



The Children's Hospital of Philadelphia

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Introduction

The Division of Orthopaedic Surgery at the Children's Hospital of Philadelphia (CHOP) enjoyed another year of significant growth, accomplishment, and innovation. Upholding our mission to provide the most comprehensive care to patients, we have continued to expand our clinical, research, and teaching programs. In 2015, *US News and World Report* ranked the Division of Orthopaedic Surgery 1st in the nation in pediatric orthopaedic surgery.

In 2015, CHOP Orthopaedics hired three surgeons, a sports medicine specialist and a non-operative orthopaedist, moved into three new facilities, renovated the Nicholson Visiting Professorship, appointed a new Director of Orthopaedic Engineering, hired a Director of Clinical Research, awarded Chair's research grants to six winners totaling \$87,000, renovated the Fellowship recruitment and interviewing process, launched multiple Development initiatives with a new Board of Visitors for Orthopaedics and partnered with CHOP Office of Clinical Quality Improvement on two major projects (Sports and Spine) to improve the efficiency, safety and value of orthopaedic surgery.

This year marked the opening of a number of state-of-the-art facilities. In May 2015, the Division began seeing patients at the new Specialty Center at King of Prussia (Figure 1). The new center is comprised of 68 exam rooms, two operating rooms, an urgent care center, and the latest imaging equipment. The facility also houses a sports medicine gym and separate physical-therapy and occupational-therapy gym. With these resources, it serves as a "one-stop shop" for children and families in need of outpatient care. In addition to King of Prussia, CHOP orthopaedic physicians see patients at the new Brandywine Valley Specialty Care and Ambulatory Surgery Center that opened in October 2015 (Figure 2). The 44,000 square-foot facility, with an ambulatory surgery center and physical therapy gym, allows CHOP clinicians to see patients



Figure 2.



Figure 3.



Figure 1.

in Pennsylvania and northern Delaware closer to home. At our main campus, CHOP orthopaedic faculty began seeing patients at the new Buerger Center for Advanced Pediatric Care in November 2015 (Figure 3). The building features a "children in motion" theme that uses images to promote a culture of wellness and activity. These new facilities across the greater Philadelphia area demonstrate CHOP's commitment to being a world leader in patient care.

This past year CHOP orthopaedic surgeons joined in a multi-surgeon team effort to perform bilateral hand transplant surgery for Zion Harvey's historic bilateral. Drs. Benjamin Chang, Ines Lin, and Robert Carrigan all held significant roles in throughout the surgery. They join other surgeons, CHOP physical therapists, social workers, and psychologists to support Zion in his care.

Clinical Program

Our orthopaedic faculty continues to expand and is currently comprised of thirty total providers, including nineteen specially trained pediatric orthopaedic surgeons

(fifteen operative and four non-operative), five pediatricians with sports medicine training, and three transition-to-adult care faculty.

CHOP Orthopaedics is pleased to announce the addition of four new providers: Dr. Patrick Cahill, Dr. Alexandre Arkader, Dr. Apurva Shah, and Dr. Danielle Magrini.



Figure 4.

Dr. Patrick Cahill (Figure 4) obtained his medical degree from the University of Illinois College of Medicine in Chicago, IL. He completed his residency in orthopedic surgery at Loyola University Medical Center and a fellowship in molecular genetics at the National Institutes of Health in Bethesda, MD. Dr. Cahill is currently a member of a number of spine-related multi-center study groups including the Chest Wall and Spine Deformity

Study Group and the Harms Study Group.



Figure 5.

Dr. Alexandre Arkader (Figure 5) began his medical education in Brazil at F.T.E Souza Marques in Rio de Janeiro (medical school), Hospital of Santa Casa de Misericordia (internship in international medicine), and Hospital de Traumatologia-Ortopedia (residency in orthopaedic surgery). In 2003, Dr. Arkader moved to the United States to continue his training and completed a fellowship in pediatric orthopaedics at The Children's Hospital of Philadelphia and a second fellowship in musculoskeletal oncology at Memorial Sloan-Kettering Cancer Center.



Figure 6.

