Wear
Bearings
Lubrication

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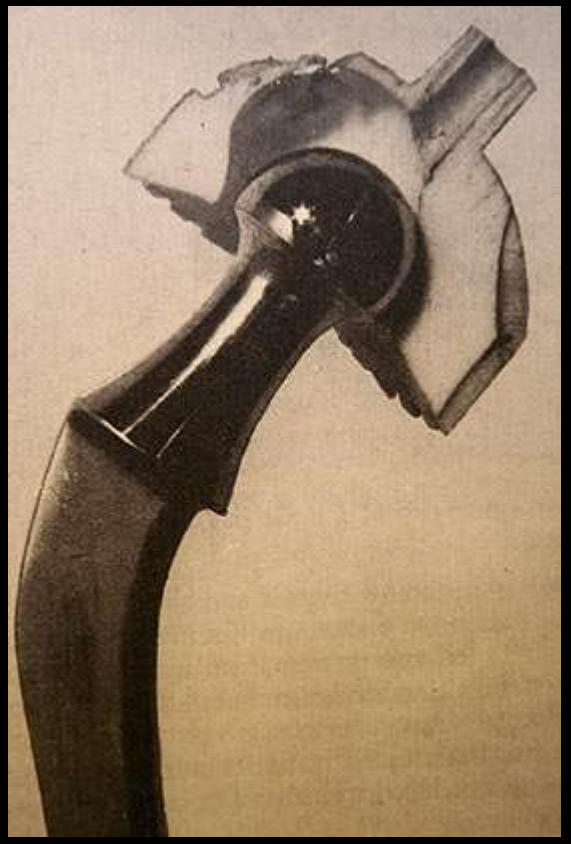
Wear

Wear

- Definition; Progressive loss of bearing surface from the material as a result of chemical or mechanical action

- (Chemical wear = usu CORROSION)

- Modes of wear
  - 1 Intended
  - 2 Not intended
  - 3 3rd body wear
  - 4 2 non bearing surfaces (backside)



Wear

- Mode 1= Intended
- Mode 2= Not intended

Wear

- Mode 3 = 3rd body

Wear

- Mechanisms
  - Abrasive wear
    - Hard on soft. 3rd body (cheese grater)
  - Adhesive wear
    - Intermolecular bonds
    - PE sticks to prosthesis and debris gets pulled off
  - Fatigue wear – Delamination (S-n curve)

Wear

- Volumetric wear
  - Volume of material detached (mm3/yr)
  - Directly related to square of the radius of the Head
- Linear wear
  - Loss of height of bearing surface (mm/yr)

Catastrophic wear

Wear consequences

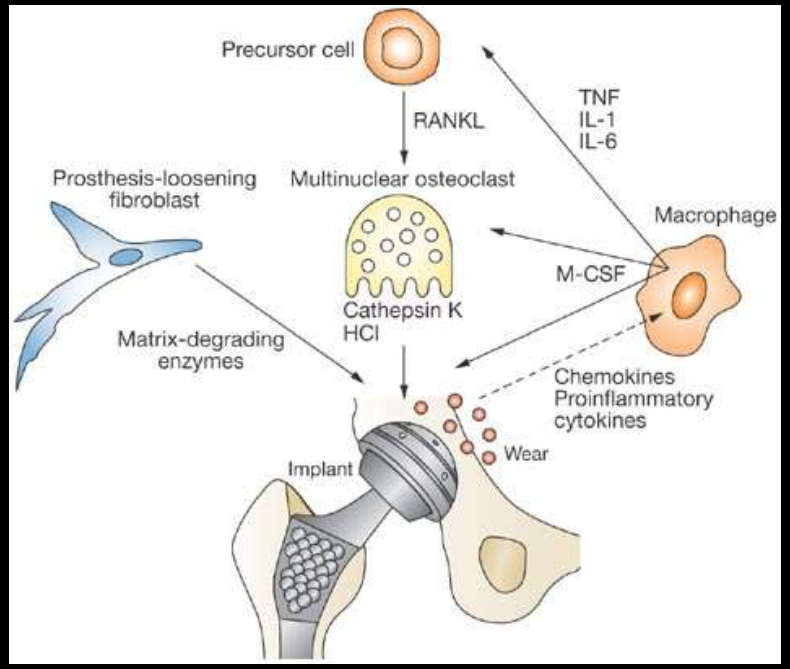
- Depend on particle size
- Poly similar size to bacteria → Macrophage
- Metal similar size to virus → Lymphocyte

