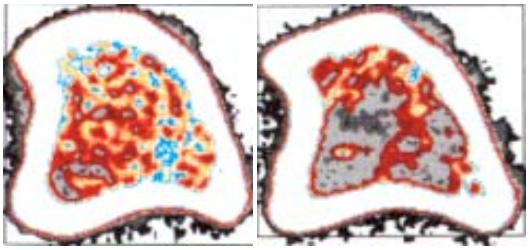
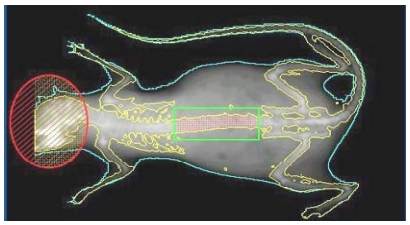
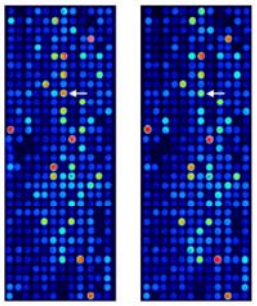
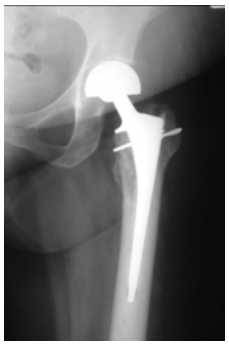
# CENTER FOR ORTHOPAEDIC RESEARCH ANNUAL REPORT

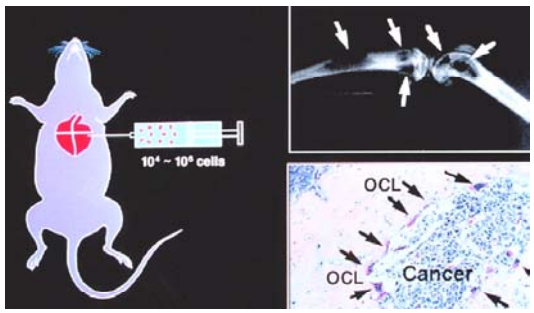
## July, 2001











# MISSION STATEMENT

## *"Provide UAMS with an internationally recognized, translational orthopaedic research and training program."*

## INTRODCUTION

The Center for Orthopaedic Research at UAMS is a new initiative within the Department of Orthopaedic Surgery. Researchers within the Center are focused on developing new approaches for the prevention and treatment of osteoporosis, arthritis and related disorders. In conjunction with the Arkansas Cancer Research Center, the Center for Orthopaedic Research has a strong commitment to understanding the mechanism of breast cancer metastasis to bone. We have conducted numerous single-center studies examining the function of orthopaedic implants, the effect of antibiotics in minimizing infection following surgery, and evaluated the effects of pharmacological agents on bone and fracture repair. We routinely partner with pharmaceutical companies to develop new assays for skeletal function and test the safety and efficacy of potential new drug treatments. Our capabilities include quantitative computer tomography for small animals (pQCT), dual energy x-ray absorptiometry (DEXA), skeletal histomorphometry, histology, mechanical testing and image analyses. Laboratories include cell and molecular biology, materials testing and tissue culture. The technological sophistication of the bone imaging techniques employed by the Center for Orthopaedic Research, coupled with our scientific expertise and extensive experience in managing clinical trials, make us unique in Arkansas

## FACULTY AND STAFF

Dr. Larry Suva
Dr. Mark Smeltzer (Adjunct Associate Professor, Leader Musculoskeletal Infection Team)
Dr. Dana Gaddy-Kurten (Adjunct Assistant Professor, Leader Bone Imaging and Histology Team)
Bob Skinner
William Hogue
Donna Montague
Frances Swain
Sandra McLaren
Charles Stewart
Ashley Browning

## HIGHLIGHTS

- Center for Orthopaedic Research established at UAMS, October 2000.
- Dr. Larry Suva appointed Director, Center for Orthopaedic Research.
- Monthly reporting process implemented (January 2001).
- Center for Orthopaedic Research Logo developed and introduced.
- Center development plan prepared and circulated (May 2001).
- Center for Orthopaedic Research web site launched (June 2001) http://www.cor.uams.edu/
- Histology and pathology efforts within the Center have been expanded.
- Peripheral quantitative computer tomography (pQCT) instrument purchased and technology introduced to UAMS.
- Osteomeasure histomorphometry instrument, with mechanical stage and multiple fluorescence detection purchased and operational.
- Procedures for standard operating procedures within the Center have been developed. Histomorphometry, histology and pQCT scanning protocols and costing are in place.
- Proposal for development and support of ROBODOC submitted and funded.
- Renovation to Hand Therapy clinic funding approved.
- Professional development review process initiated (July 2001)

