Anatomy of the Upper Limb
Welcome to MSK anatomy!

We are looking forward to working with you once again in the MTU and hope you will enjoy the sessions. A sound understanding of the structure and function of the limbs is crucial for clinical practice.

The purpose of this handbook is to help guide and focus your learning. It is not a comprehensive guide to everything you need to know, but does contain core information. It is **important that you read the relevant section of the handbook before coming to the classes**; some familiarity with the structures that you will see in the MTU will help you get the most out of the session and your discussions with each other and with the demonstrators. The questions in the handbook are designed to focus on core knowledge and stimulate active learning; they are not designed to replicate the type or difficulty of questions that will be included in the summative examinations. Discuss the answers within your group during the practical sessions – ask a demonstrator for help if you are stuck or cannot agree on the answer!

You are encouraged to read more widely around the topics using additional resources, either before or after sessions. There are many good resources available - use one that is reliable, but that also works for you – you might need to try out a few before you find ones you like. See page 4 for recommendations.

Special thanks are extended to Dr Sam Birks for creating original illustrations for this handbook.

The handbook contains core information, points of clinical relevance and some questions to help stimulate discussion in classes and consolidate your learning. However, the handbook does not contain detailed dissection instructions; only a brief overview of the dissection tasks for each practical session is included. Detailed dissection instructions will be available in the MTU when you come for your sessions and will also be uploaded to Minerva in advance of the sessions, if you would like to read them beforehand. The dissection videos will also be available on Minerva for you to watch in advance, just as in semester 1.

We hope you will enjoy the classes.

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Acknowledgments

Special thanks are extended to Dr Sam Birks for the creation of original illustrations for this handbook, which are reproduced here with permission.
Recommended Resources

Textbooks
A good quality undergraduate anatomy textbook is great for reference when you have questions or gaps in your understanding. They are also an excellent place to start if you’d like to read more widely around a topic, but without getting into excessive detail that you don’t require at this stage of your training. Textbooks are reliable as they undergo a process of peer-review by experts. Many contain high quality diagrams that can be especially helpful. The information covered is very similar across undergraduate textbooks, so choose a book based on personal preference; you’re much more likely to use a book that you like the style of and find easy to use. You don’t need the most up-to-date editions. The following books are all recommended:

- **Gosling’s Colour Atlas of Human Anatomy** (Elsevier) - contains excellent prosection images alongside text and schematic images. **Available online through the University Library**.

- **Gray’s Anatomy for Students** (Elsevier) – includes excellent images.

- **Moore’s Essential Clinical Anatomy** (Lippincott, Williams and Wilkins) – contains more text than Gray’s.

- **Moore’s Clinically Orientated Anatomy** (Lippincott, Williams and Wilkins) – the ‘parent’ of Essential Clinical Anatomy, it is a larger book which contains more detailed text and more clinical information.

- **Anatomy: An Essential Textbook** (Thieme) has excellent images and text is presented in a bullet-point style, which might work better for you than text presented in paragraphs.

If you want a book that contains only images, look for an anatomy atlas.

Online resources
There are lots of anatomy resources available online, but be discerning about which ones you choose. **TeachMeAnatomy** is a very good and well-established online resource:

[https://teachmeanatomy.info/](https://teachmeanatomy.info/)
Introduction to the Upper Limb

Why Study the Upper Limb?

It is very common for patients to present with upper limb problems. Traumatic injuries of the upper limb are common, such as fractures, joint dislocations, ligament tears and lacerations to the hands. Acute and chronic musculoskeletal problems are also commonly encountered in General Practice. Joint problems are common and can be painful, cause swelling, limit movement and may impair someone’s ability to work or go about daily tasks. Musculoskeletal pain can also be a symptom of an underlying sinister pathology, such as malignancy or deep infection, so must always be taken seriously.

The limbs contain many tissues. If a patient has a problem in a limb, such as pain, limited movement or weakness, there could be a problem with:

- **Bones**: fracture, dislocation, infection, malignancy
- **Muscles and tendons**: muscle disease, muscle spasticity, ruptured/inflamed/diseased tendon, muscle weakness, muscle ischaemia
- **Joints**: degeneration or inflammation of the articular cartilage, excess fluid in the joint, infection, debris in the joint, joint capsule pathology (e.g. a torn capsule)
- **Neurological** – pathology of the brain, spinal cord, peripheral nerves or neuromuscular junction

Approach to the Muscles and Movements of the Upper Limb

There are lots of muscles in the upper limb. Things can get complicated because:

- some muscles perform more than one action
- some muscles have a main, or prime action, but also contribute to other movements
- for some muscles, different textbooks / resources do not completely agree on all the actions they perform or contribute to

It is easy to get bogged down by this kind of thing, but try not to. We will mostly talk about the prime actions of muscles; we will mention additional actions where these are important and generally agreed upon. We will look at muscles in terms of the compartments they are situated in, and we will concentrate on the general actions of the muscles that are located in the same compartments.

Another aspect of musculoskeletal anatomy that is complex is muscle attachments. Muscle attachments are key to understanding and visualising how muscles move joints, however, most anatomy texts describe the very specific areas of bones that muscles attach to. To complicate matters, some muscles are attached to several bones, or to multiple sites on a bone. This means that muscle attachments are very
difficult to simply memorise without being able to visualise where the muscle is and how it moves its associated joint(s). We will often talk about attachments in simple terms. Where it is important to understand specific muscle attachments, we will talk about them in more detail.

The names of muscles are complicated as they are Latin. Although this can be overwhelming when you first start learning musculoskeletal anatomy, try not to let this frustrate you. The muscle names are descriptive and almost always tell you something useful about the muscle, for example, its size, shape, location, attachments or action. You will become familiar with the terminology more quickly than you think, but be patient at first!

Parts of the Upper Limb

Typically, patients will refer to the whole upper limb as the ‘arm’. In anatomy and medicine, specific terms are used to describe the different regions of the upper limb.

- The pectoral (or shoulder) girdle – this term describes the clavicle (collar bone), the scapula (the shoulder blade) and the muscles attached to these bones.

- The arm – this is the region between the shoulder and the elbow joints. The bone of the arm is the humerus. The arm contains anterior and posterior muscle compartments.

- The forearm – this is the region between the elbow and the wrist joint. The bones of the forearm are the radius and ulna. Like the arm, it contains anterior and posterior muscular compartments. The forearm compartments contain lots of muscles.

- The hand – the hand lies distal to the wrist. The hand is typically discussed in terms of the palm and the dorsum; the palm is complex and contains many small muscles that move the digits.

Joints of the Upper Limb

The upper limb contains large joints and small joints.

- Glenohumeral joint – the shoulder joint. It is a synovial ball and socket joint formed by the articulation between the scapula and the proximal humerus. It is highly mobile, which is key for allowing us to position our hand.

- Elbow joint – this allows flexion and extension of the forearm. It is a synovial hinge joint formed by the articulation of the distal humerus with the ulna and
radius. It is extremely important in allowing us to bring things towards us and is crucial for activities of daily living, such as eating and washing ourselves.

- **Proximal and distal radioulnar joints** - these synovial joints between the radius and ulna allow pronation and supination of the forearm and hand.

- **Radiocarpal joint** – otherwise known as the wrist joint. It is a synovial joint formed by the articulation between the distal radius and two of the carpal bones (small bones of the wrist). It allows flexion, extension, abduction and adduction.

The radioulnar and wrist joints are a little more complex to classify. We will look at the movements at these joints in the practical sessions.

The scapula moves on the posterior chest wall, but there is no bony articulation between these structures, so it is not a joint in the traditional sense. However, movement of the **scapula over the chest wall** is crucial for normal movement of the shoulder joint.

There are many **small joints** in the upper limb, for example, those between the carpal (wrist) bones and those between the small bones of the digits. We will look at these in due course.

**Examination of the Upper Limb and Surface Anatomy**

You will learn how to undertake an examination of the upper limbs. A sound understanding of the bones and joints of the upper limb, the muscle compartments and their innervations, and how the muscles move the upper limb joints is vital to:

- examining a patient competently
- interpreting your examination properly
- forming a differential diagnosis
- making an appropriate plan for investigation, referral or treatment

Before your first session, recap the following movements of the upper limb and we will go over them in the first practical session. **Make sure you can show the following movements on yourself.**

- **Pectoral girdle** – the scapula can move anteriorly and posteriorly on the chest wall. The anterior movement is called **protraction** – we do this when we reach out our arm to push open a door. Posterior movement is called **retraction** – otherwise known as ‘squaring the shoulders’. The scapula can also be elevated, depressed and rotated.

- **Shoulder joint** – flexion, extension, abduction, adduction, medial (internal) rotation, lateral (external) rotation, and circumduction. Movements of the
shoulder are almost always accompanied by movements of the scapula on the chest wall. When we raise our upper limb, the scapula rotates.

- **Elbow joint** – flexion and extension.
- **Radioulnar joints** – pronation (palm down) and supination (palm up).
- **Wrist joint** – flexion and extension, abduction and adduction.
- **Fingers** – flexion and extension, adduction and abduction.

Movements of the thumb are a bit more complicated; we will look at these when we study the hand.
Session 16: The Shoulder, Muscles of the Scapula and Posterior Arm.

- Dissection Video: Session 16
- Dissection Instructions: Available in the MTU and on Minerva in advance

Aims and Objectives

1. Identify and demonstrate the **key anatomical landmarks** of the clavicle, scapula and proximal humerus.
2. Describe the anatomy and **movements of the pectoral girdle**; identify the **muscles and joints** responsible for the movements of the pectoral girdle.
3. Know the **general attachments and innervations** of the muscles of the pectoral girdle.
4. Understand the factors that contribute to the **movement and stability** of the shoulder joint, including the **rotator cuff** muscles.
5. Understand the **actions, attachments and innervation of triceps** in the posterior arm.
6. Know where the **radial nerve** lies in the posterior arm and understand the **consequences of injury** to the radial nerve in the arm.

Clinical points

- Know where important neurovascular structures lie close to the bones of the shoulder and how these may be injured by fracture of the bones or joint dislocation; work out what **functional deficits** would arise from such neurovascular injuries.
- Understand the functional and clinical consequences of **shoulder dislocation**.
- Understand the term ‘**frozen shoulder**’ and how this pathology presents.
- Understand how the **rotator cuff** can be injured and how this presents.