Wear consequences

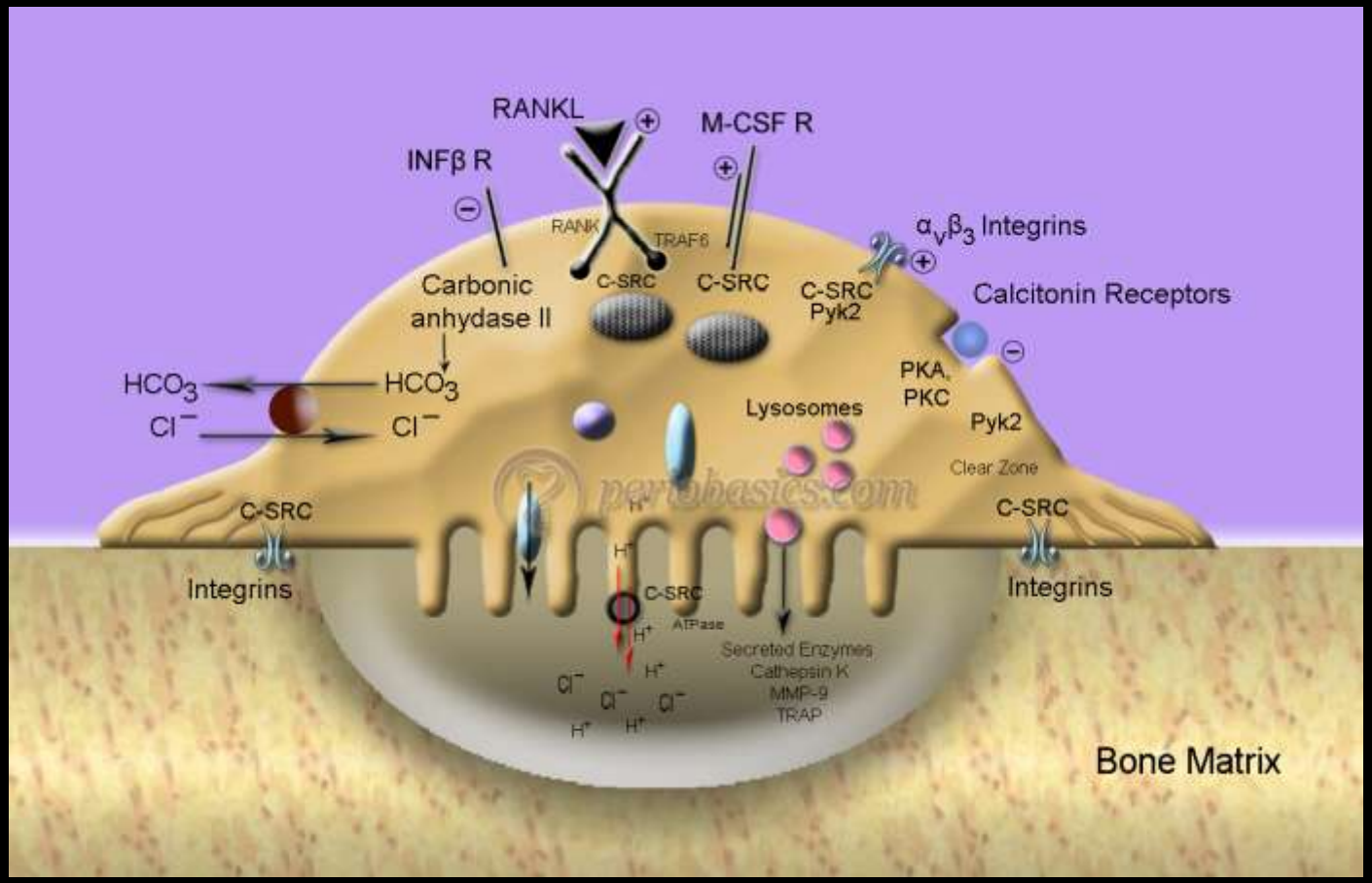
- Aseptic loosening & osteolysis

Osteolysis

- Exam favourite
- PE debris activates macrophages
  - Further macrophage recruitment
  - Macrophages release osteolytic factors
    - TNF- alpha
    - TGF-beta
    - osteoclast activating factor
    - oxide radicals
    - hydrogen peroxide
    - acid phosphatase
    - interleukins (Il-1, IL-6)
    - prostaglandins



