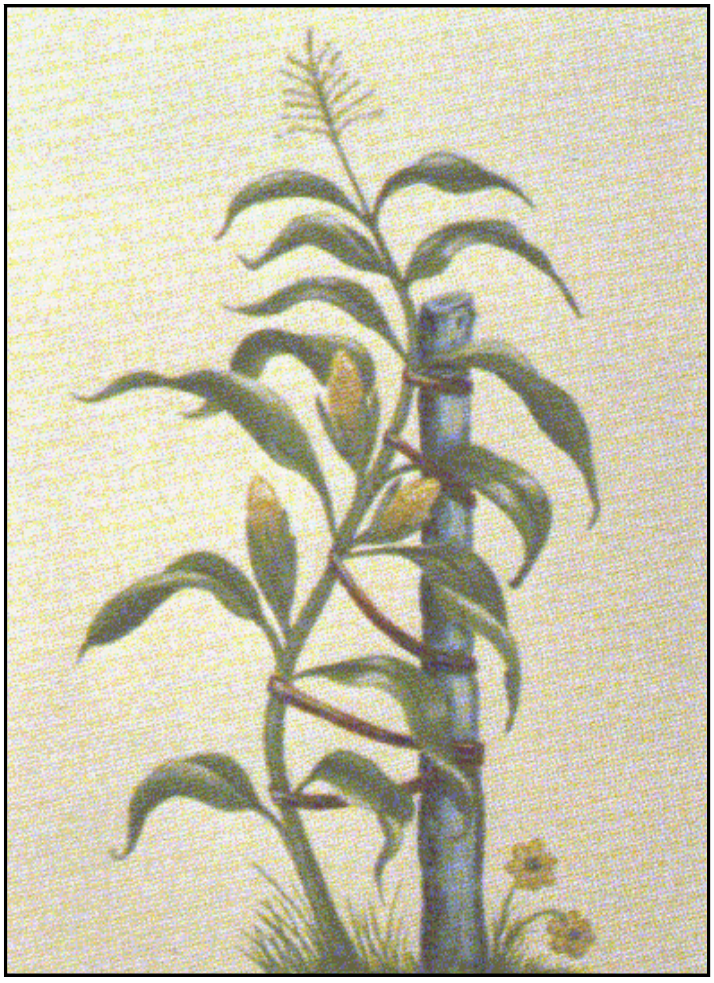
ANNUAL REPORT

ORTHOPAEDIC BIOMECHANICS LABORATORY



DEPARTMENT OF ORTHOPAEDICS & REHABILITATION
THE UNIVERSITY OF IOWA
CARVER COLLEGE OF MEDICINE
IOWA CITY, IOWA 52242-1100

July 2008 – June 2009

SEATED Left–Right: Daniel Jaramillo, Nicole (Jensen) Kunze, Lu Kang, Curt Goreham-Voss

MIDDLE Left–Right: Ellen Sauter, Catherine Pospisil, Jess Goetz, Erin Main, Anneliese Heiner, Yuki Tochigi, Junghyun Byun, Jim Rudert, Noelle Klocke, Megan O'Brien, Thad Thomas, Rachel Williams

BACK Left–Right: Tom Brown, Don Anderson, Drew Kern, Jake Elkins, Katelyn Goetz, Julie Mock, Tom Baer

NOT PICTURED: Nick Muhlenbruch, Doug Pedersen, Nick Stroud, Tanawat Vaseenon

Goals

The Orthopaedic Biomechanics Laboratory conducts basic and applied musculoskeletal research for which mechanical analysis and/or mechanical measurements are appropriate. Studies of varying scope undertaken in the Laboratory address problems of interest to orthopaedic faculty members, and serve to train students, residents, and fellows in the principles of scientific investigation. Several well-established collaborations with the other departmental research laboratories, with other departments of the Carver College of Medicine, with the College of Engineering, and with other institutions complement our own work. Financial support comes from a variety of external sources (federal agencies, foundations and other non-profit organizations, industrial/corporate grants and contracts), supplemented by internal funds.

Currently, the major areas of investigation are total joint replacement (primarily hip and spine), post-traumatic arthritis, carpal tunnel syndrome, high-energy limb trauma, osteonecrosis of the hip, and articular contact stresses as they relate to joint degeneration. Rather than a categorical disease focus, the common thread of the Laboratory's project portfolio is to apply innovative computational formulations and novel experimental approaches to clinically-oriented research problems, across the diverse spectrum of musculoskeletal biomechanics.

Highlights

There were several noteworthy developments this past year. Like most of the U.S. biomedical research community, over the spring and summer we devoted substantial effort to NIH proposal opportunities arising from the American Recovery and Reinvestment Act of 2009 (ARRA). But unlike many of our colleagues elsewhere, rather than emphasizing the Challenge Grant mechanism (we submitted only one Challenge proposal), we focused instead on Competitive Revision and Administrative Supplement proposals (twelve individual proposals) made eligible by currently active grants. Concurrently, we also pursued new supplemental funding opportunities, distinct from the ARRA, under the new BIRT program within NIAMS, and under Pilot and Feasibility project submissions within the CORT mechanism. While these various proposals individually were mostly small or intermediate in scope, collectively they represent a substantial potential funding augment ($4.6 M). Meanwhile, in early June we received a funding-range priority score on a large new NIH R01 proposal involving third-body wear of total hip replacements. Third-body wear has been a major focus area of our laboratory over the previous several years, but it had been necessary to scale back this effort during a period of no-cost extension of the grant previously supporting that work.

Another significant development on the funding front was that in April, the University of Iowa moved up from last year's #2 ranking, to now rank #1 nationally among U.S. orthopaedic programs in terms of NIH funding. This has been a gratifying achievement for all concerned, and it has been an honor for the Biomechanics Laboratory to have been a substantial part of that overall effort.

As an update regarding personnel, applications from Drs. Don Anderson and Doug Pedersen to move from the Research Engineering track into the new Research Faculty track were approved by the College of Medicine. Don and Doug are both now officially appointed as Research Associate Professors of Orthopaedics and Rehabilitation. They also hold secondary faculty appointments in the Department of Biomedical Engineering. Another new tie to the College of Engineering is that Dr. Jess Goetz has been