Dr. Apurva Shah (Figure 6) joins the Division of Orthopaedics after working as an orthopaedic surgeon at Boston Children's Hospital and the University of Iowa. Dr. Shah earned his medical degree from Columbia University College of Physicians and Surgeons and his MBA at Columbia Business School. He completed a residency in orthopaedic surgery at the University of Michigan and two Hand and Upper Extremity fellowships at Brigham and

Women's Hospital and Boston Children's Hospital. Dr. Shah has been recognized as a "Young Leader" by the American Society for Surgery of the Hand.



Figure 7.

Dr. Danielle Magrini (Figure 7) obtained her medical degree from New York College of Osteopathic Medicine in Old Westbury, New York. She served as chief resident in her final year of residency in pediatrics at Robert Wood Johnson University Hospital in New Brunswick, NJ. She subsequently completed a fellowship

in pediatric sports medicine at the Children's Hospital in Colorado in Aurora, CO. Dr. Magrini joined the Division of Orthopaedics after completing a second fellowship in non-operative pediatric orthopaedics here at CHOP.

In 2015, the department also saw significant growth in the mid-level provider staff. There are currently twenty-one nurse practitioners, seven physician assistants, and six athletic trainers who evaluate, diagnose, and treat a full range of musculoskeletal disorders.

Education Program

CHOP Orthopaedics currently funds four one-year clinical fellowships and one one-year research fellowship. The 2015-2016 clinical fellows are Evan Curatolo, MD (Figure 8); Lloydine Jacobs, MD (Figure 9); Sarah Nossov, MD (Figure 10); and Sheena Ranade, MD (Figure 11). Following the completion of their clinical fellowships, Dr. Curatolo will be returning

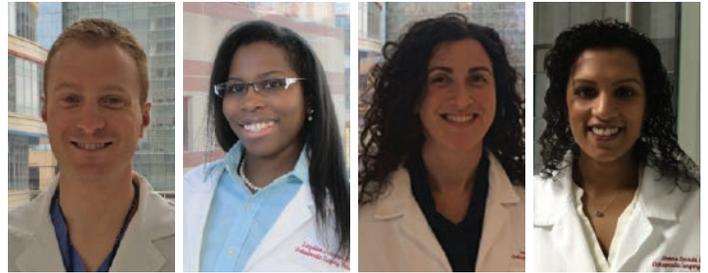


Figure 8.

Figure 9.

Figure 10.

Figure 11.

to his hospital of residency, Monmouth Medical Center in New Jersey, and joining a private group, Atlantic Pediatric Orthopaedics. Dr. Jacobs plans to serve the needs of a medically underserved community in the South by practicing the full

scope of orthopedics - pediatric and adult. Dr. Nossov will pursue a career in general pediatric orthopaedics. Dr. Ranade will be focusing on sports medicine, complex hip, and lower extremity deformity in an academic medical setting. This year's research fellow is Mazen Ibrahim, MD from Egypt (Figure 12). While at CHOP Dr. Ibrahim has focused his research efforts in lower limb deformity and basic science research.



Figure 12.

The 2014-2015 clinical fellows have continued to practice and train across the country (Figure 13). Aristides Cruz, MD joined the faculty at Brown University Orthopedics, focusing on pediatric sports surgery. Peter Fabricant, MD MPH is completing a sports medicine fellowship at Boston Children's Hospital and plans to return to HSS. Andrew Georgiadis, MD joined Gillette Children's in St. Paul, Minnesota as a pediatric orthopaedic surgeon. Mark Seeley, MD is an attending surgeon at Geisinger Health System in Wilkes-Barre, PA. To celebrate the graduation of the 2014-2015 clinical fellows, the Division hosted the Nicholson Visiting Professor Program and Fellows Graduation & Reunion



Figure 13.

in June 2015. This year's Visiting Professor was Dr. Vince Mosca from Seattle, an internationally renowned pediatric foot and ankle expert (Figure 14, center). The program consisted of a mix of short lectures and discussion, a cocktail reception, and research and end of the year remarks from the four fellows.



Figure 14.

The Division also continues to host visiting scholars and provide the opportunity to observe clinical care of pediatric patients in a high volume, academic setting. Over the past year, the Division has hosted Dr. Kunbo Park, Assistant Professor of Pediatric Orthopaedic Surgery at Inje University Haeundae Paik Hospital in Busan South Korea, and Dr. Giuseppe Orlando, School of Medicine University of Messina, Messina, Italy.

Research Program

Basic Science and Translational Research



Figure 15.

