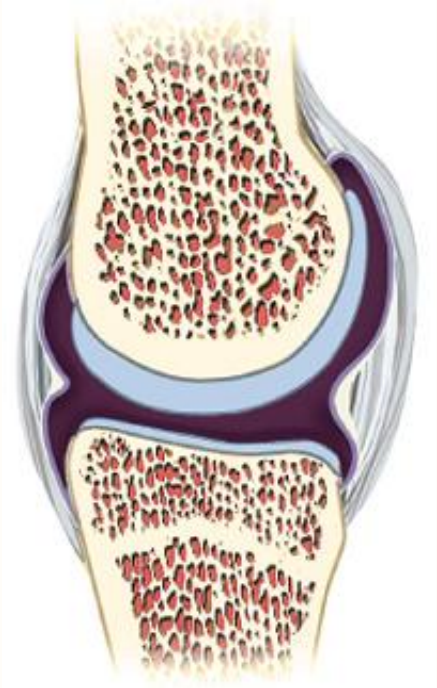
Joints

Chapter 9



- The Study of Joints
- Classification of Joints
- Synovial Joint Anatomy
- Types of Synovial Joints
- Joint Diseases and Replacements

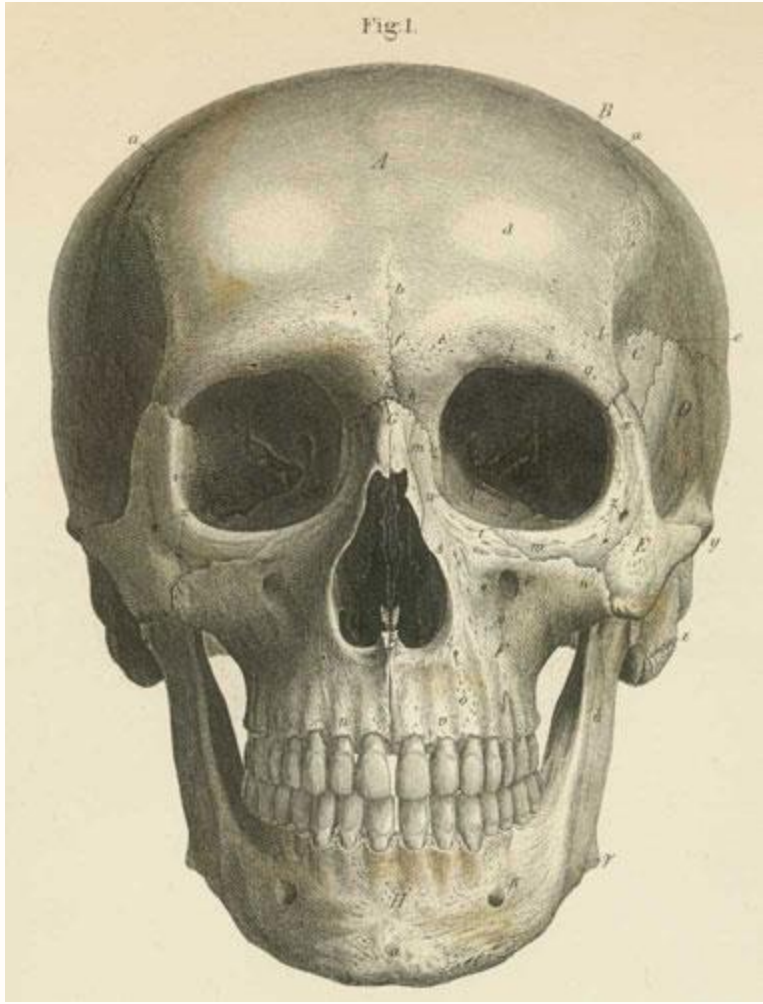
The Study and Classification of Joints

- **Arthrology** is the study of **joints**. Joints are also called **articulations**.
- **Kinesiology** is the study of musculoskeletal movement.
- **Bony Joint** = **Synostosis:** an immovable joint formed when the space between two bones ossifies and the two bones fuse into a single bone
- **Fibrous Joint** = **Synarthrosis:** bones bound together by collagen fibers
  - 3 types of fibrous joints: 1) **sutures**, 2) **gomphoses** and 3) **syndesmoses**
- **Cartilaginous Joint = Amphiarthrosis:** slightly movable joints where two bones bound to each other by cartilage
  - 2 types of cartilaginous joints: 1) **synchondroses** and 2) **symphyses**
- **Synovial Joints** occur where the cartilaginous ends of two bones are separated by a film of slippery synovial fluid.

Bony Joints: Synostoses

- Two bones, once separate, become fused by osseous tissue
- Ossification occurs with age
- Examples:
  - separate left and right mandibles and separate left and right frontal bones are present at birth
- “Syn” is a Greek root that means “with” or “together”

  “Osteo” is a Greek root that means “bone”



Metopic Suture

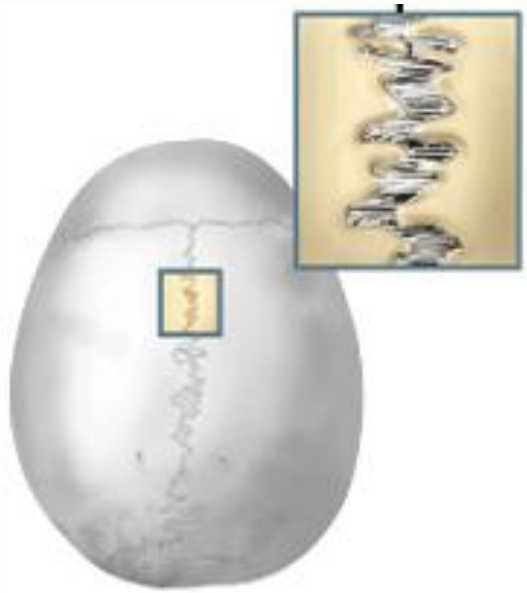
"Metop" is the Greek word root for "the forehead."
Photographs courtesy of M. Bodeen