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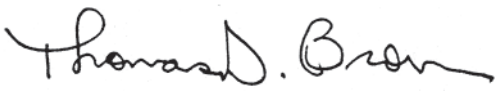
appointed as an Adjunct Assistant Professor in Biomedical Engineering. In May, we welcomed a new postdoctoral research scholar, Dr. Lu Kang. Lu received her Ph.D. in biomechanics and biomaterials for orthopaedic implants in 2008 from the University of Leeds, where her dissertation research dealt with wear studies of total joint replacements. Her work here is focusing on wear of spinal total disc replacements, and on assessment of contact stresses in articular joints. To keep pace with the increasing workload from funded grants (and hopefully with supplemental funding from the various ARRA proposals), this year we added six new graduate students. Ms. Junghyun Byun is pursuing Ph.D. research on CT-based image analysis techniques to assess injury of musculoskeletal soft tissues, with primary guidance from Dr. Don Anderson. Ms. Erin Main, a 2009 BME graduate from the University of Wisconsin, is working on tissue mechanical testing aspects of our project on median nerve insult in the carpal tunnel, under primary guidance from Dr. Jess Goetz. Ms. Megan O'Brien, a 2009 mechanical engineering graduate from Rose-Hulman Institute, is beginning M.S. research on third-body wear of total hips, under supervision from Dr. Brown. Ms. Ellen Sauter, a 2008 graduate in biology from Gustavus Adolphus College who subsequently pursued a year of mechanical engineering training at South Dakota School of Mines, has started work on combined biological and mechanical characterization of *in vivo* joint impact models in the CORT program, under primary guidance from Drs. Jim Martin and Yuki Tochigi. Ms. Noelle Klocke and Mr. Andrew Kern, both recent B.S. graduates from the BME department here at Iowa, are working on computational analyses within the Biomechanics and Imaging Core of the CORT grant under supervision from Drs. Anderson, Pedersen, and Brown. This year's externs and undergraduate research assistants include Mr. Daniel Jaramillo, a mechanical engineering major from the Universidad de Los Andes, Bogotá, Columbia (working on carpal tunnel MRI image analysis and articular joint loading), Ms. Katelyn Goetz, a physics/math major from Wake Forest University (working on image analysis of osteonecrosis), and Mr. Nicholas Muhlenbruch, Ms. Catherine (Kate) Pospisil, and Ms. Rachel Williams, all BME majors from Iowa. Kate and Rachel are involved with image analysis work with Drs. Anderson and Segal pertinent to onset of primary knee osteoarthritis. Nick is working with Drs. Femino, Tochigi and Anderson, in the area of hindfoot biomechanics.

Again this year, lab members received several research honors. In March, Mr. Krishna Iyer, a former Iowa BME undergraduate now enrolled in Iowa's M.S.T.P. program, received the Michael Bonfiglio Award for his study entitled "Biomechanical Modeling to Predict Those At Risk of Developing Painful Knee OA," work conducted under the supervision of Drs. Don Anderson and Neil Segal. Manuscripts based on that work have been accepted by the Journal of Applied Biomechanics and the Journal of Orthopaedic Research, quite a nice achievement for an undergraduate part-timer. In May, Curt Goreham-Voss, a full-time staff engineer in our lab concurrently pursuing his Ph.D., received international recognition with the best poster award at the Spine Arthroplasty Society meeting in London for his work entitled "Motion Track Variations in Alternative Wear Testing Protocols for Total Disc Replacements," co-authored by Dr. Brown. Finally, also in May, a group of investigators from the laboratory (Drs. Brown, Lundberg, Pedersen, and Callaghan) received the Nicolas Andry Award for their body of work, spanning several years of effort, summarized in a paper entitled "Clinical Biomechanics of Third Body Acceleration of Total Hip Wear." This is the highest research award from the Association of Bone and Joint Surgeons.

Director's Perspective

This has been a difficult year financially both for University of Iowa Health Care and for the University of Iowa as a whole, due to revenue stream reductions arising from adverse economic conditions in the broader state and national economy. For the first time in memory, institutional financial cut-backs reached the level of including lay-offs. Even as the general economic situation begins to show signs of improvement, adverse financial conditions institutionally are likely to persist through at least the next fiscal year. Looking further ahead, the financial viability of academic biomedical research faces uncertainty within the now-coalesced societal consensus that the growth of health-related expenditures urgently needs to be reined in.

For our laboratory to continue to succeed, it is more important than ever to demonstrate clear value both within the institution and to society as a whole. That value takes several forms. First, to remain competitive globally in the biomedical device industry, the U.S. economy needs competent research bioengineers who can hold their own (and then some) with counterparts around the world. Our laboratory's role in that regard is to build on classroom-acquired knowledge to teach Iowa's graduate (and undergraduate) students to become effective pragmatic problem-solvers in the real world of musculoskeletal research. Awards and accolades of course are welcome, but the best testimonial is that R&D leaders in the orthopaedic industry continue to regularly make decisions to hire our students. A second area of value-added is in terms of surgeon research collaborations. Private practice opportunities in orthopaedic surgery are immensely more lucrative financially than those in academic medical centers. One of the attractions for leading orthopaedic surgeons to work in academics is the opportunity to collaborate with clinically-oriented laboratory investigators to advance the scientific basis of orthopaedics as a specialty. Our lab has made it a priority to foster those types of interactions wherever the tools and capabilities of biomechanics can be fruitfully brought to bear, regardless of sub-specialty area. This has made a difference, both for several University of Iowa orthopaedic surgeons who have aspired to develop nationally visible research programs, and for numerous others whose research objectives have been more modest and focal. In addition to student training and surgeon collaborations, however, our lab's third area of value-added is the most important: creation of new knowledge relevant to improving the treatment of musculoskeletal disorders. The primary metrics of that knowledge creation are those detailed in this report: publications in the field's leading archival journals, presentations at major national and international scientific meetings, and competitive peer-reviewed grant funding.



Thomas D. Brown, Ph.D.
Director
Orthopaedic Biomechanics Laboratory

Multidisciplinary Biomechanical Characterization of Non-Pathologic Subsynovial Connective Tissue—University of Iowa OVPR Biological Sciences Funding Program
04/15/09–06/30/10, $29,145 Total Costs
Jessica E. Goetz, Ph.D., Principal Investigator
Thomas E. Baer, B.A., Mechanical Designer/Machinist
Gail L. Kurriger, B.S., H.T. (ASCP), Histology Technician
Thomas D. Brown, Ph.D., Ericka A. Lawler, M.D., Yuki Tochigi, M.D., Ph.D., Consultants

Acute Cartilage Damage Associated with Intraarticular Fractures—Orthopaedic Trauma Association
01/01/09–12/31/09, $25,000 Total Costs
Yuki Tochigi, M.D., Ph.D., Principal Investigator
Todd O. McKinley, M.D., Co-Principal Investigator
James A. Martin, Ph.D., M. James Rudert, Ph.D., Investigators

Quantification of Functional Limitation in Older Adults with Symptomatic Knee Osteoarthritis Through Evaluation of Gait Variability—Foundation for Physical Medicine & Rehabilitation
10/01/08–09/30/10, $10,000 Total Costs
Neil A. Segal, M.D., Principal Investigator
Yuki Tochigi, M.D., Ph.D., Co-Investigator

Quantifying Fracture Severity Using a 3-D Puzzle Solving Approach—NIH 1 R21 AR054015
07/01/08–03/31/10, $359,273 Total Costs
07/01/08–06/30/09, $201,537 Annual Total Costs
Donald D. Anderson, Ph.D., Principal Investigator
J. Lawrence Marsh, M.D., Thomas D. Brown, Ph.D., Co-Investigators
Andrew R. Willis, Ph.D., Principal Investigator (University of North Carolina at Charlotte)