In the MTU you will **dissect / study** the:

- muscles that attach the scapula to the spine (and therefore move the scapula)
- muscles that attach the scapula to the humerus (and therefore move the shoulder joint)
- posterior arm
- key anatomical landmarks of the clavicle, scapula, and proximal humerus
Part 1 - Key Anatomical Landmarks: the clavicle, scapula and humerus.

In this and future MSK practical sessions, you will identify the key bony landmarks of the relevant bones, either on a skeleton or using disarticulated bones. We look at bony landmarks so we can:

- understand the structure of joints and their movements
- understand muscle attachments and therefore how muscles move joints
- understand where we can palpate bony structures on clinical examination
- interpret X-ray images of bones and joints and describe our findings to colleagues
- visualise how bony injuries (fractures, dislocations) may injure nearby nerves and vessels

The Clavicle

The clavicle is a slender, S-shaped bone, which is easily palpable in most individuals. It is commonly fractured.

- It articulates with the sternum at its medial end (the sternoclavicular joint) and with the acromion of the scapula at its lateral end (the acromioclavicular joint) – both of these joints are synovial.
- The clavicle holds the limb away from the trunk so that it can move freely.

The Scapula

The scapula is mostly flat but has some important bony projections. Some parts of the scapula can easily be palpated. Movements of the scapula can also be seen on examination.

- Its posterior surface bears a ridge of bone called the spine which is usually easily palpable.
- The lateral end of the spine expands to form the acromion – this articulates with the lateral end of the clavicle. The acromion can also usually be palpated quite easily.
- The clavicle, scapula and the attached muscles comprise the pectoral girdle.
- The lateral aspect of the scapula has a shallow fossa - the glenoid fossa - which articulates with the proximal humerus to form the shoulder (glenohumeral) joint. The glenoid fossa is shallow, making it a poor fit for the humerus. This increases the range of movement possible at the shoulder, but compromises the stability of the joint.
• Just superior and inferior to the glenoid fossa are two small projections of bone – these are the supraglenoid tubercle and the infraglenoid tubercle, respectively. They are important sites for muscle attachments and we’ll come back to them.

The Humerus

The humerus is the long bone of the arm. It has a shaft and expanded proximal and distal ends. In this session we will focus on the features in the upper part of the humerus.

• The head of the humerus articulates with the glenoid fossa of the scapula. The head of the humerus bears a groove called the anatomical neck.

• Laterally, the proximal humerus bears a projection of bone called the greater tubercle – an important site for muscle attachments. A smaller anterior projection – the lesser tubercle – is also a site for muscle attachment.

• Just distal to the tubercles, the bone narrows and becomes continuous with the shaft. This region is called the surgical neck and is clinically important because:
  ➢ it is commonly fractured, especially in the elderly as a result of a fall
  ➢ the axillary nerve, runs close to this region and can be injured by fractures of the surgical neck or dislocation of the humeral head.

• The upper lateral aspect of the humeral shaft has a slight protuberance called the deltoid tuberosity; the site of attachment for the deltoid muscle.

• Another key landmark is the radial (or spiral) groove – this marks the path of the radial nerve over the posterior aspect of the upper part of the humeral shaft. The radial nerve runs very close to the humerus here and can be injured in mid-shaft humeral fractures.

Part 2 - Movements and Muscles of the Pectoral Girdle

Movements

Whilst the clavicle can move, we will concentrate on the movements of the scapula – these are vital for normal movement of the shoulder joint.

The scapula lies on the posterior chest wall. The scapula is surrounded by muscles and so there is no bony articulation between the scapula and the posterior thoracic wall. The movements of the scapula are:
• Protraction - this extends the upper limb, for example, when we stretch out the arm to push open a door.
• Retraction - ‘squaring’ the shoulders
• Elevation - shrugging the shoulders
• Depression – lowering the shoulders
• Rotation - this tilts the glenoid fossa cranially to aid elevation of the upper limb

Rotation of the scapula is very important. When raising the arm above the head, for every $2^\circ$ of abduction of the shoulder, the scapula rotates $1^\circ$. If you observe someone from behind as they raise their arm, you will see the movement of the scapula.

Muscles
Several muscles attach the scapula to the vertebral column. When these muscles contract, the scapula moves. The attachment points of the muscles and the orientation of the muscle fibres determine the direction in which the scapula moves when the muscles contract.

In this session we are looking at the muscles of the posterior aspect of the pectoral girdle; you saw the muscles of the anterior pectoral girdle (pectoralis major, pectoralis minor and serratus anterior) in semester 1. Serratus anterior is the key muscle involved in protraction of the scapula – we will return to this muscle in the next session.

There are two large superficial muscles of the posterior pectoral girdle. These are:
• Trapezius
• Latissimus dorsi

These are large, flat muscles with extensive attachments to the vertebral column (and in the case of trapezius, to the skull). Latissimus dorsi attaches to the anterior aspect of the proximal humerus, not the scapula (so it moves the shoulder joint, rather than the scapula), but it is often considered with the posterior pectoral muscles, plus we will see it in the first practical session.

Locate trapezius and latissimus dorsi on the image overleaf:
There are three smaller, deeper muscles:

- Levator scapulae
- Rhomboid major
- Rhomboid minor

These muscles attach the medial border of the scapula to the vertebral column.

Locate these muscles on the image above.

To summarise, all these muscles attach the scapula to the vertebral column, except latissimus dorsi (which inserts onto the humerus).
The movements produced by these muscles are:

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement of the scapula* (*except Latissimus dorsi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latissimus dorsi</td>
<td>Extends, adducts and medially rotates the humerus</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Elevates</td>
</tr>
<tr>
<td>Rhomboid major</td>
<td>Retracts</td>
</tr>
<tr>
<td>Rhomboid minor</td>
<td>Retracts</td>
</tr>
</tbody>
</table>

Anatomy textbooks often give very detailed information about the exact locations of muscle attachments. Being able to visualise muscle’s attachments is key to understanding why it moves a joint in the way it does, but it is not necessary to learn detailed and exact points of attachment. Attachments are often described in terms of origins and insertions. The origin is the more ‘fixed’ or stable bone, and the insertion point is located on the bone that moves when the muscle contracts.

The attachments of these muscles are:

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Attachment (Origin)</th>
<th>Attachment (Insertion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius</td>
<td>Skull, cervical and thoracic vertebrae</td>
<td>Clavicle and scapula (spine and acromion)</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>Lower thoracic vertebrae</td>
<td>Humerus - upper anterior</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Upper cervical vertebrae</td>
<td>Scapula - medial border</td>
</tr>
<tr>
<td>Rhomboid minor</td>
<td>C7 and T1</td>
<td>Scapula - medial border</td>
</tr>
<tr>
<td>Rhomboid major</td>
<td>Thoracic vertebrae</td>
<td>Scapula - medial border</td>
</tr>
</tbody>
</table>

**Innervations**

Most of the muscles of the posterior pectoral region are innervated by branches that arise from a structure called the brachial plexus - a complex network of nerves that innervate the upper limb. We will learn about the brachial plexus and dissect it in the next session.

**Trapezius** is not supplied by the brachial plexus but instead is innervated by the 11th cranial nerve; the accessory nerve (more specifically, its spinal root – we’ll learn more about this when we study the cranial nerves). Therefore, testing the function of trapezius is part of the cranial nerve examination.
Latissimus dorsi is innervated by a branch of the brachial plexus called the thoracodorsal nerve – we will look for this nerve in the next session. You do not need to know the names of the specific branches that innervate levator scapulae and the rhomboids.


Movements
The shoulder joint has an extensive range of movement. This allows us to position our hand where we want to.

The movements possible at the shoulder joint are flexion, extension, abduction, adduction, medial (internal) and lateral (external) rotation and circumduction.

Make sure you know what these look like and that you can demonstrate them on yourself.

When we look at the scapula and humerus, we can see that the fit between the joint surfaces – the glenoid fossa of the scapula and the head of the humerus – is poor. This is key for extensive mobility at the joint. The downside of this poor fit is that the joint is less stable – the shoulder joint is the most commonly dislocated joint in the body.

Muscles
Six muscles attach the scapula to the humerus. They move and stabilise the shoulder joint. You may see them in textbooks referred to as 'scapulo-humeral' muscles. Except for deltoid, all of these muscles lie deep to the posterior scapular muscles (discussed above).

The six muscles are:

- Deltoid
- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres minor
- Teres major
Alongside their individual actions moving the shoulder joint, four of these muscles work together to provide vital stability to the shoulder joint – they are referred to as the 'rotator cuff’. The four rotator cuff muscles are supraspinatus, infraspinatus, subscapularis, and teres minor.

**Deltoid and Teres Major**

**Deltoid** is the large muscle over the lateral aspect of the shoulder. It attaches the humerus to the lateral part of the clavicle and to the spine of the scapula. It gives the shoulder its rounded contour.

- It inserts onto the humerus at a landmark called the **deltoid tuberosity**. We will look for this landmark in the practical session.
- It is a powerful **abductor** of the shoulder joint. However, deltoid cannot initiate abduction – another muscle initiates the first 20° (or so) of abduction before deltoid takes over. Additionally, the anterior and posterior fibres of deltoid contribute to **flexion and extension** of the shoulder, respectively.
- It is innervated by a major branch of the brachial plexus called the **axillary** nerve. Injury to the axillary nerve can lead to **atrophy** and **weakness** (or even paralysis) of deltoid, which impacts greatly on activities of daily living (imagine not being able to abduct your shoulder).

**Teres major** is an interesting muscle as although it arises from the posterior aspect of the scapula, it inserts onto the **anterior** aspect of the humerus. This arrangement explains its action as a **medial rotator and adductor** of the shoulder joint. If you’re struggling to visualise this, ask a demonstrator for help in the session.

**The Rotator Cuff**

**Supraspinatus, infraspinatus, teres minor** and **subscapularis** all move the shoulder joint. They are short muscles which attach the scapula to the tubercles of the humerus.

- **Supraspinatus, infraspinatus** and **teres minor** originate from the **posterior** surface of the scapula and insert onto the **greater tubercle**. Their tendons fuse with the **fibrous capsule** that surrounds the shoulder joint.

- Identify these three muscles on the image overleaf, which shows the **posterior** aspect of the pectoral and shoulder region:
• On the diagram above, locate the **quadrilateral space**. This is a square-shaped space bounded by: teres minor above, teres major below, the long head of triceps medially and the surgical neck of the humerus laterally. The **axillary nerve** travels through this space to enter the posterior scapula region and innervate deltoïd and teres minor.