This past year, our Orthopaedic Basic Research Program, led by Maurizio Pacifici, Ph.D. (Figure 15) has continued to make impressive progress and has generated new, exciting and far-reaching data and insights on basic and translational medicine aspects of skeletal biology and pediatric musculoskeletal

pathologies. Our faculty members and their associates—including postdoctoral fellows, visiting scientists and research technicians - continued to tackle and fulfill the goals of several current NIH R01 grants, one Department of Defense (DOD) grant, one Muscular Dystrophy Association (MDA) grant and one Veterans Administration (VA) grant. These biomedical research projects which focus on basic cellular, biochemical and genetic mechanisms of skeletal formation and growth, also addressed the very complex tissue-tissue interplays that orchestrate the morphogenesis and three-dimensional organization of limb and craniofacial skeletal elements. The resulting data and insights continue to be used to uncover pathogenic mechanisms that subtend pediatric and adult conditions including Hereditary Multiple Exostoses (HME), Fibrodysplasia Ossificans Progressiva (FOP), Duchenne Muscular Dystrophy and other musculoskeletal pathologies. Work on HME was carried out under the supervision of Drs. Pacifici and Eiki Koyama and is supported by one of the RO1 NIH grants. This rare and orphan disorder is characterized by benign cartilaginous tumors that form at multiple locations in the growing skeleton of children. The tumors can often exceed a total number of 100 and thus, can cause a number of problems including skeletal deformities, growth retardation, chronic pain, interference with blood vessel and nerve function, and other problems. In 2 to 5% of the children, the benign tumors can become malignant and thus life threatening. Our clinical Division remains a major national and international center of diagnosis, care and surgical treatment for children affected by HME. Under the auspices of the NIH, we are actively engaged in understanding the cellular and molecular pathogenesis of HME, using animal models and cells in vitro. We have made much progress and have published a number of papers over the last two years that have revealed novel aspects of the pathophysiology of HME and have uncovered new and previously unsuspected possible targets of therapeutic intervention. To extend these basic research efforts and accelerate the pace of research toward translational medicine outcomes, our senior investigator—Dr. Paul Billings—has further developed new cell-based bioassays to screen chemical libraries and identify drugs able to correct the specific polysaccharide deficiency that causes HME. Such pharmacological treatment could be used in combination with surgical interventions to provide a more effective and comprehensive therapy for HME patients in the future. In a felicitous development, Drs. Billings and Pacifici received funding from the U Penn Center on Rare and Orphan Diseases that has permitted an acceleration and expansion of the research and a search for possible drugs using additional and more diverse chemical repositories. Together, these considerable investments of time, effort and funds are paying off in a considerable manner and have provided not only new insights into the mechanisms of HME pathogenesis, but also on how a basic polysaccharide deficiency could be corrected in this and related pathologies.

Studies carried out under the auspices of the Muscular Dystrophy Association (MDA) and led by another one of our faculty members—Dr. Masahiro Iwamoto - have made progress

toward testing an effective therapy to stimulate muscle tissue repair and/or decrease muscle cell death after trauma or in congenital conditions such as muscular dystrophies, using pharmacological treatments. Our faculty member Dr. Eiki Koyama joined forces with a faculty member in the CHOP Division of Plastic and Reconstructive Surgery—Dr. Hyun-Duck Nah—to understand the development and growth of the temporomandibular (TMJ) joint and to identify possible therapeutic means to treat TMJ osteoarthritis, a condition particularly common in women and quite debilitating. The data and insights stemming from their work led to the publication of several important studies, and all their work and dedication were rewarded by a new 5 year NIH RO1 grant they received last year. An equally important area of research led by another faculty member—Dr. Motomi Enomoto-Iwamoto - was supported by a R21 grant from the NIH and focused on tendon and ligament biology. These research efforts aim to find ways to stimulate structural and functional repair in those essential structures when damaged by trauma or overuse. Some of this work is carried out in close collaborations with members of the Department of Orthopaedic Surgery at Penn and in particular Dr. L. Soslowky. Work by Dr. Enomoto-Iwamoto was also supported by a grant from the Arthritis Foundation to study a cell membrane component that affects the behavior and function of surface cells in articular cartilage, cells that are essential for the frictionless movement of the joints and are responsible for the production of key lubricating macromolecules including hyaluronate and phospholipids. These ongoing studies should shed important light on the biology of cartilage surface cells, should suggest ways to maintain their function during normal function and even aging. These studies will also pave the way to identify more effective and aggressive means by which function of joint surface cells could be restored in severe and chronic conditions including osteoarthritis and after acute joint injury in pediatric and adult patients. In a related development, Dr. Pacifici joined forces with Dr. Robert Mauck in the Department of Orthopaedic Surgery at Penn to study whether progenitor cells isolated from developing embryonic synovial joints can repair articular cartilage more effectively than generic stem or progenitor cells - including bone marrow—or fat tissue-derived mesenchymal stem cells—currently used by most groups. These innovative studies are supported by a grant from the VA that Drs. Pacifici and Mauck received recently.