Objective Assessment of Fracture-Associated Soft Tissue Injury Using CT-Based Texture Analysis—Orthopaedic Trauma Association
01/01/08–06/30/09, $25,000 Total Costs
Donald D. Anderson, Ph.D., J. Lawrence Marsh, M.D., Principal Investigators
Thomas D. Brown, Ph.D., Investigator

Biomechanics of Total Hip Impingement & Dislocation—Department of Veterans Affairs
10/01/07–09/30/11, $549,500 Total Costs
10/01/08–09/30/09, $147,600 Annual Total Costs
John J. Callaghan, M.D., Principal Investigator
Thomas D. Brown, Ph.D., H. John Yack, Ph.D., Co-Investigators
Douglas R. Pedersen, Ph.D., Investigator
Thomas E. Baer, B.A., Mechanical Designer/Machinist

New Approaches to Assess and Forestall Osteoarthritis in Injured Joints—NIH 5 P50 AR055533

09/10/07–08/31/12, $7,334,803 Total Costs
09/01/08–08/31/09, $1,831,274 Annual Total Costs
Joseph A. Buckwalter, M.D., CORT Director
Thomas D. Brown, Ph.D., CORT Associate Director

Project 1: Cartilage Extracellular Matrix Fragments and Trauma-Induced Chondrolysis

09/10/07–08/31/12, $912,112 Total Costs
09/01/08–08/31/09, $213,107 Annual Total Costs
Joseph A. Buckwalter, M.D., Principal Investigator
James A. Martin, Ph.D., Co-Principal Investigator
Gene A. Homandberg, Ph.D., Prem Ramakrishnan, Ph.D., Hongjun Zheng, Ph.D., Investigators

Project 2: Acute Versus Chronic Mechanical Damage in the Etiology of Post-Traumatic OA

09/10/07–08/31/12, $1,041,257 Total Costs
09/01/08–08/31/09, $221,468 Annual Total Costs
Todd O. McKinley, M.D., Principal Investigator
James A. Martin, Ph.D., Prem Ramakrishnan, Ph.D., M. James Rudert, Ph.D.,
Yuki Tochigi, M.D., Ph.D., Investigators

Project 3: Validation and Application of MRI Biomarkers in Assessing Articular Cartilage Health

09/10/07–08/31/12, $1,065,413 Total Costs
09/01/08–08/31/09, $234,906 Annual Total Costs
Douglas R. Pedersen, Ph.D., Principal Investigator
Annunziato Amendola, M.D., Co-Principal Investigator
James A. Martin, Ph.D., Daniel R. Thedens, Ph.D., Glenn Williams, Ph.D., Investigators

Project 4: Quantifying Injury Severity to Assess the Risk for Post-Traumatic Osteoarthritis

09/10/07–08/31/12, $971,370 Total Costs
09/01/08–08/31/09, $200,801 Annual Total Costs
J. Lawrence Marsh, M.D., Principal Investigator
Donald D. Anderson, Ph.D., Co-Principal Investigator
Thomas A. DeCoster, M.D., Principal Investigator (University of New Mexico)
Douglas R. Dirschl, M.D., Principal Investigator (University of North Carolina–Chapel Hill)

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Administrative Core
09/10/07–08/31/12, $733,644 Total Costs
09/01/08–08/31/09, $475,740 Annual Total Costs
Joseph A. Buckwalter, M.D., Program Director
Thomas D. Brown, Ph.D., Associate Program Director
Martha L. Gray, Ph.D., Walter Herzog, Ph.D., Jack L. Lewis, Ph.D.,
Stefan Lohmander, M.D., Ph.D., Carol Vorwald, R.N., Advisory Group
Stephen L. Hillis, Ph.D., Biostatistician
Lois A. Lembke, M.S., Grant Administrator

Biomechanics & Imaging Core
09/10/07–08/31/12, $1,819,385 Total Costs
09/01/08–08/31/09, $345,732 Annual Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
Thomas E. Baer, B.A., George Y. El-Khoury, M.D., Curtis M. Goreham-Voss, M.S.,
Anneliese D. Heiner, Ph.D., M. James Rudert, Ph.D., Investigators
Andrew R. Willis, Ph.D., Principal Investigator (University of North Carolina at Charlotte)

Tissue and Experimental Modeling Core
09/10/07–08/31/12, $791,624 Total Costs
09/01/08–08/31/09, $139,520 Annual Total Costs
Yuki Tochigi, M.D., Ph.D., Principal Investigator
Douglas C. Fredericks, B.S., James A. Martin, Ph.D., M. James Rudert, Ph.D., Investigators
Annunziato Amendola, M.D., Thomas D. Brown, Ph.D.,
Michael G. Conzemius, D.V.M., Ph.D., Diplomate, A.C.V.S., Consultant (University of Minnesota)

Local Biomechanics of Median Nerve Insult in Carpal Tunnel—NIH 5 R01 AR053899
09/07/07–08/31/11, $1,019,058 Total Costs
09/01/08–08/31/09, $249, 300 Annual Total Costs
Thomas D. Brown, Ph.D, Principal Investigator
Jessica E. Goetz, Ph.D., Ericka A. Lawler, M.D., M. James Rudert, Ph.D., Daniel R. Thedens, Ph.D.,
Yuki Tochigi, M.D., Ph.D., Co-Investigators
Thomas E. Baer, B.A., Mechanical Designer/Machinist

Biomechanics of the Dysplastic Hip—NIH 5 R01 AR053344
07/01/07–06/30/12 $1,265,988 Total Costs
07/01/08–06/30/09 $252,466 Annual Total Costs
Jeffrey A. Weiss, Ph.D., Principal Investigator (University of Utah)
Christopher L. Peters, M.D., Co-Principal Investigator
Gerard Ateshian, Ph.D., Consultant

University of Iowa Subaward
07/01/07–06/30/12 $366,606 Total Costs
07/01/08–06/30/09 $70,998 Annual Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
M. James Rudert, Ph.D., Thomas E. Baer, B.A., Investigators

Non-Invasive Assessment of Cartilage Health: A New Approach to T1ρ MRI—American Orthopaedic Society for Sports Medicine
04/01/07–03/31/09, $106,481 Total Costs
04/01/08–03/31/09, $34,506 Annual Total Costs
Annunziato Amendola, M.D., Principal Investigator
Daniel R. Thedens, Ph.D., James A. Martin, Ph.D., Douglas R. Pedersen, Ph.D., Investigators

Three-Dimensional Virtual Orthopaedic Reconstruction of Comminuted Fractures—University of Iowa Roy J. and Lucille A. Carver College of Medicine Roy J. Carver Charitable Trust Medical Research Initiative
02/01/07–03/31/09, $20,000 Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
Donald D. Anderson, Ph.D., Co-Investigator
Andrew R. Willis, Ph.D., Consultant (University of North Carolina at Charlotte)