• **Subscapularis** originates from the **anterior** surface of the scapula and inserts onto the **lesser tubercle** of the humerus. The image on the next page shows the **anterior** aspect of the pectoral and shoulder region - we can **subscapularis** and the insertion of **teres major** onto the **anterior** aspect of the humerus.
The attachments and actions of deltoid, teres major and the rotator cuff are summarised below:

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Action at the shoulder joint</th>
<th>Origin from the scapula</th>
<th>Insertion (on the humerus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltoid</td>
<td>Abduction beyond $\sim 20^\circ$</td>
<td>Spine and acromion (plus clavicle)</td>
<td>Deltoid tuberosity</td>
</tr>
<tr>
<td>Teres major</td>
<td>Medial rotation</td>
<td>Posterior surface, inferior part of lateral border</td>
<td>Anterior humerus</td>
</tr>
<tr>
<td></td>
<td>Adduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>First $20^\circ$ of abduction</td>
<td>Supraspinous fossa</td>
<td>Greater tubercle - superior facet</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>Lateral rotation</td>
<td>Infraspinous fossa</td>
<td>Greater tubercle - middle facet</td>
</tr>
<tr>
<td>Teres minor</td>
<td>Lateral rotation</td>
<td>Lateral border</td>
<td>Greater tubercle - inferior facet</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>Medial rotation</td>
<td>Subscapular fossa</td>
<td>Lesser tubercle</td>
</tr>
</tbody>
</table>
Supraspinatus is **clinically important** because as it travels from the supraspinous fossa to the greater tubercle it travels under the **acromion**. The tendon can become inflamed and **pinched** between the acromion and humerus during movements of the shoulder. This is called **impingement** and the typical finding on examination of the patient is a ‘**painful arc**’.

**Stability**

The poor fit of the articular surfaces allows for the extensive range of movement at the shoulder joint (facilitated by a **loose joint capsule**), but this compromises stability. However, although shoulder dislocation is common, most of us have **not** dislocated a shoulder. This tells us that there are factors working to stabilise the joint and **compensate** for the poor fit of the articular surfaces.

As a group, the four **rotator cuff** muscles provide vital **stability**:

- contraction of the rotator cuff muscles holds the head of the humerus in the shallow glenoid.
- the rotator cuff tendons **fuse** with the **capsule** of the shoulder joint.

The rotator cuff muscles and/or tendons can be injured, become inflamed or degenerate. When this happens, patients usually experience pain and impaired movement, and the stability of the joint is compromised.

Other structures contribute to the stability of the shoulder:

- a rim of fibrocartilage around the margin of the glenoid fossa – the **glenoid labrum** – deepens the shallow fossa and aids stability. We’ll look for this in the in the next practical session
- the capsule is reinforced by **ligaments**
- the **tendon of biceps brachii**, which lies in the anterior arm, also reinforces the joint – we will see this in the MTU too.

**Part 5 - Posterior Arm**

The arm lies between the shoulder and elbow. Intermuscular septa, which extend from the deep brachial fascia which surrounds the arm, separate the arm into anterior and posterior **compartments**.

A single large muscle – **triceps brachii** – lies in the posterior compartment of the arm. It has three muscle bellies, or heads (*tri* = three; *ceps* = head) which all converge via a common tendon onto a single insertion point – the **olecranon** of the ulna. The muscle crosses the posterior aspect of the elbow joint, therefore when it contracts, it **extends** the elbow.
The three heads of triceps are individually named and originate from different regions:

- **Long** head: infraglenoid tubercle of the scapula. It is the most medial part of triceps.
- **Lateral** head: posterior humerus, proximal to the radial groove.
- **Medial** head: posterior humerus, distal to the radial groove.

Because of its attachment to the scapula, the **long head** is able to contribute to extension of the **shoulder** joint.

All three parts of triceps are innervated by the **radial nerve**. The radial nerve is a major terminal branch of the **brachial plexus**. It winds around the **posterior** aspect of the humerus in the radial (spiral) groove between the medial and lateral heads of...
triceps. The nerve lies on the bone in this region, thus fractures of the shaft of the humerus can injure it (see Part 6: Clinical Relevance – Radial nerve injury)

Part 6 - Clinical Relevance

Adhesive capsulitis = ‘Frozen shoulder’

The main symptoms of this condition are pain and stiffness in the shoulder. The capsule of the joint becomes inflamed, stiff and tight. Adhesions may develop. It tends to be seen in middle-aged people, and is more common in women and people with diabetes, but the cause is not understood. There is no cure, and supportive treatment with physiotherapy is the main treatment. It can take up to three years to resolve.

Rotator cuff injury

The rotator cuff can be injured by acute trauma or by repetitive use. The tendons can also degenerate with age. Tears of the rotator cuff are usually painful at rest and on movement, and cause weakness.

If the supraspinatus tendon becomes injured and inflamed it may become impinged between the acromion and the humeral head, as the space here is small. The first part of abduction is not painful, but between 60° – 120° of abduction, the inflamed tendon is compressed against the acromion, and this is when patients experience pain. Beyond this, the pain subsides again. This presentation is called a ‘painful arc’ and is indicative of supraspinatus tendon pathology. An inflamed tendon may ultimately rupture.

Dislocation of the shoulder

In a dislocation, the humeral head moves out of the glenoid fossa. Anterior dislocation is common and almost all dislocations are anterior. It is often caused by blunt force trauma, such as a fall. Posterior dislocation is very uncommon – but for this reason it can be easily missed. Posterior dislocation is associated with vigorous muscle contraction, such as an epileptic seizure. X-ray imaging confirms the direction of displacement of the humeral head and whether there is an associated fracture. Both types of dislocation can injure the axillary nerve – see below.
Axillary nerve injury

Because of its close proximity to the surgical neck of the humerus, the axillary nerve can be injured by fractures in this region (which are common in the elderly) or dislocation of the shoulder joint. The motor fibres of the axillary nerve innervate deltoid and teres minor. Its sensory fibres innervate a patch of skin over the upper lateral arm. Injury to the axillary nerve can therefore result in weakness or paralysis of deltoid – this presents functionally as difficulty abducting the shoulder - and altered sensation or numbness over the upper lateral arm.

Radial nerve injury

As it travels along the radial groove of the posterior humerus, the radial nerve lies very close to the bone, thus fractures of the humeral shaft can injure the nerve. This can lead to weakness or paralysis of the muscles that are innervated by the radial nerve ‘downstream’ of the point at which the nerve is injured. This causes weakness of triceps; on examination, the patient would have impaired elbow extension. A radial nerve lesion at the level of the mid-arm also affects movements at the wrist, because the radial nerve innervates all the muscles of the posterior forearm, which extend the wrist. We’ll come back to this when we study the forearm.

Part 7 - Questions to Consolidate Learning

Aim to have a serious attempt at these and discuss them with your group in the session before checking your answers in Minerva. If you’re struggling with any of the questions, discuss them with a demonstrator in the class.

1. Which muscles are responsible for shoulder abduction?
2. Describe the movements of the scapula and the humerus during shoulder abduction.
3. Which nerve innervates trapezius? How would you test if the nerve was functioning?
4. Which nerve is at risk of injury in shoulder dislocation? What functional deficits would result and how would you examine a patient to test for these deficits?
5. What structures stabilise the shoulder joint?
6. Which parts of the pectoral girdle and shoulder joint can be palpated on examination?
7. In a patient with a mid-shaft humeral fracture:
   a) What movements could you test to try and ascertain whether the radial nerve had been injured?
   b) Why might triceps be weak compared to the unaffected arm, but not paralysed?
8. Which muscles comprise the rotator cuff, and where do they insert on the humerus?
Session 17: The Axilla, Brachial Plexus and Anterior Arm.

- Dissection Video: Session 17
- Dissection Instructions: Available in the MTU and on Minerva in advance

Aims and Objectives

1. Describe the **boundaries of the axilla** and its **contents**.
2. Appreciate the clinical significance of the **axillary lymph nodes**.
3. Describe the origin and course of the **axillary artery** and **vein**.
4. Describe the anatomy of the **brachial plexus** from its origin in the neck to its terminal branches (i.e. roots, trunks, divisions, cords and branches).
5. Describe the origin and course of the **axillary, radial, musculocutaneous, median and ulnar nerves** in the arm. Know which **muscle compartments** and **areas of skin** these nerves innervate.
6. Understand that, when the plexus is injured, the motor and sensory deficits seen will vary depending on the site of the injury; appreciate that careful history-taking and examination are required to deduce where a lesion is located.
7. Name and identify the **muscles** in the **anterior compartment** of the arm; know their actions, innervations and general attachments.

Clinical points

- Neurovascular structures at risk from **injuries** to the axilla
- **Axillary lymph nodes** and breast malignancy
- **Ulnar nerve** injury
- **Brachial plexus injuries**:
  - Upper brachial plexus injury (Erb’s Palsy)
  - Lower brachial plexus injury (Klumpke’s Palsy)
  - Horner’s syndrome – may be associated with brachial plexus injury
- **Brachial plexus block**

In the MTU you will **dissect / study** the:

- axilla
- brachial plexus
- muscles in the anterior compartment of the arm
- anterior aspect of the rotator cuff (i.e. we will see subscapularis)
- key anatomical landmarks of the humerus
Part 1 - Key Anatomical Landmarks: the humerus.

In the practical session, you will identify the key bony landmarks of the humerus.

- The humerus is the long bone of the arm. In the last session we looked at the features in the upper part of the humerus. They comprise the head, anatomical neck, surgical neck, greater tubercle, lesser tubercle, the deltoid tuberosity and the radial (or spiral) groove. We will recap these in the practical session.

- The shaft of the humerus expands distally to form bony prominences called the medial and lateral epicondyles – these are palpable on examination. The distal humerus bears further prominences, the trochlea and capitellum, which articulate with the trochlear notch of the ulna and the head of the radius, respectively, at the elbow joint.

Part 2 - The Axilla

The axilla is the anatomical term for the armpit – the space between the trunk and the upper arm. It is pyramid-shaped and has six boundaries. The boundaries and the structures that form them are listed below:

- **Anterior wall** – pectoralis major and minor
- **Posterior wall** – subscapularis, teres major and latissimus dorsi
- **Lateral wall** – upper humerus
- **Medial wall** – serratus anterior and chest wall
- **Apex** – first rib, clavicle and scapula. It is the passage between the neck and the axilla
- **Base** – skin and fascia between the chest wall and arm

The axilla contains fat and several important structures:

- **Lymph nodes** – drain the upper limb, chest and the abdominal wall as far as the umbilicus.
- **Axillary artery** – the major artery of the upper limb.
- **Axillary vein** – the major vein draining the upper limb.
- **Brachial plexus** (specifically the cords and branches) – innervates the upper limb.

