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Guest Editorial

A Brief History of USNCB: Motivation and Formation

1 Introduction

In what follows, the intent of the authors is to provide a historical perspective on the U. S. National Committee on Biomechanics, i.e., USNCB. In Sec. 2, we will provide background on the emergence of biomechanics as an important area of research. This will then be followed by a section on the formation of USNCB, including the discussions that were part of this process, and a section describing the activities of USNCB over the last three decades. Finally, we conclude with a very brief look into the future.

2 Background

Prior to the emergence of modern *biomechanics* in the mid-20th century, brilliant and intrepid engineers, mechanists and scientists were already making important, but oftentimes rather infrequent, contributions to this field of biomechanical science. For example, Galileo had conducted research in the area of bone mechanics. Fung in 1981 attributed to Hermann von Helmholtz the title, "father of bioengineering" [1]. Then beginning around the mid 1950's, some ingenious and creative engineers (fluid dynamists, aeronautical, chemical, civil, and mechanical engineers, etc.) and applied mathematicians began detailed studies of biologically motivated problems including classical conundrums in physiology. These investigators were located at various places throughout the U.K. (e.g., at Cambridge University, Imperial College, Oxford University, University of Leeds, Strathclyde University), the U.S. (e.g., Columbia University, MIT, Stanford University, University of Pennsylvania, University of Washington, UCSD, and Wayne State University) and across the globe. While time and space do not permit a full listing, what follows are brief descriptions of some advances in two very important areas of biomechanics highlighted in a recent publication [2].

Individual groups of talented scientists and engineers were advancing the field of *musculoskeletal biomechanics* even before the beginning of the twentieth century. As early as the 1890's, Wolff in the Department of Surgery at the University of Berlin was using equations developed by the civil engineer, Culmann, to try and predict trabecular bone architecture and adaptation. In 1939, Lissner, Professor of Engineering Mechanics at Wayne State University, helped to initiate research into mechanisms of blunt head trauma and skull fracture. Motivated by the need to simulate pilot ejection from fast flying airplanes and automobile crashes, Lissner's team sought to understand how impact affected the human body and its segments. The pace of musculoskeletal biomechanics quickened by the mid-1960s. Freeman, an orthopaedic surgeon at Imperial College, London, led a team of engineers and surgeons to study structure-function relationships in tissues such as the articular cartilage of mammalian diarthrodial joints and intervertebral discs in the spine. During the same time period, Goodfellow, an orthopaedic surgeon at Oxford University, led a team of engineers, including O'Connor, to develop total knee replacements. At the University of Leeds, Wright, a rheumatologist, and Dowson, an engineer, directed a group of engineers to study biotribology (friction, lubrication and wear of animal and prosthetic joints) and the etiology of osteoarthritis. Paul at the University of Strathclyde was conducting parallel research that would revolutionize methods to analyze human gait in healthy, injured and surgically operated subjects. Carl Hirsch, first at the Nobel Institute, Stockholm, and later at Sahlgrenska Hospital of Gothenburg, Sweden attracted numerous U.S. orthopaedic surgeons and engineers to Sweden as visiting scholars to pursue biomechanics studies on orthopaedics and musculoskeletal problems. But probably the most successful example of collaborative orthopaedic research was that of Sir John Charney's team of surgeons and engineers at the Wrightington Hospital's Centre for Hip Surgery, who developed a PMMA cementing technique (borrowed from dentistry) to better anchor femoral and acetabular prosthetic components into arthritic hips. Their combined efforts led to a *revolution* in orthopaedic hip joint replacements for many patients suffering advanced stages of osteoarthritis, thus enabling orthopaedic surgeons worldwide to successfully replace damaged hips, knees, shoulders, wrist and finger joints. Such advances led to the large and international influx of bioengineers into the field of orthopaedic and sports medicine research. Taken collectively, this period of musculoskeletal research set the stage for the dramatic advances made in the next 30–40 years.