Articular Contact—Identifying Patients At Risk For Painful Knee Osteoarthritis—University of Iowa OVPR Biological Sciences Funding Program
02/01/07–08/31/08, $30,000 Total Costs
Neil A. Segal, M.D., Principal Investigator
Donald D. Anderson, Ph.D., Co-Investigator
Morgan Brubaker, Research Assistant
Stephen L. Hillis, Ph.D., Consultant

Development of an Animal Model of Human Intra-Articular Fracture—University of Iowa OVPR Biological Sciences Funding Program
02/01/07–12/31/08, $29,867 Total Costs
Yuki Tochigi, M.D., Ph.D., Principal Investigator
James A. Martin, Ph.D., M. James Rudert, Ph.D., Investigators
Thomas D. Brown, Ph.D., Todd O. McKinley, M.D., Consultants
Michael G. Conzemius, D.V.M., Ph.D., Diplomate A.C.V.S., Consultant (University of Minnesota)

The Effects of Osteochondral Defects and Focal Resurfacing on Joint Contact Mechanics—Arthrosurface, Inc.
01/01/07–12/31/08, $60,738 Total Costs
Annunziato Amendola, M.D., Principal Investigator
Donald D. Anderson, Ph.D., Yuki Tochigi, M.D., Ph.D., Co-Principal Investigators
M. James Rudert, Ph.D., Douglas R. Pedersen, Ph.D., Thomas D. Brown, Ph.D., Co-Investigators
Thomas E. Baer, B.A., Mechanical Designer/Machinist

Quantifying Intra-articular Fracture Severity as a Risk Factor for Post-traumatic Osteoarthritis—World Arthrosis Organization
01/01/07–12/31/08, $50,000 Total Costs
J. Lawrence Marsh, M.D., Principal Investigator
Donald D. Anderson, Ph.D., Co-Principal Investigator
Joseph A. Buckwalter, M.D., Investigator

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Implant/Construct Interactions in the Biomechanics of Total Hip Dislocation—NIH 5 R01 AR053553

09/25/06–08/31/10, $1,207,471 Total Costs
09/01/08–08/31/09, $311,879 Annual Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
John J. Callaghan, M.D., Co-Investigator
Douglas R. Pedersen, Ph.D., M. James Rudert, Ph.D., Yuki Tochigi, M.D., Ph.D., Investigators
Jeffrey A. Weiss, Ph.D., Principal Investigator (University of Utah Subaward)

Wear Analysis of Intervertebral Disc Replacements—NIH 5 R01 AR052653

09/22/05–06/30/10, $2,496,667 Total Costs
07/01/08–06/30/09, $498,202 Annual Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
Douglas R. Pedersen, Ph.D., Sergio A. Mendoza, M.D., Co-Investigators
John Fisher, Ph.D., Richard M. Hall, Ph.D., Eileen Ingham, Ph.D.,
Co-Investigators (University of Leeds Subaward)
Heinz-Michael Mayer, M.D., Ph.D., Co-Investigator (Spine Center Munich Subaward)

Pathogenesis–Prevention of Post-Traumatic OA—NIH 5 P50 AR048939

09/16/02–08/31/08, $4,647,276 Total Costs
09/01/07–08/31/08, No Cost Extension
Joseph A. Buckwalter, M.D., SCOR Director
Thomas D. Brown, Ph.D., SCOR Associate Director

Project 1: Mechanical Determinants of Post-Traumatic OA

09/16/02–08/31/08, $795,301 Total Costs
09/01/07–08/31/08, No Cost Extension
J. Lawrence Marsh, M.D., Principal Investigator
Donald D. Anderson, Ph.D., Thomas D. Brown, Ph.D., George Y. El-Khoury, M.D.,
Steven L. Hillis, Ph.D., Todd O. McKinley, M.D., Douglas R. Pedersen, Ph.D., Investigators
Joseph A. Buckwalter, M.D., Consultant
Charles L. Saltzman, M.D., Consultant (University of Utah)

Project 2: Effects of Distraction and Motion on Osteoarthritis

09/16/02–08/31/08, $1,045,190 Total Costs
09/01/07–08/31/08, No Cost Extension
Annunziato Amendola, M.D., Principal Investigator
Thomas D. Brown, Ph.D., George Y. El-Khoury, M.D., Steven L. Hillis, Ph.D.,
James A. Martin, Ph.D., M. James Rudert, Ph.D., Alan L. Stolpen, M.D., Ph.D.,
Daniel R. Thedens, Ph.D., Investigators

Project 4: Oxidative Stress in Post-Traumatic OA

09/16/02–08/31/08, $837,974 Total Costs
09/01/07–08/31/08, No Cost Extension
Joseph A. Buckwalter, M.D., Principal Investigator
James A. Martin, Ph.D., Anneliese D. Heiner, Ph.D., Investigators
Aloysius J. Klingelhutz, Ph.D., Collaborator
Garry R. Buettner, Ph.D., Herbert Dircks, Consultants

Administrative and Biostatistics Core

09/16/02–08/31/08, $707,346 Total Costs
09/01/07–08/31/08, No Cost Extension
Joseph A. Buckwalter, M.D., Principal Investigator
Stephen L. Hillis, Ph.D., Investigator
Lois A. Lembke, M.S., Grant Administrator

Biomechanics Core

09/16/02–08/31/08, $1,261,464 Total Costs
09/01/07–08/31/08, No Cost Extension
Thomas D. Brown, Ph.D., Principal Investigator
Donald D. Anderson, Ph.D., Douglas R. Pedersen, Ph.D.,
M. James Rudert, Ph.D., Investigators

Quantifying 3rd Body Challenge in Total Hip Arthroplasty—NIH 1 R01 AR057780-01 (Scored 10th Percentile)

07/01/10–06/30/15, $2,767,618 Total Costs
07/01/10–06/30/11, $578,104 Annual Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
John J. Callaghan, M.D., Eileen Ingham, Ph.D., Co-Investigators
Anneliese D. Heiner, Ph.D., Investigator
John Fisher, Ph.D., Consortium Principal Investigator (The University of Leeds)
John J. Lannutti, Ph.D., Consortium Principal Investigator (The Ohio State University)
Thomas E. Baer, B.A., Mechanical Designer/Machinist

Influence of Chondrocyte Death on Cartilage Stability—NIH 3 P50 AR055533-03S2

09/01/09–08/31/10, $149,387 Total Costs
Joseph A. Buckwalter, M.D., Contact Principal Investigator
James A. Martin, Ph.D., Geoffrey McLennan, Ph.D., Co-Principal Investigators
Douglas R. Pedersen, Ph.D., Daniel R. Thedens, Ph.D., Yuki Tochigi, M.D., Ph.D., Co-Investigators
Eman Namati, Ph.D., Consultant (Harvard University)

New Approaches to Assess and Forestall Osteoarthritis in Injured Joints—NIH 3 P50 AR055533-03S3