Let’s look at each of these in turn.

**Axillary Lymph Nodes**

- There are five groups of lymph nodes in the axilla. They drain the upper limb, breast, chest wall, scapular region and the abdominal wall as far as the umbilicus.
• The lymph nodes located in the apex of the axilla – the **apical nodes** – receive lymph from all other lymph nodes in the axilla. Because they drain lymph from a large area, the axillary lymph nodes are often involved in the spread of cancer (metastasis).

• The axillary lymph nodes are particularly associated with cancer of the breast. Detection of a lump in the armpit may be the first sign of breast malignancy. The axillary lymph nodes can also enlarge in response to infection.

**Axillary Artery and Vein**

• The **axillary artery** is the continuation of the subclavian artery – recall where the right and left subclavian arteries arise from. The subclavian artery travels under the clavicle and into the axilla. The axillary artery gives rise to several branches; one above pectoralis minor, two behind it and three below it. The axillary artery continues into the arm as the **brachial artery** (it becomes the brachial artery as it crosses the inferior border of teres major).

• The **axillary vein** is a large vein which drains the upper limb and is continuous with the subclavian vein. The axillary vein travels alongside the axillary artery. Recap how the right and left subclavian veins return venous blood to the heart. The axillary vein is formed by the union of the deep veins of the arm with the basilic vein – we’ll learn more about these structures later.

• Penetrating wounds of the axilla can cause **life-threatening bleeding** if either of these vessels are injured. One can attempt to halt bleeding from these vessels by compressing them against the humerus.

**The Brachial Plexus**

The word **plexus** derives from Latin and translates as ‘braid’ or ‘plait’. In anatomy, the term ‘plexus’ is used to describe complex networks of nerves or veins.

• The brachial plexus is the network of nerves that provides motor and sensory innervation to the upper limb.

• It is formed by the **spinal nerves** that leave the lower cervical spinal cord segments and the first thoracic spinal cord segment: these are spinal nerves C5, C6, C7, C8 and T1. The spinal nerves are mixed nerves, which carry motor and sensory fibres.

• The brachial plexus is often discussed in five segments: **roots, trunks, divisions, cords and branches**.
**Roots:** the five spinal nerves (C5 - T1) that exit the spinal cord and collectively give rise to the brachial plexus. They are found in the neck.

**Trunks:** also located in the neck
- C5 and C6 combine to form the **superior trunk**
- C7 continues as the **middle trunk**
- C8 and T1 combine to form the **inferior trunk**

**Divisions:** each trunk divides into an **anterior** and a **posterior** division under the clavicle

**Cords:** named relative to their position around the second part of the axillary artery
- anterior divisions of the **superior and middle trunks** combine = **lateral cord**
- posterior divisions of **all the trunks** combine = **posterior cord**
- anterior division of the **inferior trunk** continues as the **medial cord**

**Branches:** located in the axilla
- **Axillary** – a branch from the **posterior** cord
- **Radial** – the continuation of the **posterior** cord
- **Musculocutaneous** – a branch from the **lateral** cord
- **Ulnar** – a branch from the **medial** cord
- **Median** – formed by branches from the **lateral and medial** cords

In addition to giving rise to the five large terminal branches in the axilla, the different segments of the brachial plexus give rise to other nerves that innervate the shoulder and pectoral muscles. We will name some of these branches and the muscles they innervate, but you do not need to know from which parts of the brachial plexus they arise.

We will concentrate on the origin and course of the five major **terminal branches** and the muscle compartments and regions of skin they innervate.
Part 3 - Terminal Branches of the Brachial Plexus

Axillary Nerve

We looked at the axillary nerve in the last session. It innervates deltoide and teres minor and a small region of skin over the upper lateral arm.

- It is a branch of the posterior cord and contains fibres from spinal nerves C5 and C6.
- It runs close to the surgical neck of the humerus and is vulnerable to injury in fractures of the surgical neck of the humerus or dislocations of the humeral head.

Radial Nerve

We also looked at the radial nerve in the last session. The radial nerve innervates triceps in the posterior arm. The radial nerve also innervates all the muscles in the posterior compartment of the forearm – these muscles are extensors of the wrist and digits. The radial nerve also innervates regions of skin over the arm, forearm and hand.

- It is the continuation of the posterior cord and contains fibres from C5 - T1.
- It runs along the radial (spiral) groove on the posterior surface of the humerus and is vulnerable here in mid-shaft fractures of the humerus.

Musculocutaneous Nerve

The musculocutaneous nerve innervates the three muscles in the anterior arm – we will see these muscles in this session.

- It arises from the lateral cord and contains fibres from spinal nerves C5 - C7.
- It continues as a sensory nerve that innervates a region of skin over the forearm.
- Because of its location, the musculocutaneous nerve is rarely injured in isolation.

Median and Ulnar Nerves

The median and ulnar nerves do not innervate any muscles in the arm. These nerves innervate muscles in the anterior forearm and the hand. We will see them in more detail in later sessions. For now, we will just consider their formation and course through the arm.
The **median nerve** is formed from contributions from both the **lateral** and **medial cords**.

- It contains fibres from **C6-T1** (some texts say C5-T1 as it may receive a small contribution from C5 - do not worry about this).
- It innervates **most** of the muscles of the **anterior forearm**, which are **flexors** of the **wrist and digits**.
- It also innervates the **small muscles of the thumb**. It innervates skin over the lateral aspect of the palm of the hand and over the lateral digits*.
- It is most **vulnerable** in the **arm** as it crosses the anterior aspect of the elbow, in a region called the **cubital fossa**.

The **ulnar nerve** is formed by the continuation of the **medial cord**, after it has given a contribution to the median nerve.

- It contains fibres from spinal nerves **C8 - T1**.
- It innervates **most** of the **small muscles in the hand** and therefore is vital for fine movements of the digits.
- It also innervates skin over the medial aspect of the hand and medial digits*.
- It is **vulnerable** to injury **behind the medial epicondyle** as it lies in a superficial position here (it is easily palpable in this location) – most injuries to the ulnar nerve occur here.

**Injuries** to different parts of the brachial plexus result in different clinical presentations. The most catastrophic type of brachial plexus injury occurs when all five roots of the brachial plexus are injured – this is uncommon but devastating, as it effectively denervates the whole of the upper limb.

* We will look at the innervation of the skin of the hand by the median, ulnar and radial nerves in more detail when we study the hand.

**Part 4 - Anterior Arm**

The anterior compartment of the arm contains three muscles: biceps brachii, brachialis and coracobrachialis.

- All three act as **flexors**
- All three are innervated by the **musculocutaneous** nerve.
**Biceps brachii**

Biceps brachii (bi = two; ceps = head) lies most superficially in the anterior arm. It has two muscle bellies – the long head and the short head. Proximally, both heads are attached to the scapula; the long head to the supraglenoid tubercle and the short head to the coracoid process.

The two muscle bellies converge via a common tendon onto the radial tuberosity of the radius. The tendon of the long head of biceps pierces the capsule of the shoulder joint and helps to stabilise the joint.

Biceps is a flexor of the elbow joint – you can feel biceps contracting if you place a hand over it whilst flexing your elbow. However, because it crosses the shoulder joint, it is also capable of contributing to flexion of the shoulder joint.

Biceps is also a powerful supinator of the forearm when the elbow is flexed. The design of screwdrivers (for right-handed people) capitalises on this. When a right-handed person tightens a screw (turning to the right) they supinate the forearm – however, the power to turn the screw very tightly depends upon the elbow being flexed at the same time; supination is much weaker if the elbow remains extended. If you are struggling to visualise this, ask a demonstrator in the practical class.

**Brachialis**

Brachialis lies deep to biceps. Proximally, it is attached to the anterior aspect of the lower half of the shaft of the humerus and also crosses the elbow joint to insert distally upon the ulna tuberosity. It is a powerful flexor of the elbow joint. It does not cross the shoulder joint, so cannot act upon it.

**Coracobrachialis**

Coracobrachialis is a smaller muscle that attaches proximally to the coracoid process of the scapula and distally to the medial aspect of the middle part of the humerus. It crosses the shoulder joint and acts upon it as a weak flexor.

**Part 5 - Cubital Fossa**

The cubital fossa is the region anterior to the elbow joint. In clinical practice it is often referred to as the antecubital fossa and abbreviated in medical notes to 'ACF'.

The cubital fossa is a triangular-shaped region with three borders:

- the lateral border is formed by brachioradialis, a posterior forearm muscle
- the medial border is formed by pronator teres, an anterior forearm muscle
the superior border (or base) is formed by an imaginary line drawn between the **medial** and **lateral epicondyles** of the **humerus**.

The **apex** is most distal, ‘pointing’ towards the forearm and hand.

**Contents of the Cubital Fossa**

- **The tendon of biceps brachii** can be traced into the cubital fossa as it travels to its insertion point on the **radial tuberosity**. The tendon can **easily be palpated** with the elbow flexed – the tendon feels hard. The biceps tendon is tapped with a tendon hammer to examine the biceps **reflex** – you’ll learn more about this when you learn to perform a peripheral neurological examination.

- **The bicipital aponeurosis** is a fascial extension of the biceps tendon. It separates the superficial veins from deeper structures in the fossa; the **brachial artery** and the **median nerve**.

- **The brachial artery** lies medial to the biceps tendon – it can usually be easily palpated (palpation is easiest with the elbow extended). The brachial artery **bifurcates** into its terminal branches – the **radial** and **ulnar** arteries – in the cubital fossa. Great care must be taken during venepuncture and cannulation to avoid puncturing the brachial artery. Deep veins accompany the arteries.

- **The median nerve** lies medial to the brachial artery. The median nerve does not innervate any muscles in the arm, but travels through the anterior compartment of the arm and the cubital fossa on its journey to the anterior forearm and hand.

- **The radial nerve** also passes through the lateral aspect of the cubital fossa. It lies deep to brachioradialis.

The **superficial veins** that lie in the subcutaneous tissue over the cubital fossa are of clinical importance as they are commonly accessed for:

- venepuncture (taking blood)
- intravenous access (i.e. placing a cannula for administering fluids or drugs)

It is important to understand the anatomy of this region to perform these procedures safely – the median nerve and brachial artery **must not** be mistakenly punctured or cannulated.