Osteolysis



- An increase in production of RANK and RANKL gene transcripts leads to osteolysis

Wear consequences…

- Synovitis
- Systemic distribution
- Immune reaction
- Malalignment of joint / failure

Bearings

Bearings

- Hard vs Soft

- Polymers, ceramics, metals

Bearings

- Femoral head materials
  - Stainless steel
  - Cobalt-chrome alloy
  - Ceramic
  - Titanium alloy

Bearings

- UHMWPE
  - In use since 1960's
  - Machined into solid form
  - Produced by ram extrusion or compression moulding
    - Heated and squeezed into block
    - Machined into desired shape

Bearings

- Sterilisation
  - Initially by ethylene oxide
  - Gas plasma more recently
  - 1975-1995 Gamma irradiation in air –Introduces cross linking

Bearings

- UHMWPE
  - Early 1990's recognised gamma irradiation in air led to oxidation (free radicals)
  - Most manufacturers currently gamma irradiate in inert atmosphere (nitrogen, argon, vacuum)

Bearings-UHMWPE

- Conventional UHMWPE
- Advantages
  - Tough
  - Ductile
  - Resilient
  - Resistant to wear

Bearings-UHMWPE

- Disadvantages
  - Susceptible to abrasion
  - Wear usually caused by third body inclusions
  - Thermoplastic (may be altered by extreme temperatures)
  - Weaker than bone in tension

Bearings

- Highly Cross-linked UHMWPE
- Advantages
  - Higher doses of irradiation + heat increases crosslinking
  - Reduced free radicals
  - Lab studies show significantly lower wear rates
- Disadvantages
  - Mechanical and fatigue properties are reduced

Stainless Steel (316L)

- Components
  - Primarily iron-carbon alloy (lesser elements of chromium may be added to prevent corrosion)
  - 3= Molybdenum
  - 16= Nickel
  - L= Low carbon content

Stainless Steel (316L)…

- Advantages
  - Very stiff & strong
  - Ductile
  - Fracture resistant
  - Reasonable biocompatibility
  - Cheap
- Disadvantages
  - Susceptible to corrosion
  - Stress shielding of bone due to superior stiffness

Cobalt alloy

- Components
  - Cobalt
  - Chromium
  - Molybdenum
  - Nickel
  - Carbon
  - Tungsten

- Advantages
  - Very strong and biocompatible
  - Better resistance to corrosion than stainless steel

- Disadvantages
  - Expensive

Ceramics

- Advantages
  - Strong, stiff, biocompatible
  - Best wear characteristics with PE
  - High compressive strength
  - Scratch resistant
  - Good friction characteristics (wettable)
  - Inert
  - Don’t corrode

Ceramics

- Disadvantages
  - Susceptible to abrasive wear and edge loading
  - Typically brittle, low fracture toughness
  - High Young's modulus
  - Low tensile strength
  - Poor crack resistance characteristics
  - Expensive

Metal on Poly

- Metal (stainless steel / cobalt-chrome) femoral head on polyethylene acetabular liner

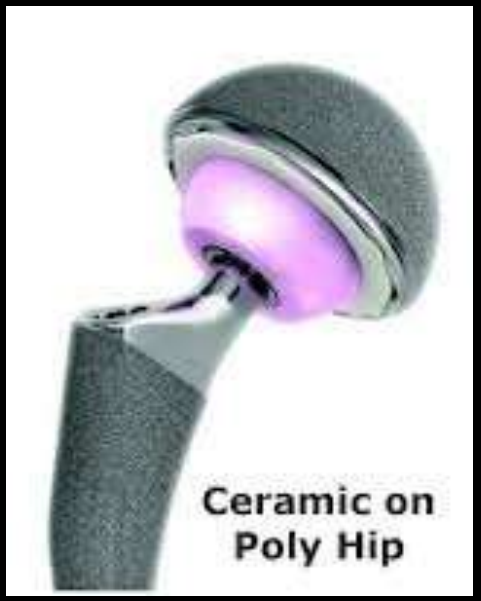
- Advantages
  - Longest track record of bearing surfaces
  - Lowest cost
  - Most modularity