## EDUCATION AND HONORS

- The Center for Orthopaedic Research continues to be involved in graduate and medical student education (Advanced Physiology lectures for graduate students; student seminar and PBL (osteoporosis) for medical students).
- Larry Suva on the Ph.D. thesis examination committee for Kenian Liu (Physiology and Biophysics).
- Larry Suva continues his teaching responsibilities in the Dental School. Biochemistry Department, University of Pennsylvania (Adjunct Associate Professor).
- Larry Suva admitted to the graduate faculty, UAMS.
- Larry Suva was elected to the council of the American Society for Bone and Mineral Research (ASBMR) 2001-2003.
- Larry Suva was elected president of Advances in Mineral Metabolism (AIMM) for 2001-2003.
- Bob Skinner and Donna Montague invited to National Society for Histotechnology Symposium Workshop, Charlotte, NC, September 2001.
- Larry Suva member of the Arkansas Arthritis Action Plan Working Group.

## EXPLORATORY RESEARCH & TECHNOLOGY DEVELOPMENT

**Clinical Densitometry**

Bone density measurement (DEXA) provides an accurate measure of bone density and body composition. This instrument represents state-of-the-art technology for the determination of soft tissue composition (fat/lean tissue analysis). This technology is critical for improving the care of patients in Orthopaedic surgery and efforts to establish a bloodless surgery center.

There is a large unmet medical need in Orthopaedic departments across the country regarding the diagnosis of osteopenia and osteoporosis in patients presenting with distal radial fracture. It is well known that postmenopausal women who have sustained a distal radial fracture have decreased bone mineral density and twice the risk of a future hip fracture. Since nearly all patients who suffer a distal radius fracture visit an orthopaedic surgeon for treatment, there is a unique opportunity in the department to diagnose and treat osteoporosis. A recent publication (Freedman et. al., *Journal of Bone and Joint Surgery*, **82**:1063-1070, 2000) concluded that current physician practice maybe inadequate for the diagnosis and treatment of osteoporosis in postmenopausal women who have sustained a distal radial fracture).

- The Center for Orthopaedic Research will contribute to enhanced Orthopaedic patient care by initiating bone densitometry in the department clinic.
- The DEXA clinic will improve patient care for Orthopaedics patients.
- We are currently developing a state-wide screening protocol using ultrasound heel BMD measurements.

**DEXA spine hip and total body**
**pDEXA: forearm, finger, heel**
**SXA: heel**
**QUS: heel, shin**
**QCT: spine**
**pQCT: forearm**

**Figure 1:** Bone densitometry sites and instruments

**Peripheral quantitative computer tomography (pQCT)**

- pQCT is a method of assessing bone mineral density which uses multiple cross-sectional x-rays to reconstruct a volumetric model of the bone density distribution
- Analyzed bone mineral density is presented as $mg/cm^3$ (true volumetric bone density).
- Measurements can be made in-life or ex-vivo.
- Other densitometric technologies (e.g.: DEXA; ultrasound), yield results based on a weighted average of combined trabecular and cortical bone via only a 2-D projection. This analysis super-imposes trabecular and cortical bone, and is unable to isolate and quantify specific bone compartments.


**Figure 2:** Norland XCT-SA pQCT instrument

Geometric parameters measured by pQCT:

- Cortical thickness
- Endosteal and periosteal circumferences
- Total and cross-sectional bone area
- Axial and polar moment of inertia
- Axial and polar section modulus
- Strength strain index
- Bone mineral density and Bone mineral content

**Robotic surgical systems (ROBODOC)**

The Center for Orthopaedic Research has played a major role in the introduction of the ROBODOC surgical system to UAMS. We have partnered with hospital administration to prepare a recently funded (Health Resources Services Administration (HSRA)) proposal. The proposal outlined the utility of robotic surgical systems for improving the care of orthopaedic surgery patients in Arkansas, and across the US. The Orthopaedic Surgery Department will conduct a multi-center FDA safety trial of Robodoc. William Hogue and Sandra McLaren from the Center for Orthopaedic Research play critical roles in the ROBODOC initiative at UAMS.