It is worth mentioning that although the anatomy of the superficial veins in the region of the cubital fossa is represented similarly across textbooks / images, the arrangement of the veins can be variable between individuals (and different between the right and left arms of the same person).
Part 6 - Clinical Relevance

Axillary lymph node metastasis

Because lymph from the breast drains to the axillary lymph nodes, breast malignancy typically metastasizes first to these nodes. A malignant axillary node may be felt as a lump in the armpit, and may be noticed before a mass in the breast itself. Axillary lymph nodes can be biopsied to assess whether or not breast malignancy has metastasized and can be removed as part of the patient’s treatment.

Because they drain lymph from the upper limb, removal of the nodes can lead to fluid accumulation and swelling in the affected upper limb.

Removing axillary lymph nodes potentially risks two nerves that are in close proximity to the axilla:

- The long thoracic nerve innervates serratus anterior and lies superficially on the surface of the muscle in the medial wall of the axilla. Injury to this nerve causes weakness or paralysis of serratus anterior. One of the functions of this muscle is to hold the medial border of the scapula flat against the posterior chest wall. If the muscle is paralysed, the medial border lifts off the chest wall and appears to ‘stick out’. This is called a ‘winged’ scapula.

- The thoracodorsal nerve to latissimus dorsi is also vulnerable to injury as it runs along the subscapularis muscle, which forms the posterior wall of the axilla.

Ulnar nerve injury

The ulnar nerve is vulnerable in the lower arm as it travels behind the medial epicondyle – it is superficial here. Fractures of the medial epicondyle may injure the nerve here. Injury to the nerve at this level leads to motor impairments of the hand (as it innervates most of the small muscles of the hand) and causes sensory impairment in the hand (the medial side of the hand and the medial 1½ fingers). It is extremely common to bang the elbow in this region - referred to as the ‘funny bone’. A blow to the nerve here causes pain and tingling in the same regions of the hand.

Upper brachial plexus injury = ‘Erb’s Palsy’

In this type of injury - which is uncommon - the upper parts of the brachial plexus are affected. It may involve C5 - C6, or C5 - 7. The typical picture is one of paralysis of the lateral rotators of the shoulder and the extensors of the wrist. The affected limb typically appears medially rotated with the wrist flexed.
It is typically caused by trauma – specifically mechanisms that stretch the head away from the shoulder. This is typically seen when someone is thrown from a motorbike or a horse. It may also be seen in newborns if the baby’s shoulder becomes stuck during delivery and its neck is excessively stretched.

**Lower brachial plexus injury** = ‘Klumpke’s Palsy’

This type of injury is also uncommon. The lower parts of the brachial plexus are affected, typically C8 and T1. The typical picture is one of paralysis of the **small muscles of the hand**. Again, it is typically caused by trauma – specifically mechanisms that forcefully and suddenly pull the arm upwards – this stretches the lower nerves of plexus. It may be sustained by babies during delivery if the arm is forcefully pulled.

**Horner’s syndrome**

Horner’s syndrome is the triad of drooping of the eyelid (ptosis), a constricted pupil (miosis) and lack of sweating (anhidrosis) on one side of the face. It results when the sympathetic nerve supply to the face is interrupted. The T1 spinal nerve carries sympathetic fibres which are destined to supply the face. Therefore a brachial plexus injury affecting the T1 nerve root may result in Horner’s syndrome.

**Brachial plexus block**

This is a form of regional anaesthesia and can be used as an alternative to general anaesthesia for surgery on the upper limb. Under ultrasound guidance, local anaesthetic is infiltrated around the nerves of the plexus, which anaesthetises the upper limb. Before surgery commences, the anaesthetist tests the sensory and motor function of the upper limb to ensure complete anaesthesia; if the block is not complete, more local anaesthetic can be infiltrated, using ultrasound to target the specific nerves which are not completely anaesthetised.
Part 7 - Questions to Consolidate Learning

Aim to have a serious attempt at these and discuss them with your group in the session before checking your answers in Minerva. If you’re struggling with any of the questions, discuss them with a demonstrator in the class.

1. Describe the route of arterial blood from the left ventricle to the right axillary artery and from the left ventricle to the left axillary artery.
2. Draw and label a diagram of the brachial plexus showing the roots, trunks, divisions, cords and the five terminal branches.
3. Describe how the cords of the brachial plexus are situated relative to the second part of the axillary artery.
4. Which regions of the body drain directly to the axillary lymph nodes? Briefly outline the clinical importance of the axillary lymph nodes.
5. What key structures can be found in the cubital fossa? Where are they located relative to each other?
Session 28: The Anterior Forearm and Wrist.

➢ Dissection Video: Session 28
➢ Dissection Instructions: Available in the MTU and on Minerva in advance

Aims and Objectives

1. Identify and demonstrate the key anatomical landmarks of the radius and ulna
2. Identify the bones of the carpus, hand and digits; identify those that are commonly injured
3. Recap the anatomy of the cubital fossa: location, boundaries and contents
4. Know the actions of the muscles of the anterior compartment of the forearm; understand they are arranged into superficial, middle and deep layers
5. Identify the carpal tunnel and know what structures pass through it. Describe and understand the typical presentation of carpal tunnel syndrome
6. Describe the origin, course and distribution of the major arteries of the forearm and hand and their branches; understand the importance of anastomoses between branches
7. Demonstrate where the pulses of the brachial, radial and ulnar arteries can be palpated
8. Describe the course of the major veins of the upper limb; understand the difference between deep and superficial veins
9. Identify the common sites for intravenous access

Clinical points:

- Intravenous access at the superficial veins of the cubital fossa
- Carpal tunnel syndrome
- Fracture of the forearm bones
- Medial epicondylitis
- Flexor tendon injuries
- Neurovascular injuries
- Ganglion

In the MTU you will dissect / study the:

- superficial veins of the forearm
- muscles of the anterior forearm
- major arteries of the forearm and branches
- key anatomical landmarks of the radius, ulna, carpus and hand
Part 1 - Key Anatomical Landmarks: the radius, ulna, wrist and hand.

In the practical session, you will identify the key bony landmarks of the radius, ulna, carpus and hand.

Radius and Ulna

The radius and ulna are the two bones of the forearm. In life, they are connected by an interosseous membrane.

- They articulate at their proximal ends with the distal humerus to form the elbow joint: the trochlea notch of the ulna articulates with the trochlea of the humerus and the radial head articulates with the capitellum of the humerus. Flexion and extension occur at the elbow joint.

- The radius and ulna also articulate with each other at the proximal and distal radioulnar joints. These joints allow pronation and supination of the forearm and hand. The radius pivots around the ulna. The anterior compartment of the forearm contains two muscles that act as pronators.

- Distally, the radius articulates with two of the small bones of the wrist, or carpus, to form the radiocarpal joint. The radiocarpal joint is referred to as the wrist joint. Flexion, extension, abduction and adduction occur at the wrist joint. These movements are achieved by muscles in the anterior and posterior forearm.

The Carpus

The carpus is comprised of eight small bones that articulate with each other at small joints. The bones are roughly arranged into two rows of four bones, one proximal, one distal. The distal radius articulates with two of the bones in the proximal row – the scaphoid and lunate – to form the radiocarpal joint.

- The proximal row of carpal bones comprises, from lateral to medial: the scaphoid, lunate, triquetral and the pisiform. The pisiform is not a true carpal bone, but rather is a small bone that develops in the tendon of flexor carpi ulnaris.

- The distal row of carpal bones comprises, form lateral to medial: the trapezium (base of the thumb), trapezoid, capitate (located centrally and is the largest carpal bone) and the hamate. The hamate bears a bony process anteriorly (the hook), which is obvious on the bone and is palpable on examination.
The most commonly fractured carpal bone is the **scaphoid** – usually by a fall on to an outstretched hand. A scaphoid fracture has potentially serious consequences – we’ll look at this when we study the hand.

**The Hand**

The hand is composed of many small bones and joints.

- The **metacarpals** lie distal to the carpus.
- The bones of the digits are **phalanges**; there are three phalanges in each finger and two phalanges in the thumb.

Several muscles of the forearm travel into the hand and move the fingers and thumb. We will learn more about the bones and joints of the hand when we study the hand.

**Part 2 - Cubital Fossa**

Let’s recap the anatomy of the cubital fossa, as it is important clinically and important for this practical session. It is the triangular-shaped region anterior to the elbow, bounded by **brachioradialis laterally** and **pronator teres** medially.

- **Pronator teres** is an **anterior forearm** muscle which we’ll look at in the next section
- **Brachioradialis** is considered a **posterior forearm** muscle and we’ll learn more about it when we look at the posterior forearm.
- The **superior border** (or base) is formed by a line drawn between the **medial** and **lateral epicondyles** of the humerus.

Recall the important structures found in the cubital fossa:

- **Biceps tendon**
- **Median nerve**
- **Brachial artery** which bifurcates into the radial and ulnar arteries
- **Superficial veins** lie in the subcutaneous tissue over the cubital fossa and are key sites for IV access
Part 3 - Muscles of the Anterior Compartment

The first thing to say is that the muscles of the forearm are complex and difficult to understand – there are lots of them and they have complex names. Try not to feel overwhelmed. **It will take time for you to get your head around, so be patient!** Remember that the names of the muscles will almost always give you some helpful information – for example, the action of the muscle or its attachments. Use the names to help you, rather than allowing them frustrate you!

There are eight muscles in the anterior compartment. We can make some general statements about them as a group:

- They are arranged in **three** layers: superficial, middle and deep
- **Most** of them act as **flexors** of the wrist, fingers or thumb
- **Most** of them are innervated by the **median** nerve

**Superficial Layer**

There are **four** muscles in the superficial layer. From lateral to medial these are:

- Pronator teres
- Flexor carpi radialis
- Palmaris longus
- Flexor carpi ulnaris

These superficial muscles are attached proximally to the **medial epicondyle** of the humerus. For this reason, this region of the humerus is also commonly referred to as the **'common flexor origin'.**

On the diagram on the next page, **identify** the four superficial muscles, their tendons and the common flexor origin.
**Pronator teres** – as its name suggests – is a pronator (of the proximal radioulnar joint), rather than a flexor.

**Flexor carpi radialis** (FCR) flexes and abducts the wrist. It inserts onto the radial ‘side’ of the wrist, hence “flexor carpi radialis”.
**Palmaris longus** has a small muscle belly but a long, thin, easily recognised tendon when present (approx. 15% of us do not have one – you wouldn’t miss it!). Its tendon inserts into the fascia of the palm of the hand.

