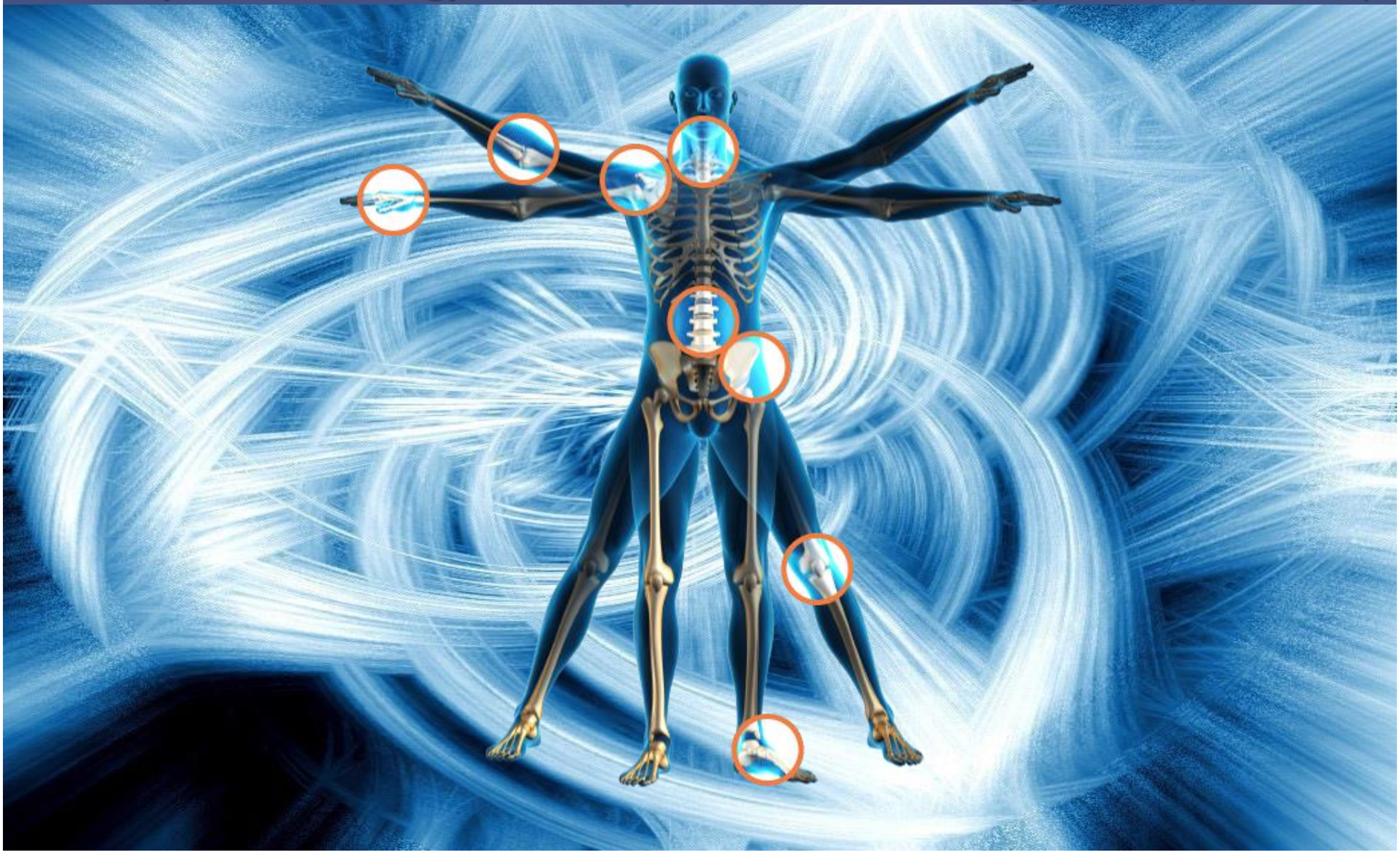
Orthopaedic Biology, Biomaterials and Tribology Labs (OrBBiT)



Fabrizio Billi, PhD

California Orthopaedic Association

Indian Wells - April 23-26, 2015

Fundamentals of Wear and Corrosion

David Geffen School of Medicine

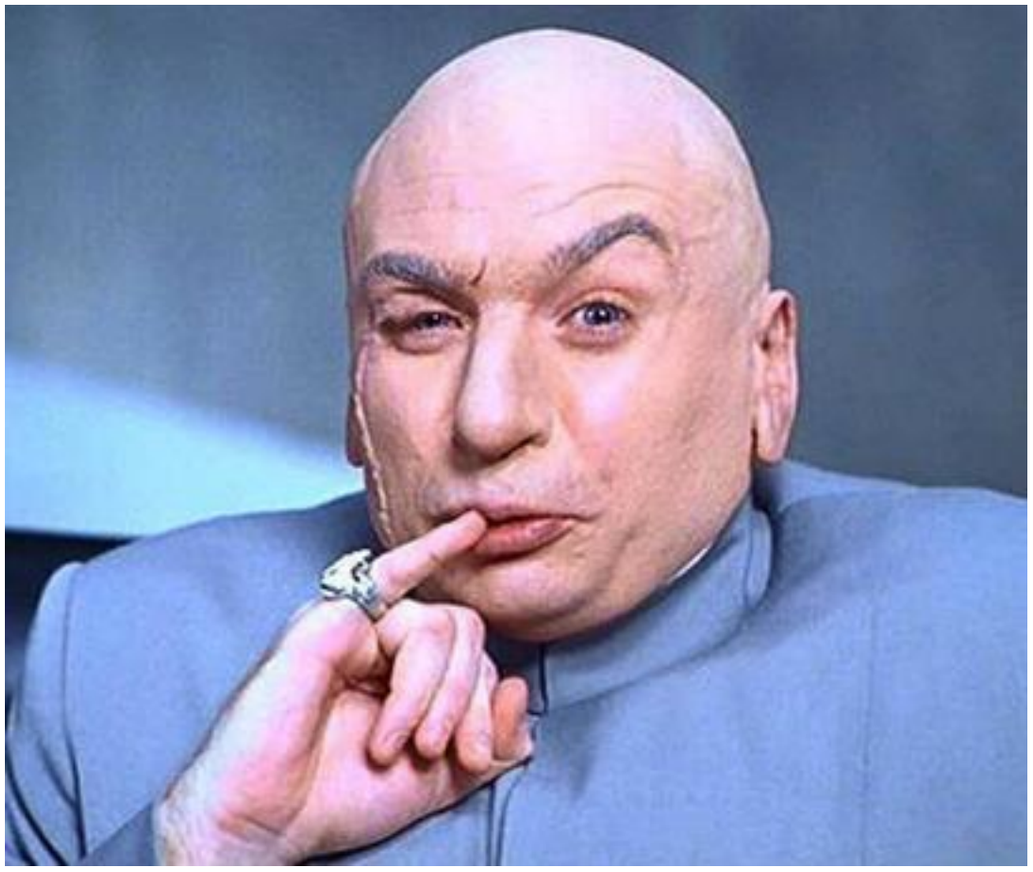
Disclosure

Research Grants & Contracts from Industry

Biomet, Bruin Biometrics, DePuy,

Orchid Orthopedics, Stryker,

Wright Medical Technology, Zimmer



Federal Grants

Supported by the

National Institutes of Health

NIAMS

National Institute of Arthritis and Musculoskeletal and Skin Diseases

Other Grants/Research Contracts

Orthopaedic Institute for Children, Hospital for Special Surgery

WEAR & CORROSION

to say nothing about metal ion release

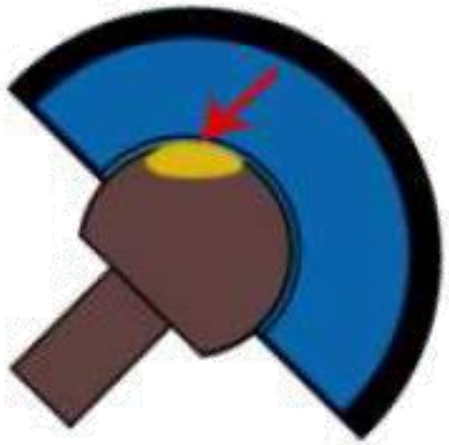
WEAR

"The removal and deformation of material on a surface as a result of mechanical action of the opposite surface."

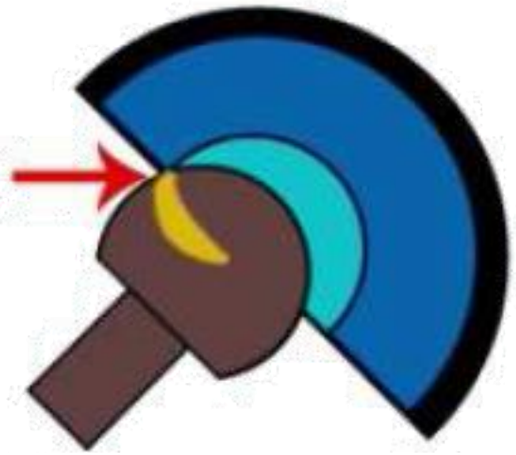
"Wear is a function of use, not time."