3 types of Fibrous Joints:

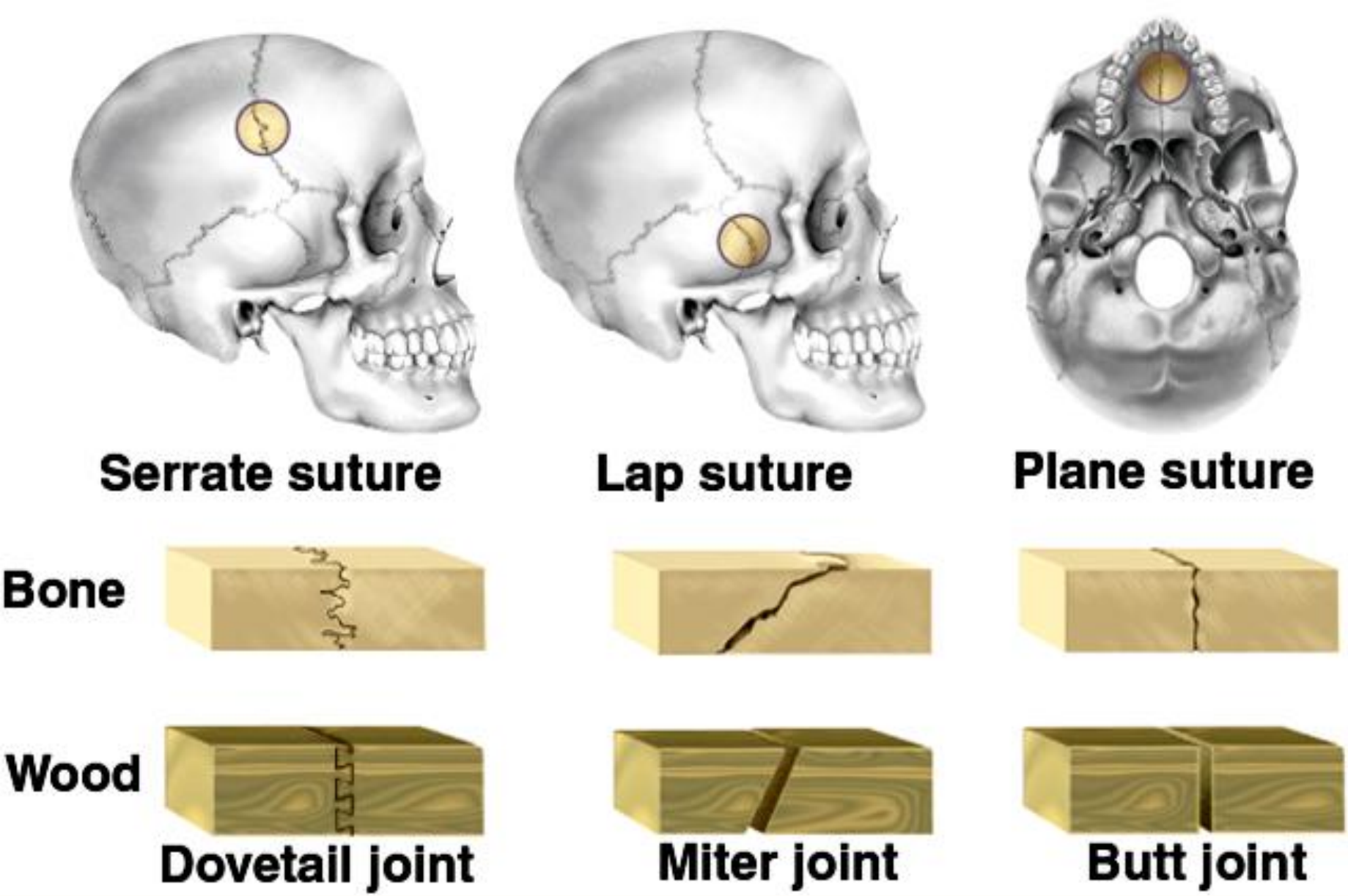
1) **sutures**
2) **gomphoses**
3) **syndesmoses**

1) Sutures

- Sutures are immovable fibrous joints that bind the bones of the skull to each other.
- **Serrate Sutures** appear as interlocking wavy lines.
  - coronal, sagittal & lambdoid sutures
- **Lap or Squamous Sutures** are 2 bones with overlapping beveled edges
  - squamousal suture between temporal and parietal bones
- **Plane or Butt Sutures** have straight, nonoverlapping edges
  - between left and right palatine processes of the maxillae