As indicated in our report last year, our basic research work on FOP has led to an ongoing phase 2 clinical trial sponsored by the Canadian-based pharmaceutical company Clementia. FOP is an extremely severe pediatric disorder in which extraskeletal bone (collectively called heterotopic ossification or HO) forms and accumulates throughout the body over time, progressively limiting the ability of patients to carry out daily functions and often leading to premature death. Studies we first published in 2010 and 2011 showed for the first time that synthetic agonist ligands for nuclear retinoic acid receptors are very potent inhibitors of HO in experimental animal models of FOP. The clinical trial was launched in July 2014 in close collaboration with our colleagues at the U Penn

FOP Research Center Drs. Fred Kaplan, Bob Pignolo and Eileen Shore and is expected to be completed later this year. This is a major milestone achievement for our basic Research Division and shows that years of basic research can and do translate into possible new treatments for severe pediatric skeletal disorders. We continue to use our two-pronged approach that combines basic and translational medicine to tackle, and hopefully find treatments for, other orphan musculoskeletal disorders affecting and afflicting children and their families worldwide.

Genetic Research

CHOP Orthopaedics continues to work in collaboration with the Center for Applied Genomics (CAG), led by Dr. Hakon Hakonarson and Dr. Struan Grant, to compile a registry of DNA and RNA samples. These samples are obtained from patients and families with a variety of orthopaedic conditions including adolescent idiopathic scoliosis (AIS), osteocondritis dissecans (OCD) of the knee, and multiple hereditary exostoses (MHE). This past year, in conjunction with colleagues in genetics and basic science at CHOP and St. Luke's Orthopedics in Boise, ID preliminary results from a study of genetic predispositions for OCD were published in the *Journal of Pediatric Orthopaedics*. The study discussed the relevance and applicability of genome-wide association study (GWAS) in studying a genetic basis for OCD. The study also identified top signals that may suggest loci involved in coordinated expression as well as a transcription factor involved in development that may be highly relevant to this trait. Additional advances in 2015 include identifying a novel copy number variation (CNV) deletion that was common between a mother and daughter who both suffered from the absence of the anterior and posterior cruciate ligaments of the knees. Future efforts in genetics research include a push to perform whole exome sequencing and GWAS of OCD samples collected from the Research in Osteochondritis Dissecans of the Knee (ROCK) group.

Orthopaedic Engineering

In 2015 Dr. Saba Pasha, PhD was appointed as the new Director of Orthopedic Engineering. Dr. Pasha's research focuses on application of 3D imaging and computer simulation in surgical planning, use of predictive models in surgical decision making, and exploring gait and motion analysis for a more personalized treatment.

With new emerging technology, such as the EOS x-ray imaging system, comprehensive information about a patient's condition is now readily available. Dr. Pasha's work utilizes advanced imaging and motion analysis to collect data on a range of conditions and patient populations. These tools will help us to visualize and determine the best treatment options for patients. Currently, research is focused in two areas—skeletal deformities and sports medicine.

Clinical Research

The Division of Orthopaedic Surgery is currently conducting 117 IRB approved clinical research projects. This includes 50 prospective randomized clinical trials and

observational studies. CHOP Ortho faculty are also members of a number of multicenter study groups including the Harms Study Group (HSG), Research in Osteochondritis Dissecans of the Knee (ROCK), and International Hip Dysplasia Institute (IHDI). Investigators within the division have been awarded funding from both internal and external sources to conduct these studies. In 2015, the Division published over 107 articles in major orthopaedic journals, including JBJS, Spine, JPO, and CORR.