TP Schmalzried, The John Charnley Award, 2000

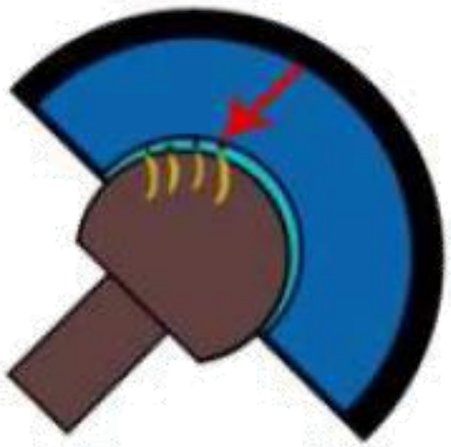
Wear – Bearing Surfaces



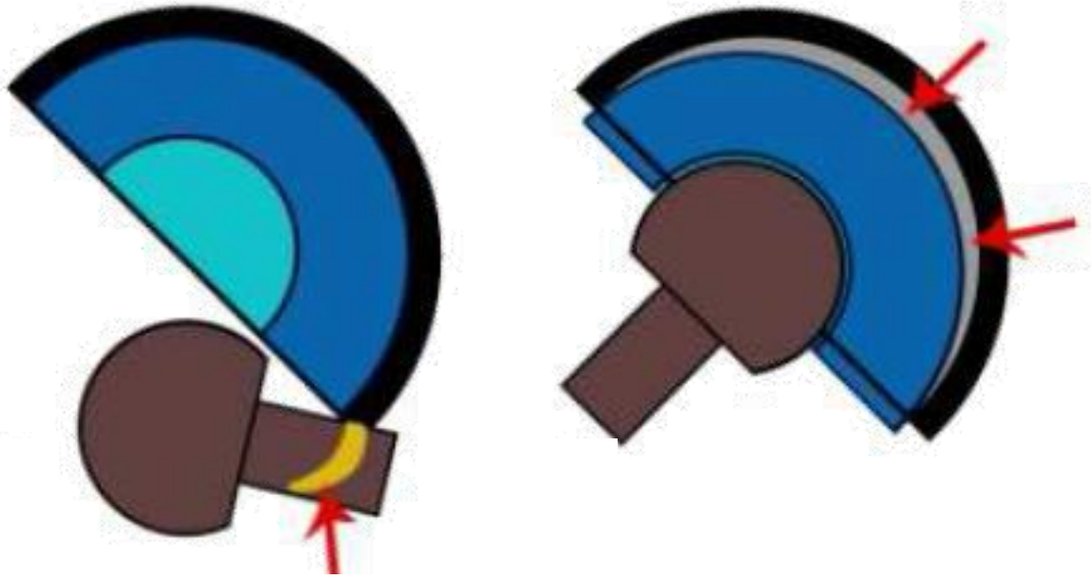
MODE 1: normal wear



MODE 2: wear between bearing and non-bearing surface

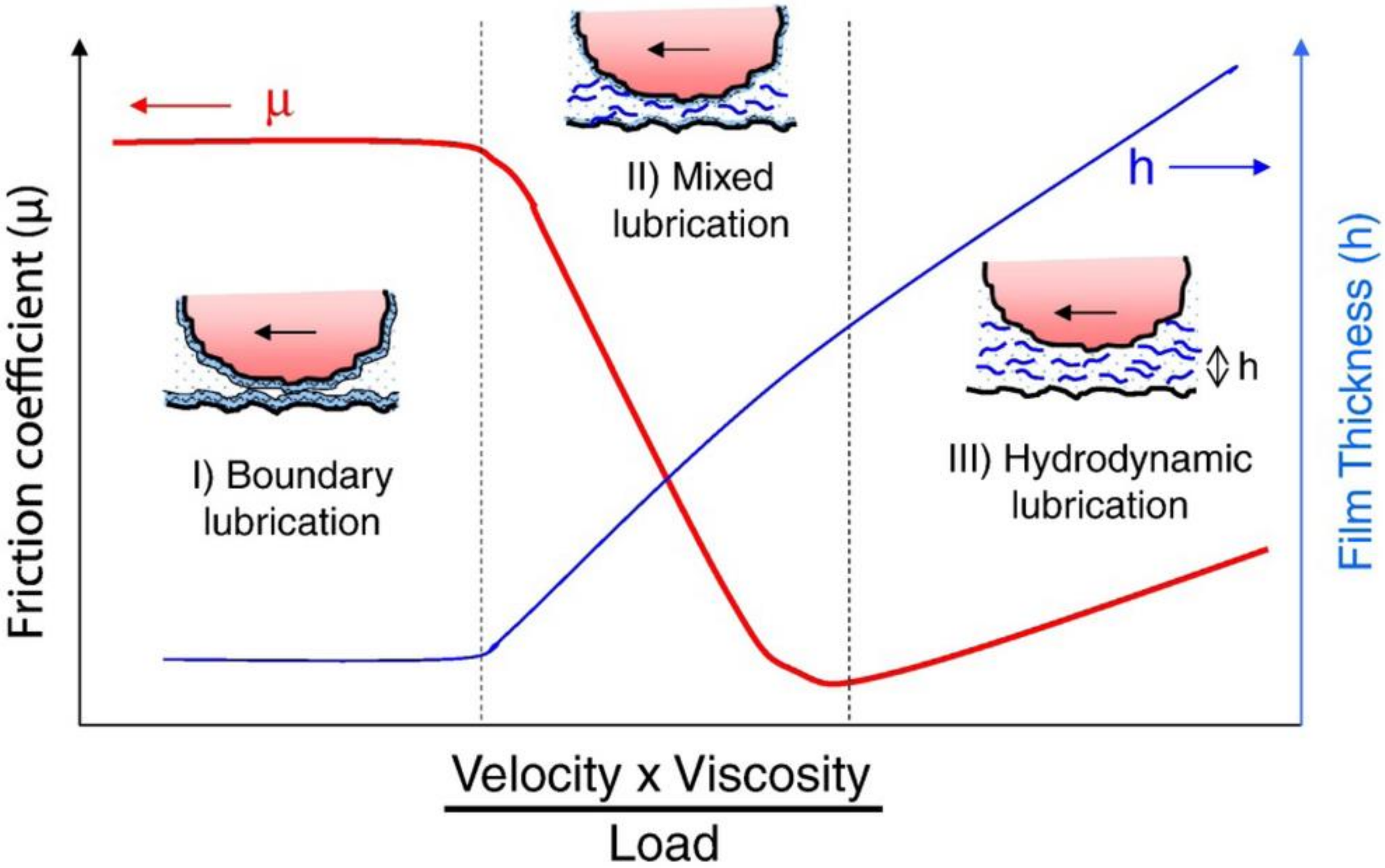


MODE 3: third-body abrasive wear

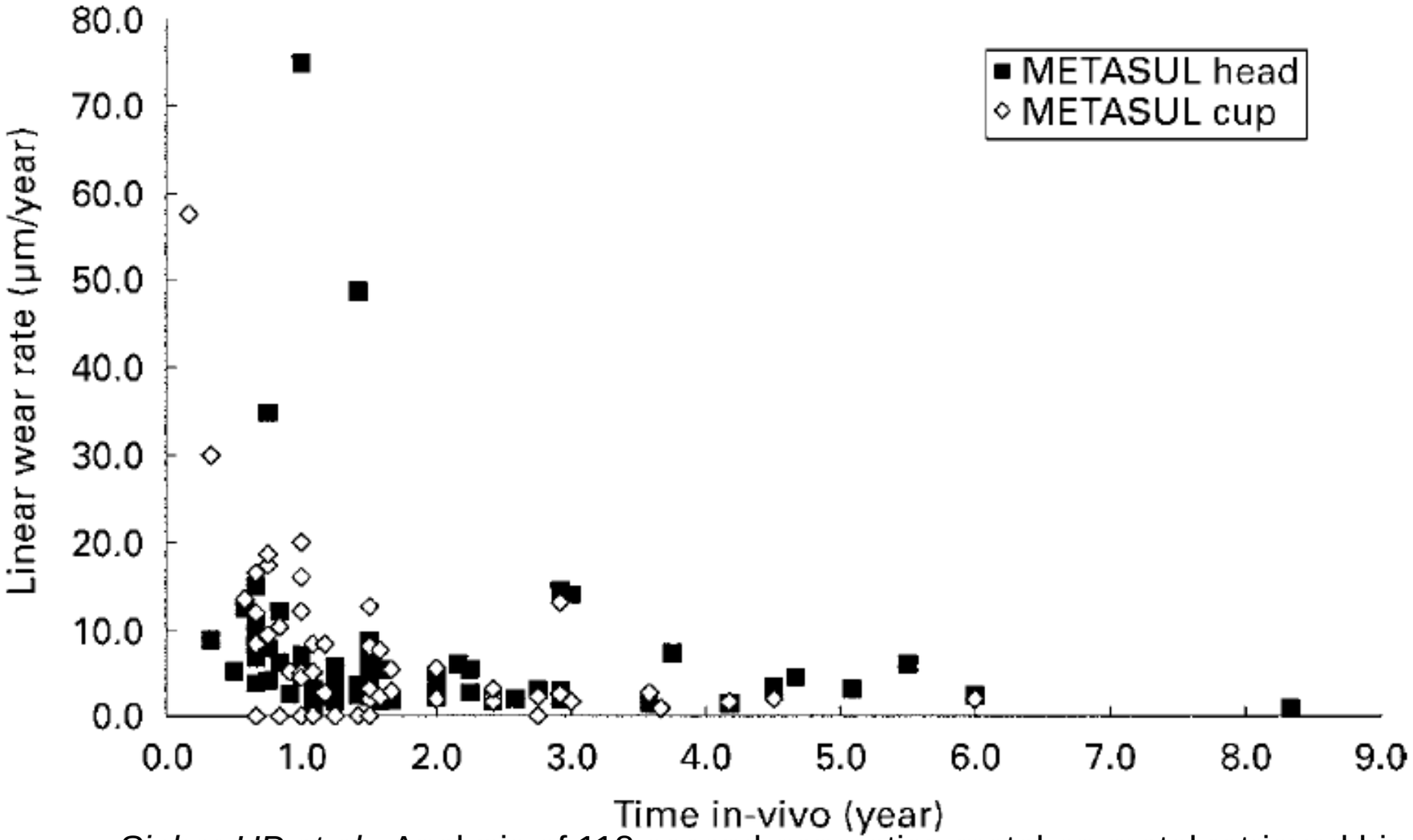


MODE 4: refers to two secondary (non-primary) surfaces.

Wear – Bearing Surfaces