09/01/09–08/31/11 $1,872,766 Total Costs
09/01/09–08/31/10, $1,008,809 Annual Total Costs
Joseph A. Buckwalter, M.D., Principal Investigator
Donald D. Anderson, Ph.D., Douglas R. Pedersen, Ph.D.,
Yuki Tochigi, M.D., Ph.D., Project Principal Investigators
Annunziato Amendola, M.D., J.L. Marsh, M.D., Co-Principal Investigators
Douglas C. Fredericks, B.S., Jessica E. Goetz, Ph.D., Anneliese D. Heiner, Ph.D.,
James A. Martin, Ph.D., Daniel R. Thedens, Ph.D., Co-Investigators
Annunziato Amendola, M.D., Mary P. Stolley, Advisors
Todd O. McKinley, M.D., M. James Rudert, Ph.D., Consultants
Michael G. Conzemius, D.V.M., Ph.D., Consultant (University of Minnesota)

Local Biomechanics of Median Nerve Insult in Carpal Tunnel—NIH 3 R01 AR053899-03S1

09/01/9–08/31/11, $323,041 Total Costs
09/01/09–08/31/10, $177,472 Annual Total Costs
Thomas D. Brown, Ph.D, Principal Investigator
Jessica E. Goetz, Ph.D., Ericka A. Lawler, M.D., M. James Rudert, Ph.D.,
Yuki Tochigi, M.D., Ph.D., Co-Investigators
Thomas E. Baer, B.A., Mechanical Designer/Machinist

Implant/Construct Interactions in the Biomechanics of Total Hip Dislocation—NIH 3 R01 AR053553-04S1

05/01/09–08/31/10, $244,117 Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
Curtis M. Goreham-Voss, M.S., M. James Rudert, Ph.D., Yuki Tochigi, M.D., Ph.D., Investigators
Thomas E. Baer, B.A., Mechanical Designer/Machinist

Wear Analysis of Intervertebral Disc Replacements—NIH 3 R01 AR052653-04S1
05/01/09–06/30/10, $237,991 Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
Thomas E. Baer, B.A., Mechanical Designer/Machinist

Biomechanics of the Dysplastic Hip—NIH 3 R01 AR053344-03S1
08/01/09–07/31/11 $310,245 Total Costs
08/01/09–07/31/10 $168,048 Annual Total Costs
Jeffrey A. Weiss, Ph.D., Principal Investigator (University of Utah)

University of Iowa Subaward
08/01/09–07/31/11 $83,042 Total Costs
08/01/09–07/31/10 $49,971 Annual Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
Thomas E. Baer, B.A., Lu Kang, Ph.D., M. James Rudert, Ph.D., Investigators

Dynamic MR Imaging of Carpal Tunnel Tissue Kinematics—NIH 1 RC1 AR058234-01
09/30/09–09/29/11, $580,300 Total Costs
09/30/09–09/29/10, $316,836 Annual Total Costs
Daniel R. Thedens, Ph.D., Principal Investigator
Jessica E. Goetz, Ph.D., Co-Investigator
Ericka A. Lawler, M.D., Thomas D. Brown, Ph.D., Investigators
Thomas E. Baer, B.A., Mechanical Designer/Machinist

Biomarkers of the Risk for Post-Traumatic Osteoarthritis—NIH 1 RC1 AR058403-01
09/30/09–09/29/11, $366,724 Total Costs
09/30/09–09/29/10, $182,311 Annual Total Costs
James A. Martin, Ph.D., Principal Investigator
Donald D. Anderson, Ph.D., J.L. Marsh, M.D., Co-Investigators

The Influence of Osteochondral Defect Characteristics upon Ankle Joint Contact Mechanics—NFL Charities Medical Research Grants
01/01/10–12/31/10, $123,758 Total Costs
Donald D. Anderson, Ph.D., Principal Investigator
Annunziato Amendola, M.D., M. James Rudert, Ph.D., Yuki Tochigi, M.D., Ph.D., Investigators

Expediting Patient-Specific Assessment of Chronic Contact Stress Exposure—University of Iowa Center of Research Translation (CORT) Pilot and Feasibility Projects on Post-traumatic Osteoarthritis
09/01/09–08/31/11, $141,450 Total Costs
09/01/09–08/31/10, $70,725 Annual Total Costs
Donald D. Anderson, Ph.D., Principal Investigator
Thomas D. Brown, Ph.D., J. Lawrence Marsh, M.D., Milan Sonka, Ph.D., Investigators

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Shape-Machined Structural Fillers for Juxta-Articular Segmental Bone Defects—University of Iowa Center of Research Translation (CORT) Pilot and Feasibility Projects on Post-traumatic Osteoarthritis
09/01/09–08/31/11, $137,178 Total Costs
09/01/09–08/31/10, $74,839 Annual Total Costs
Thomas D. Brown, Ph.D., Principal Investigator
Donald D. Anderson, Ph.D., Yuki Tochigi, M.D., Ph.D., Investigators
Matthew C. Frank, Ph.D., Consortium Principal Investigator

Mitochondrial Dysfunction Causing Chondrocyte Death After Impact Injury—University of Iowa Center of Research Translation (CORT) Pilot and Feasibility Projects on Post-traumatic Osteoarthritis
09/01/09–08/31/11, $149,052 Total Project Costs
09/01/09–08/31/10, $74,526 Annual Total Costs
Todd O. McKinley, M.D., Principal Investigator
Anneliese D. Heiner, Ph.D., Investigator

Local Biomechanics of Median Nerve Insult in Carpal Tunnel—NIH 3 R01 AR053899 Administrative Supplement
09/01/09–08/31/11, $163,612 Total Costs
09/01/09–08/31/10, $91,436 Annual Total Costs
Thomas D. Brown, Ph.D, Principal Investigator

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Thomas TP, Anderson DD, Van Hofwegen CJ, **Brown TD, Marsh JL.** A pathomechanical study of post-traumatic osteoarthritis: Linking intra-articular fracture incongruity to cartilage degeneration. OARSI World Congress on Osteoarthritis 2008, September 18–21, 2008, Rome, Italy. Abstract 07-A-276-OARSI, Poster Presentation #263. Osteoarthritis Cartilage 2008;16(Supp 4):S119–120.

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Thomas TP, Anderson DD, Van Hofwegen CJ, **Marsh JL, Brown TD.** Long-term effects of residual incongruities following intra-articular fractures: Spatial correlation between elevated contact stress and cartilage degeneration. 55th Annual Meeting of the Orthopaedic Research Society, February 22–25, 2009, Las Vegas, Nevada. Abstract ID: ORS2009-1666, Podium Presentation, Paper #387, Short Talk Session 14: Foot and Ankle.

Thomas TP, Anderson DD, Willis AR, **Marsh JL, Brown TD.** A development platform for three-dimensional puzzle solving of comminuted articular fractures. 55th Annual Meeting of the Orthopaedic Research Society, February 22–25, 2009, Las Vegas, Nevada. Abstract ID: ORS2009-2455. Poster Presentation #802, Poster Session 13: Fracture.

Thomas TP, Mosqueda TV, **Anderson DD,** Van Hofwegen CJ, **Brown TD, Marsh JL.** Predicting outcomes of tibial plafond fractures from CT-based measures of acute fracture severity. 76th Annual Meeting of the American Academy of Orthopaedic Surgeons, February 25–28, 2009, Las Vegas, Nevada. Application Number 4779, Podium Presentation #489.