**Breast cancer metastasis**

The Center for Orthopaedic Research has introduced a model of human breast cancer metastasis to bone to UAMS. The high morbidity and mortality rates caused by human breast cancer are more strongly correlated with the metastasis to secondary sites than with the primary tumor in the breast. Bone is the primary site of breast cancer metastasis. However, other soft tissue metastases to lung and other organs occur as well. The process of metastasis is a complex, multi-step process whose mechanisms cannot be completely studied *in vitro*. The development of new therapies for metastatic cancer depends on a better understanding of the mechanism of homing of the tumor cells to distant sites, such as bone, and the factors required for tumor growth at metastatic sites.

Our ongoing analysis includes the search for phenotypic differences between the cell lines in vitro and a preliminary microarray screen profiling gene expression in the cells and searching for genes whose expression is altered between the two cell lines.

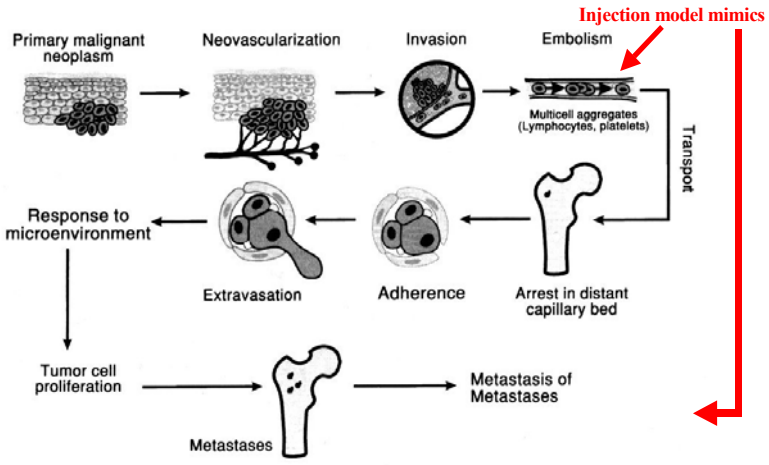



**Figure 3**: Pathogenesis of human breast cancer metastasis

**Skeletal phenotyping**

The Center for Orthopaedic Research has initiated and effort to provide platform skeletal phenotyping of all transgenic and mutant mice generated by UAMS faculty. The phenotype provides meaning to the genotype. This effort (outlined below) has been initiated to ensure that:

1.) No skeletal phenotypes, independent of the manipulated gene of interest or procedure, are missed.
2.) Testing will occur at N1 (will avoid 12 month delay for N6).
3.) All avenues of funding for the evaluation of the mutant phenotypes can be pursued.
4.) The value of the mice is returned to the PI and the University.

Ongoing skeletal phenotype analyses in the Center for Orthopaedic Research:

- Pim-1 (-/-) mice (Jennings, Physiology and Biophysics)
- SMAD 4 transgenic mice (Gaddy-Kurten, Physiology and Biophysics)
- Biotin deficiency (Mock, Biochemistry & Molecular Biology)
- Wnt 10b (-/-) mice, (Ormond MacDougald University of Michigan Medical School)

**Human mesenchymal stem cell differentiation**

The Center for Orthopaedic Research has a long-standing interest in the differentiation of human mesenchymal stem cells (MSC). In humans, there is an inverse relationship between marrow fat and osteogenic capacity, such that elderly osteoporotic patients have increased marrow fat. It is well established that human mesenchymal stem cells can be induced to differentiate along a number of different lineages (Figure 4). However, the mechanism for this is unknown. We have

been attempting to understand several of the steps in the pathway differentiating human mesenchymal stem cells down the osteoblastic, adipogenic, muscle and chondrocyte lineages. Our investigations have been focused on the effects of TGF β family members activin and inhibin on osteoblast and adipocytes and the influence of biological scaffolds on chondrocyte dedifferentiation. These studies have great potential for the development of stem cell therapy to treat many diseases including AVN and arthritis.