**Flexor carpi ulnaris** (FCU) flexes and adducts the wrist. It inserts onto the ulnar ‘side’ of the wrist, hence “flexor carpi ulnaris”. This muscle is another exception to the general rule, as it is innervated by the **ulnar** nerve, not the median. The ulnar nerve and artery lie at the lateral side of its tendon at the wrist.

We will look at the **insertion points** of these muscles in the next session when we look at the palm of the hand.

**Middle Layer**

There is one muscle in the middle layer; **flexor digitorum superficialis** (FDS). It gives rise to **four tendons**. Its name tells us that it is a flexor of the digits – so we can deduce that its tendons must travel beyond the wrist, into the hand and to the fingers (digits 2-5). We will look at the **insertion points** of the tendons in more detail in the next session when we dissect the palm of the hand.

On the diagram on the previous page, **identify** flexor digitorum superficialis and its tendons. It is innervated by the median nerve, which travels **between** flexor digitorum superficialis and one of the deep muscles, flexor digitorum profundus.

**Deep Layer**

There are three muscles in the deep layer:

- Flexor digitorum profundus
- Flexor pollicis longus
- Pronator quadratus

**Flexor digitorum profundus** (FDP) is a flexor of the digits, and lies deep to flexor digitorum superficialis. It too gives rise to **four tendons**, which travel into the hand and to the fingers (digits 2-5). The tendons of superficialis and profundus are closely related in the hand and digits – we will look at the **insertion points** of its tendons in more detail in the next session when we dissect the palm of the hand.

The muscle is interesting as it has a **dual** innervation.

- The **lateral half** of the muscle, which gives rise to the tendons that travel to the index and middle fingers, is innervated by the **median** nerve.
- The **medial half** of the muscle, which gives rise to the tendons that travel to the ring and little fingers, is innervated by the **ulnar** nerve.
This is clinically important as injuries to either the ulnar or median nerve only affect one half of the muscle.

On the diagram below, identify the three deep muscles:
**Flexor pollicis longus** (FPL) flexes the thumb (pollex = thumb). ‘Longus’ distinguishes it from another muscle, flexor pollicis brevis, which is much smaller and lies within the hand (we’ll see this when we look at the hand).

**Pronator quadratus** is the deepest forearm muscle (it is considered a fourth layer by some). It is square-shaped (‘quadratus’) and lies over the distal ends of the radius and ulnar. It pronates the distal radioulnar joint.

On the diagram on the previous page, **identify** the three deep muscles.

To summarise, all the anterior forearm muscles are:
- **flexors**, except for pronator teres and pronator quadratus
- innervated by the **median** nerve, except FCU and the medial half of FDP.

**Part 4 - The Carpal Tunnel**

The **carpal tunnel** is a narrow passageway at the wrist.
- Its floor and sides are formed by the **carpal bones**.
- A fibrous band called the **flexor retinaculum** completes the tunnel, forming the **roof**. It is attached to the scaphoid and trapezium laterally and to the hook of the hamate and pisiform medially.

The **tendons** of the **anterior forearm** muscles that insert into the digits travel through the carpal tunnel. These are the tendons of:
- flexor digitorum superficialis (4 tendons, to digits 2-5)
- flexor digitorum profundus (4 tendons, to digits 2-5)
- flexor pollicis longus (1 tendon, to the thumb [1st digit])

The **median nerve** also travels through the carpal tunnel. The carpal tunnel is very narrow – the tendons and median nerve are tightly packed into it. Any condition that further reduces space in the carpal tunnel, such as swelling of the tendons or arthritis between the joints of the carpal bones, will increase the pressure in the tunnel. This can **compress** the median nerve and cause **carpal tunnel syndrome** (CTS).

A patient with carpal tunnel syndrome typically presents with:
- **impaired** or **altered sensation** over the skin of the hand supplied by the median nerve - the patient may experience tingling, numbness or pain in the hand.
- **weakness** of the hand muscles supplied by the median nerve – particularly the **small muscles of the thumb**.
It is important to recognise and treat CTS. If left untreated, the small muscles of the thumb may **atrophy** and weakness may be **permanent**, which has serious consequences for a patient. The **flexor retinaculum** is divided to alleviate the compression.

The radial artery, ulnar artery and ulnar nerve do **not** travel through the carpal tunnel.

**Part 5 - Major Vessels of the Forearm**

**Arteries**

The brachial artery bifurcates in the cubital fossa into two terminal branches – the **radial** artery and the **ulnar** artery.

- The **radial** artery travels along the **lateral** aspect of the forearm and it can usually be easily palpated at the wrist.
- The **ulnar** artery travels along the **medial** aspect of the forearm – it can also be palpated at the wrist, but it is often not as easy to palpate as the radial artery, as it may be partly covered by the tendon of flexor carpi ulnaris.

**Locate these pulse points on yourself.**

The radial and ulnar arteries **enter the hand**. They **anastomose** in the palm of the hand to form **palmar arches** – we shall see these when we look at the hand. These anastomoses ensure that the hand **remains adequately perfused** in the event that either artery becomes occluded or injured.

**Veins**

There are both **superficial** and **deep** veins in the upper limb, which **communicate** with each other. Ultimately, all venous blood drains to the **axillary** vein.

Two important **superficial veins** of the upper limb are the **cephalic vein** and the **basilic vein**.

- The **cephalic** vein courses **laterally** in the forearm and the **basilic** vein courses **medially**.

- They are typically connected to each other in the region of the **cubital fossa** by the **median cubital** vein.
• **Try and identify these superficial veins on yourself.** Even if you can’t see them, you may be able to **palpate them** – they will feel springy. They are commonly used for venepuncture and intravenous access.

• The **basilic** vein courses proximally into the arm. It receives the **deep veins** of the arm to form the **axillary** vein. The **cephalic** vein courses proximally in the lateral aspect of the arm and drains into the **axillary** vein.

**Deep veins** accompany arteries and they are often paired. For example, two brachial veins accompany the brachial artery. Deep veins of the upper limb ultimately drain to the axillary vein.

**Part 6 - Clinical Relevance**

**Fracture of the forearm bones**

Because the ulna and radius are connected by joints, the interosseous membrane, ligaments and muscles, they tend to act as one. Injuries often fracture both bones, or cause a fracture of one and a dislocation in the other.

• Fracture of the **radial head** is a common, usually sustained by a fall onto the outstretched hand. The tricky bit is that these fractures are not always apparent on X-ray images. However, abnormal soft tissue signs on X-ray are often an indirect sign that a fracture is present, even if one cannot be seen.

• Fracture of the **distal radius**, otherwise known as a Colles’ fracture, is very common in older people, especially females (in whom osteoporosis is more common). It is usually caused by a fall onto an outstretched hand.

**Medial epicondylitis**

This is inflammation of the tendinous insertions of the superficial forearm flexors at the medial epicondyle. It tends to be caused by repetitive use and strain of the muscles. Pain is felt around the medial epicondyle and may radiate down the forearm. Also called ‘Golfer’s elbow’, as it is seen in golfers.

**Injury to the flexor tendons**

The flexor tendons are at risk from lacerations over the anterior forearm and wrist. In patients with such injuries, it is important to **test the movements of the wrist and fingers** to ascertain whether any tendons have been injured. Patients with
confirmed or suspected tendon injuries require a surgical assessment. Failure to recognise tendon injuries may leave patients with permanent impairment.

**Neurovascular injuries in the anterior forearm**

Injuries to the anterior forearm and wrist can also injure nerves and vessels.

- The *radial artery*, *ulnar artery* and *ulnar nerve* lie relatively superficially at the wrist. Injury to the ulnar nerve at the wrist impairs the function of most of the small muscles of the hand.
- The *median nerve* lies deep in the forearm and so is fairly well protected, but it can be injured by deep lacerations. At the wrist the nerve lies more superficially, so may be injured here. Injury to the median nerve at the wrist impairs the function of the small muscles of the thumb and sensation in the regions of the hand supplied by the median nerve.
- Vessels and nerves may also be compressed or kinked by fractures or dislocations of the forearm or carpal bones. Patients must always be appropriately assessed for neurovascular injuries.

**Ganglion**

A ganglion is a cystic swelling that commonly appears on the dorsum of the wrist. They feel soft and are typically non-tender. They contain synovial fluid.

**Part 7 - Questions to Consolidate Learning**

Aim to have a serious attempt at these and discuss them with your group in the session before checking your answers in Minerva. If you’re struggling with any of the questions, discuss them with a demonstrator in the class.

1. Name the three major superficial veins of the forearm. What course do they take?
2. Name the three major nerves that enter the forearm. What muscle compartments do they supply?
3. Where is the common flexor origin?
4. How would you test the muscles of the forearm supplied by the median nerve?
5. Where can the brachial, radial and ulnar pulses be palpated? Which is easier to palpate, and why?
6. Which muscles allow pronation and supination? Make sure you can demonstrate these movements.
Session 29: The Palm of the Hand.

➢ Dissection Video: Session 29.
➢ Dissection Instructions: Available in the MTU and via Minerva in advance.

Aims and Objectives

1. Identify and demonstrate the key anatomical landmarks of the carpus and hand.
2. Identify and name the joints of the hand and digits; understand the movements that occur at these joints.
3. Give examples of important grips, such as power, hook and precision grips.
4. Understand the difference between extrinsic and intrinsic hand muscles.
5. Identify and trace the tendons of the anterior compartment muscles into the hand and digits and know where they insert.
6. Know where the tendons of FDS, FDP and FPL insert in the hand and how to test them.
7. Understand the structure and function of the flexor tendon sheaths.
8. Name the intrinsic muscles of the hand, know their locations, actions and innervations.
9. Describe the relative positions of the tendons, vessels and nerves at the wrist.
10. Understand the function of the flexor retinaculum.
11. Know the cutaneous innervation of the hand and the blood supply of the hand.

Clinical points:

- Neurovascular structures close to the wrist and how these may be injured. Work out what functional deficits would arise from such neurovascular injuries.
- Testing the tendons of FDS, FDP and FPL
- Recap carpal tunnel syndrome
- Dupuytren’s contracture
- Tenosynovitis
- Scaphoid fracture and avascular necrosis
- Fracture of the 5th metacarpal

In the MTU you will dissect / study the:

- long flexor tendons in the hand and the carpal tunnel
- intrinsic muscles of the hand
- cutaneous innervation and blood supply of the hand and digits
- key anatomical landmarks of the carpus and hand
Part 1 - Key Anatomical Landmarks: the carpus and hand

The Carpus

The carpus is comprised of eight small bones that articulate with each other at small joints. The bones are roughly arranged into two rows of four bones: one proximal, one distal.

