enables cardiac diagnostics.
2. Contraction Process of the Heart Myocardium: Development of stress in the left ventricular wall contractility index, by which the intra-ventricular pressure rises adequately to be able to promote LV ejection³.
3. Intra-Ventricular Blood Flow Analysis: Governing equations of fluid flow, and analysis of blood flow patterns in the LV, to show how adequate pressure is generated to open the aortic valve. Doppler echo images.
4. Blood Flow into the Aorta and Pulse Wave Propagation: Determine pulse wave propagation velocity in terms of the aortic constitutive property to characterize arteriosclerosis; carry out analysis of blood flow into the aorta to yield the differential equation for aortic pressure in terms of the aortic inflow by Doppler Echocardiography; solve the differential equation to obtain aortic pressure-time profile⁴.
5. Blood Flow in the Coronary Vasculature: CFD modelling of the Navier-Stokes equations to determine flow patterns, wall shear stress and wall pressure gradient in imaging-based coronary arterial models.
6. Cardiac Perfusion Analysis: Compute intra-myocardial blood flow velocity and pressure patterns, by carrying out myocardial perfusion SPECT imaging; to quantify decreased blood flow in ischemic areas of the myocardium⁵.

Unit 2: Pulmonary System:

1. Lung Ventilation modelling (with application to lung disease determination): Differential equation of lung volume (V) response to lung driving pressure (PN) (in an intubated patient), in terms of

lung compliance (C) and resistance-to-airflow (R); these R and C parameters are then combined into non-dimensional ventilatory performance indices, for detection of lung fibrotic lung disease, obstructive lung disease, and emphysema⁶.

2. Lung Gas-transfer performance analysis: Analysis of inspired and expired air composition analysis, based on mass balances; derive expressions for O₂ and CO₂ diffusion coefficients in terms of O₂ consumption-rate and CO₂ production-rate (from the inspired-expired air composition analysis), alveolar air O₂ and CO₂ partial pressures, and O₂ and CO₂ concentrations in the venous blood; formulation of non-dimensional Gas-transfer Index (NDGTI) in terms of DO₂, DCO₂, O₂ consumption-rate and CO₂ production-rate; this NDGTI can be employed to assess the gas-transfer capacity of the lung-capillary bed system⁷.

Unit 3: Nervous System

1. Central Nervous System: Neurons, Autonomic Nervous System: Autonomic Control of the Heart, Cardiac Efferents and Afferents.
2. Somatic Nervous System: Temporal and Spatial Summation of Synaptic Potentials; Excitatory and Inhibitory Synapses; the Brain, Bioelectrical processes leading to generation of EEG; signal processing of EEG for neurological disease detection.
3. Propagation of Axon Potential: In an axon that has been excited at one end, the action potential is positive; positive ions move towards this end on the outside and away from it inside; this decreases the charges on the adjacent portion of the membrane, so that the axoplasm potential rises to the action potential threshold; this triggers increased Na permeability, leading to Na influx and an action potential at the adjacent portion of the membrane; this is how the axon potential propagates.

Unit 4: Glucose-Insulin Regulatory System, and Diabetes detection by oral glucose tolerance test

1. Glucose-Insulin Regulatory System: Derivation of governing second-order differential equations (DEQs) of glucose and insulin concentration responses to glucose ingestion represented by an impulse function, in oral glucose tolerance test (OGTT)⁸.

2. Determining the system response: The model parameters are determined by making the solution (for underdamped, overdamped and critically damped) for glucose and insulin responses match the OGTT clinical data⁹.
3. Diabetes non-dimensional index (DNNDI): is then developed in terms of the model parameters; this DNNDI has distinct ranges underdamped response of normal subjects, overdamped response of diabetic subjects, and critically damped response of at-risk subjects; this enables more precise diagnosis of diabetic subjects¹⁰.

Unit 5: Renal System

1. Analysis of the operating characteristics of the Renal system: Examine the optimal features of several aspects of renal physiological engineering mechanisms, particularly, the counter current multiplier mechanism for urine concentration and how optimal renal function in terms of renal clearance is maintained.
2. Analytical model of the loop of Henle and Renal handling of metabolic substrates: This modelling is carried out to show how the renal system is optimized for filtration and regulation of urine concentration by the counter current mechanism in the loop of Henle and its medullary environment, which is largely physiologically engineered to increase and maintain at steady-state the high osmolality of the urine fluid to as high as 4 times normal blood osmolality. The renal clearance of substrates is modelled as a single-compartment kinetic model, with continuous input of metabolic substrates. The analytical solution obtained from the continuous input of creatinine predicts the plasma creatinine concentration to be an inverse hyperbolic function of the renal clearance. The formula predicts reasonable estimates of the actual serum creatinine levels in the body based on renal clearance and substrate input parameters.