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Tochigi Y, Martin JA, **Rudert MJ,** McCabe D, **Goreham-Voss CM, Buckwalter JA, Brown TD.** Acute phase pathology of cartilage injury in human ankle intraarticular fractures. 55th Annual Meeting of the Orthopaedic Research Society, February 22–25, 2009, Las Vegas, Nevada. Abstract ID: ORS2009-2661, Poster Presentation #1078, Poster Session 25: Cartilage Impact Models.

Tochigi Y, Anderson DD, Rudert MJ, Vaseenon T, Brown TD, Amendola A. Effect of implantation height upon contact stresses in the human ankle with a focal resurfacing implant. 55th Annual Meeting of the Orthopaedic Research Society, February 22–25, 2009, Las Vegas, Nevada. Abstract ID: ORS2009-2175, Podium Presentation, Paper #109, Session 20: Foot and Ankle.

Tochigi Y, McKinley TO, Vaseenon T, Fredericks DC, Heiner AD, Martin JA, **Rudert MJ, Brown TD.** Degree of joint instability determines severity of cartilage degeneration in rabbit knees. 55th Annual Meeting of the Orthopaedic Research Society, February 22–25, 2009, Las Vegas, Nevada. Abstract ID: ORS2009-3220, Poster Presentation #1115, Poster Session 28: Osteoarthritis Animal Models.

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Nicholas J. Stroud, B.S.E.*	M.S. Candidate	Began May 2008
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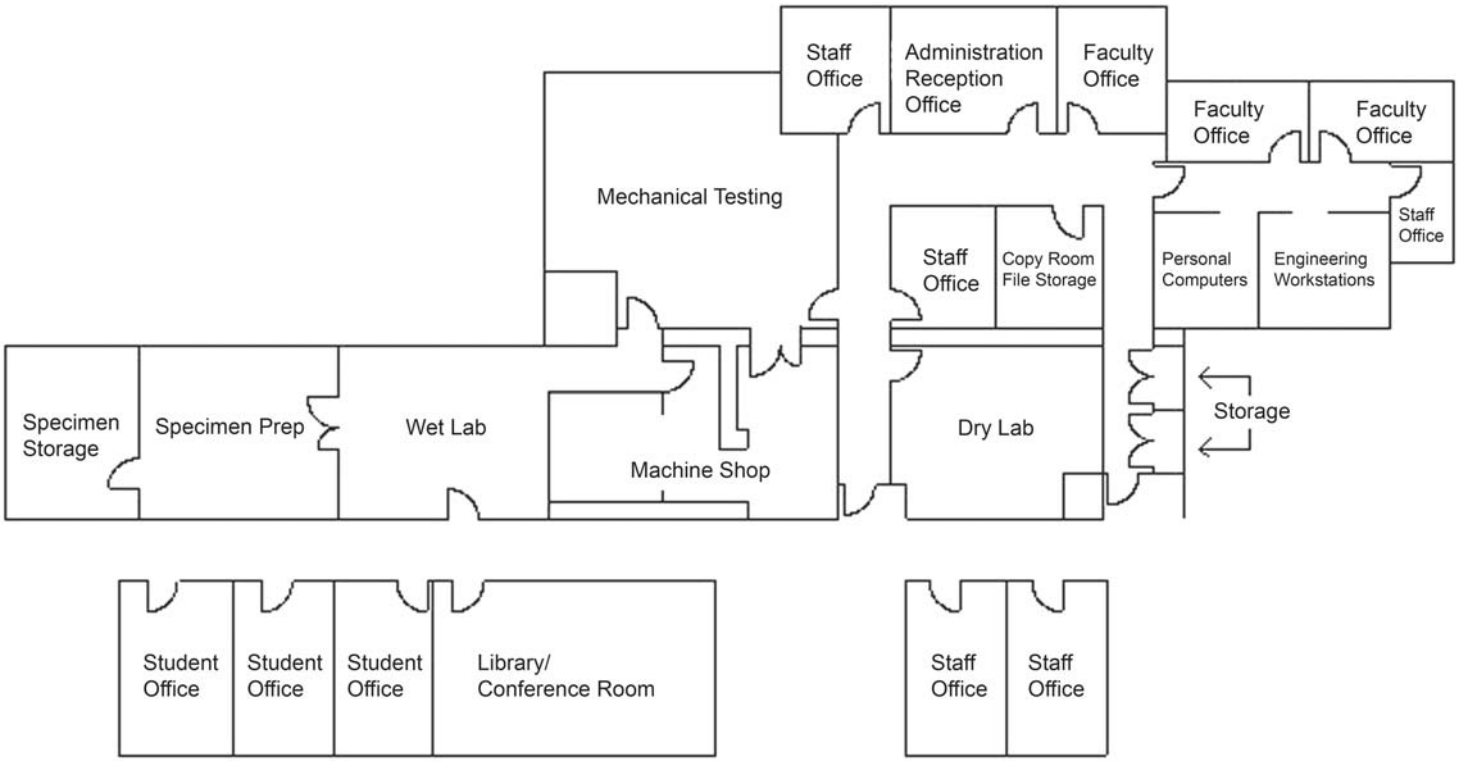
*Personnel based in the Orthopaedic Biomechanics Laboratory.

Facilities

The Laboratory occupies 22 individual rooms (5,333 ft²) in contiguous space on the ground floor of the Westlawn building. Located on a bluff overlooking the Iowa River, this five-floor building was originally constructed in 1926, and underwent major reconstruction in 1996–1998 as part of the College of Medicine's capital improvement program. About half of the Laboratory's space is in a newly constructed wing added to the back of the building and half is in renovated pre-existing space. The Laboratory is currently configured primarily for macroscopic-level physical testing of musculoskeletal constructs (e.g., bones, articular joints, orthopaedic implants) and for corresponding computational modeling. The physical testing area includes a 320 ft² multi-purpose wet lab, a 360 ft² multi-purpose dry lab, a 320 ft² surgical preparation room, a 750 ft² mechanical testing room, a 360 ft² machine shop, and a 250 ft² specimen storage area. The computational modeling area (380 ft²) is arranged around 8 separate workstation seats in two adjoining partially partitioned areas. Adjacent to these core operational areas are 3 faculty offices, 5 research staff offices, 3 student/fellow offices (4 desk spaces each), an administrative/reception area (330 ft²), and a library and conference room (450 ft²).