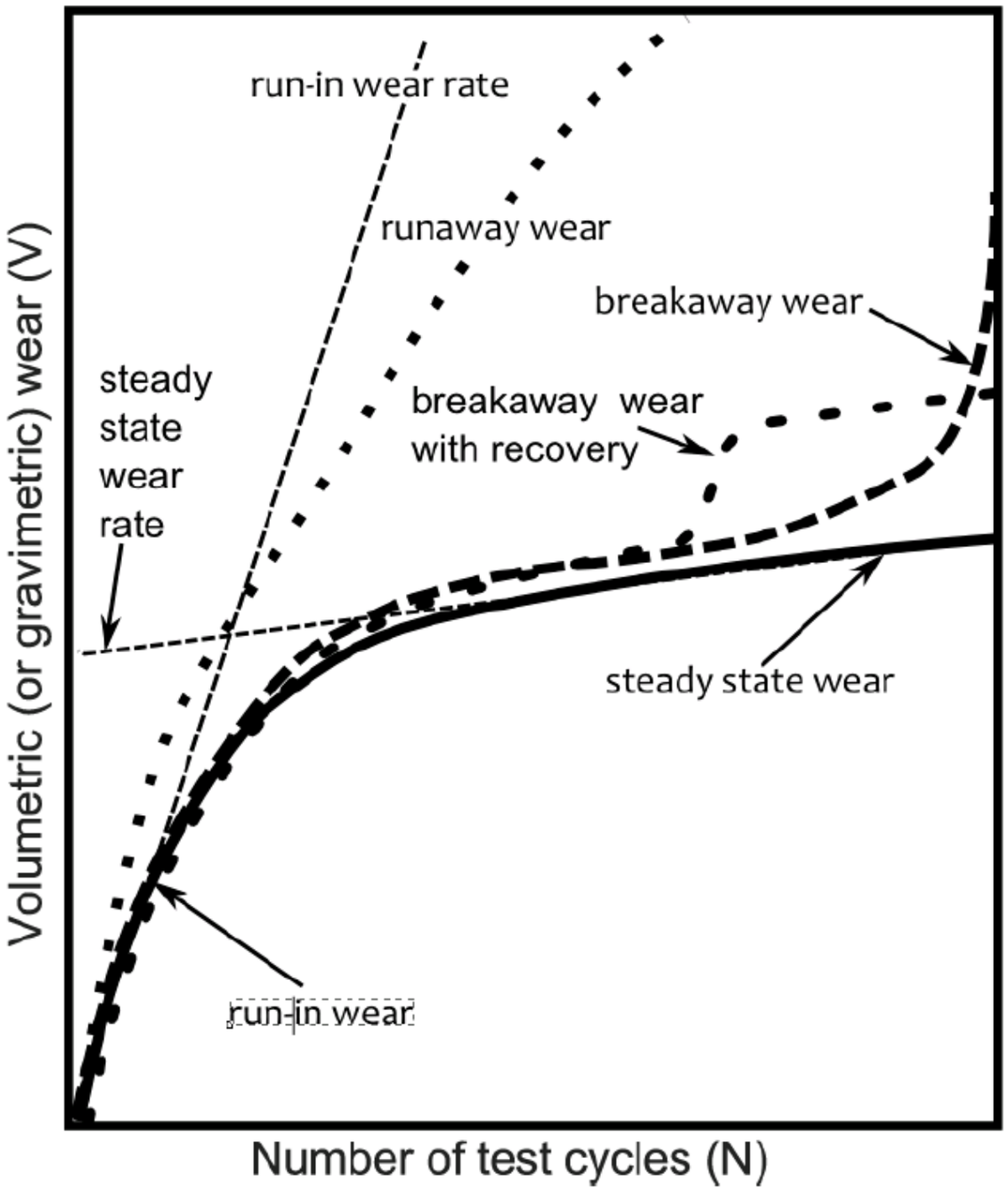


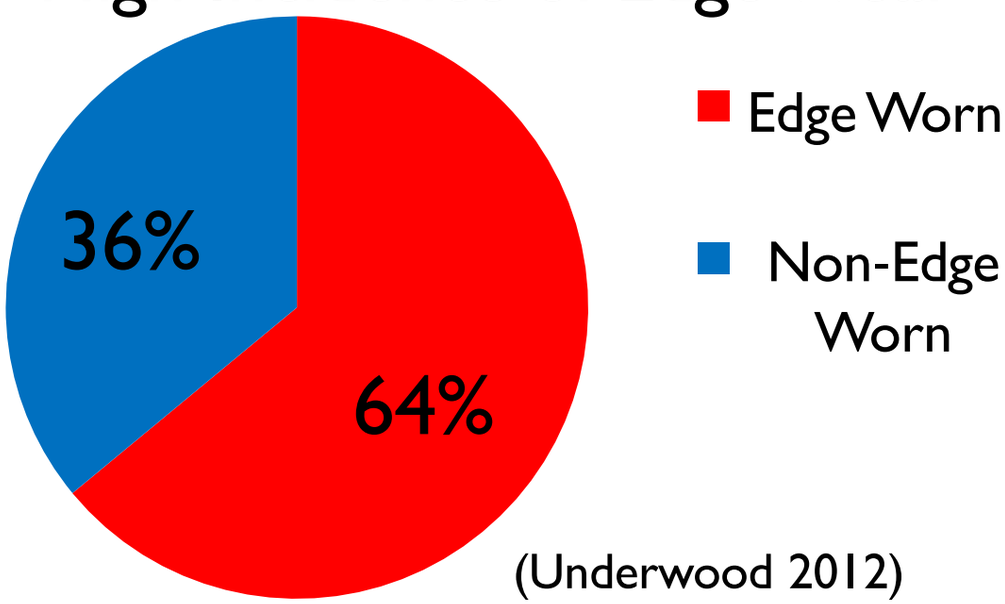
Some MoM designs have shown very low wear rate



Sieber HP et al., Analysis of 118 second-generation metal-on-metal retrieved hip implants. *J Bone Joint Surg Br. 1999 Jan; 81(1):46-50.*

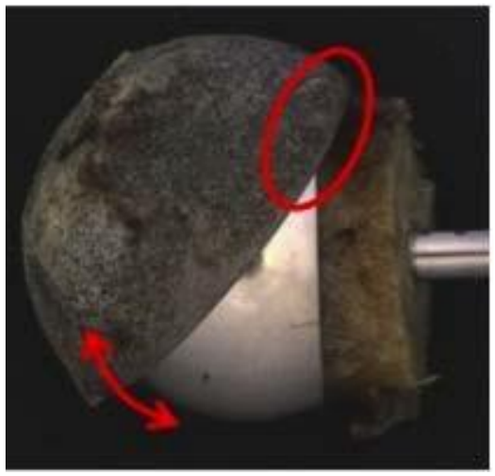
Wear – Bearing Surfaces





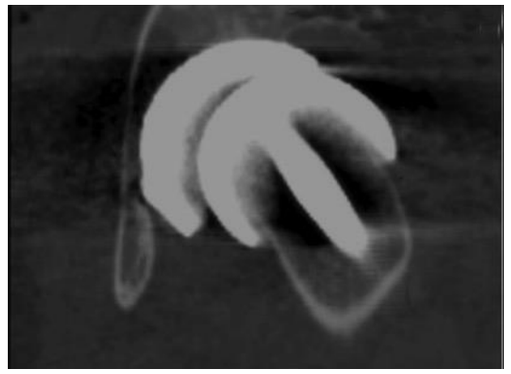
Underwood et al, Proc. IMechE Part H 2012 226(3) 217–226