In the area of *biofluid mechanics* and as early as the late 1950's, researchers like Sir Taylor at Cambridge University were investigating propulsion mechanisms for sperms swimming through a viscous fluid and Sir Lighthill began studies on mechanisms for birds flying, fish swimming and other forms of micro- and macro-aquatic animal propulsion. It was shortly thereafter that fluid mechanists made some of the most important early contributions in solving problems related to the cardiovascular system and to lung function. These leaders included Fung; Richard Skalak and his collaborator in physiology, Shu Chien; Max Anliker at Stanford University, later at ETH Zurich; and Lighthill. Fung, first at Cal Tech and then at UCSD, not only investigated blood flow in the mammalian vasculature but also used principles of aeroelasticity to study air flow through the airways of the lung. At the same time, Richard Skalak and Shu Chien's research at Columbia and then, from 1988, at UCSD was directed at problems in microcirculation. Max Anliker, was also conducting innovative research on the cardiovascular system. It was, however, Lighthill who in the formation of the Physiological Flow Studies Unit (PFSU) at Imperial College London, first assembled a multidisciplinary team. The PFSU group of researchers was composed of engineers, clinicians, mathematicians, and physiologists. The focus of the research at PFSU was both on cardiovascular disease, e.g., blood flow in large arteries, and on issues related to lung function. When Lighthill left for Cambridge in 1969, a physiologist at PFSU, Colin Caro, became its director, providing a continuing major influence on biomechanics. Much of this research, both in and stimulated by PFSU, was due to interactions with physiologists and pathologists who recognized the important role of hemodynamic factors in the disease, atherosclerosis. It was their findings that led researchers to focus part of their efforts at the cellular level, in particular the vascular endothelium and endothelial cells. PFSU also greatly influenced U.S. researchers, working in fluid mechanics to spend 6-month visits in the unit at Imperial College in the 1970s. Such efforts in America would come later once the critical mass of researchers was in place.

Investigators sought to communicate these early findings at society-sponsored research conferences and in various biomechanics publications. The early impact studies of Lissner were collated posthumously in a 1967 ASME publication [3]. It was also Roberts (Duke University) and Evans (University of Michigan) who would later establish the *Journal of Biomechanics*, one of today's flagship journals of the field. Upon their retirement, Rik Huiskes, a Dutch bioengineer of the University of Nijmegen, succeeded them as editor-in-chief for the next 30 years. Currently, this journal is edited by Farsh Guilak of Duke University. A series of ASME-sponsored conferences in the early 1970's then provided a venue for researchers to present their biomechanics research. The first symposium held at Georgia Tech in June 1973 was timely and successful, attracting young, traditionally trained aeronautical, civil, electrical, materials, and mechanical engineers, as well as applied mathematians [4]. What followed was a series of ASME conferences, culminating in the annual *Summer Bioengineering Conference*, SBC, which just celebrated its 20th anniversary (40 years after the 1973 Georgia Tech biomechanics symposium) and remains one of the major forums for bioengineering and biomechanics. These advances were accompanied by a maturation of bioengineering within ASME from interactions between the Applied Mechanics and Fluid Mechanics Divisions to a separate Division on Biomechanical and Human Factors. This division was a predecessor to ASME's current Bioengineering Division and a driving force in the creation of the *Journal of Biomechanical Engineering (JBE)* beginning in 1978 with Brighton and Fung as its first Technical Editors.

Biomechanics and biomedical engineering grew rapidly during this period with young and talented engineers being trained in relatively few biomedical engineering departments. Over the years three ASME named achievement awards were established: the Lissner medal, for outstanding senior bioengineers; the Mow medal, for outstanding midcareer bioengineers; and the Fung medal, for outstanding young investigators in bioengineering. Such achievement awards remain an essential component of a well-developed discipline. Moreover, many of its winners now played prominent roles in the activities of the U.S. National Committee on Biomechanics (USNCB).

3 Formation of USNCB

These aforementioned activities helped to motivate Professor Fung and other senior members in the field of biomechanics to recognize the need for a U.S. national committee focused on this emerging field. As part of their discussions, the group initially explored the possibility of forming an International Union of Biomechanics under the auspices of the International Council for Scientific Unions (ICSU) formed in 1931 as a global organization of national scientific bodies (120 Members, representing 140 countries) and international scientific unions (31 Members). ICSU's mission has been to: (1) address major issues of importance to science and society; (2) facilitate interactions among scientists across discipline and country; (3) promote international participation of scientists; and (4) help stimulate constructive dialogue between the scientific community, government, society, and the private sector. Such a council was a possible home for an International Union of Biomechanics to broadly exchange ideas and information and to develop standards as they formulated symposia and scientific meetings and published newsletters, handbooks and journals. This new union could be modeled after the International Union for Theoretical and Applied Mechanics (IUTAM), proposed in 1922 after World War I to overcome political tensions and to avoid rivalries between individual national congresses on applied mechanics. It was not, however, until 1946–1947 that applied mechanists and applied mathematicians, led by Burger, adopted statutes for the formation of IUTAM and that ICSU accepted IUTAM as an adhering body. It was this model that was appealing to leaders in biomechanics who sought a national and international voice to advocate for the field.