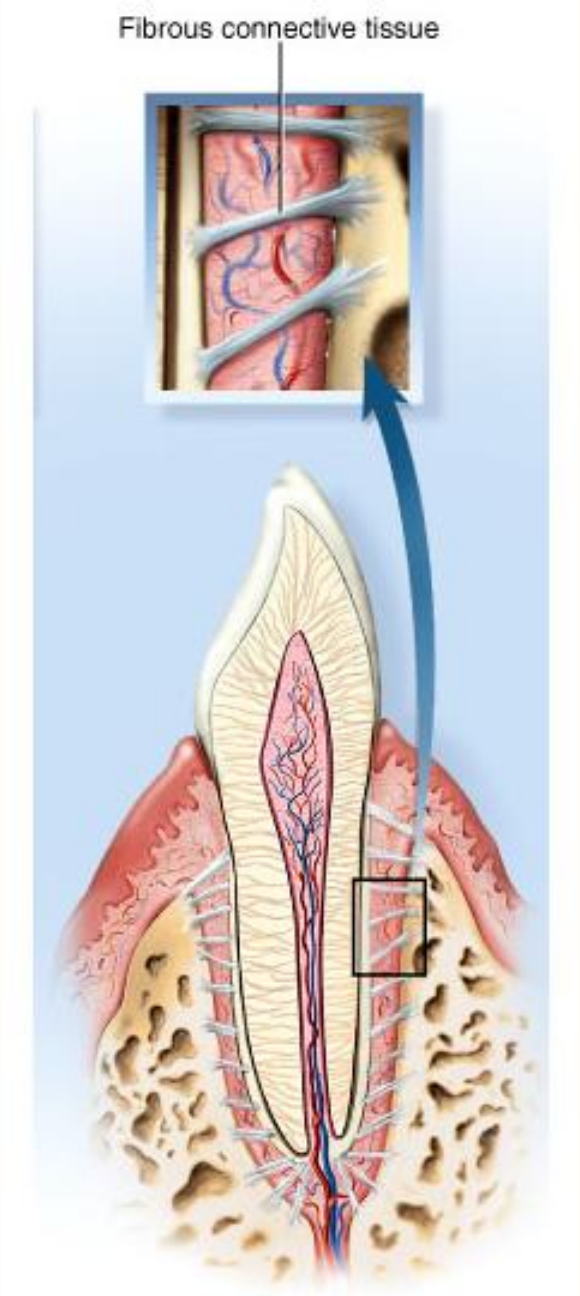


Examples of the 3 Types of Sutures



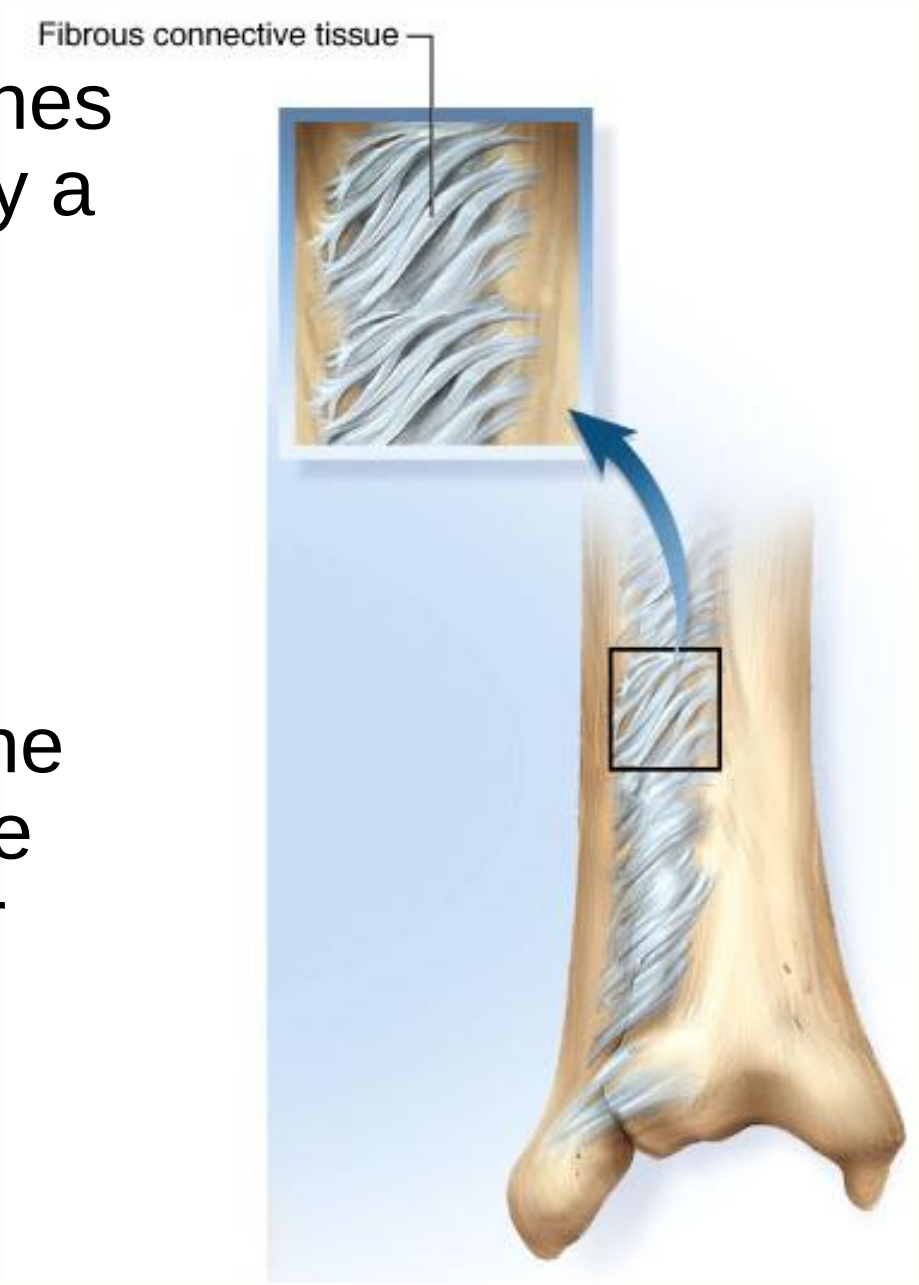
2) Gomphoses

- Attachment of a tooth to its socket is a joint called a gomphosis.
- Gompho (G) a tooth.
- Teeth are held in place by the fibrous periodontal ligament:
  - collagen fibers extend from the periosteum of the jaw bone to the root of the tooth
  - Vitamin C is necessary for collagen synthesis
- Holds tooth firmly, but also absorbs shock while biting down and chewing.