Item 3. Precision Quantitative Medicine Program (Jointly with the College of Medicine)

This Precision Medicine Program is based on my Biomedical Engineering developments in (i) Physiology, Medicine, Orthopaedics and Surgery, (ii) Sports Biomechanics and Medicine, and (iii) Mind-Body Medicine in Psychiatry.

This Precision Quantitative Medicine Program can be offered as an MD-PhD (Biomedical Engineering) Program, jointly

between the Biomedical Engineering Department and the College of Medicine.

I can also help to set up a new format of STEM College of Medicine, in which there would be a Biomedical Engineering Foundation course in semester 1 of Year 1. Then in semester 2 of Year 1, the above-described Quantitative Physiology course can be offered. Thereafter the below-described Quantitative Medicine and Surgery courses could be offered in Year 3.

Quantitative Medicine and Surgery Courses:

1. Cardiovascular Medicine: Left Ventricular Wall Stress and Contractility Index³, 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, Pulse wave velocity and Detection of Arteriosclerosis¹¹, Aortic Pressure Profile and Aortic stiffness determination¹², Coronary Bypass surgery design for maximal patency^{13,14}, Prosthetic Aortic and Mitral Valve designs.
2. Pulmonary Medicine: Lung Ventilation modelling for lung disease detection, Lung Ventilatory Index, Lung Gas Transfer performance analysis, Determination of O₂ and CO₂ Diffusion coefficients, Non-dimensional Gas-transfer index, Indicators for Extubation of Mechanically ventilated COPD patients^{6,7}.
3. Diabetic Medicine: Glucose-Insulin Regulatory Control systems, Oral Glucose Tolerance Test modelling and model parameters determination, Non-dimensional indices for glucose and insulin responses, Non-dimensional Diabetic Index for Diabetes detection⁸⁻¹⁰.
4. Nephrology: Kidney Functional analysis, Counter current mechanisms and modelling 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 modelling and determination of normalized urine flow rate index to differentiate between obstructed and normal kidneys¹⁵.
5. Orthopaedic 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^{16,17}.
6. Spinal Biomechanics and Surgery: Biomechanical Simulation of Scoliotic Spinal deformity and Correction, Presurgical Finite-element Simulation of Scoliosis Correction^{18,19}; Structural analysis of the Spinal Vertebral body as an intrinsically optimal lightweight and high-strength structure, Fractured Vertebral body fixation techniques and design of a vertebral body cage, Clinical Biomechanics of Spinal Fixation: Anterior, Posterior Fixations²⁰; Structural analysis of Intervertebral Disc as an intrinsically optimal minimally deformed structure under spinal loading, Nucleotomized Disc model analysis and solution for disc herniation²¹.
7. Sports Science, Biomechanics and Medicine: Optimal Walking Modality based on modelling the leg as a Simple-compound pendulum, Optimal Jogging Mode based on Double-compound model of the lower limb²²; Analysis of Spinning Ball Trajectories of Soccer kicks and Basketball throws²³, 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 test²⁴, Evaluation of Hip Joint based on Differential equation model of the Swinging Leg motion, to determine the hip joint damping and stiffness parameters.
8. Mind-Body Psychosomatic Medicine, Therapy for Psychiatric Disorders, Regenerative Medicine: 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; Development of non-volitional EEG Biofeedback System Therapy for treating neurological disorders²⁵.
9. Non-dimensional Physiological Indices in Medical Assessment: New Concept of Non-dimensional Physiological Indices (NDPIs) or Physiological Numbers (PHYNs) for analysing Physiological Systems and Medical Tests' Data, 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 operation²⁶.

Item 4. MD-PhD (Biomedical Engineering) Program (Jointly with the College of Medicine)

This Program is intended for medical students interested in combining medical practice with competency in biomedical engineering, to implement BME technologies in clinical research and applications in clinical care in hospitals. The program emphasizes computational medicine and computational surgery.