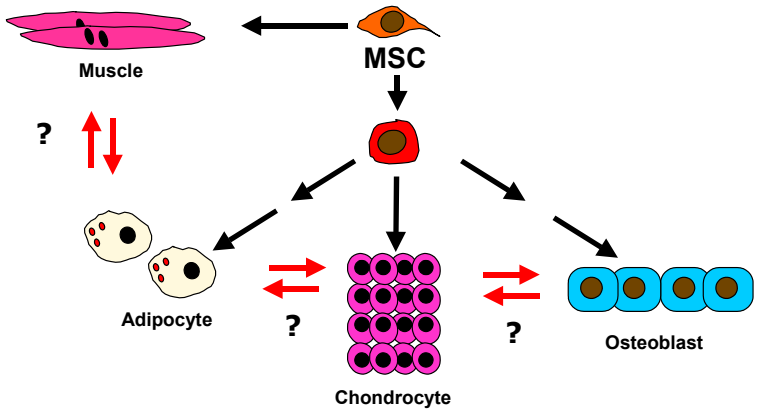



**Figure 4:** Capacity of hMSCs to differentiate along osteoblast and adipocyte lineages

**Distraction osteogenesis**

The Center for Orthopaedic Research has continued to develop its long-standing interaction with Drs. Aronson and Lumpkin regarding the histological evaluation of distraction osteogenesis. A number of papers were published during the last year (see publications section) and an abstract accepted for the 2001 ASBMR. The well-established rat model of Ilizarov distraction osteogenesis has been extended to examine the distraction process in the mouse. These pioneering studies will allow the molecular dissection of distraction osteogenesis, by taking advantage of the many available murine mutants. Our efforts in the future will support the programs of Drs. Aronson and Lumpkin and extend it by the application of new imaging technologies (pQCT, microCT) as well as extend the histological evaluation to examine the effects on mineralization using plastic histology. To this end, Bob Skinner has produced excellent sections revealing the mineralization front of the distraction zone (Figure 5).

In collaboration with Drs. Lumpkin and Badger, the Center for Orthopaedic Research has applied our pQCT technology to explore the effects of total enteral nutrition, aging and ethanol on distraction osteogenesis in the rat. Bill Hogue has been able to measure specific changes in volumetric trabecular bone density using pQCT that were previously unknown. These studies and others are continuing, as the Center for Orthopaedic Research facilitates the investigation of the effects of Il-1, TNF blockers and other agents on distraction osteogenesis.

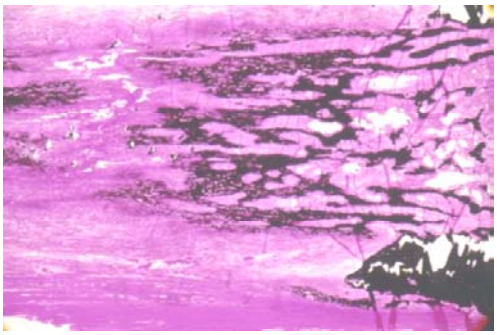


**Figure 5:** Von Kossa stained GMA section identifying the mineralization front in the distraction zone.

**Osteomyelitis**

*Staphylococcus aureus* (*S. aureus)* is an opportunistic pathogen capable of causing a diverse array of both nosocomial and community-acquired infections. It is a particularly prominent pathogen in the specific context of musculoskeletal infection. Indeed, *S. aureus* is the single leading cause of osteomyelitis and non-gonococcal septic arthritis in the community. *S. aureus* can reach the bone through penetrating wounds, direct spread from a contiguous soft tissue focus of infection (osteomyelitis secondary to a contiguous focus of infection), or seeding of the bone with blood-borne bacteria (hematogenous osteomyelitis). The ability to treat musculoskeletal infections is complicated by several factors, not the least of which is the continued emergence of *S. aureus* strains that are resistant to multiple antibiotics.

In collaboration with Drs. Mark Smeltzer and Mohamed Elasri, Dr. Carl Nelson and the Center for Orthopaedic Research have continued to investigate the role of the *S. aureus* collagen-binding adhesin (Cna) and other virulence factors in bone and joint infection. These experiments are carried out using a well-established rabbit model of acute osteomyelitis and a recently developed murine model of hematogenous infection. Virulence factors that contribute to the ability to cause bone infection are identified by comparing the virulence of an original patient-isolate (UAMS-1) with isogenic mutants (e.g. UAMS-237, a *cna* mutant derived from UAMS-1). We have also initiated studies aimed at providing a comprehensive assessment of the genomic distinctions between UAMS-1 and other strains of *S. aureus* that do not cause osteomyelitis. Using an adaptation of the rabbit osteomyelitis model that employs orthopaedic implants as part of a reconstructive procedure, these studies will be incorporated into additional experiments aimed at characterizing the adaptive response of *S. aureus* to growth within a biofilm. A grant to support these efforts has been submitted to the National Institutes of Health (National Institute of Arthritis and Musculoskeletal and Skin Disorders).