The distal radius articulates with the scaphoid and lunate to form the radiocarpal joint. Identify the carpal bones on the image below, which shows the palmar surface of the carpus and hand. Identify the pisiform and the hook of the hamate.

The most commonly fractured carpal bone is the scaphoid – usually by a fall on to an outstretched hand. A scaphoid fracture has potentially serious consequences (see page 65). Although uncommon, the lunate may dislocate. It is very important not to miss an anterior dislocation of the lunate as it compresses the median nerve.
**The Hand**

The hand is composed of many small bones and joints.

- The **metacarpals** lie distal to the carpus. They are numbered 1 – 5 from the lateral (thumb) side to the medial (little finger) side.

- The bones of the digits are **phalanges** (singular = **phalanx**). There are three phalanges in each finger (digits 2-5) and two phalanges in the thumb (digit 1).

- The three phalanges of the fingers are named proximal, middle and distal phalanges.

- The two phalanges of the thumb are named proximal and distal phalanges.
Small joints lie between the carpal bones, metacarpals and phalanges.

- **Carpometacarpal** joints (CMCJs) – lie between the distal row of carpal bones and the proximal parts (the bases) of the metacarpals.

- **Metacarpophalangeal** joints (MCPJs) – lie between the distal parts (the heads) of the metacarpals and the proximal phalanges.

- **Interphalangeal** joints (IPJs) – lie between the phalanges.

- The **thumb** contains **two phalanges** so there is only **one** interphalangeal joint (IPJ) in the thumb.

- The **fingers** contain **three phalanges** so there are **two** interphalangeal joints:
  - the **proximal** interphalangeal (PIP) joints lie between the proximal and middle phalanges
  - the **distal** interphalangeal (DIP) joints lie between the middle and distal phalanges.

**Part 2 - Movements of the Hand and Digits**

Movements of the hand and digits are complex. We will talk about different muscles and their main functions, but it is important to appreciate that movements of the hand and digits usually involve the actions of lots of muscles working together.

**Grips**

The human hand is highly evolved and allows us to manipulate objects in a myriad of ways. The hand and digits can perform a wide range of **grips**. For example, we use a **power grip** to hold or squeeze objects tightly. The **hook grip** is important for carrying objects with handles, such as bags. The **precision grip** allows us to hold objects between the pads of our thumb and index finger, such as a pen or needle. This can be performed with or without power.

Impaired function of the hand and digits can have a devastating effect on patients.

**Movements of the fingers**

The fingers (digits 2-5) are able to move in the following ways:

- Flexion
- Extension
- Abduction (moving the fingers apart)
- Adduction (bringing the fingers together)
Movements of the thumb

The movements of the thumb are a little more complex. They are:

- Flexion
- Extension
- Abduction
- Adduction
- Opposition

Make sure you can demonstrate the movements of the fingers and thumb on yourself. We will cover these in the practical session.

Part 3 – Extrinsic Muscles of the Hand

Movements of the fingers and thumb are controlled by both extrinsic and intrinsic muscles.

The extrinsic muscles lie in the anterior and posterior forearm and their tendons travel into the hand. We have seen the anterior compartment muscles and in this session we will follow their tendons to their insertions in the hand.

The intrinsic muscles lie within the hand. We will see these in this session.

Muscles of the Anterior Forearm

The muscles of the anterior forearm that are the prime flexors of the wrist are:

- Flexor carpi radialis - inserts onto the 2nd metacarpal
- Flexor carpi ulnaris - inserts onto the 5th metacarpal
- Palmaris longus (if present) - inserts into the palmar fascia

Anterior compartment muscles also flex the digits. They travel through the carpal tunnel and into the hand:

- Flexor digitorum superficialis (FDS)
- Flexor digitorum profundus (FDP)
- Flexor pollicis longus (FPL)

Because their tendons cross the wrist, these muscles also contribute to wrist flexion.

Recap the position of these muscles. The tendons of these muscles are shown in the following image.
• The tendon of **flexor digitorum superficialis** (FDS) splits into two slips which insert on either side of the **middle phalanx** of digits 2-5. It **flexes** the **MCP** joints and **PIP** joints of digits 2-5.

• The tendon of **flexor digitorum profundus** (FDP) passes through the slit in the FDS tendon to insert onto the palmar aspect of the **distal phalanx** of digits 2-5. It is the only muscle capable of **flexing** the **DIP** joint. It also **flexes** the **PIP** joint and the **MCP** joint of digits 2-5.

• The tendon of **flexor pollicis longus** (FPL) inserts onto the **distal phalanx** of the thumb. It **flexes** the **IP** joint of the thumb and is the **only** muscle that can do so.
It is important for clinical practice to know these specific distal insertion points of the long flexor tendons. When patients present with injuries to the hand, such as lacerations, you must be able to test the movements of the digits to assess if the tendons have been injured – being able to do this competently relies on knowing where the tendons insert and what movements they control.

**Flexor Tendon Sheaths**

Fibrous sheaths enclose the long flexor tendons. They maintain the position of the flexor tendons in the midline of each finger. Within the fibrous sheaths, the tendons are enclosed within a synovial sheath, which reduces friction and allows the tendons to slide freely within their fibrous sheath during flexion and extension.

If penetrating injuries of the hand and fingers (e.g. lacerations, thorns piercing the skin) pierce the tendon sheaths they may become infected. Inflammation of the tendon and synovial sheath is called **tenosynovitis**.

The thick **palmar aponeurosis** protects the long flexor tendons, tendon sheaths and vessels in the central palm.

**Part 4 – Intrinsic Muscles of the Hand**

Also referred to as the **small muscles** of the hand. Both their origins and insertions are **within** the hand.

There are **four groups** of intrinsic muscles and one single muscle that does not ‘fit’ into any of the groups. The four groups are the:

- **thenar eminence** – contains three muscles
- **hypothenar eminence** – contains three muscles
- **lumbricals** – there are four
- **interossei** – there are seven

The remaining muscle is a muscle of the thumb called **adductor pollicis**.

The intrinsic muscles of the hand are innervated by the **ulnar** and **median** nerves.

**Thenar Eminence**

This is the fleshy mass on the palm of the hand at the base of the thumb. It contains three muscles that act upon the thumb:

- **Flexor pollicis brevis** (FPB) - flexes the thumb
- **Abductor pollicis brevis** (APB) - abducts the thumb
- **Opponens pollicis** - (OP) - opposes the thumb
The **opponens pollicis** lies deep to the flexor and abductor, as seen on the following image. The thenar muscles are attached to the **carpal bones** proximally. Their distal attachments, actions and innervation are summarised below:

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement</th>
<th>Insertion</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPB</td>
<td>Flexion</td>
<td>Proximal phalanx</td>
<td>Recurrent branch of the <strong>median</strong> nerve</td>
</tr>
<tr>
<td>APB</td>
<td>Abduction</td>
<td>Proximal phalanx, lateral aspect</td>
<td>Recurrent branch of the <strong>median</strong> nerve</td>
</tr>
<tr>
<td>OP</td>
<td>Opposition</td>
<td>1st metacarpal</td>
<td>Recurrent branch of the <strong>median</strong> nerve</td>
</tr>
</tbody>
</table>
The **recurrent branch** of the median nerve leaves the median nerve after it has passed through the carpal tunnel, therefore the thenar eminence muscles are affected in **carpal tunnel syndrome**. Left untreated, they become weak and atrophy.
**Adductor Pollicis**

This muscle moves the thumb, but differs from the thenar eminence muscles in two ways:

- it lies deep in the palm, not in the thenar eminence
- it is innervated by the **ulnar** nerve

Adductor pollicis is attached to the 3rd metacarpal and to the proximal phalanx of the thumb. Contraction of the muscle pulls the thumb towards the palm – adduction.

The thenar muscles are important for a precision grip. The thumb is abducted, flexed and medially rotated at the CMC joint so it can oppose with the one of the fingers. It can be performed with or without power.
Hypothenar Eminence

This is the fleshy mass on the medial side of the palm of the hand, proximal to the little finger. It contains three small muscles that act upon the little finger:

- **Flexor digiti minimi** (FDM) - flexes the little finger
- **Abductor digiti minimi** (ADM) - abducts the little finger
- **Opponens digiti minimi** (ODM) - opposes the little finger

The images on pages 53 and 54 illustrate the positions and attachments of these muscles - they mirror the thenar eminence muscles, in their names and locations.

The hypothenar muscles are attached to the **carpal bones** proximally. Their distal attachments, actions and innervation are summarised below:

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement</th>
<th>Insertion</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDM</td>
<td>Flexion</td>
<td>Proximal phalanx</td>
<td>Deep branch of the ulnar nerve</td>
</tr>
<tr>
<td>ADM</td>
<td>Abduction</td>
<td>Proximal phalanx</td>
<td>Deep branch of the ulnar nerve</td>
</tr>
<tr>
<td>ODM</td>
<td>Opposition</td>
<td>5th metacarpal</td>
<td>Deep branch of the ulnar nerve</td>
</tr>
</tbody>
</table>

The Lumbricals

There are **four** lumbrical muscles, one for each finger (digits 2-5). They:

- arise from the tendons of flexor digitorum profundus
- travel along the lateral aspects of digits 2-5
- insert onto the dorsal aspects of digits 2-5

These muscles are illustrated on the image on page 51. They **flex** the MCP joints and simultaneously **extend** the IP joints.

The innervation of the lumbricals follows that of the FDP tendons from which they arise:

- the **lateral** two (digits 2 and 3) are innervated by the **median** nerve
- the **medial** two (digits 4 and 5) are innervated by the **ulnar** nerve

The Interossei

These muscles are attached to and lie between the **metacarpals** and insert onto the dorsal aspects of digits 2-5. There are two groups, a **palmar** group, and a **dorsal** group.

- There are three **palmar** interosseous muscles (1-3) and four **dorsal** interosseous muscles (1-4).
- The arrangement of the **palmar interossei** and their insertion points allows them to **adduct** the fingers (i.e. draw them towards the middle finger) when they contract.
- The arrangement of the **dorsal interossei** and their insertion points allows them to **abduct** the fingers (i.e. away from the middle finger) when they contract.