The PhD component of the Program can consist of Courses in:

- i. Quantitative Physiology, Medical Signal and Image Processing;
- ii. Cardiological and Cardiac Surgical Engineering, Renal Engineering, Neurological engineering;
- iii. Orthopaedic and Spinal Surgical Biomechanics, Rehabilitation Engineering.

These courses lead to teaching and application of computational medicine and computational surgery.

Computational Medicine involves biomedical engineering models of physiological systems and medical procedures, using computationally based solution methods and algorithms, to develop precision medical diagnostic, treatment and rehabilitative procedures and systems. Examples of Computational Medicine are (i) Development of cardiac contractility formula index in terms of the maximum rate of change of LV systolic wall stress normalized to intra-LV pressure, $d(\sigma/P)/dt_{max}$ or $d\sigma^*/dt_{max}$, where $\sigma^* = \sigma/P$, and its application to diagnose heart failure, and (ii) ECG waveform signal analysis for detection of cardiac arrhythmias^{27,28}.

Computational Surgery involves the use of medical imaging, robotics, patient-specific surgical simulation and information technology to analyse and plan patient-specific surgical procedures for obtaining optimal outcomes. Examples of computational surgery are (i) Cardiac Surgical Engineering, such as in computational planning of coronary bypass surgery^{13,14}, and (ii) Orthopaedic & Spinal Surgical Engineering, such as design of helical bone plates for oblique bone fractures^{16,17}, and design of hyperboloid shaped spinal vertebral body cage for vertebral body fractures²⁰.

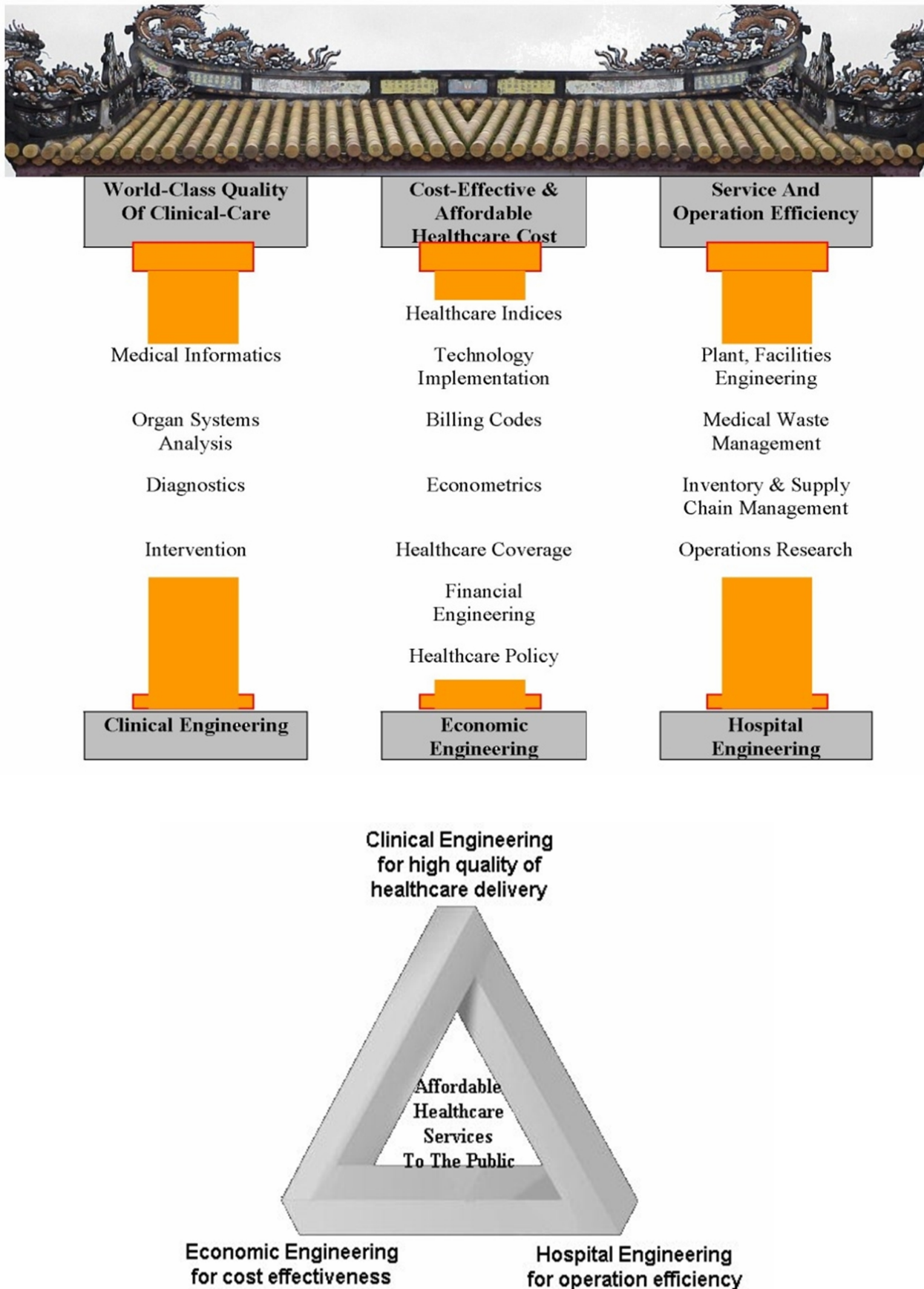
This novel program can provide a quantitative approach to disease processes, medical diagnosis and treatment, surgical simulation and techniques. This Program can be offered to educate medical doctors (for academic medicine career) who want to learn about biomedical engineering formulations of medical systems and surgical procedures, and implement them in clinical care.