Other funded studies arising from the utility of the rabbit osteomyelitis model include:

- Tobramycin elution from bone cement/calcium sulphate pellets.
- The Treatment of Experimental Osteomyelitis and Bony Defect by Surgical Debridement and the Implantation of Calcium Sulfate-Tobramycin Pellets with Demineralized Bone Matrix.

- Effect of pulsed electromagnetic fields (PEMF) on bone infection and bone formation.

## HISTOLOGY SERVICES

**Introduction**

The full range of histological analysis afforded by the Center for Orthopaedic Research provides Orthopaedics faculty with whole mount slides of resected joints, large slides of tumors and slides of bone-metallic implant interface zones. These preparations are not only valuable diagnostically, but continue to support case portfolios, grand rounds, resident conferences and publications. Decalcified bone and soft tissue paraffin preparations continue to constitute the bulk of our primary histology service. The recent recruitment of Frances Swain (Special procedures technician) enables the Center to now provide methyl methacrylate processing and sectioning for bone histology and histomorphometry. The lab continues to provide microtome and cryostat blade maintenance and microtome tune-ups on request. In addition, a working agreement has been established between the Center for Orthopaedic Research and the Pathology Core facility to process and section any research material which does not conform to their automated equipment.

**Clinical specimens**

The Center for Orthopaedic Research is directly receiving resected tumors and specific samples of a variety of joint diseases for processing. Bob Skinner (joint appointment in the Department of Pathology) is the hospital bone histology technician responsible for these specimens. The Center for Orthopaedic Research also processes material from UAMS collaborators, area hospitals and groups, as well as other universities.

**Histomorphometry**

The Center for Orthopaedic Research has recently established plastic embedding and sectioning facilities. With the purchase of the Osteomeasure histomorphometry workstation, The Center for Orthopaedic Research has established preclinical and clinical bone histomorphometry protocols. The inclusion of this critical methodology completes our full skeletal analysis capability. Our histomorphometry capacity currently accommodates the evaluation of whole femoral head sections. We can evaluate paraffin and plastic processed sections stained in H&E, Masson's Trichrome or Saffranin O/Fast Green. The recent recruitment of Frances Swain to the Center's staff provides the final key component to our histomorphometry effort.

## COLLABORATIONS/SERVICES

- Dr. Theresa Guise, UT Medical Center, San Antonio, TX (Breast cancer metastasis to bone)
- Dr. Roby Thomas, UAMS Department of Pathology (Osteomyelitis pathology).
- Dr. Mark Smeltzer, UAMS, Department of Microbiology and Immunology. (Microbiology, Osteomyelitis)
- Dr. Michael Jennings, UAMS, Department of Physiology and Biophysics. (skeletal phenotyping of pim 1 -/- mice
- Dr. Dana Gaddy-Kurten, UAMS, Department of Physiology and Biophysics. (human mesenchymal stem cell differentiation; skeletal phenotyping of smad 4 transgenic mice)
- Dr. Charles Lumpkin, UAMS, Department of Pediatrics (Distraction osteogenesis; ethanol and osteogenesis; nutritional components of bone development)
- Dr. Donald Mock, UAMS, Department of Biochemistry and Molecular Biology (Skeletal consequences of biotin deficiency)
- Dr. Brian Leatherman, Dr. John Dornhoffer, UAMS Department of Otolaryngology (Analysis of implants in Rat Skull)
- Dr. Ward Gardner, Dr. John Dornhoffer and Dr. Oliver Simmons UAMS Department of Otolaryngology (Analysis of implants in gerbil skull)
- Dr. John Dornhoffer, UAMS Department of Otolaryngology (GelFoam vs. GelFilm in inner ear surgery).
- Dr. Roger Rank, Dr. Toni Darville UAMS Department of Microbiology (Histologic evaluation of compromised guinea pig organs).
- Dr. Lori Setton, Charlene Flahiff, Duke University, Department of Biomedical Engineering This began as a one time decalcified paraffin histology workup on (Biomechanics of the guinea pig patella).
- Dr. Nicole Erhardt, University of Illinois, College Of Veterinary Medicine, Urbana IL (Effect of pre-operative itradiation on large segment cortical allograft incorporation).
- Dr. Warren Haggard, Wright Medical (Osteomyelitis).
- Dr. Bruce Simon, EBI (Osteomyelitis and pulsed electromagnetic fields).
- Dr. Bruce Robie, Implex Pty. Ltd (Hedrocel and stem cells).
- Dr. Steven Bain, Skeletech (High throughput assay development).
- Dr. Mark Nuttall, GlaxoSmithKline (Nuclear hormone receptor analogs).