3) Syndesmoses

- Joint in which two bones are bound together by a ligament (the interosseus membrane)
- Most movable of the fibrous joints
- Interosseus membrane binds the radius to the ulna in the forearm or tibia to fibula in leg
- Desmo (G) a bond, a ligament

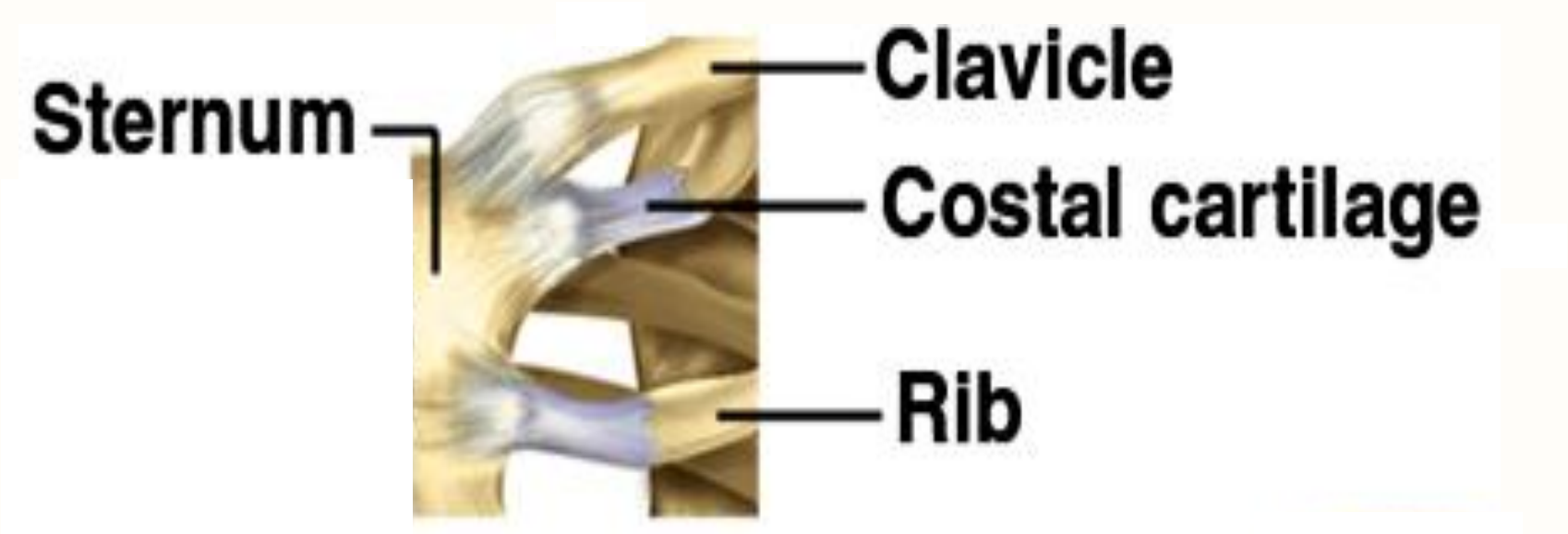


2 types of Cartilaginous Joints:

1) **Synchondroses**

2) **Symphyses**

1) Synchondroses

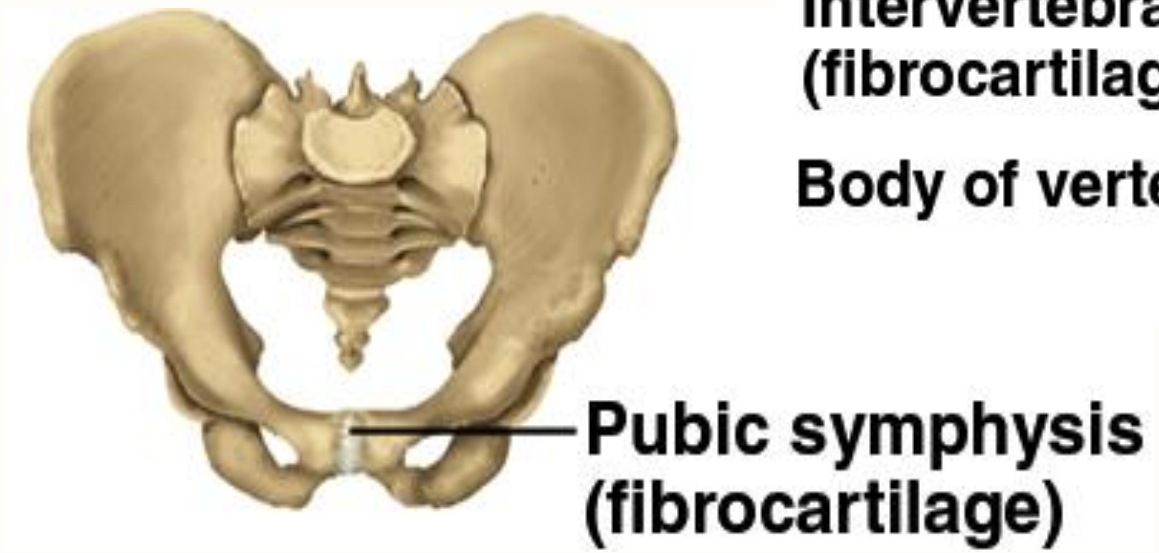


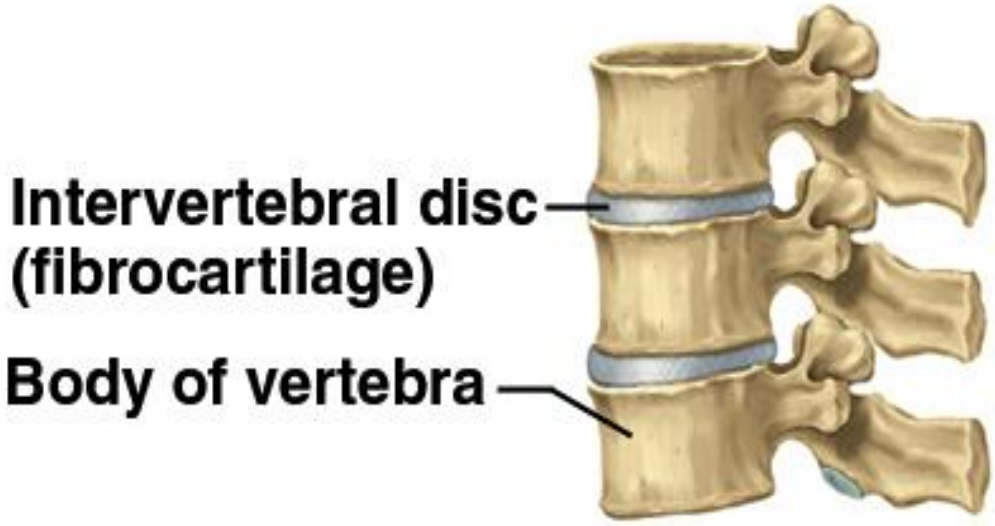
Bones joined by hyaline cartilage

- rib attachment to sternum by costal cartilage
- epiphyseal plate in children binds epiphysis and diaphysis