Item 5. Hospital and Healthcare Management (MBA and MD-MBA) Program (Jointly with College of Business and College of Medicine)

The Hospital and Healthcare (HOHM) Program is designed to provide the relevant multidisciplinary knowledgebase in business administration, clinical and hospital engineering, economic and financial management, related to cost-effective operation of hospitals and healthcare delivery (as represented by the three pillars of HOHM depicted below), to healthcare and hospital administrators.

This program is designed to offer MBA (HOHM) and PhD degrees in the School of Business. It can also be offered as MD-MBA (HOHM) in the College of Medicine.

The HOHM program is designed to prepare graduates for careers as administrators in hospitals (in hospital operations management) and healthcare organizations, in providing cost-effective healthcare delivery. The figure below represents a balanced approach to an affordable healthcare delivery system.



The HOHM professional MBA program in the School of Business would be a heavily subscribed program. We could even offer an exciting MD-MBA (HOHM) program to those students in the MD program who are interested in a career in hospital administration or in setting up and managing a community healthcare system²⁹⁻³¹.

The HOHM program can comprise the following courses:

- Health Care Organization, Policy, and Administration
- Healthcare Economics
- Principles of Biostatistics
- Healthcare and Hospital Operations and Logistics Management
- Principles of Cost-effective Management of Hospitals and Healthcare Delivery System
- Healthcare Informatics Technology for Better Patient Care
- Billing Codes for Biomedical Engineering Operations in a Tertiary-care Hospital
- Maximizing Hospital's Bed-occupancy and Patient Flow
- Integrated Cost-Performance Indices of Hospital Departments
- Hospital Budget Management: to determine the Resource index for all the hospital departments to obtain acceptable values of their Cost-Performance indices.

Item 6. In Conclusion

Biomedical Engineering drives modern healthcare through its integration with medicine. By enabling advanced measurement, targeted therapies, and data-driven treatments, the field has fundamentally transformed how we understand human physiology and deliver patient care.

1. Quantitative Physiology

Modern biomedical engineering transforms qualitative biological observations into actionable data and predictive mathematical models.

- Computational Modelling: Biomedical Engineers can develop models to simulate cardiovascular hemodynamics, respiratory mechanics, and neurological pathways.
- Advanced Biosensors: Wearable and implantable sensors provide real-time, longitudinal data on physiological parameters, allowing for continuous monitoring and diagnostic insights.

2. Precision Medicine

Biomedical engineers can tailor medical treatments and interventions to the specific molecular and genetic characteristics of each individual patient.

- Genomics and Diagnostics: High-throughput sequencing technologies and microfluidics enable rapid, cost-effective genetic profiling.
- Targeted Drug Delivery: Nanotechnology utilizes engineered nanoparticles to transport chemotherapeutics directly to tumour cells, sparing healthy tissue and minimizing side effects.

3. Quality Healthcare Delivery

Biomedical innovations can increase access to care, improve surgical precision, and enhance patient outcomes across diverse clinical settings.

- Medical Imaging and Robotics: Innovations in MRI, PET, and robot-assisted surgical systems allow for minimally invasive procedures and pinpoint anatomical accuracy.
- Telehealth and mHealth: Interoperable connected health platforms and remote patient monitoring tools expand care beyond traditional hospital walls, reducing readmission rates.