## SUMMMER STUDENT RESEARCH PROJECTS 2000-2001

The summer medical and graduate students participating in research projects over the last year are listed below:

| | |
|---|---|
| Menali Bendra (graduate student, Physiology) | Breast cancer metastasis microarray |
| David Bibbs (medical student) | MSC differentiation (chondrocyte) |
| Sam Bledsoe (PIR) | MSC differentiation (osteoblast) |
| Andy Daniel (medical student) | MSC differentiation (adipocyte) |
| Kelly Johnson (medical student) | Skeletal phenotyping, histology |
| Jay Paladino (PIR) | Evaluation of breast cancer cell lines *in vitro* |

The students can be seen on the Center for Orthopaedic Research web site

## EXISTING FUNDING

- EPsCOR
- Carl L. Nelson Chair of Orthopaedic Surgery
- Arkansas Breast Cancer Fund
- UAMS, Department of Pathology
- UAMS, Department of Physiology and Biophysics
- Wright Medical; Zimmer
- EBI
- Center for Orthopaedic Research contracts
- ACH contracts

## PUBLICATIONS (2000-2001)


1. Four American Society for Bone and Mineral Research (ASBMR) abstracts will be on the program at the 2001 Annual meeting.
2. Ronis MJJ, Aronson J, Gao GG, **Hogue WR**, **Skinner RA**, Badger TM, Lumpkin CK Jr. Skeletal Effects of Developmental Lead Exposure in Rats. J.Toxicol. Sci.**62** 321-329, 2001
3. **Skinner RA, Hogue WR**, Flahiff CM, Lumpkin CK, "Old Technology: The Foundation for Today's Cutting Edge Research", HistoLogic Vol. XXXIV, No. 1, May 2001
4. Aronson J, Gao GG, Shen XC, **McLaren SG, Skinner RA**, Badger TM, Lumpkin CK Jr. The effect of aging on distraction osteogenesis in the rat. J. Orthop. Res. **19**:421-7, 2001.
5. Aronson J, **Hogue WR**, Flahiff CM, Gao GG, Shen XC, **Skinner RA**, Badger TM, Lumpkin CK Jr. Development of tensile strength during distraction osteogenesis in a rat model. J. Orthop. Res. **1**:64-9, 2001
6. Nuttall ME, Pendrak I, Emery JG, Nadeau DP, Fisher PW, Nicholson TA, Zhu Y, **Suva LJ,** Kingsbury WD and Gowen M. Antagonism of oestrogen action in human breast and endometrial cells in vitro: potential novel antitumor agents. Cancer Chemotherapy and Pharmacology **47**:437-443, 2001.
7. Ferrari SL, Traianedes K, Thorne M, LaFage-Proust MH, Genever P, Cecchini MG, Behar V, Bisello A, Chorev M, Rosenblatt M, **Suva LJ.** A role for N-cadherin in the development of the differentiated osteoblastic phenotype. Journal of Bone and Mineral Research **15**:198-208, 2000.
8. Colleran PN, Wilkerson MK, Bloomfield SA, **Suva LJ**, Turner RT, Delp MD Alterations in skeletal perfusion with simulated microgravity: a possible mechanism for bone remodeling. Journal of Applied Physiology **89**: 1046-54, 2000.
9. Prichett WP, Patton AJ, Field JA, Brun KA, Emery J, Tan KB, Rieman D, McClung H, Nadeau DP, Mooney JL, **Suva LJ**, Gowen M, Nuttall ME. Identification and cloning of a human urea transporter HUT 11, which is down-regulated during adipogenesis of explant cultures of human bone. Journal of Cellular Biochemistry **76**:639-650, 2000.
10. Nuttall ME, Fisher PW, **Suva LJ**, Gowen M. The selective oestrogen receptor modulators idoxifene and raloxifene have fundamentally different cell-specific oestrogen-response element (ERE)-dependent/independent mechanisms *in vitro*. European Journal of Cancer **36**: S59-S67, 2000.
11. Lee D, Long SA, Adams JL, Chan G, Vaidya KS, Francis TA, Kikly K, Winkler JD, Sung CM, Debouck C, Richardson S, Levy MA, DeWolf WE, Jr., Keller PM, Tomaszek T, Head MS, Ryan MD, Haltiwanger RC, Liang P, Janson CA, McDevitt PJ, Johanson K, Concha NO, Chan W, Sherin S, Meguid A, Badger AM, Lark MW, Gowen M, **Suva LJ**, Nadeau DP, Nuttall ME. Potent and Selective Nonpeptide Inhibitors of Caspases 3 and 7 which Inhibit Apoptosis and Maintain Cell Functionality. Journal of Biological Chemistry **275**:16007-16014, 2000.

