Joint Structure and Function

Types of Joints

Components of Joints

Joint mechanics

Dave Buttle K131 <d.j.buttle@sheffield.ac.uk>
The Function of Joints

- To allow movement in 3-dimensions
- To bear weight
- To transfer the load evenly to the musculoskeletal system
Tissues associated with joints

• Bone
• Muscle
• Cartilage
• Synovium
• Synovial fluid
• Dense fibrous tissue/capsule, tendons and ligaments
Types of joints – structural classification

**Fibrous**
e.g. teeth sockets

**Cartilaginous**
e.g. intervertebral discs

**Synovial**
e.g. metacarpophalangeal

[http://rst.gsfc.nasa.gov/Intro/Part2_26b.html](http://rst.gsfc.nasa.gov/Intro/Part2_26b.html)
**Types of joints – functional classification**

1. **Synarthroses** - immovable joints, mostly fibrous (eg. skull sutures)

2. **Amphiarthroses** - slightly moveable joints, most cartilaginous (eg. intervertebral discs)

3. **Diarthroses** - freely moveable joints, mostly synovial (eg. hip)
Fibrous joints 1- Sutures

Occur only between bones of the skull (allow skull growth in development)
Adjacent bones interdigitate
Junction filled with very short tissue fibres
To allow growth after birth a baby has fibrous tissue between skull bones which develops into sutures.
Fibrous joints 2 - Syndesmoses

Bones are connected by a cord (ligament) or sheet (interosseous membrane) of fibrous tissue. Amount of movement permitted is proportional to length of fibre.
Fibrous joints 3 - Gomphoses

A peg-in-socket fibrous joint found only in tooth articulation
Cartilaginous joints - Synchondroses

The bones are directly connected by hyaline cartilage. These are usually amphiarthroses ie. slightly moveable eg. costal cartilage of the ribs.
Cartilaginous joints - Symphyses

Here the connecting cartilage is a pad or plate of fibrocartilage eg. Intervertebral discs

Cartilaginous Joint — Symphysis

- Pubic bone
- Gelatinous core
- Band of fibrocartilage
- Body of vertebra
- Spinous process
- Intervertebral disks
- Fibrocartilaginous disk of symphysis pubis
Intervertebral disc

Designed to take load; water-binding proteoglycan-rich nucleus pulposus surrounded by tough fibrous annulus fibrosus – a shock absorber
Joint Classification Summary

- Suture
- Fibrous → Synarthrosis → Syndesmosis → Gomphosis
- Cartilaginous → Amphiarthrosis → Synchondroses
- Synovial → Diarthrosis
Synovial Joints

Articulating bones are separated by a fluid-filled cavity

Most joints of the body fit into this category

There are five characteristic features of synovial joints....
1. Articular cartilage

2. Joint capsule - the inner layer is the **synovial membrane**.

3. Joint (synovial) cavity - a space filled with synovial fluid.

4. Synovial fluid

5. Reinforcing ligaments
Types of Cartilage

Elastic Cartilage
- Elastic fibers
- Interacellular material
- Nucleus
- Chondrocyte
- Lacuna

Fibrocartilage
- Nucleus
- Collagenous fiber
- Interacellular material
- Chondrocyte in lacuna

Hyaline Cartilage
- Nucleus
- Interacellular material
- Chondrocyte in lacuna
- Nucleus
- Intercellular material
Additional components associated with some synovial joints

1. Bursae – fluid filled sacs lined by synovial membrane
2. Menisci – Discs of fibrocartilage
Articular (Hyaline) Cartilage

- Almost frictionless surface
- Resists compressive loads
- High water content
- Low cell content
- No blood supply
**Hyaline Cartilage: The secret to a pain-free joint.**

Low friction coefficient = friction-free articulation!