Metal on Poly

- Disadvantages
  - Higher wear and osteolysis rates compared to metal-on-metal and ceramics
  - Smaller head (compared to metal-on-metal) leads to higher risk of impingement (smaller head:neck ratio)

Ceramic on poly

- Alumina widely used
- Reduced scratching to head
- Lab studies show decreased wear
- Clinical experience too short at present
- NJR data starting to emerge



Metal-on-Metal

- DON’T BRING IT UP
- Know MHRA guidelines surveilence

- Advantages
  - Larger head allows for increased ROM before impingement (large head:neck ratio)
  - Lower dislocation rate (large head size)

- Disadvantages
  - High failure / implant recall (ASR)
  - More expensive than metal-on-poly

Metal on Metal

- Increased metal ions, (highest at 12-24 months)
- Formation of pseudotumor / ALVAL
- No proven cancer link

Ceramic on Ceramic

- Advantages
  - Best wear properties of all bearing surfaces
  - Lowest coefficient of friction
  - Inert particles, no concern for cancer risk
  - Newer generation Delta ceramic much lower # rate

- Disadvantages
  - More expensive than metal-on-poly
  - Worst mechanical properties (brittle)

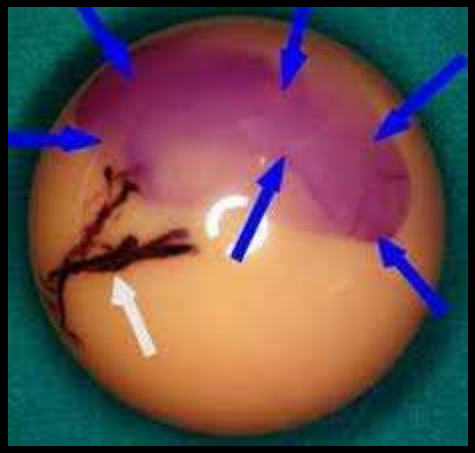
Ceramic on Ceramic

- Squeaking
  - Edge loading
  - Impingement
  - Acetabular malposition
  - Third-body wear
  - Loss of fluid film lubrication
  - Thin, flexible (titanium) stems

Ceramic on Ceramic

- Less modularity (fewer neck length options)

- Stripe wear
  - Contact between femoral head & rim of cup during partial subluxation, results in crescent shaped line on the femoral head



LUBRICATION

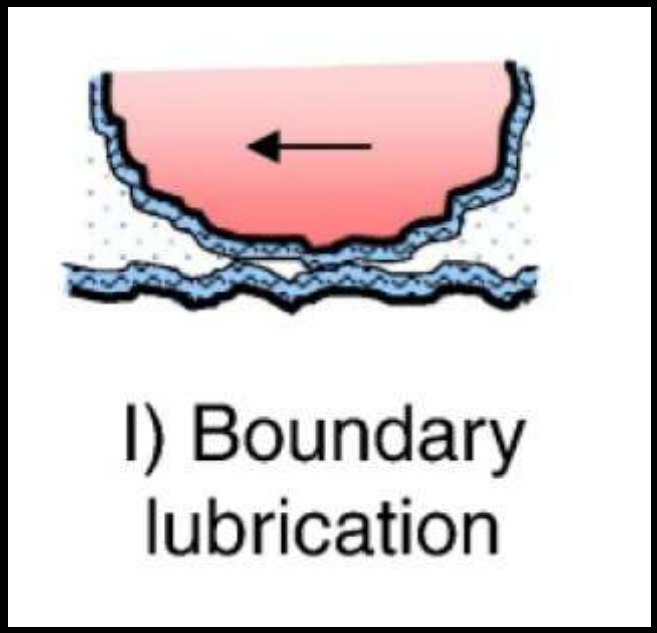
Types of lubrication

- 2 main categories = Fluid Film lubrication / Boundry

- Lambda ratio= ratio of fluid film thickness to surface roughness. >3= FFL

Types of lubrication

- Boundary lubrication
  - The lubricant (synovial fluid) not thick enough to prevent some contact
  - Separates the surfaces enough to prevent severe wear
  - Seen in metal-on-poly
  - Bearing surface is non-deformable