Our pediatric orthopaedic faculty continues to present research studies at orthopaedic conferences around the world, including the American Academy of Orthopaedic Surgeons (AAOS), the Pediatric Orthopaedic Society of North America (POSNA), the European Pediatric Orthopaedic Society (EPOS), the Scoliosis Research Society (SRS), the American Orthopaedic Society for Sports Medicine (AOSSM), the International Meeting on Advanced Spine Techniques (IMAST), the Societe Internationale de Chirurgie Orthopedique et de Traumatologie (International Society of Orthopaedic Surgery and Traumatology, SICOT) and many more.



Figure 16.

The Division continues to award the annual Benjamin Fox Scholarship Award for medical students who are interested in conducting a year of clinical research within orthopaedics. In June, Christopher Brusalis (Perelman School of Medicine at the University of Pennsylvania) and Christian Refakis (Stony Brook University School of Medicine), were awarded with the scholarship. While at CHOP, Chris (Figure 16) has concentrated his research on novel educational interventions for orthopaedic surgery residents, the impact of surgeon experience on clinical outcomes, and supracondylar humerus fractures. Christian (Figure 17) has focused his research on the complications of posterior spinal fusions for scoliosis, the management of neuromuscular scoliosis and hip dislocation in the setting of cerebral palsy, the incidence and management of concussion in sports, the management of pediatric shoulder instability, and the patient-reported outcomes of All-Epiphyseal ACL reconstruction.



Figure 17.

Recognition and Achievements

Our Attendings have assumed several leadership roles within the pediatric orthopaedic community over the past year.

Alexandre Arkader, MD was the International Guest and Keynote Speaker at the 9th TROIA (Brazilian Pediatric Orthopedic Trauma Meeting) in Curitiba, Brazil. He also served as a guest speaker and International Faculty at the 4th Combined SLAOTI/POSNA/EPOS meeting in Bogota, Columbia.

Keith Baldwin, MD, MSPT, MPH is the current Director of Clinical Research and Associate Director of Orthopaedic Trauma in the Division of Orthopedic Surgery. This past year he earned the Jacqueline Perry Award Paper from the Orthopaedic Rehabilitation Organization. Dr. Baldwin currently serves as a reviewer for a number of journals including the *Journal of Orthopedic Trauma*, *Journal of Bone and Joint Surgery - American*, and the American Academy of Pediatrics and an editorial board member of the *American Journal of Orthopedics* and *World Journal of Orthopedics*.

Patrick Cahill, MD was awarded the Scoliosis Research Society Traveling Fellowship. Dr. Cahill joined other North American fellows to visit major spinal deformity centers in Asia under the guidance of a senior SRS fellow. He continues to serve as an Associate Editor for *Spine Deformity Journal* and reviewer for the *Journal of Bone and Joint Surgery - American* and the Thrasher Research Fund. Dr. Cahill served as faculty for the 2015 Early Onset Scoliosis Seminar in Nagoya, Japan.

Robert Campbell, MD continues to expand and develop the Center for Thoracic Insufficiency at CHOP. He was also awarded the Pennsylvania Bio's Patient Impact Award. The award recognizes a company or organization that has made a significant contribution to the quality of healthcare or length of life of patients." Previously, the University of Pennsylvania and CHOP were jointly given the award for their groundbreaking immune therapy research. In 2015, Dr. Campbell and Dr. Udupa (Perelman School of Medicine) were awarded a NIH R21 Grant for their project "Dynamic MRI Image Analysis for Studying Thoracic Insufficiency Syndrome". Drs. Campbell and Udupa plan to study quantitatively pre- and post-operative dynamic MRIs of TIS patients and compare these quantitative measures to pulmonary function tests and patient outcome to understand the effectiveness of surgery.

Robert Carrigan, MD is a team member of the Hand Transplantation Program and took part in the first pediatric double hand transplant. Dr. Carrigan continues to serve on the POSNA Resident Newsletter Committee. Together with his wife, Dr. Carrigan and his family welcomed their third child, Sam, in 2014.

B. David Horn, MD is the current chair of the AAOS Pediatric Evaluation Committee and is in the process of editing the 2016 Pediatric Self Assessment Examination. He also served as the organizer and moderator of the instructional course Office Pediatric Orthopedics at the AAOS annual meeting in Las Vegas, NV. In August, Dr. Horn traveled with Dr. Davidson to serve as facilitators the 25th Annual Baltimore Limb Deformity Course.