2) Symphyses

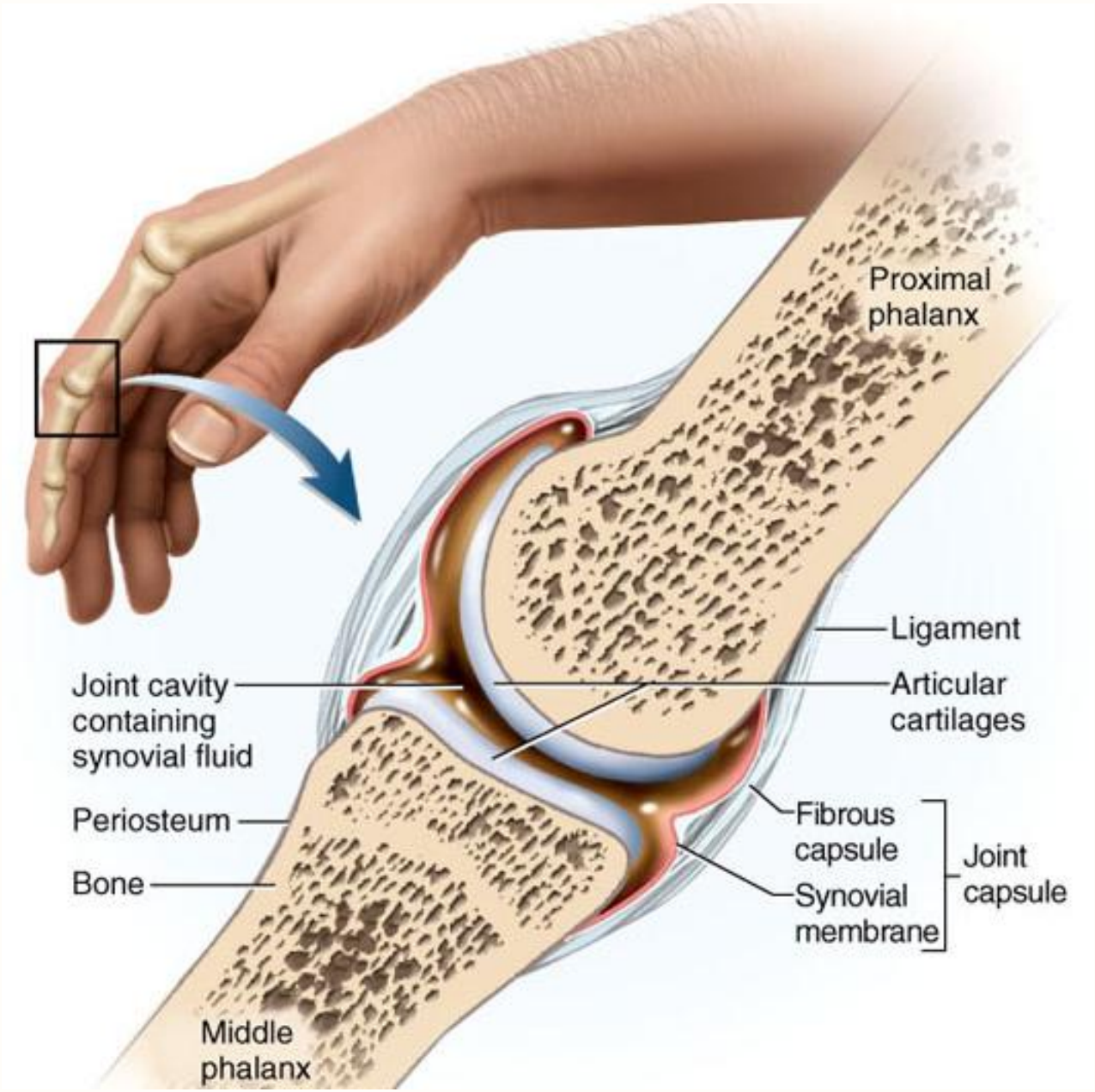
- **2 bones joined by fibrocartilage**
  examples: pubic symphysis and intervertebral discs
- **Only slight amount of movement is possible**
- **Absorbs shock**



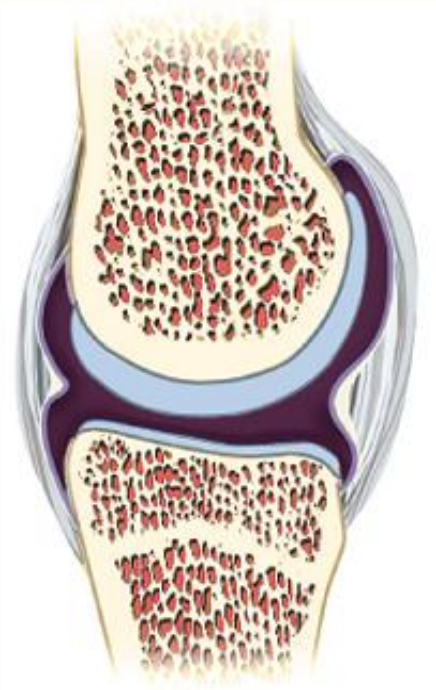


Synovial Joints

- Synovial Joints are the most freely movable type of joint in which two bones are separated by a fluid-filled space called a joint cavity.



Anatomy of Synovial Joints



- Joint Capsule
  - fibrous capsule lined by synovial membrane
  - continuous with periosteum of bones
- Synovial Fluid
  - viscous, slippery fluid rich in albumin and hyaluronic acid secreted by the synovial membrane
- Articular Cartilages
  - hyaline cartilage rich in chondroitin and glucosamine covers the joint surfaces
- Meniscus of fibrocartilage is present in some joints including: jaw, wrist, knee and sternoclavicular joints
  - meniscus absorbs shock and guides bone movements

http://www.mayoclinic.com/health/glucosamine/AN00619

MATERIALS SCIENCE

Sweet, Hairy, Soft, and Slippery

Synthetic polymer lubricants inspired by biological systems may be the key to water-based lubrication.