DECLARATIONS

Funding: None Declared.

Conflict of Interests Disclosure: The author has declared that no competing interests exist.

Declaration of Generative AI and AI-Assisted Technologies: The author declares that no generative AI or AI-assisted technologies were used in the preparation of this manuscript.

ARTICLE INFORMATION

Accepted for Publication: April 12, 2026

Published: June 27, 2026

Peer Review: Externally Peer Reviewed.

Open Access: This is an open access article distributed in accordance with the Creative Commons Attribution Non-Commercial (CC BY- NC 4.0) license, which permits others unrestricted use, distribution, and reproduction in any medium, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any

changes made indicated, and the use is non-commercial.

Copyright: © 2026 By The Author

REFERENCES

1. Left Ventricular shape-based contractility indices, by Liang Zhong, Dhanjoo N. Ghista, Eddie Y-K. Ng, Lim Soo Teik and Chua Siang Jin, CN Lee, in *Journal of Biomechanics*, 2006, 39: 2397-2409.
2. Validation of a novel non-invasive cardiac index of left ventricular contractility in patients, by Zhong L, Tan RS, Ghista DN, Ng E. Y-K, Chua LP, Kassab GS, in *Am J Physiol Heart Circ Physiol* 2007, 292:H2764-2772.
3. Left Ventricular Wall Stress: A Compendium, by Zhong L, Ghista DN, Tan RS, *Computer Methods in Biomechanics and Biomedical Engineering*, Volume 15, Issue 10, 2012, pages 1015-1041.
4. 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, in *Journal of Mechanics in Medicine & Biology* 2004, 4(4):499-509.
5. Cardiac Perfusion Analysis and Computation of Intra-Myocardial Blood Flow Velocity and Pressure Patterns, by Dhanjoo N. Ghista, Eddie Y.K. Ng, Ru San Tan, Jian-Jun Shu, and Reginald Jegathese, Chapter 7 in *Cardiology Science and Technology*, by Dhanjoo N. Ghista, CRC Press (Taylor & Francis), 2016.
6. Lung Ventilation Modelling for Lung Disease Diagnosis, by Dhanjoo N. Ghista and Meena Sankaranarayanan, Chapter 5 in *Applied Biomedical Engineering Mechanics*, by Dhanjoo N. Ghista, CRC Press (Taylor & Francis), 2009.
7. Lung Gas-Transfer Performance Analysis, by Dhanjoo N. Ghista and Kah Meng Loh, Chapter 6 in *Applied Biomedical Engineering Mechanics*, by Dhanjoo N. Ghista, CRC Press (Taylor & Francis), 2009.
8. Glucose Tolerance Test Modelling & Patient-Simulation for Diagnosis, by Sarma Dittakavi and Dhanjoo N. Ghista, in *Journal of Mechanics in Medicine & Biology*, Vol. 1, No.2, Oct. 2001.
9. Clinical Simulation of OGTT Glucose Response Model for Diagnosis of Diabetic Patient, by Dhanjoo N. Ghista, Patrick S.K. Chua, Andy Utama Aulia, Peter L.P. Yeo, in *Journal of Mechanics in Medicine & Biology* 2005, Vol 5, No. 1.
10. Nondimensional diabetes indices for accurate diagnosis of diabetic subjects, by Dhanjoo N. Ghista, Foad Kabinejadian, Vinithasree Subbhuraam, in *Computer Methods and Programs in Biomedicine*, May 2023.
11. Determination of Arterial Pulse Wave Propagation Velocity and Arterial Properties, by Dhanjoo Ghista and Foad Kabinejadian, Chapter 12, in *Cardiology Science and Technology*, by Dhanjoo N. Ghista, CRC Press (Taylor & Francis), 2016.
12. Vascular Biomechanics, by Dhanjoo N. Ghista and Liang Zhong, Chapter 4 in *Applied Biomedical Engineering Mechanics*, by Dhanjoo N. Ghista, CRC Press (Taylor & Francis), 2009.
13. 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.
14. Coronary Artery Bypass Grafting Anastomoses' Hemodynamics and Designs: A Biomedical Engineering Review, Dhanjoo N Ghista and Foad Kabinejadian, *BioMedical Engineering Online*, 2013.
15. Determining Kidney Obstructions by Renogram Data Modelling, by Dhanjoo N. Ghista, Kah Meng Loh, Foad Kabinejadian, Vidya Sudarshan, Yin Kwee Ng, and David Chee-Eng Ng, Chapter 10 in *Biomedical Engineering of Pancreatic, Pulmonary, and Renal Regulatory Systems, and Applications to Medicine*, by Dhanjoo N. Ghista, Academic Press, 2023.
16. 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, in *The Japan Society of Mechanical Engineers Series C*, Vol 47 (4), pp 1086-1094, 2005.
17. Biomechanics of Bone-fracture Fixation by Stiffness-Graded Plates in Comparison with Stainless-steel Plates, by V. K. Ganesh, K. Ramakrishna, D. N. Ghista, in *Biomedical Engineering online*, 2005, 4:46.
18. Developmental and Corrective Biomechanics for Scoliosis, by G.P. Noone, J. Mazumdar and D.N. Ghista, in *IEEE Engineering in Medicine and Biology (Special International Issue)*, Vol. 10, No. 2, June 1991.
19. Biomechanical Simulations of Scoliotic Spinal Deformity and Correction, by G. Noone, J. Mazumdar, K.P. Kothiyal, D.N. Ghista, K. Subbaraj and G.R. Viviani, in *Journal of Australian Physical and Engineering Science in Medicine*, Vol. 16, No. 2, June 1993.