Three Causes of Edge Wear



Impingement

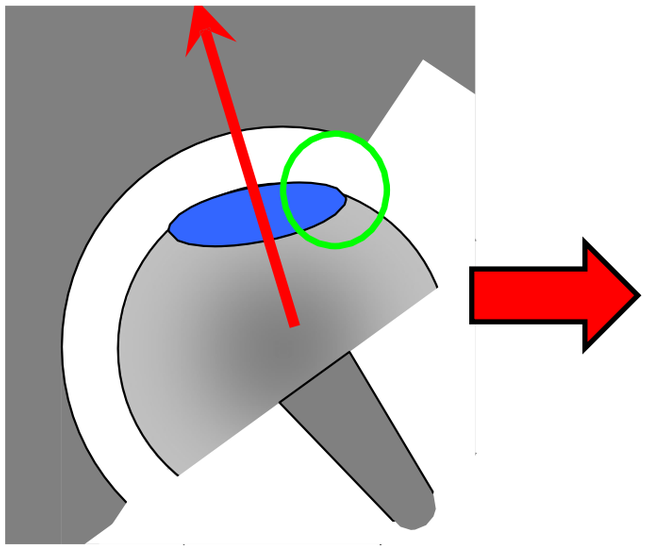
(Matthies 2011)



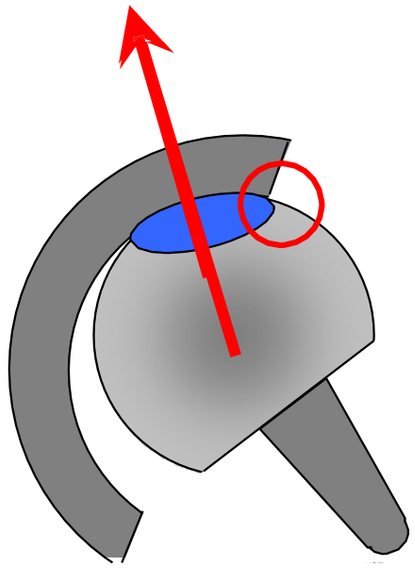
Micro Separation

(Underwood 2011a)

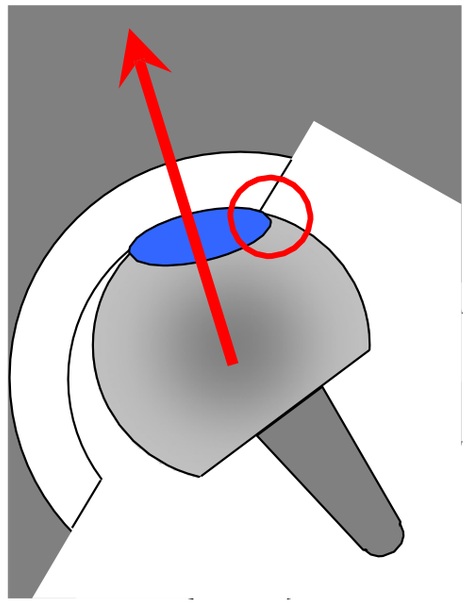
Edge Loaded Hip



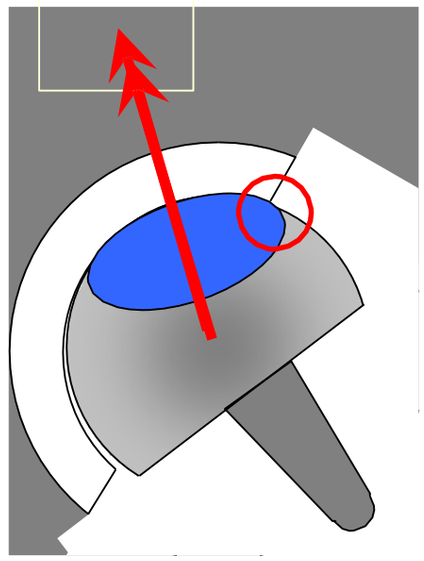
Steep Inclination



Reduced Coverage



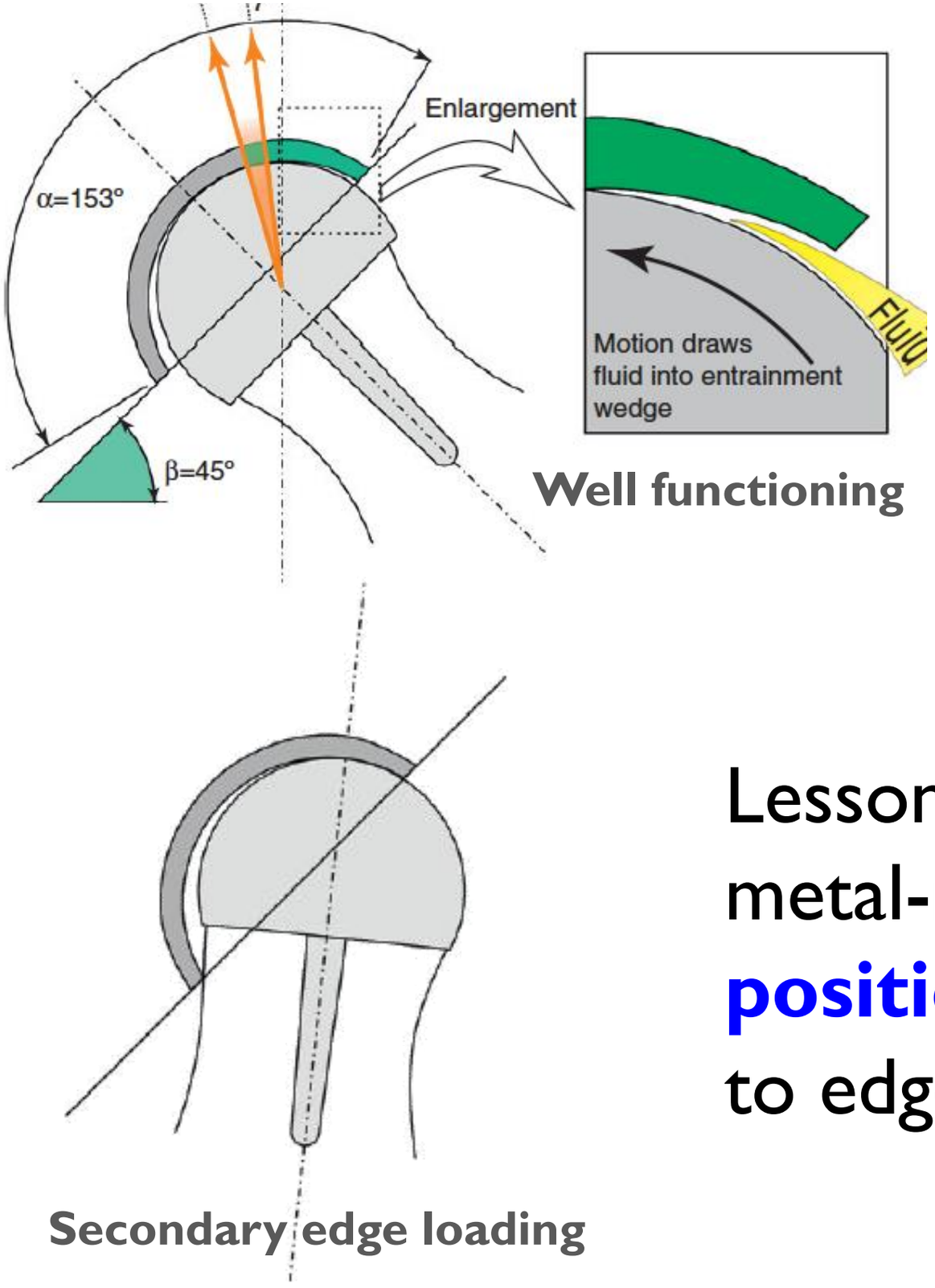
Reduced Clearance



(Underwood 2011b)

Matthies et al, "Retrieval analysis of 240 MoM hip components, comparing modular THR with hip resurfacing," JBJS[Br] 2011;93-B:307-14.
Underwood et al, "What Are The mechanisms of Edge Loading In MoM Hips? A study of 400 Explanted Hip Components" 2011 ORS Annual Meeting
Underwood et al, "Edge loading in metal-on-metal hips: low clearance is a new risk factor," Proc. IMechE Part H 2012 226(3) 217–226