Seunghwan Lee and Nicholas D. Spencer

Water, together with surfaces containing sugar chains, forms the basis of all biological lubrication systems, from the slithering of a snail to the passage of food along the digestive tract. Yet humans have typically lubricated their machines with oils and fats. Understanding of biological lubrication has now advanced to the point where these principles can be applied to systems of technological importance using synthetic polymers.

Water lubrication is used in some niche applications such as reservoir pumps, and oil-water emulsions are often used for metal cutting, taking advantage of the effectiveness of water as a coolant. In the mining industry, hydraulic fluids are frequently based on water so as to exclude flammable materials from underground working areas. Interest in water lubrication is also high in the food, textile, and pharmaceutical industries, where product contamination by oil is a concern (*1*).

Water on its own is, however, generally a poor lubricant, and unlike oil, its viscosity does not rise substantially with pressure. This property is essential to the mechanism by which oils can form a lubricating film in high-pressure, nonconformal contacts of hard materials such as gears or ball bearings (*1*).

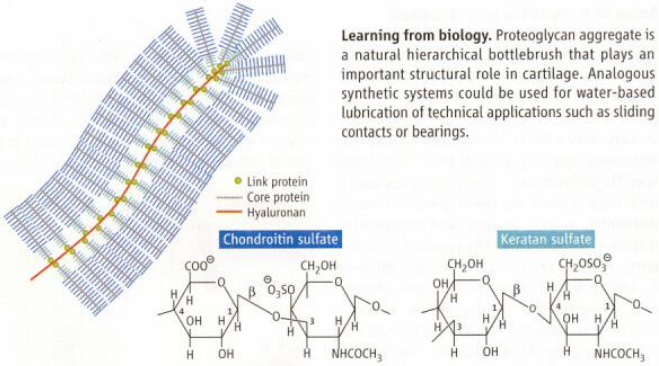
The low viscosity of water at high pressures can be overcome by biological lubricant additives, usually glycoproteins, in which large numbers of sugar chains are bound along a protein backbone. For example, mucins are found in most parts of the human body that need lubricating, such as eyes and knees (*2*). These molecules probably aid lubrication both via their intrinsic viscoelastic properties in solution (*3*) and via their behavior when adsorbed on the sliding surfaces. The characteristic bottlebrush structure of the molecules is crucial to this mechanism: The hydrophilic sugars immobilize large amounts of water within the contact region, while the backbone interconnects to other bottlebrushes or to a surface. Hierarchically structured, sugar-based bottlebrushes also play a key role in the mechanical properties of cartilage (see the figure) (*4*).

One biomimetic approach is to decorate the sliding surfaces with a high density of brush-forming polymer chains. Klein *et al.* have shown that when two mica surfaces bearing polymer brushes are rubbed past each other under compression in "good solvents," the interfacial friction forces lie below the detection limit (*5*, *6*). The remarkable lubricating effect of such hairy polymer layers is ascribed to interchain repulsion, which leads to the incorporation of large quantities of solvent. The resulting fluid-like cushioning layer on the surface can sustain the externally applied pressure, thereby lowering the friction forces (*7*). This behavior, first observed for polystyrene chains in toluene, is a result of the interplay between the polymer and solvent rather than an intrinsic property of either component. Thus, it can also be observed for hydrophilic polymers such as polyethylene glycol (PEG) in water (*8*–*10*).

How high a pressure can brush-like polymer layers withstand? With increasing pressure, the compression and interpenetration of opposing polymer brushes also increase, even in good solvents; the disruption of the brushes, and thus the onset of substantial friction forces, occurs at pressures between 0.01 and 1 MPa, corresponding to pressures in contacts between internal organs or non–load-bearing mammalian joints (*11*). Nonetheless, Müller *et al.* attached dense PEG brushes to steel and glass surfaces sliding in water to investigate their lubricating properties under conditions approaching those of industrial bearings (*12*). They found that the formation of a lubricating film was substantially enhanced by the brushes at contact pressures as high as 0.5 GPa (conditions where water alone cannot form a lubricating film), but the brush layer became detached during sliding contact, and direct contacts between peaks in the surface roughness could not be suppressed completely.

Another important characteristic of natural tribological systems is that they usually involve soft surfaces, as exemplified by slugs, eyes, tongues, and cartilage-coated articular joints. In response to external loads, such soft surfaces deform elastically and increase the contact area, resulting in a relatively low contact pressure. This is why liquids whose viscosity increases only slightly with pressure, such as water, can form lubricating films in soft contacts. This property sparked an extensive study of the aqueous lubrication of elastic polymers (rubbers or elastomers) (*13*) and has led to applications, for example, in tires, seals, windshield wipers, and biomedical implants.

The synergistic combination of hairy polymers and soft surfaces for water lubrication has, however, been investigated only recently. For example, end-grafted PEG chains can greatly enhance the water lubrication of silicone-rubber surfaces, especially at low speeds (*14*). In contrast, short-chain surfactants only led to minor reductions in friction in comparison to brush-like systems (*15*). Gong *et al.* have gone a step further in biomimicry by using hydrogels for aqueous lubrication. In addition to being soft, hydrogels allow water



Learning from biology. Proteoglycan aggregate is a natural hierarchical bottlebrush that plays an important structural role in cartilage. Analogous synthetic systems could be used for water-based lubrication of technical applications such as sliding contacts or bearings.