Despite the presence of this model, there were many reasons why it was not possible to establish an international union in the area of biomechanics. Primary among them was the fact that two similar International Unions (Pure and Applied Biophysics as well as Physical and Engineering Sciences in Medicine [IUPESM]) already existed, the latter including an International Federation of Medical and Biological Engineering (IFMBE). ICSU was concerned that the existence of IUPESM and its component IFMBE would restrict and limit the scope of an international union on biomechanics. Leaders in biomechanics thus decided to abandon the idea of such a union but rather to define the concept, scope and by-laws for a U.S. National Committee on Biomechanics (USNCB). Then early in 1982, regular meetings of USNCB began (Fig. 1), mostly at ASME bioengineering forums. An IUTAM-like strategy was developed for the USNCB meetings with three mission-oriented objectives that included the need to: (1) establish and coordinate national and international meetings on biomechanics; (2) pursue and foster new areas of biomechanics and bioengineering research; and (3) take a leadership role in establishing an umbrella organization for biomechanics and bioengineering.

Armed with this plan and inspired by the foresight of Prof. Fung, USNCB then co-initiated a series of international biomechanics conferences (Fig. 1). The first U.S.-China-Japan biomechanics meeting was held in Wuhan, China, May 9–12, 1983 with symposium proceedings published the next year [5]. Participants included delegates from the U.S. (15); Japan (8); China (71); and France, Netherlands, and Italy (1 each). American participants (in alphabetical order) included: Fung (UCSD), Huang (University of Houston), Katz (RPI), Li (University of Virginia), Mow (RPI), Nerem (University of Houston), Skalak (Columbia), Weibaum (CCNY), Woo (UCSD), and Wu (Cal Tech). Subsequent quadrennial U.S.-China-Japan meetings were held at the University of Osaka, Japan (1987), Georgia Tech (1991), Taiyuan, China (1995), and Sendai University, Japan (1998). This conference was then broadened to include Singapore in 2004 to increase geographic coverage. These meetings have had a major influence in promoting biomechanics on the international stage.

USNCB also led the difficult and lengthy process of creating an umbrella organization to represent all of biomechanics and bioengineering. These efforts began modestly in 1988 when a group of biomechanicians from USNCB visited the National Science Foundation in Washington D.C. to meet with White, Assistant Director for Engineering. White emphasized the need to create a unified

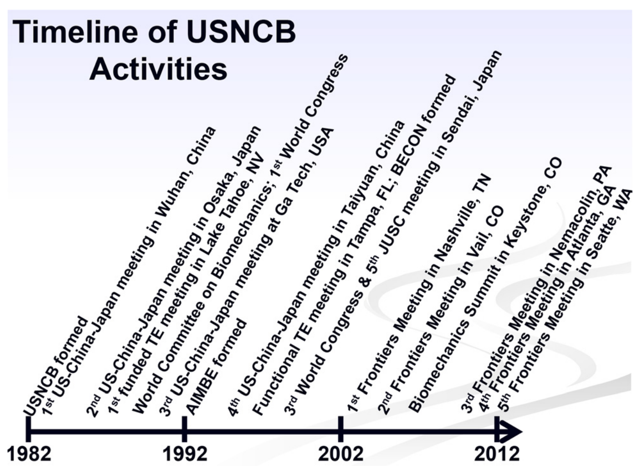

Fig. 1 Timeline showing events and activities for which USNCB played a pivotal role

organization for bioengineering. This then resulted in a series of workshops that led to the formation of the American Institute for Medical and Biological Engineering (AIMBE). AIMBE is now a nonprofit organization in Washington, D.C., representing 50,000 individuals and the top 2% of medical and biological engineers and has assumed a role in facilitating interactions with various Congressional committees and Federal agencies.

The creation of AIMBE also permitted USNCB leadership to reexamine its role in leading biomechanics efforts into the last quarter of the 20th century. Although electing not to establish an international union for biomechanics, 1990 was an important year for new developments. USNCB leaders including Professor Fung formed a World Committee for Biomechanics and the First World Congress on Biomechanics was held in La Jolla, California (Fig. 1). Within a few years, these efforts culminated in a World Council for Biomechanics whose primary function became the organization of a World Congress of Biomechanics every four years. More will be said about this in Sec. 4.

4 USNCB Activities 1982–2013

USNCB has remained active in promoting biomechanics since its formation on April 21, 1982 (see Fig. 1). The first Executive Committee with Professor Schultz as Chair created a mission statement that included a set of goals and bylaws. The National Science Foundation funded a 1984 proposal and a very successful workshop to identify future research directions and needs in biomechanics [6] and helped to focus USNCB activities over the next 30 years.