Cup positioning



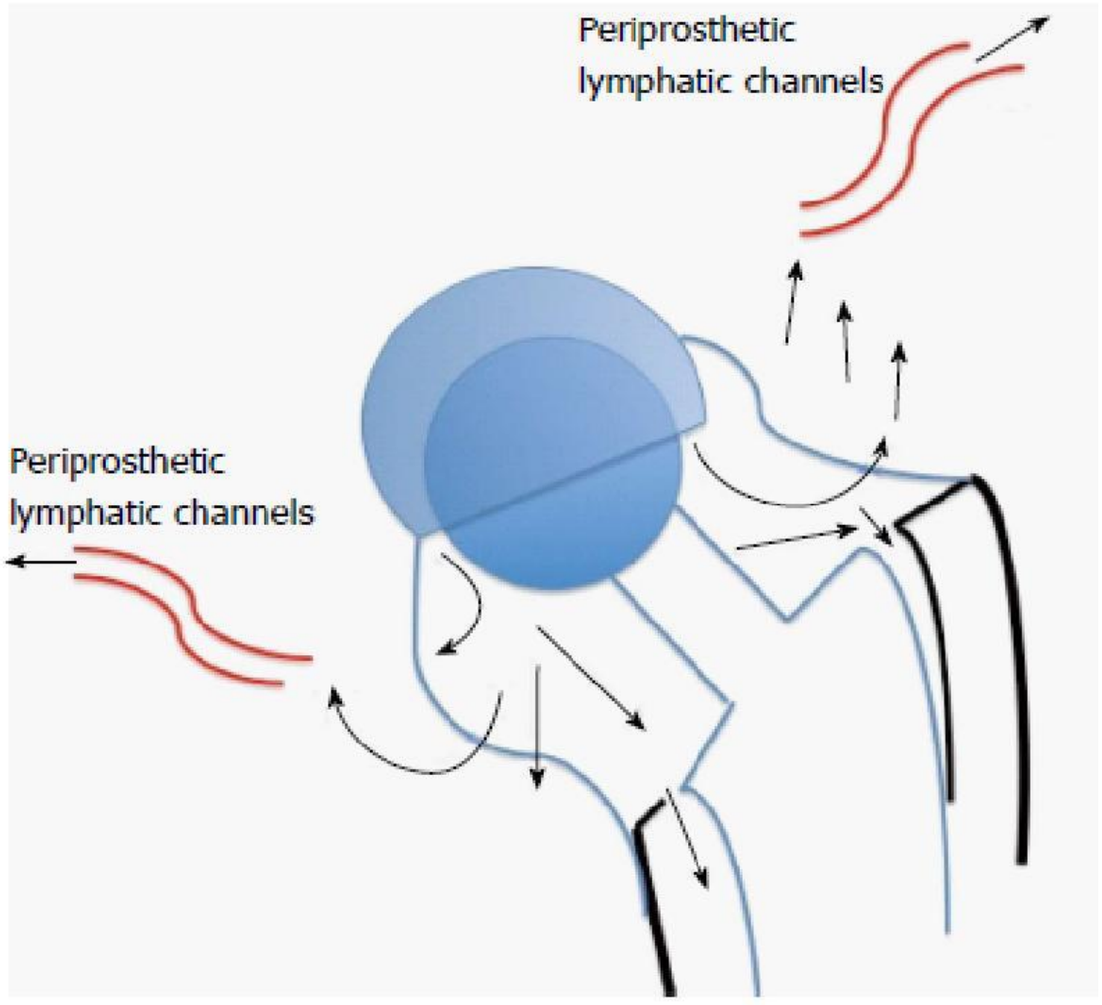
Well functioning

Primary edge loading

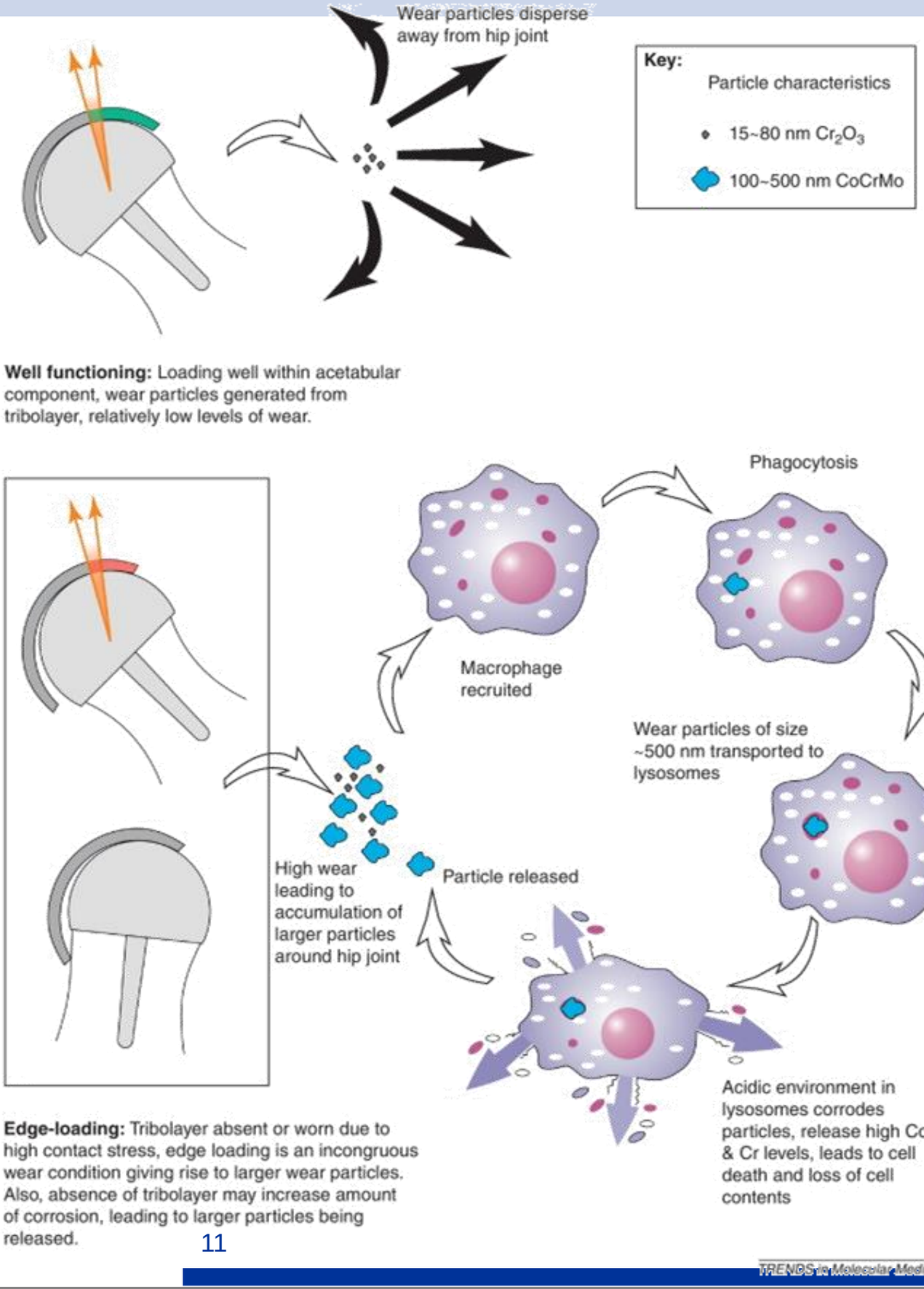
Secondary edge loading

Lesson learnt:
metal-metal bearing wear is all about **position and kinematics** that lead to edge loading and wear.

Willert-Semlitsch Concept



If production of wear debris exceeds the ability of the lymph channels to clear it, the debris then “spills” over into the effective joint space and initiates osteolytic pathways.



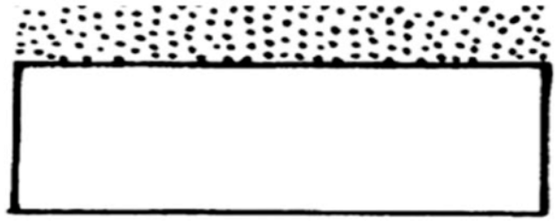
CORROSION

"**Corrosion** is the deterioration of a metal as a result of chemical reactions between it and the surrounding environment."

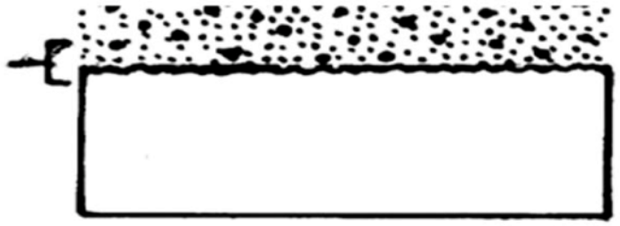
"The fundamental cause or driving force for all corrosion is the lowering of a system's Gibbs energy."

"**Corrosion of most metals is inevitable**."

"This type of damage typically produces **oxide(s)** or **salt(s)** of the original metal."



Uniform



Intergranular

Galvanic

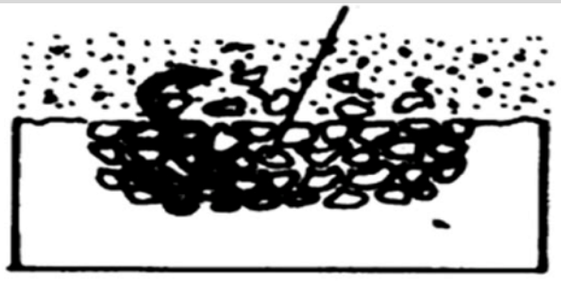
Surface cracks

Internal voids

ge

DISRUPTION OF THE PROTECTIVE OXIDE LAYER

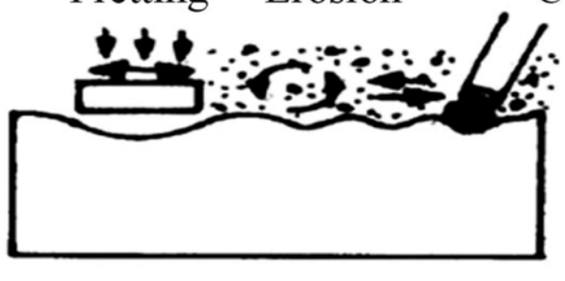
Stress corrosion



Corrosion fatigue

Hydrogen induced cracking

Fretting Erosion Cavitation



Cavitation, erosion and fretting

How does this oxide layer get disrupted?