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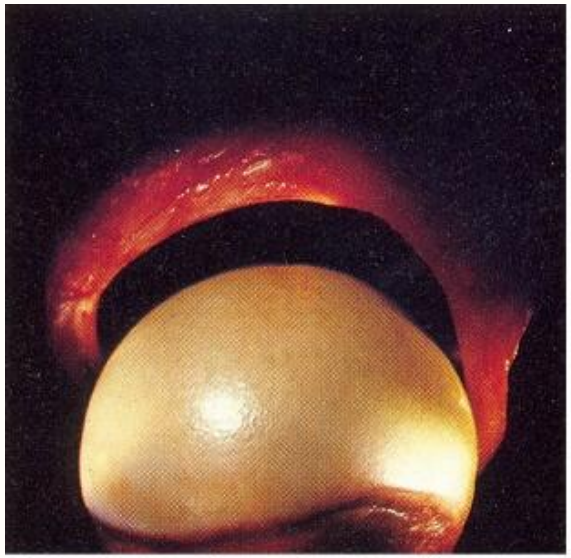
Types of Synovial Joints and Examples

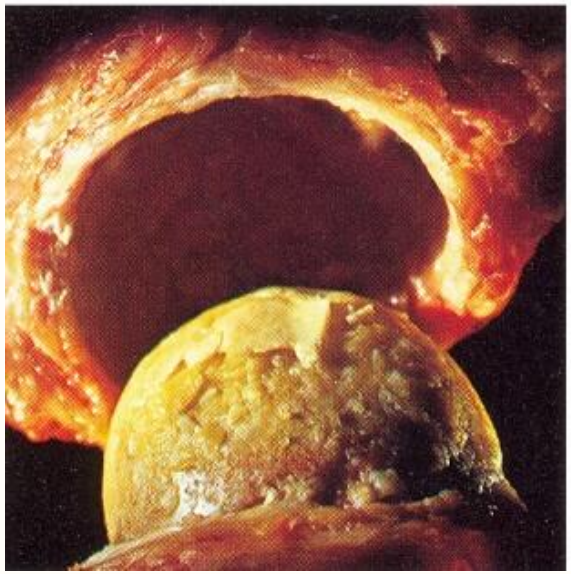
- Ball and Socket Joint
  - shoulder and hip
- Hinge Joint
  - elbow (humeroulnar), knee
- Saddle joint
  - carpometacarpal joint at base of thumb
- Pivot Joints
  - between dens and atlas or radioulnar joint at elbow
- Gliding Joint
  - between carpals of wrist or between tarsals of foot
- Condyloid Joint
  - metacarpophalangeal joints at the bases of the fingers
- Temporomandibular joint has some aspects of condyloid, hinge and gliding joints.

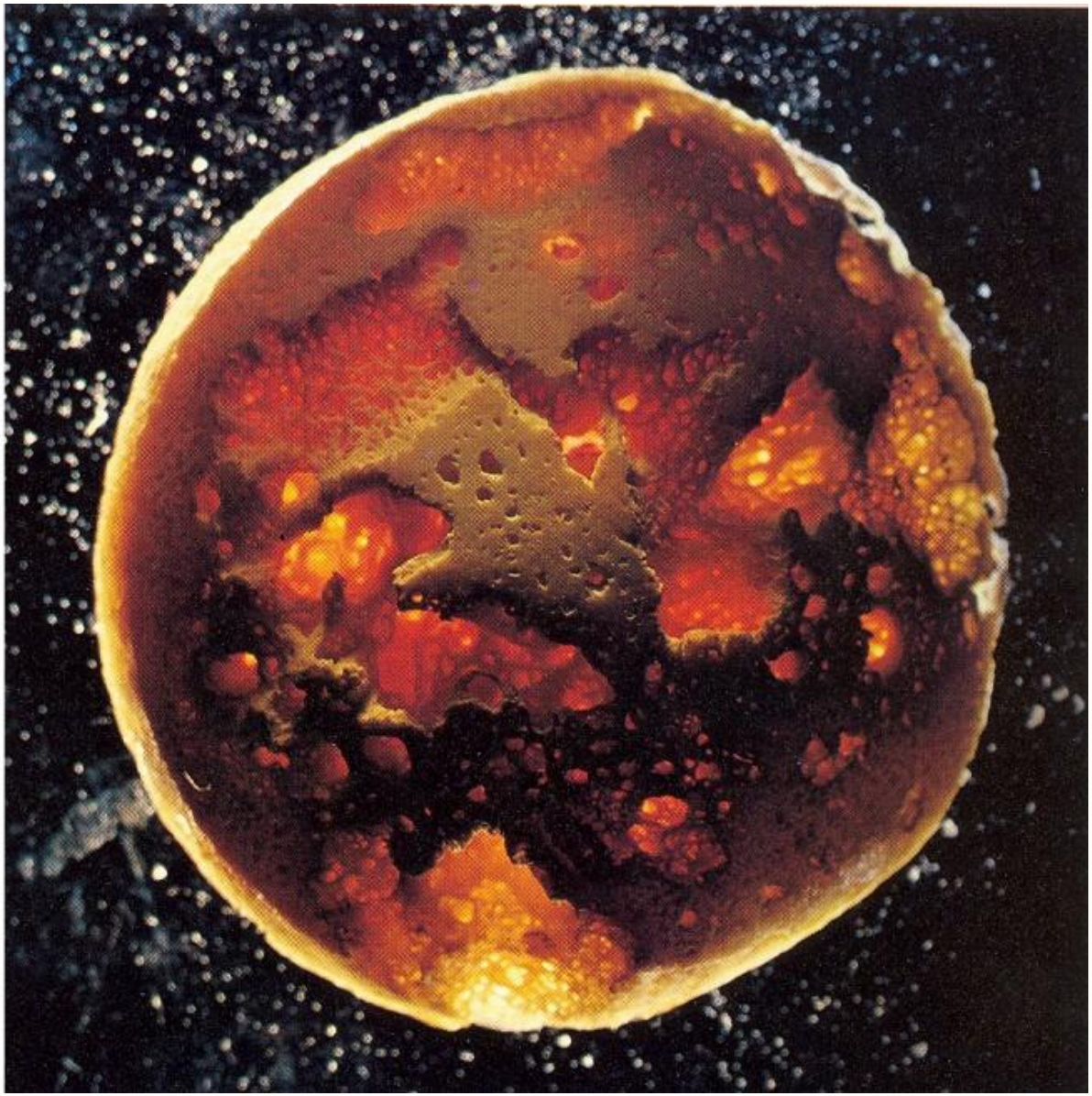
Arthritis

- Arthritis is a broad term for joint pain and inflammation.
- Osteoarthritis results from years of joint wear
  - articular cartilage degenerates
  - bone spurs develop on exposed bone tissue
  - symptoms include crackling sounds during movement and pain
- Rheumatoid Arthritis is an autoimmune attack on the joint
  - immune cells attack the joint with antibodies and enzymes
  - degrades the cartilage and synovial membrane
  - remissions occur, steroids and aspirin may control inflammation