Jack Flynn, MD, Chief of the Division of Orthopaedic Surgery, continues serve his 10-year term as a Director of the American Board of Orthopaedic Surgery and a 4-year term as AAOS Chair of Continuing Medical Education. He also Co-Chairs the International Pediatric Orthopaedic Symposium and the sold-out Spine Surgery Safety Summit. Dr. Flynn is co-editors of two textbooks: *Rockwood and Wilkins: Fractures in Children* and *Operative Techniques in Orthopaedic Surgery—Pediatrics*. He continues his service on the Board of Directors of the

Children's Spine Study Group, and is active in the Harms Study Group, a multi-center collaboration of researchers studying care improvements for pediatric spine deformity surgery.

Theodore Ganley, MD is the Sports Medicine Director at CHOP, supporting clinical, research, and outreach initiatives which continue to grow. He was selected as moderator or instructor at instructional course lectures for the following annual meetings: AAOSM, AAOS, AAP, IPOS, and POSNA. In 2015, he was invited to speak the Penn Cartilage Repair Symposium. Dr. Ganley continues to serve on the Advisory Board of the International Pediatric Orthopaedic Symposium, on the Executive Committee of the Research in Osteochondritis Dissecans of the Knee (ROCK) group, and as Co-founder and Treasurer of the Pediatric Research in Sports Medicine (PRISM) group.

John Todd Lawrence, MD, PhD, through an OMeGa grant, recently completed the development of a distal radius fracture model (patent pending) which will improve resident performance in fracture reduction and casting techniques. The model was recently validated in conjunction with a multicenter pediatric simulation group and is currently being marketed. He continues to serve as a reviewer for the *American Journal of Sports Medicine (AJSM)* and *Journal of Shoulder and Elbow Surgery (JSES)*.

Wudbhav Sankar, MD is the Director of the Young Adult Hip Preservation Program at CHOP. In 2015, he was promoted to Associate Professor of Orthopaedics Surgery. Dr. Sankar completed his term on the POSNA Board of Directors and is currently Chair of the POSNA Fellowship committee. He remains active in several study groups including Academic Network of Conservational Hip Outcomes Research (ANCHOR) and International Perthes Study Group. Dr. Sankar is currently a reviewer for the scientific program of the POSNA annual meeting and an Editorial Board Reviewer of the journal *Techniques in Orthopaedics*. In addition to his professional accomplishments, Dr. Sankar and his wife welcomed their third child, Kiran Oliver on November 20, 2015.

Apurva Shah, MD, MBA currently serves as co-PI on the POSNA Directed Research Grant "Improving value delivery in pediatric distal radius fracture care". The primary aims of the grant include accessing practice pattern variation and comparing treatment costs across institutions and geographic regions and between low and high volume centers. This past year, he has continued to serve as senior investigator on two OREF grants studying time-driven activity based costing and trigger finger injections. At the 2015 Mid-America Orthopaedic Association Annual Meeting, he received the award for Best Poster. In October 2015, Dr. Shah served as team leader and traveled to Sigua Tepeque, Honduras for a pediatric hand surgery medical mission.

David Spiegel, MD was awarded the Children's Hospital of Philadelphia Global Health Pilot Grant. Together with Dr. Bibek Banskota the funds will be used in Nepal to conduct the longest follow-up in the world's literature of patients treated by the Ponseti method in a low-middle income country. Dr. Spiegel continues his work with the World Health Organization, traveling to Geneva, Switzerland and Nepal. Following the Nepal earthquake in April 2015, Dr. Spiegel traveled to the country to support his friends with their work to treat patients. In December he took part in four sessions at the 12th Annual International Pediatric Orthopaedic Symposium in Orlando, FL.

Lawrence Wells, MD is the Associate Director of the Sports Medicine Performance Center at CHOP and Director of Quality, Safety, Value, and Patient Experience in the Division of Orthopaedic Surgery. In 2015, he joined the POSNA EPIC Steering Committee and POSNA Quality, Value, Safety committee, and the Pediatric Research in Sports Medicine Society (PRISM). Dr. Wells was also appointed as an external reviewer on the Committee of Appointments and Promotions at the University of California San Diego School of Medicine.