MECHANICAL DAMAGE

- Load/Pressure
- Wear
- Fretting
- Micromotion
- Scratching

Tribocorrosion

CHEMICAL DAMAGE

- pH
- T
- Cl ions
- proteins

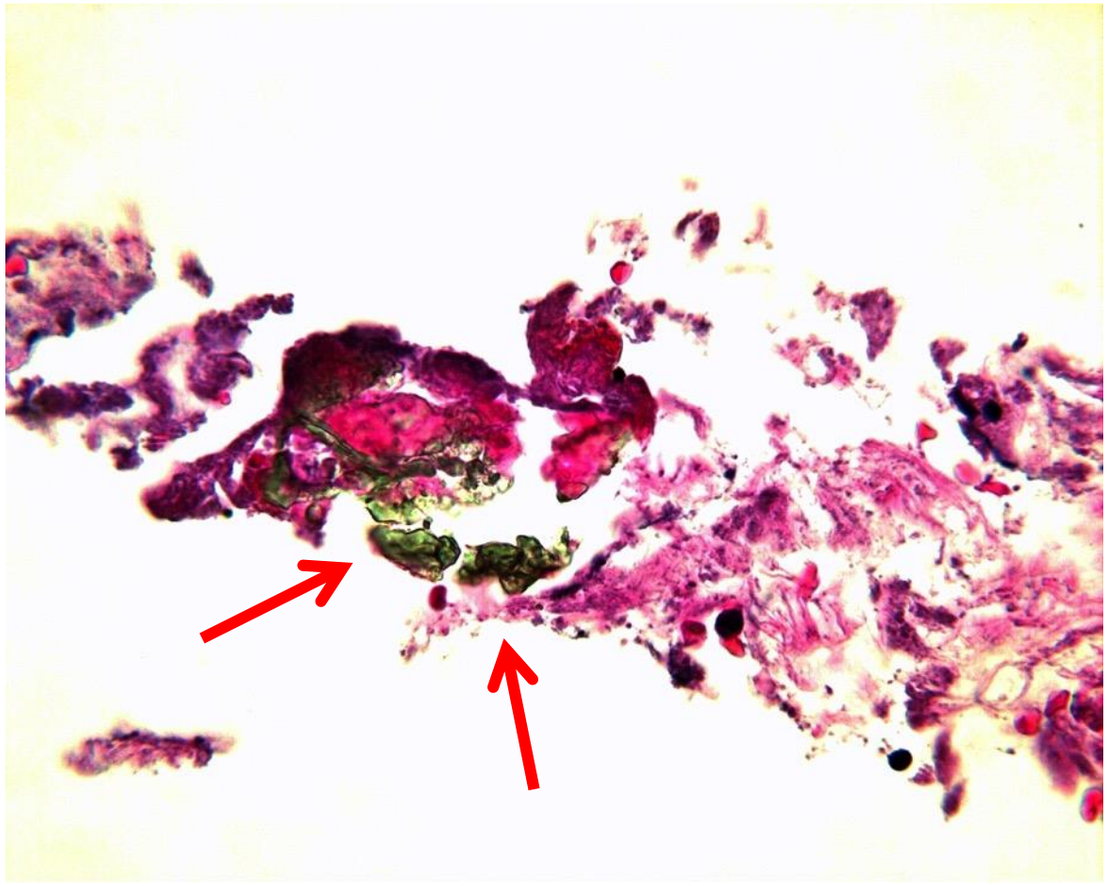
ENVIRONMENT

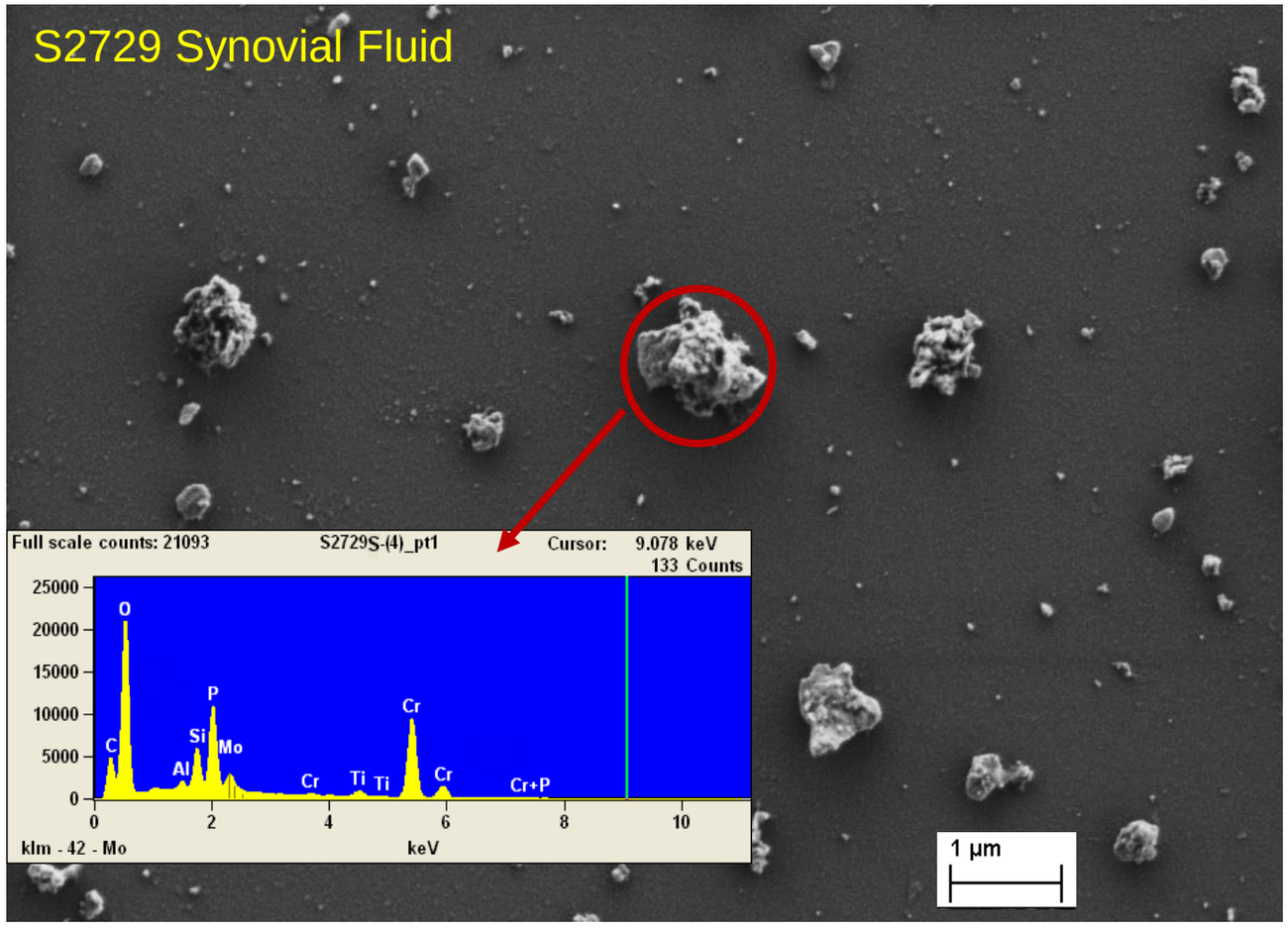
- Wear Particles

- Corrosion Products
- New "Oxide" Layer

- Corrosion Particles
- Metal Ions

Tribo-Corrosion





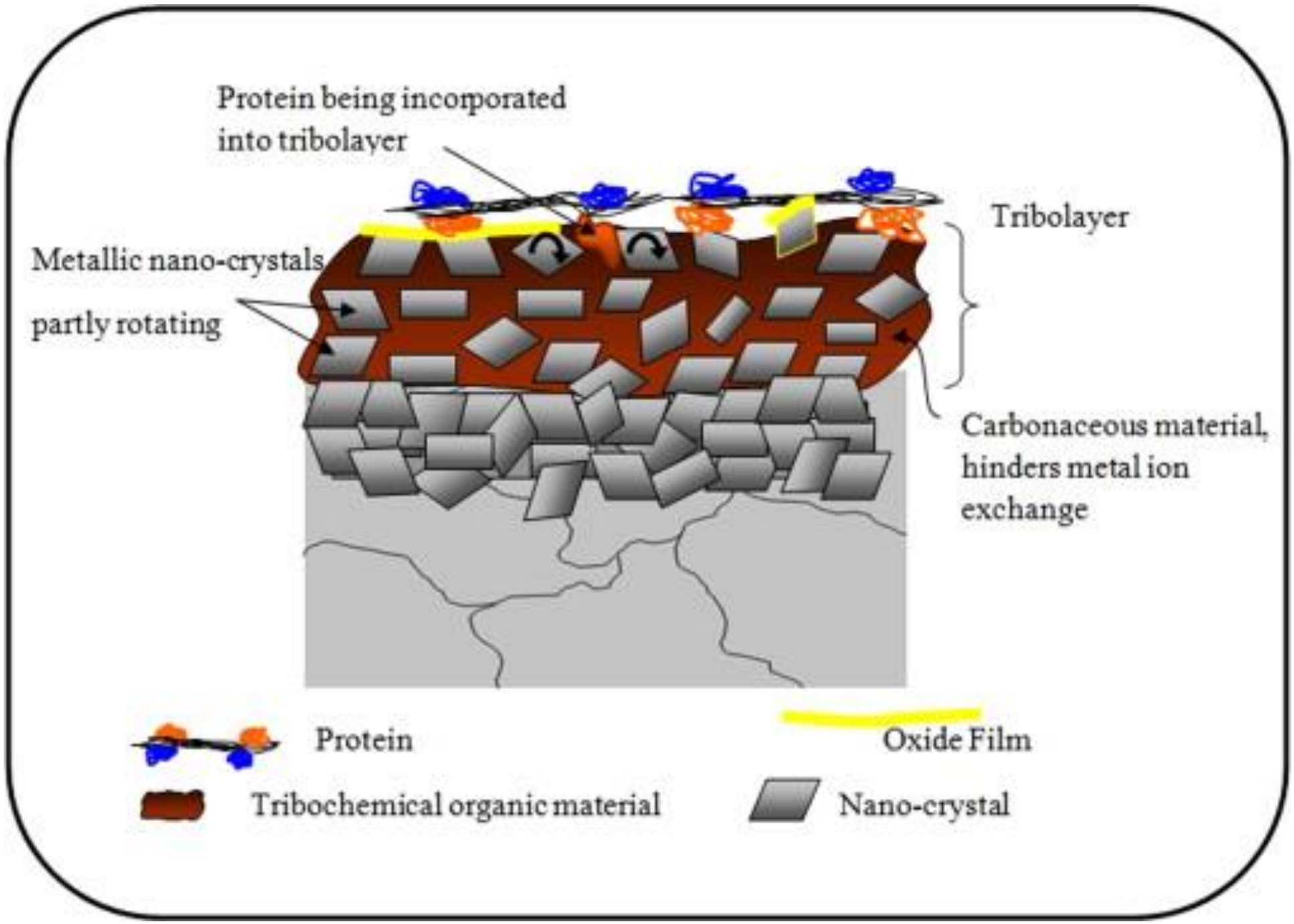
The Relationship Between Activity and Ions in Patients with Metal-on-Metal Bearing Hip Prostheses

Christian Heisel, MD; Mauricio Silva, MD; Anastasia K. Skipor, MS; Joshua J. Jacobs, MD; Thomas P. Schmalzried, MD

J Bone Joint Surg Am, 2005 Apr; 87 (4): 781 -787 . http://dx.doi.org/10.2106/JBJS.D.01820

THE JOURNAL OF BONE & JOINT SURGERY
JB&JS

Tribolayer formation in a metal-on-metal (MoM) hip joint



M.T. Mathew , *et al.* Journal of the Mechanical Behavior of Biomedical Materials, Volume 29, 2014, 199 - 212

The Synergistic Effect of Wear and Corrosion

TRUNNION AND MODULAR INTERFACES