**Table 7.4: Typical friction coefficients**

<table>
<thead>
<tr>
<th>Materials and conditions</th>
<th>μ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber on concrete, wet or dry, static</td>
<td>1.0</td>
</tr>
<tr>
<td>Brake material on cast iron, clean and dry, static</td>
<td>0.4</td>
</tr>
<tr>
<td>Brake material on cast iron, lubricated with mineral oil, static</td>
<td>0.1</td>
</tr>
<tr>
<td>Graphite on steel, static</td>
<td>0.1</td>
</tr>
<tr>
<td>Hickory on dry snow, waxed, 4 m/s, −3°C, dynamic</td>
<td>0.18</td>
</tr>
<tr>
<td>Hickory on dry snow, unwaxed, 4 m/s, −3°C, dynamic</td>
<td>0.08</td>
</tr>
<tr>
<td>Ice on ice, 4 m/s, 0°C, dynamic</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Articular cartilage in human joints, dynamic:</strong></td>
<td></td>
</tr>
<tr>
<td>Human knee; Charmley (1960)</td>
<td>0.005–0.02</td>
</tr>
<tr>
<td>Porcine shoulder; McCuichen (1962)</td>
<td>0.02–0.35</td>
</tr>
<tr>
<td>Canine ankle; Linn (1967, 1968)</td>
<td>0.005–0.01</td>
</tr>
<tr>
<td>Unsworth et al. (1975)</td>
<td>0.01–0.04</td>
</tr>
<tr>
<td>Malcom (1976)</td>
<td>0.002–0.03</td>
</tr>
</tbody>
</table>

# Cartilage: Composition

Water, proteoglycans, collagen

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Collagen (% dry wt.)</th>
<th>Proteoglycan (% dry wt.)</th>
<th>H₂O (% wet wt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articular cartilage</td>
<td>50-73</td>
<td>15-30</td>
<td>58-78</td>
</tr>
<tr>
<td>Meniscus</td>
<td>75-80</td>
<td>2-6</td>
<td>~70</td>
</tr>
<tr>
<td>Intervertebral disc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- nucleus pulposus</td>
<td>15-25</td>
<td>~50</td>
<td>70-90</td>
</tr>
<tr>
<td>- annulus fibrosus</td>
<td>50-70</td>
<td>10-20</td>
<td>60-70</td>
</tr>
</tbody>
</table>

Table I. Composition of articular cartilage, meniscus, and intervertebral disc.
Articular Cartilage: Structure

Alignment of collagen fibrils
Articular cartilage zones

Superficial

Middle

Deep

Synovial Fluid – the joint lubricant

- Covers articulating surfaces with thin film (e.g. healthy knee just 0.5 ml fluid)
- Modified from plasma by synovial membrane (synoviocytes)
- Fluid, proteins, charged sugars that bind water eg. hyaluronate
- Result: slimy fluid (like egg white)
- Reduces friction during articulation
Synovial membrane

- Sits on the joint capsule and encloses **synovial cavity**
- Only a few cells thick
- Can have villi and projections to increase surface area
- Secretes synovial fluid components eg. hyaluronate

http://www.anatomy.dal.ca/Human_Histology/Lab6/2LH12.html
### Tendons and Ligaments

<table>
<thead>
<tr>
<th>Ligaments: connect bone to bone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stabilise joints</strong></td>
</tr>
<tr>
<td>Similar to a tendon but with less regularly arranged fibres</td>
</tr>
<tr>
<td>Can stretch up to 6% before breaking and may contain more elastic fibres than tendon (generalisation)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tendons: connect bone to muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stabilise joints</strong></td>
</tr>
<tr>
<td>Made of dense regular connective tissue, rich in type I collagen</td>
</tr>
<tr>
<td>Allow muscles to be accommodated at a distance from their insertion, e.g. muscles of the forearm move the fingers. Provides a solid base (insertion to bone) on which muscles can pull</td>
</tr>
</tbody>
</table>

**Muscles** also **stabilise joints**
Tendon structure – the use of collagen modules (tropocollagen) and hierarchical structure

The musculotendinous junction – where most ruptures occur

Tendon and muscle.
A lever can apply a torque (twist) about a fulcrum, proportional to force $\times$ distance.