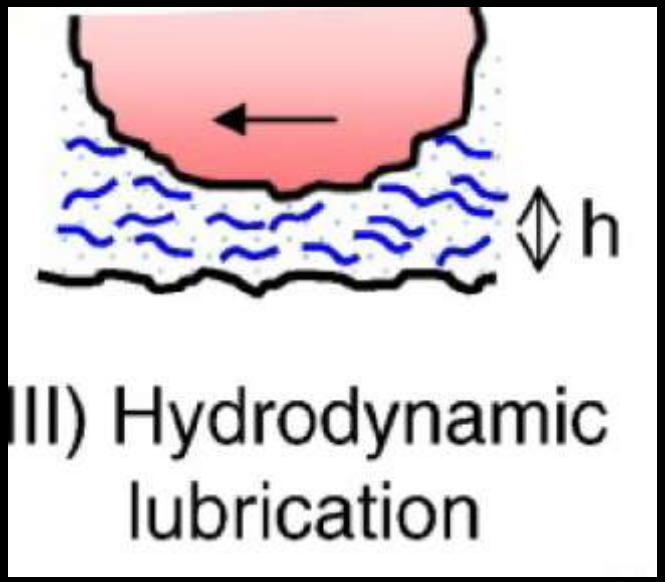


Types of lubrication

- Fluid film lubrication

1) Hydrodynamic lubrication

- Opposing surfaces are completely separated by a lubricant
- Occurs when one surface slides over the other



Types of lubrication

2) Elastohydrodynamic

- Main mechanism during dynamic joint function
- Elastic deformation of articular surfaces
- Thin films of lubricant separate the surfaces

3) Boosted (fluid entrapment)

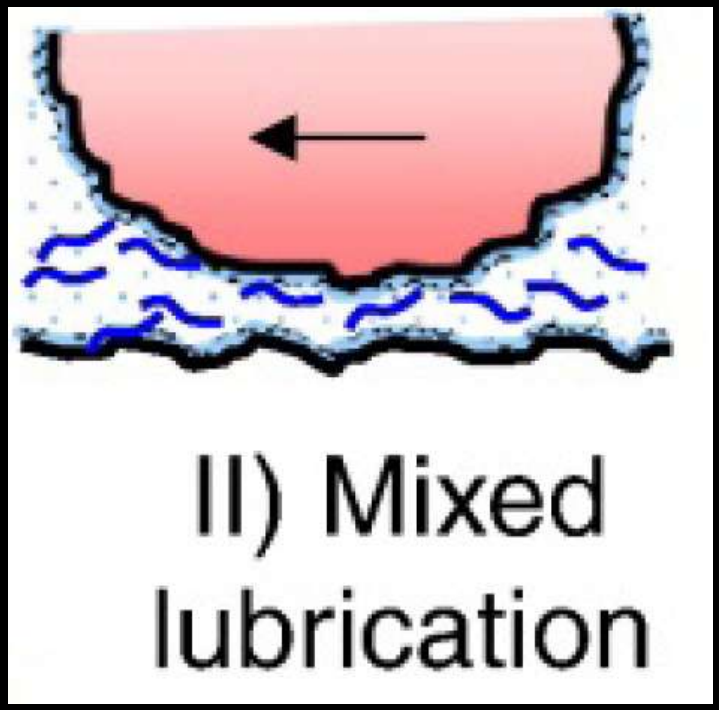
- Concentration of lubricating fluid in pools
- Trapped by regions of bearing surfaces that are making contact