Clin Orthop Relat Res
DOI 10.1007/s11999-014-3746-z

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

SYMPOSIUM: ABJS CARL T. BRIGHTON WORKSHOP ON IMPLANT WEAR AND TRIBOCORROSION OF TOTAL JOINT REPLACEMENTS

What is the Trouble With Trunnions?

**Christina I. Esposito PhD, Timothy M. Wright PhD,
Stuart B. Goodman MD, PhD, Daniel J. Berry MD,
The Clinical, Biological and Bioengineering Study Groups from the Carl T. Brighton Workshop**

Online Submissions: http://www.wjgnet.com/esps/
wjo@wjgnet.com
doi:10.5312/wjo.v4.i4.161

World J Orthop 2013 October 18; 4(4): 161-166
ISSN 2218-5836 (online)

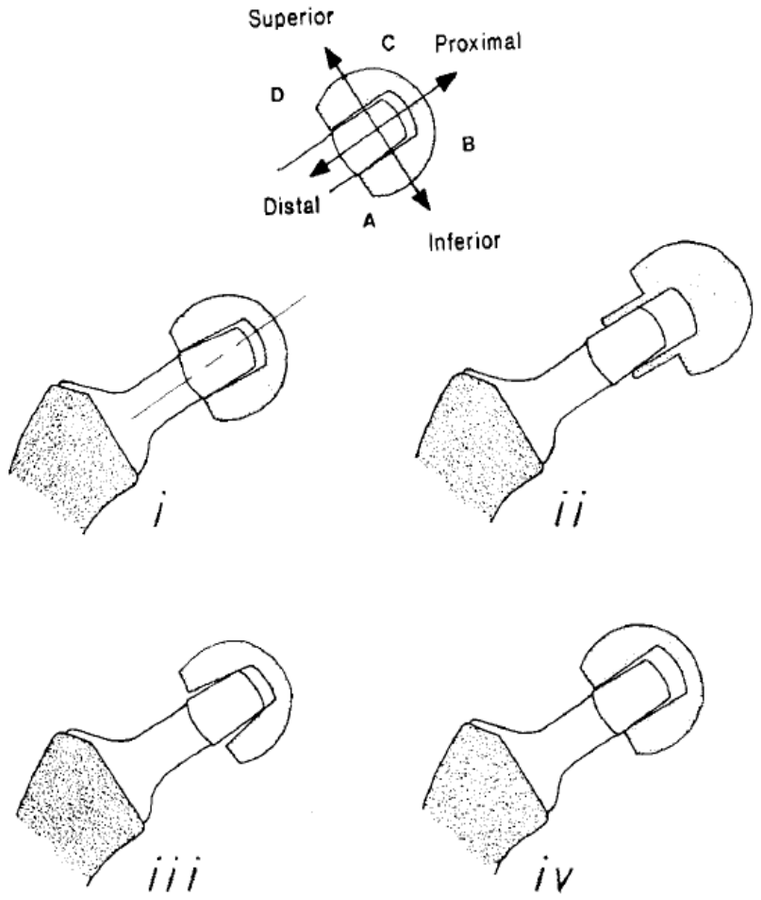
EDITORIAL

Trunnionosis: A pain in the neck

Philip S Pastides, Matthew Dodd, Khaled M Sarraf, Charles A Willis-Owen

Source of relative motion - fretting

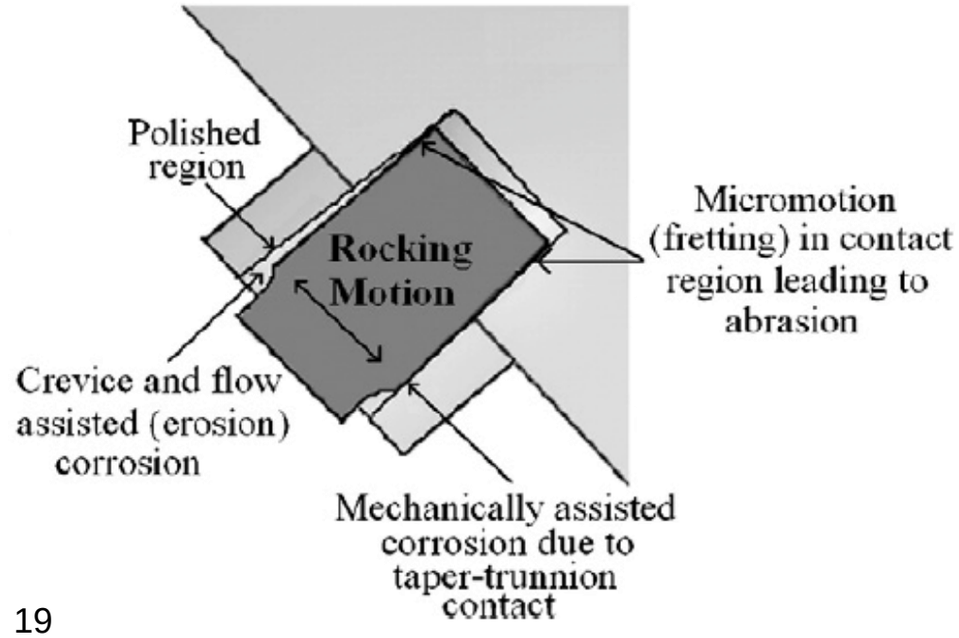
i. Bending in the cone
ii. Bending of the long neck extension (skirt) with proximal-distal slipping
iii. Bore angle too large
iv. Bore angle too small