## PUBLICATIONS (2000-2001)


**12.** Nuttall ME, Stroup GB, Fisher PW, Nadeau DP, Gowen M, **Suva LJ.** The mechanism of action of osteoprotective selective estrogen receptor modulators is different in breast and osteoblastic cells. Am. J. Physiol., **279**:C1550-C1557, 2000.

**13.** **Smeltzer MS**, Gillaspy AF Molecular pathogenesis of staphylcoccal osteomyelitis. Poult. Sci. **7**:1042-9, 2000

**14.** **Smeltzer, MS,** Characterization of staphylococcal adhesins for adherence to host tissues, Pgs 411-444 *In* An, Y. H. and Friedman, R.J. (Eds), 2000, Handbook for Studying Bacterial Adhesion, Humana Press, Totowa, NJ.


## PRESENTATIONS

- **Montague, D.**, Interdisciplinary Techniques for the Study of Bone Pathophysiology: Quantitative Analysis, Tinctorial and Immunohistochemistry, and Molecular Biology. 2001 NSH Symposium/Convention, September 22, 2001
- **Skinner, RA**. Decalcified Paraffin Bone Preparations: Still an Important Part of Hard Tissue Histology. National Society for Histotechnology Symposium Workshop, Charlotte, NC, September 2001.
- **Elasri, MO**, Thomas, JR, Skinner, RA**,** Blevins, JS, Beenken, KE, Nelson, CL, Smeltzer, MS. The *Staphylococcus aureus* Collagen Adhesin Contributes to the Pathogenesis of Osteomyelitis. 45th Annual Wind River Conference on Prokaryotic Biology, Estes Park, CO, June 2001
- **Skinner, RA**. Supersizing Your Slides: It's Not That Big A Problem. New York State Histotechnological Society Annual Meeting. Syracuse, NY. May 5, 2001.
- **Suva, LJ.** Structural biomaterials. Arkansas Technical University, Russellville, AR, 2001.
- **Skinner, RA**. Decalcified Paraffin Bone Preparations: Still an Important Part of Hard Tissue Histology. National Society for Histotechnology Symposium/Convention Workshop, Milwaukee, Wisconsin. September 2000.
- **Suva, LJ.** The scientist's desktop: What should (and shouldn't) be there. 95th Annual Meeting, Special Library Association, (SLA), Philadelphia, PA 2000
- **Suva, LJ.** "The therapeutic potential of modulating osteoblast-adipocyte differentiation" The Matthias Schleiden & Theodore Schwann Lecture in Cell Biology at the 3rd International Symposium on Fibrodysplasia Ossificans Progressiva, University of Pennsylvania School of Medicine, Philadelphia, PA 2000

# THE FUTURE

The future of the Center for Orthopaedic Research is extremely exciting. In the coming year we will continue to impact patient care, medical education and basic research in the Department and on campus. Our ongoing initiatives for 2001-2002 include:

- Obtaining NIH funding
- Expanding the financial support for the Center
- Providing state-of-the art research support at UAMS
- Acquiring essential equipment (micro CT)
- Developing a bone densitometry clinic
- Improving our national ranking amongst Orthopaedics Departments
- Recruiting new faculty (1st)
- Continuing to build national and international recognition of the Center for Orthopaedic Research