In a first class lever, the fulcrum is in the middle (the elbow joint) the force is at one end (the triceps muscle) and the resistance is at the other end (the weight being pulled).
In a **second class** lever, the fulcrum is at one end (e.g. **Temperomandibular joint**) the force is at the other end (the muscles of the chin) and the resistance is in the centre (the muscles attached to the **coronoid process**).
In a **third class** lever, the fulcrum is at one end (eg. **elbow joint**), the force is in the middle (the **biceps muscle**) and the resistance is at the other end (the **weight** being pulled).
Movement of synovial joints

(a) Ball-and-socket joint
(b) Condyloid joint
(c) Gliding joint
(d) Hinge joint
(e) Pivot joint
(f) Saddle joint
Body movements

Joint Movements (1)
- Hyperextension
- Extension
- Flexion
- Dorsiflexion
- Plantar flexion
- Adduction
- Abduction

Joint Movements (2)
- Extension
- Flexion
- Rotation
- Supination Pronation
- Circumduction

Joint Movements (3)
- Protraction
- Retraction
- Elevation
- Depression
- Eversion
- Inversion
Ball and socket joint

Held securely in place by strong ligaments and heavy cylindrical joint capsule
Hip joint ligaments

Main stabilising ligaments:
- Iliofemoral
- Pubofemoral
- Ischiofemoral
A **ball and socket** joint

Stability sacrificed for range of movement. Joint capsule is loose. Dislocation of the shoulder quite common. The rotator cuff muscles help in stabilisation but are prone to injury, especially at tendon insertion sites.
Ligaments stabilising the shoulder

Glenoidal labrum - fibrocartilage
Coracohumeral ligament
Three glenohumeral ligaments
Transverse humeral ligament
Tendons and Muscles stabilising the shoulder

Long head of **Biceps brachii**

Tendons of the rotator cuff: **subscapularis**, **supraspinatus**, **infraspinatus** and **teres minor**
Knee Joint – complex!

Not a hinge joint, femur/tibia is condyloid (ovoid head of one bone moves in an elliptical cavity of another) and femur and patella gliding. Joint capsule thin but strengthened by many tendons and ligaments.
Knee joint – ligaments

Femur

Lateral condyle

Lateral meniscus

Lateral condyle

Fibular collateral ligament

Fibula

Tibia

Posterior cruciate ligament

Medial condyle

Anterior cruciate ligament

Medial meniscus

Medial condyle

Tibial collateral ligament

Patellar ligament (cut)

Knee Joint Ligaments — Anterior View
Injuries to weight-bearing joints

• Can cause changes in the stability of the joint which can lead to inappropriate weight-bearing and the development of osteoarthritis later in life

• Beware, all you sports-people!
Elbow Joint

Classic **hinge joint** between humerus and ulna and **gliding joint** between humerus and radius

Single joint cavity but synovial membrane partly divides ulnar and radial portions
Ligaments and tendons at the elbow

Medial

Ulnar Collateral Ligament

Humerus

Medial epicondyle

Tendon of biceps brachii muscle

Annular ligament

Radius

Ulna

Coronoid process

Ulnar collateral ligament

Lateral

Radial Collateral Ligament

Humerus

Lateral epicondyle

Annular ligament

Radial collateral ligament

Radius

Ulna

Olecranon process
Joints are **spaces** between bones bridged by fibrous and/or cartilaginous tissue.

Cartilaginous joints allow more movement than fibrous joints, **synovial joints** allow the most movement.

In synovial joints the bone ends are covered by cartilage to aid **friction-free movement** and **absorb compressive stresses**.

**Synovial fluid** in the joint cavity increases lubrication of the joint.

**Ligaments and tendons**, dense connective tissue, stabilise the joints.