Rheumatoid Arthritis

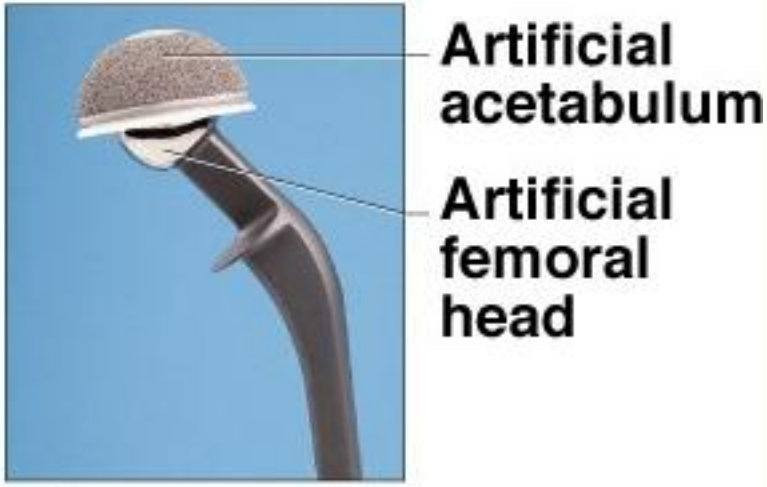






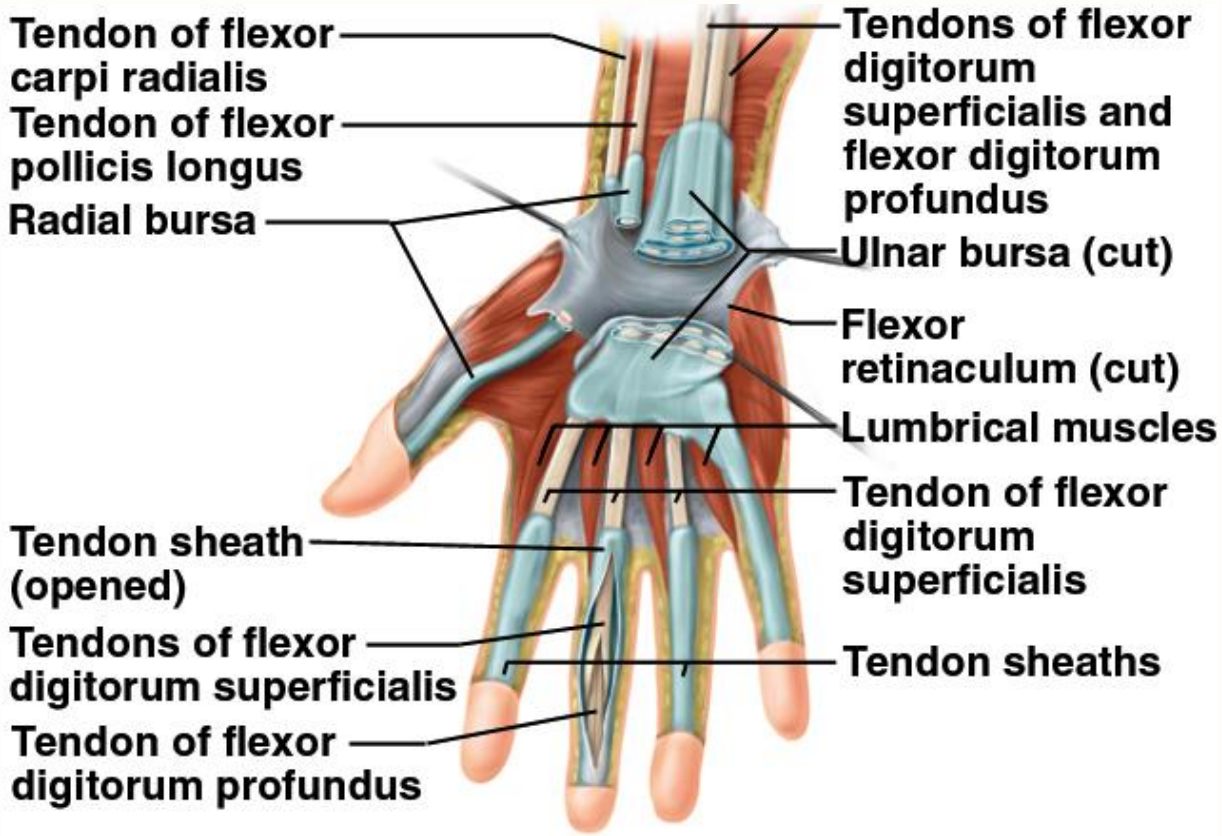
Upper left image is the head of the humerus from a young, healthy individual. Lower left image is the humeral head of a person with rheumatoid arthritis. Image at the right is the head of a femur from an individual with rheumatoid arthritis. from “The Body Victorious” by L. Nilsson (1987) ISBN 0-385-29507-3

Joint Prostheses



Arthroplasty is replacement of a diseased joint with an artificial device called prosthesis.

Tendon Sheaths and Bursae



- Tendon sheaths are tubes of synovial membrane that wrap around tendons as in the hand and foot.
- Bursa is a saclike extension of a joint capsule that extends between or around nearby tendons allowing them to slide easily past each other.