20. Human Lumbar Vertebral Body as an Intrinsic Functionally-optimal Structure, by D.N. Ghista, S.C. Fan, K. Ramakrishna, I. Sridhar, in *International Journal of Design and Nature*, 2006, 1(1): 34-47.
21. The Optimal Structural design of the human Spinal Intervertebral disc, by D.N. Ghista, S.C. Fan, I. Sridhar, K. Ramakrishna, in *International Journal of Design and Nature*, 2006, 1(2).
22. 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 in *Applied Biomedical Engineering Mechanics*, by Dhanjoo N. Ghista, CRC Press (Taylor & Francis), 2009.
23. Analysis of Spinning Ball Trajectories of Soccer Kicks and Basketball Throws, by Dhanjoo N. Ghista and Xiang Liu, Chapter 15 in *Applied Biomedical Engineering Mechanics*, by Dhanjoo N. Ghista, CRC Press (Taylor & Francis), 2009.
24. Cardiac Fitness Index based on Treadmill HR monitoring: Its Novelty, Providing Cardiac Diagnostics in terms of correlation of CFI with LV EF, and Enabling Medical Management of the subject, by Dhanjoo Ghista, Ronit Kapoor, Siva Mullapudi, Vara Wuyyuru, and Prashanth Nyalakanti, in *International Journal of Development Research*, Vol 13, Issue No 6, July 2023.
25. Home Healthcare Biomedical-Engineering and Yoga-Science Solutions: For Preventive and Managed, Fitness and Rehabilitation Care, by Dhanjoo Ghista, Thambipillai Srikanthan, Mahesh Veezhinathan, U. Rajendra Acharya, Dipnarayan Guha, Chapter 17 in *Distributed Diagnosis and Home Healthcare (D2H2)*, edited by U. Rajendra Acharya et al., American Scientific Publishers, January 2010.
26. Physiological Systems' Numbers in Medical Diagnosis and Hospital Cost-effective Operation, by Dhanjoo N. Ghista, in *Journal of Mechanics in Medicine & Biology* 2004, Vol 4, No. 4.
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*, Volume 3, No 2, August 2021.
28. Left Ventricular Shape & Size based Contractility Index (LVSCI), for effectively (i) designating normal well-contracting left ventricles, and (ii) depicting cardiomyopathic left ventricles and risk of heart failure, Dhanjoo N. Ghista, Vinithasree Subbhuraam, and Vidya K. Sudarshan, *International Journal of Current Research*, Vol. 16, Issue 7, July 2024.
29. Impact of deficient healthcare service quality, by PM Lee, PW Khong, DN Ghista, in *The TQM Magazine*, 2006, 18(6): 563-571.
30. Healthcare Engineering for an efficient medical care system, by P. W. Khong and D.N. Ghista, in *International Journal of Healthcare Technology & Management*, 2006, 7(5): 429-439.
31. Hospital and Healthcare Management Program: Roles of Hospital Administrators, Program Curriculum and Outcome, by Dhanjoo Ghista, *Pac. J. Med. Health Sci.* 2022; 4(3): 13-21.