These efforts have been varied and quite effective. (1) USNCB has organized and successfully carried out national and international meetings. As stated above, the organization has directed each World Congress of Biomechanics meeting (see Fig. 1). (2) USNCB has co-sponsored and provided programming support for meetings like the Biomedical Engineering Society while also supporting young investigators with government agency funding to attend these meetings. (3) USNCB played a key role in the workshop held at Tampa, FL and publications [7–9] related to functional tissue engineering (FTE). The effects of the Tampa workshop, where participants formulated the principles of FTE, and the subsequent book [9] that provided examples of where biomechanics could impact tissue engineering, continue to this day. (4) The committee has identified themes for topic issues of journals such as ABME that have resulted in the formation of subfields (e.g., cellular mechanics) and tools (e.g., computational mechanics) as well as spotlighting the need to solve critical health problems (e.g., the April 2002 issue of ABME on Biomechanical Approaches to Atherosclerosis). (5) USNCB has held retreats to set its direction. At a 1999 retreat in Chicago, USNCB leaders not only developed 5–10 year goals and specific activities to meet them but also agreed on changes in USNCB structure, membership and operations to achieve these goals. By 2005, for example, USNCB had proposed to create biomechanics teaching tools for engineers and nonengineers; to establish peer status with other "neighboring" life science and clinical disciplines; to significantly and broadly enhance interactions with relevant industries; and to provide society at large with a much greater understanding of biomechanics and its potential contributions to the solution of societal problems. (6) This continuous planning process also resulted in a 2006 decision to change USNCB focus from organizing the *US-China-Japan Biomechanics Meetings* to discovering how biomechanics could participate in new and nontraditional fields. USNCB has held 5 very successful Frontiers in Biomechanics meetings (2003, 2005, 2011–2013, see Fig. 1) to stretch the traditional boundaries of biomechanics in new cross-cutting and transformative fields like protein misfolding, venous disease, bioMEMS, embryonic growth mechanics, mechanics of speciation and evolutionary biology, mechanics of development, and most recently, mechanics in oncology. Many of these topics have become regular sessions in traditional biomechanics meetings. (7) USNCB also held a Biomechanics Summit in Keystone, Colorado in 2007 where participants defined the directions for biomechanics research in the next decade. They organized their discussions along length scales from molecular to cellular to tissue to organ to organism. This summit resulted in four very important position papers for biomechanics [10–13]. Taken together, these efforts (meetings, workshops, summits, etc.) have helped to redefine the field of biomechanics, leading, for example, to a tremendous growth in the new discipline of mechanobiology, and the wonderful success of the recently developed journal, *Cellular and Molecular Bioengineering*, as part of the BMES portfolio of journals. The USNCB has served a critical function in helping to facilitate these new directions, and more generally, has had enormous impact on our profession and beyond. (8) Finally, USNCB has continued to organize special events such as the special 80th birthday symposium organized by Woo for Fung at the 1999 Summer Bioengineering Conference in Big Sky, Montana. It is to the credit of USNCB and its leadership that the organization has had such a broad impact over these past 32 years (Table 1).

Table 1 Leadership of USNCB since its formation on April 21, 1982

Albert Schultz	1982–1985
Richard Skalak	1985–1988
Robert Nerem	1988–1991
Van Mow	1991–1994
Savio Woo	1994–1997
Mort Friedman	1997–2000
Robert Spilker	2000–2003
Steve Goldstein	2003–2006
Roger Kamm	2006–2009
David Butler	2009–2011
Geert Schmid–Schonbein	2011–2014
Jay Humphrey	2014–2016

5 Looking Into the Future

The above describes the history of the formation of USNCB and its activities and some of the people involved over the past three decades. Although much has been accomplished in fostering the continued emergence of biomechanics, more remains to be accomplished. Fortunately, the current generation of leaders brings the needed vitality and momentum. Indeed, collective efforts in biomechanical engineering, biomechanics, tissue engineering, and biomedical imaging, bodes well for USNCB to continue its rich historical tradition, and to serve a vital role for advancing the field of biomechanics.

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Van C. Mow
Stanley Dicker Professor of Biomedical Engineering and Orthopedic Bioengineering, Columbia University

David L. Butler
Emeritus Professor of Biomedical Engineering, Department of Biomedical, Chemical and Environmental Engineering, University of Cincinnati

Robert M. Nerem
Institute Professor Emeritus, Parker H. Petit Institute for Bioengineering and Bioscience, Georgia Institute of Technology