The mechanical testing room is fully equipped for studying the response of musculoskeletal tissues and/or implant constructs to mechanical loads. Two servo-hydraulic materials testing machines are maintained: an MTS Model 858.20 (Bionix), and an MTS Model 810. The Bionix is configured for experiments requiring independent axial and torsional loading, and has ratings of ± 25 kN (5,500 lbs) axially and ± 250 N-m (2,500 in-lbs) in torsion. Maximum stroke length is ± 100 mm (4 inches) axially and ± 50 degrees rotationally. In addition to this system's standard axial/torsional load cell (spanning the full range of system load rating), a higher sensitivity axial/torsional load cell (MTS Model 662.20C-01, 2500 N and 25 N-m



full scale range), and higher-sensitivity load cells (Lebow Models 3167-50, 3167-25, and 3108-5, with 220 N, 110 N, and 20 N full scale ranges, respectively)are available for experiments requiring precise detection of low forces and/or low torques. The controller was upgraded in 2003 to increase system versatility, to a current total of four control channels and seven transducer conditioners configurable for AC or DC, and twelve A/D channels. The transducer conditioners and A/D channels can be used to facilitate synchronous recordings from ancillary sensors such as strain gages, extensometers, displacement transducers, or pressure transducers. This MTS also has 16 channels each of digital input and digital output. The MTS 810 is an axial-only loading system, with tension/compression rating of 10 kN (2,200 lbs), and a maximum stroke length of ± 100 mm (4 inches). This system also has one extra transducer conditioner and two digital input/output channels. Each system has its own hydraulic pump, housed in a maintenance room located in the basement of the building. A wide variety of fixturing and specimen grips are available for both machines. Both systems operate with graphical user interfaces under the control of digital-computer-based TestStar controllers, running TestWare control software under the Windows XP operating system. Individual users can software-configure the systems to the needs of their particular experiments and can program specimen loading protocols using either simple menu waveforms (e.g., steps, ramps, haversines) or more complex input profiles (e.g., physiologic loading histories) obtained by concatenating individual waveform segments. As needed for additional processing, input and output data from the MTS controllers can be seamlessly ported from their respective Pentium-based control computers to other workstation platforms on the laboratory network. Our newest mechanical testing system is an MTS Insight 1, a tabletop electromechanical system with 1000 N force capability and a crosshead travel of 750 mm. The Insight is an axial-only system intended for static and quasi-static testing at lower forces. Our Insight system includes a 1000 N load cell and a 100 N load cell, an extensometer channel, tensile grips, and compression platens. The Insight runs on TestWorks software, which we upgraded to allow for more extensive test programming capability.

Multi-channel data collection and control is performed with a 12-bit, 8-channel SCXI-1000 system from National Instruments. This includes isolation amplifiers with capabilities for remote/portable applications, such as data collection from specialty instrumentation developed for operating room measurements. Additional mechanical instrumentation includes an 8-channel Honeywell 218 dynamic bridge amplifier, a Vishay system 5000 strain data collection system running Strain Smart software, a Vishay P-350 strain indicator, a Vishay 10-channel switch and balance unit, an AMTI 6 degree-of-freedom load cell, three extensometers, and two Bell & Howell physiologic pressure transducers. High-precision, non-contact displacement measurement capabilities are provided by a Kamon KD-2400 eddy current proximeter, an Aromat Model LM100 laser sensor (5 μm resolution) and an EDP Sonaswitch Model 1700 ultrasonic sensor (100 μm resolution). *In situ* displacement measurements are provided by three Lucas/Schaevitz Model GCA-121 linear variable displacement transformers (LVDTs) with 1 μm resolution, six Microstrain Model M-DVRT-3 differential variable reluctance transducers (DVRTs) with 1.5 μm resolution, and six Microstrain Model SG-DVRT-8 differential variable reluctance transducers (DVRTs) with <3 μm resolution.

Full three-dimensional rigid body kinematic motion measurement is provided by a Flock of Birds DC electromagnetic motion tracking system (4 receivers, each with 6 degrees of freedom).

CONTINUED ON PAGE 28

Motion tracking can alternatively be performed using a four-camera optoelectronic Qualisys motion capture system operated with the Qualisys Track Manager software. The four Oqus 300 cameras capture motion data in 1.3 megapixels at rates up to 500 frames per second, and motion data at rates up to 10,000 frames per second at reduced resolution. Two of the four system cameras can also capture synchronized high-speed black and white video of the motion event. This system is highly portable because it utilizes passive retroreflective markers illuminated by infrared strobes on the camera, which can be placed in any configuration on the specimen or subject of interest, and the cameras are "daisy chained" together using combination power/data cords. Larger markers allow for evaluation of whole-joint motion, and small markers (1 mm hemispheres) allow for evaluation of specific tissue motions in experimental tests. Transient contact stress measurement capability is provided by a Tekscan K-Scan system, which includes high-resolution sensors customized specifically to fit the ankle joint. This new sensor design enables the system to display and record dynamic real-time pressure distribution at 2 ½ times greater spatial resolution and 7 times better magnitude resolution than was possible with earlier generation sensor designs.

General purpose electronic equipment includes: a 4-channel programmable digital storage oscilloscope (Hewlett-Packard Model 54601A), two digital multimeters (HP Model 3465A and Fluke Model 8012A), an HP Model 8011 pulse generator, a function generator (BK Precision Model 3025), a Heathkit Model IP-27 regulated power supply, two HP DC power supplies (Models E3611A and E3620A), and several custom-built power supplies. Flexible data collection is provided by two portable PCs with 32 channels A/D and with four 8-pin outputs (2 channels of digital and 2 channels of analog output). Photographic and video equipment includes a Kodak Professional DCS 315 digital camera, a Nikon 35 mm SLR macro camera, and a 19-inch high resolution color monitor (NEC Model CM-1951A). A Canon XL-1 Digital/Video camera provides high resolution acquisition of digital video, easily transferred to our personal computers.

The conference room (seating for ~ 25 people) is equipped with a Dell Inspiron 9100, Sony SLV-D300P VCR/DVD player, WolfVision VZ8 Light Document Camera, WolfVision LB-9 Light Box, Hitachi CP-X328 ceiling-mounted projector, Audio Technic Wireless Mic System, and GyroPro Wireless Keyboard and Mouse.

The machine shop is fully equipped for fabricating mechanical testing fixtures, implant prototypes, etc. Facilities include a Haas TM-1 CNC Tool Room Mill, a Haas HPCL CNC Precision Collet Lathe, a Sherline model #4530 miniature machining station, a 1/3-hp 13-inch 5-speed drill press, a 2-hp 18-inch 4-speed band saw, machinist's precision layout tools, a 24 × 18 × 3-inch granite surface plate, and a wide assortment of portable power tools, hand tools, and hardware supplies.