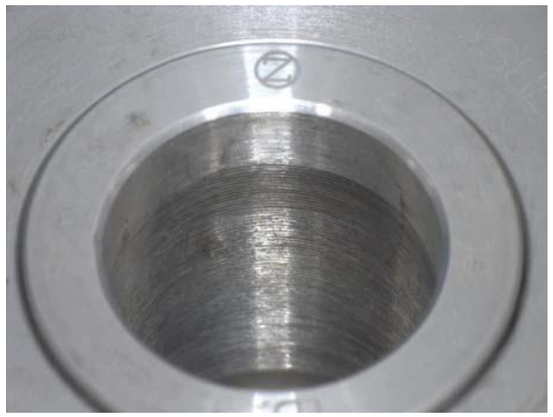
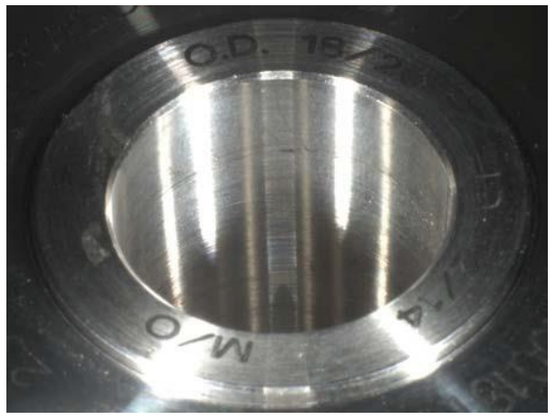
Brown *et al.,* Journal of Applied Biomaterials, 1995

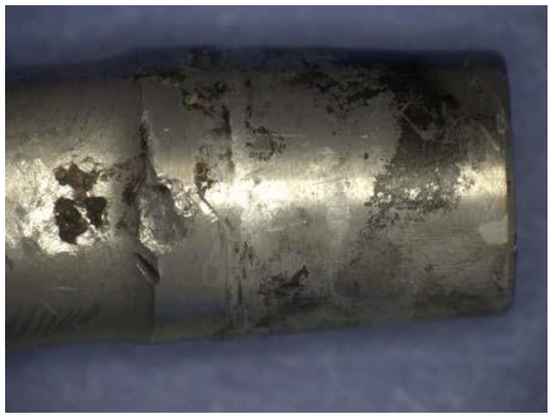
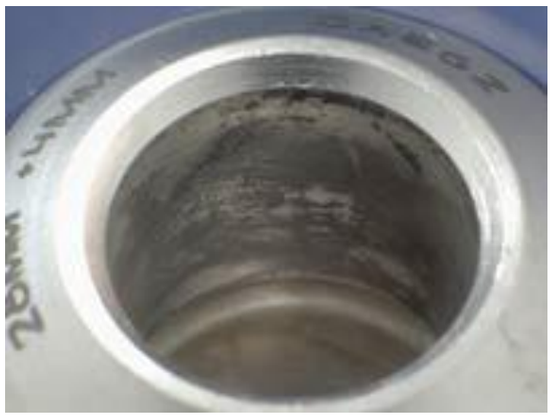
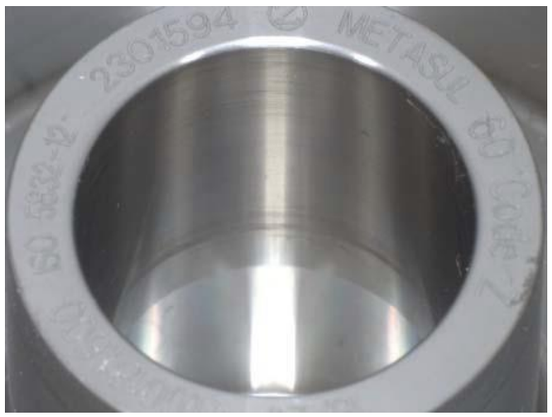
Contributing design features:
- head diameter
- off-set
- length
- surface roughness

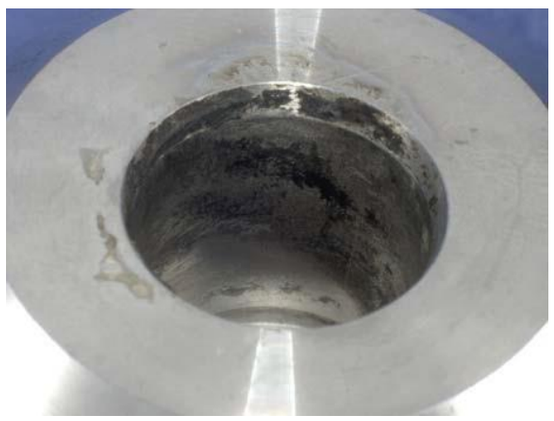
Contributing environmental factors:
- Fluid penetration
- pH (inflammation)
- Tissue contamination



Taper Corrosion is Not New

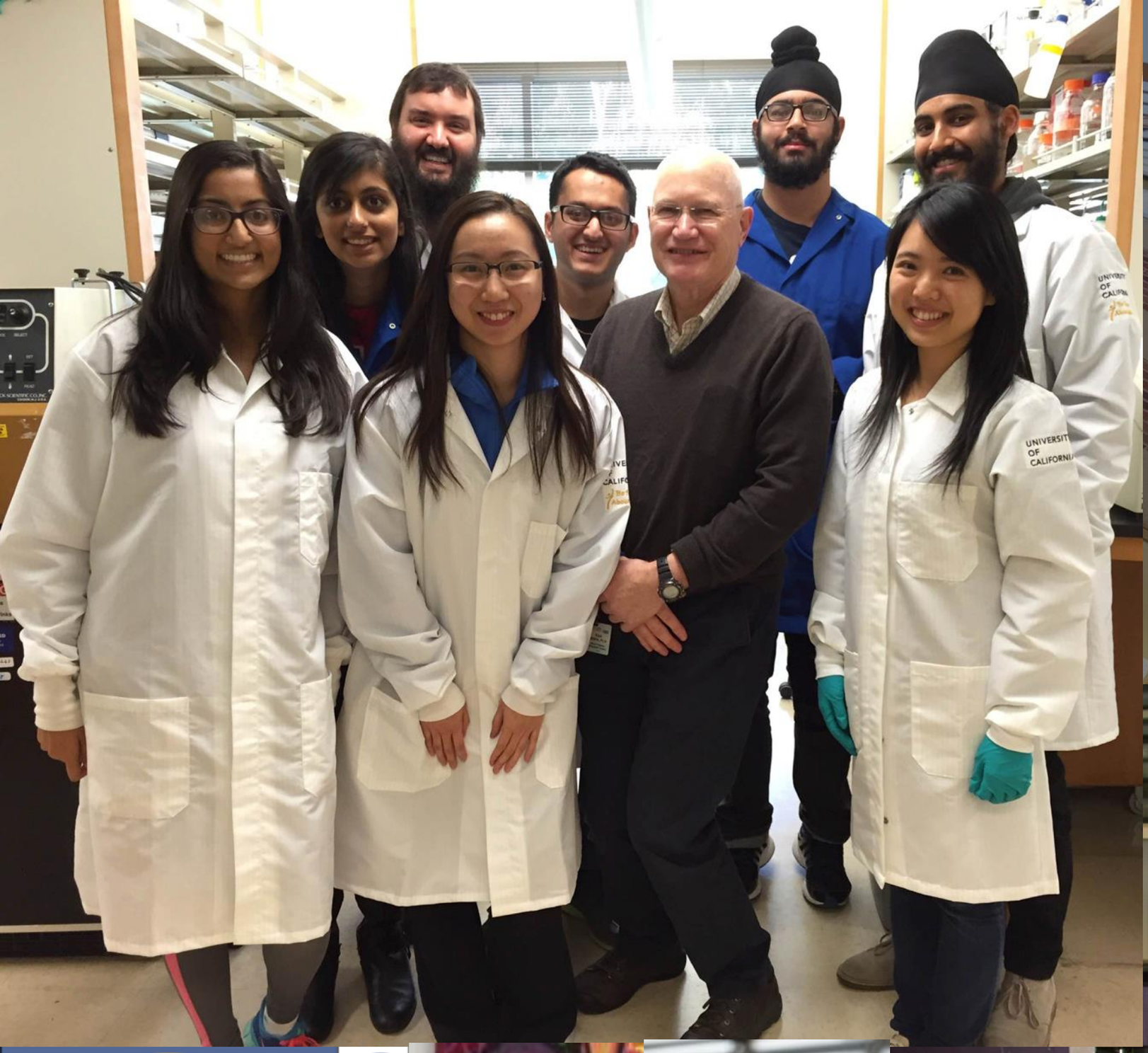


[1]Goldberg et al, "A multicenter retrieval study of the taper interfaces of modular hip prostheses," CORR. 2002;401:149.

- Corrosion can occur at any modular junction, with the potential for release of metal debris and ions into the surrounding local environment.
- Is multifactorial: taper geometry, constituent materials, forces applied to the junction, femoral head size, component offset, and method of assembly.
- Local effects include: ALTR, component fracture or failure, instability, and osteolysis and loosening.

Conclusions

1) Metal-metal wear is position sensitive.
2) Although most modular connections work as expected modular parts needs to be assembled clean, dry, and forceful.
3) There is no wear without corrosion but corrosion can occur without wear.
4) The implant wear and corrosion debris, and metal ions influence the extent of reaction in the patients but the patient may affect the extend of corrosion of an implant.
5) Corrosion needs to be kept on the list of pathologies when a joint isn't doing as well as expected. Blood ion tests are a good screening tool.



THANKS!

David Geffen School of Medicine

OrBBiT