4) Weeping

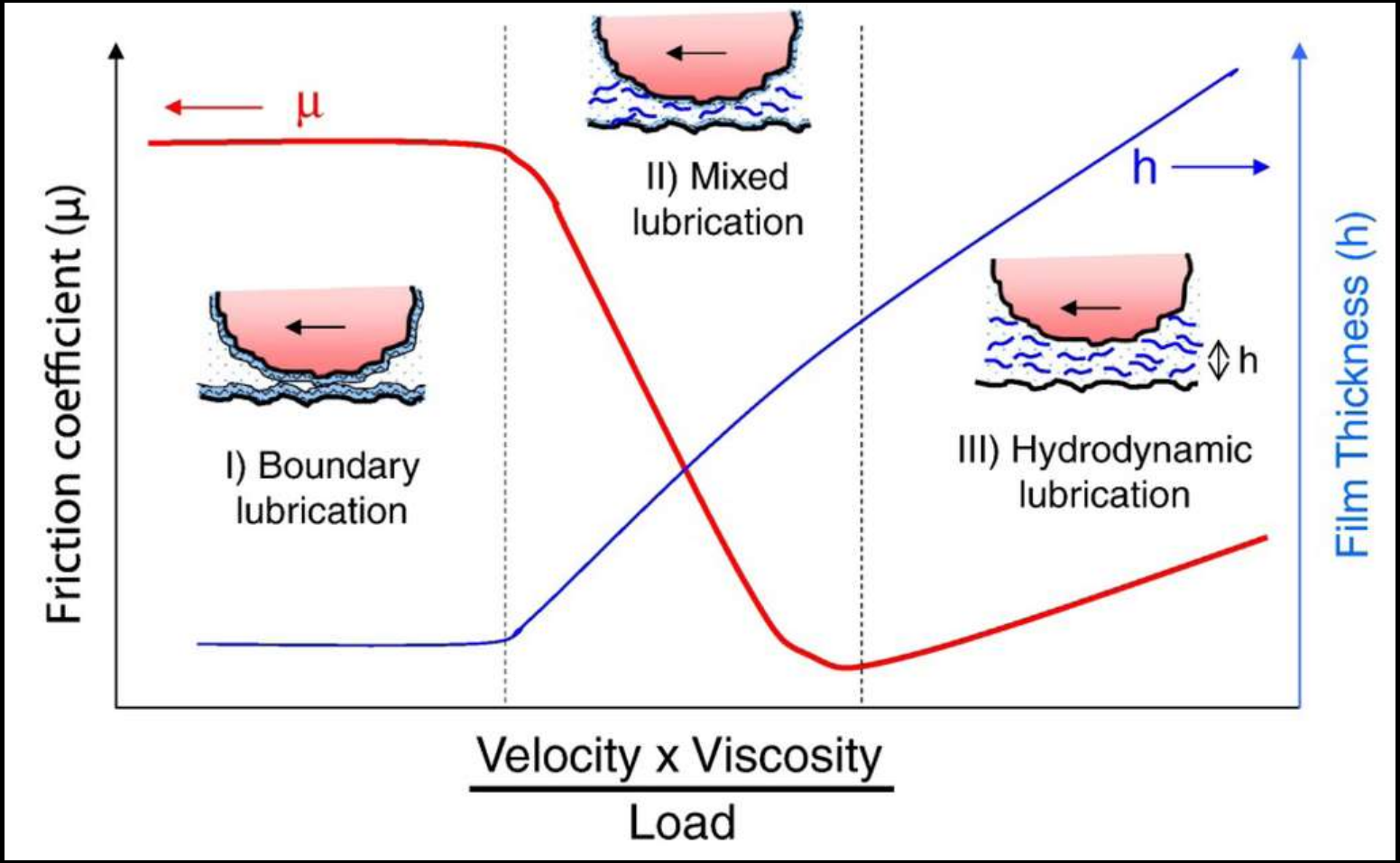
- Fluid shifts out of articular cartilage in response to load
- Surfaces separated by hydrostatic pressure

Mixed lubrication

- Combination of boundary and hydrodynamic lubrication
- Hydrodynamic when in motion
- Boundary when at rest or with slow motion
- Seen in metal-on-metal and cermic-on-ceramic



Lubrication



Summary

- Wear
  - Modes
  - Mechanisms
  - Consequences
  - Aseptic loosening & osteolysis

Bearings

- Hard on soft
- Hard on hard
- Polyethylene
- Titanium
- Stainless Steel
- Cobalt alloy
- Ceramics
- Combinations of above
- Manufacture / sterilisation

Lubrication

- Types
- Boundary
- Fluid film
  - Hydrodynamic
  - Elastohydrodynamic
  - Weeping
  - Boosted

Thank You