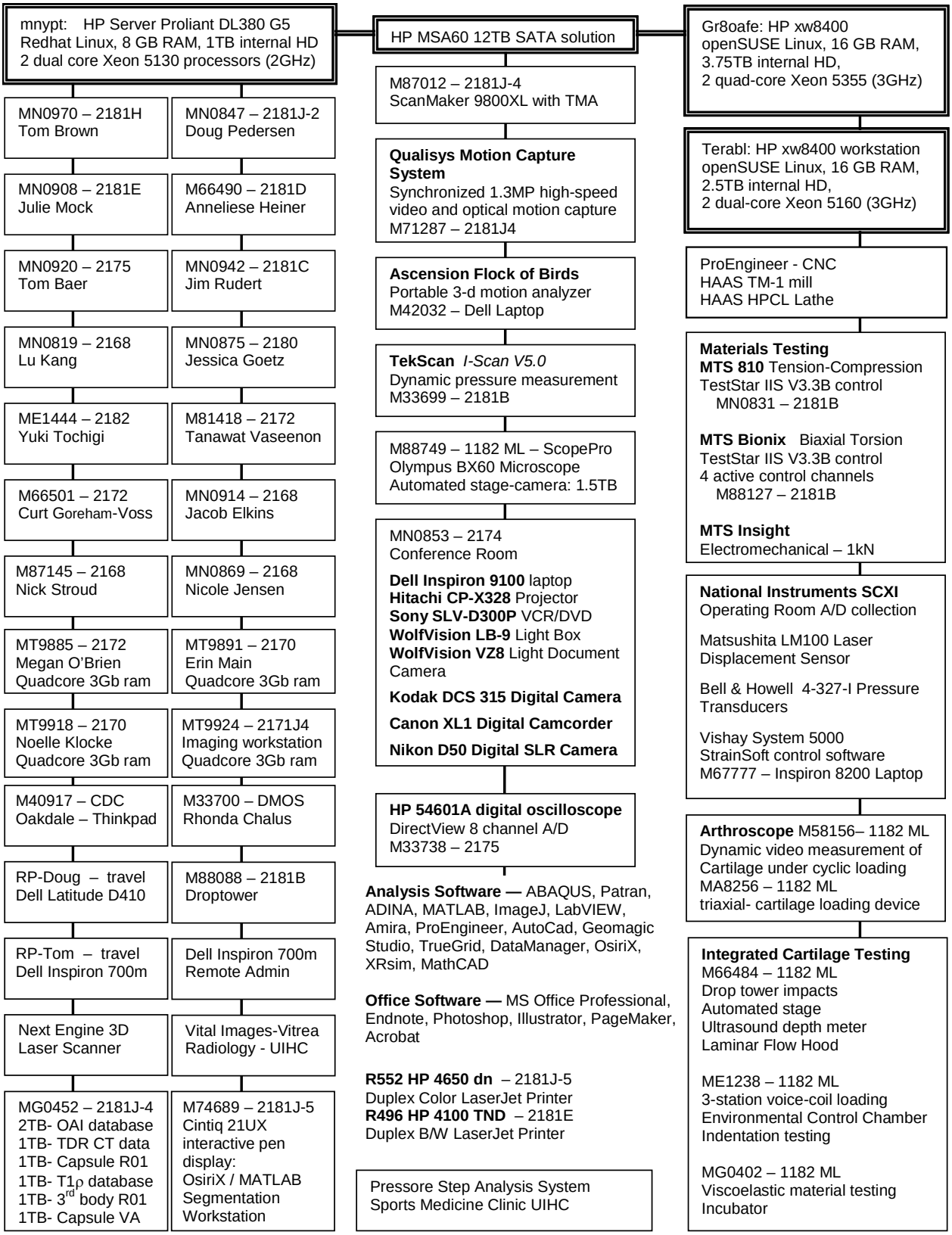
The specimen preparation room is equipped with a Shandon-Lipshaw 8-foot stainless steel autopsy/dissection table, specially augmented for bio-hazard runoff treatment. A full complement of orthopaedic surgical instruments and supplies is maintained, along with an alternative set of power tools (band saw, drill press) and hand tools exclusively for use on tissue specimens. An Xonics Ultima CD mobile x-ray unit and Kodak Lanex Fine Screen film cassettes (35 × 43 cm and 20 × 25 cm) are available for dry bone, cadaver, and living specimen radiographs. A swivel-base orthogonal grid fiducial box is used in conjunction with this unit for high-precision biplanar radiography. Also available are two floor-mounted surgical microscopes (a Zeiss and a fiberoptic-equipped MICROSurgical unit), a Harvard Apparatus Dual Phase Respirator Pump, a Valley Lab Coagulator, a Tracer Bone Mill, a temperature monitor, thermal pads, and an Olympus NDT 35DL-M3-E4 Precision Digital Ultrasonic Thickness Gage with V309-SU-F-1.00-IN-PTF,

Immersion and M201 Sonopen transducers. Three large chest freezers, six upright freezers, and a large refrigerator are used for perishable specimen storage.

The computational facilities (schematic on page 30) are configured to provide seamless data transfer among three inter-related types of applications: compute-intensive mechanical analysis on engineering workstations, laboratory instrumentation support, and office operations.

An HP Proliant DL380 server with 2 Dual-Core 2 GHz Intel Xeon processors provides primary lab access to an HP Integrity rx4640 with 600 GB fibre channel hard disk drive, an HP xw8400 with 2 Dual-Core 3 GHz Intel Xeon processors, and an HP xw8400 with 2 Quad-Core 3 GHz Intel Xeon processors. The Proliant server runs RedHat server OS for its 1TB internal and 12TB external disk arrays. The Integrity system uses a 64-bit HP-UX operating system, while the xw8400 workstations run under open SUSE. All three are specially tailored to perform very large nonlinear, large deformation, finite element analysis contact problems, as well as computational fluid dynamics and fluid-structure interaction problems (ABAQUS, ADINA). Three-dimensional finite element model generation (PATRAN,TrueGrid) can begin with manufacturer's blueprints or with engineering drawings (ProEngineer, AutoCAD, VectorWorks). Alternatively, models are generated directly from medical images (CT, MRI, and plane-film) using OsiriX, Geomagic Studio, and/or MATLAB on desktop personal computers. Medical image segmentation is facilitated by two Wacom Cintiq 21UX interactive pen displays. A Vital Images Vitrea workstation, configured identically to those in the UI Radiology/Hospital network, facilitates analyses of patient images. Finally, laser surface scanning capability is afforded by a NextEngine Desktop 3D scanner, when geometry must be derived from actual objects.

Desktop PCs are maintained in each of the faculty, staff, and student/fellow offices, running Microsoft Windows XP / Office 2007 Professional or Mac OS X 10.5 / Office 2008. NoMachine's NX server, SAMBA, and Secure-Shell permit direct access to both laboratory and remote computers from the desktop PCs. Networked Pentium PC's operate the MTS Insight, MTS Bionix and MTS 810 materials testing machines, the Flock of Birds motion tracking system, LabView data collection through a National Instruments SCXI A/D converter, an RDI 8/12-bit whole-film transmissive scanner, and a Microtek ScanMaker 9800XL large format flatbed scanner with TMA 1600 transparency media adapter. Printing is provided by HP 4100TN duplex B/W and HP 4650DN duplex color laser printers. Laboratory personnel also maintain seven laptops: two for database compilation at Des Moines Orthopaedic Surgeons PC for ongoing collaborative studies of total hip and knee follow-up, and five for off-site data collection and ad hoc travel use.



Websites: Laboratory (http://poppy.obrl.uiowa.edu/) Department (http://www.medicine.uiowa.edu/Ortho/)