Their movements can be remembered by ‘**PAD-DAB**’ (Palmar ADduct, Dorsal ABduct). The interossei contribute to **extension** of the fingers at the **IP** joints.

- The **first palmar interosseous** arises from the medial side of the 2\(^{nd}\) metacarpal and inserts onto the medial aspect of the 2\(^{nd}\) proximal phalanx.
- The **second palmar interosseous** arises from the lateral side of the 4\(^{th}\) metacarpal and inserts onto the lateral aspect of the 4\(^{th}\) proximal phalanx.
- The **third palmar interosseous** arises from the lateral side of the 5\(^{th}\) metacarpal and inserts onto the lateral aspect of the 5\(^{th}\) proximal phalanx.
- The **first dorsal interosseous** arises from the medial side of the 1st metacarpal and the lateral side of the 2\textsuperscript{nd} metacarpal and inserts onto the lateral aspect of the 2\textsuperscript{nd} proximal phalanx. It moves the index finger, not the thumb.
- The **second dorsal interosseous** arises from the medial side of the 2\textsuperscript{nd} metacarpal and the lateral side of the 3\textsuperscript{rd} metacarpal and inserts onto the lateral aspect of the 3\textsuperscript{rd} proximal phalanx.
- The **third dorsal interosseous** arises from the medial side of the 3\textsuperscript{rd} metacarpal and lateral side of the 4\textsuperscript{th} metacarpal and inserts onto the medial aspect of the 3\textsuperscript{rd} proximal phalanx.
- The **fourth dorsal interosseous** arises from the medial side of the 4\textsuperscript{th} metacarpal and lateral side of the 5\textsuperscript{th} metacarpal and inserts onto the medial aspect of the 4\textsuperscript{th} proximal phalanx.
To summarise, the small muscles of the hand are innervated by the ulnar nerve and the median nerve. The radial nerve does not supply any muscles in the hand.

**Part 5 – The Wrist and Carpal Tunnel**

Pathology at the wrist or in the carpal tunnel can affect the long flexor tendons, nerves and vessels.

We looked at the carpal tunnel and carpal tunnel syndrome previously. Remember that the carpal tunnel is a narrow passageway through the wrist, between the forearm and hand. It is formed by the carpal bones and the flexor retinaculum. The flexor retinaculum prevents the flexor tendons from bowing when the wrist is flexed.

Important structures travelling through the carpal tunnel are the:
- long flexor tendons of FDS, FDP and FPL
- median nerve

Other structures cross the wrist, but travel over (superficial to) the flexor retinaculum, rather than through the carpal tunnel. These include the:
- tendons of FCR, FCU and PL
- radial artery - travels on the lateral aspect of the wrist
- ulnar artery and ulnar nerve - travel over the medial aspect of the wrist, close to the tendon of FCU.

**Part 6 – The Cutaneous Innervation of the Hand**

Understanding the pattern of innervation of the skin of the hand is important for clinical examination. Sensation in the hand can be assessed by examining:
- the territories of the peripheral nerves
- the dermatomes

**Peripheral Nerves**

Several peripheral nerves innervate the skin of the upper limb, as illustrated in the image on the next page. However, we are only going to concentrate on the territories of the median, ulnar and radial nerves in the hand. The territories of these nerves are as follows:
- **Median**: the palmar surface of the lateral side of the hand. The palmar surface of the lateral 3 ½ digits. The skin over the dorsum of the distal phalanges of the lateral 3 ½ digits.
• **Ulnar**: the palmar and dorsal surfaces of the medial side of the hand and the medial 1 ½ digits.

• **Radial**: the dorsal surface of the lateral side of the hand. The skin over the dorsum of the lateral 3 ½ digits as far as the DIP joint.

These are the *approximate* territories of each nerve – there is some variation between individuals. For this reason, sensation is tested over specific areas, where we can be fairly sure that the skin is innervated by the peripheral nerve we want to assess:

• **Median**: palmar surface of the middle finger
• **Ulnar**: medial border of the hand
• **Radial**: dorsum of the hand, lateral aspect.

The cutaneous branches of the medial and ulnar nerves that supply the **palm** of the hand arise in the **forearm**. Therefore injuries to the median or ulnar nerves at the wrist usually **do not** impair sensation over the palm of the hand. However, injury to the median nerve at the wrist (or in the carpal tunnel) or the ulnar nerve at the wrist **does** result in sensory impairment over the palmar aspect of the corresponding fingers, as the cutaneous branches to the fingers arise from the nerves **distal** to the wrist.
Dermatomes

A dermatome is a region of skin innervated by a single spinal nerve. The upper limb is innervated by the brachial plexus and spinal nerves C5 – T1. The regions innervated by these nerves are:

- **C4**: the upper shoulder
- **C5**: the lateral side of the anterior and posterior aspects of the arm
- **C6**: the lateral side of the anterior and posterior surfaces of the forearm, the lateral sides of the anterior and posterior surfaces of the palm, and the anterior and posterior surfaces of the thumb and index fingers
- **C7**: the anterior and posterior surfaces of the middle finger and middle of the palm (over the 3rd metacarpal)
- **C8**: the medial side of the anterior and posterior surfaces of the forearm, the medial side of the anterior and posterior surfaces of the palm, and the anterior and posterior surfaces of the fourth and fifth fingers
- **T1**: the medial side of the anterior and posterior surfaces of the arm.

Testing sensation in dermatomes C5 – T1 gives us information about the spinal nerves and their corresponding spinal cord segments.

The areas of skin innervated by the spinal nerves (dermatomes) are different to the areas supplied by peripheral nerves because of how the spinal nerve fibres are ‘shuffled’ in the brachial plexus and distributed within the peripheral nerves.

To test the dermatomes, sensation is tested over the following areas:

- **C5**: upper lateral arm
- **C6**: thumb
- **C7**: middle finger
- **C8**: medial border of the hand
- **T1**: medial border of the arm
Part 7 – The Blood Supply of the Hand

The radial and ulnar arteries supply the hand. These are the terminal branches of the brachial artery.

- The **radial artery** courses down the lateral aspect of the forearm. The radial pulse can be palpated over the lateral aspect of the wrist.

- The **ulnar artery** courses down the medial aspect of the forearm. The ulnar pulse can be palpated over the medial aspect of the wrist, but the artery may be partially covered by the tendon of flexor carpi ulnaris, making it harder to palpate than the radial pulse. The **ulnar nerve** travels alongside the ulnar artery.
The radial and ulnar arteries **anastomose** deep in the palm of the hand to form two **palmar arches**:

- the **superficial palmar arch** is formed **largely** by the **ulnar artery** with a smaller contribution from the radial artery
- the **deep palmar arch** is formed **largely** by the **radial artery** with a smaller contribution from the ulnar artery.

The palmar arches give rise to metacarpal and digital arteries that supply the palm and digits. These are accompanied by digital nerves.

The anastomoses between the radial and ulnar arteries ensure perfusion of the hand is maintained in the event that one of the vessels is occluded or injured. The **patency** of each vessel should be assessed before undertaking arterial puncture (e.g., for an arterial blood gas or placing an arterial line), as such procedures can potentially cause thrombus formation and occlusion of the vessel.

**Part 8 – Clinical Relevance**

**Testing the tendons of FDS, FDP and FPL**

In the case of palmar injuries (e.g., a laceration over the palmar aspect of a finger), we need to assess if the long flexor tendons are intact. The tendons of FDS and FDP both cross, and hence can move, the PIP joint. However, only FDP can move the DIP joint. This means we need to isolate and test each tendon in turn. To test **FDP**, the PIP joint is held immobile by the examiner and the patient is asked to flex the finger. If the FDP tendon is intact, flexion is seen at the DIP joint. To test **FDS** in a finger, the patient turns the hand supine. The examiner uses a hand to keep all the fingers not being tested straight - this immobilises FDP. The patient is then asked to flex the finger that remains free. If the FDS tendon is intact, flexion occurs at the PIP joint and this is due to the action of FDS alone. To test the tendon of **FPL**, movement at the IP joint of the thumb is assessed.

**Carpal tunnel syndrome**

Carpal tunnel syndrome typically presents with impaired sensation, pins and needles or pain in the hand over the **palmar aspect** of the **lateral 3 ½ digits**. Sensation in the **palm** of the hand is usually unaffected in carpal tunnel syndrome, as the branches of the median nerve that innervate the skin of the lateral palm arise in the forearm and **do not** travel through the carpal tunnel, so are unaffected by compression of the median nerve in the carpal tunnel.
Dupuytren’s contracture

In this condition, the fingers are pulled into flexion by progressive fibrosis of the palmar fascia and palmar aponeurosis. The palmar fascia is attached to the flexor tendon sheaths of the fingers. The fascia shortens and pulls the fingers into flexion. The fascia can be released.

Tenosynovitis

Inflammation of a flexor tendon and its synovial sheath may result if the sheath is breached by a penetrating injury. The finger swells and movement is painful. Infection may potentially spread to the forearm.

Scaphoid fracture

The scaphoid forms from two bones, each with its own blood supply, that fuse together. With fusion, the artery to the proximal end degenerates, and the bone is supplied from its distal end. When the scaphoid fractures, the proximal part of the bone may be disconnected from the blood supply and death of the proximal segment results – this is called avascular necrosis.

Avascular necrosis is a serious problem because the proximal scaphoid articulates with the distal radius at the wrist joint. For this reason, fractures must not be missed. However, scaphoid fractures are not always evident on X-rays taken soon after the fracture has occurred. If a fracture is suspected but not seen on X-ray, patients are still followed-up.

Fracture of the 5th metacarpal

Otherwise known as a ‘boxer’s fracture’, as it is typically sustained by punching something. There is usually pain, swelling and tenderness over the 5th metacarpal.

Part 9 – Questions to Consolidate Learning

Aim to have a serious attempt at these and discuss them with your group in the session before checking your answers in Minerva. If you’re struggling with any of the questions, discuss them with a demonstrator in the class.

1. Which carpal bone is most prone to fracture? What complication may result if a fracture of this bone is missed?
2. What is the cutaneous distribution of the median, ulnar and radial nerves in the hand? Which regions of skin would you test to assess these nerves?
3. In which regions of the hand would you assess dermatomes C6, C7 and C8?
4. Which muscles comprise the thenar eminence? Which nerve innervates them?
5. How would you test the function of the interosseous muscles?
6. How would a patient present if they injured their median nerve at their wrist? In comparison, how would a median nerve injury at the elbow present?
7. A patient with carpal tunnel syndrome has normal sensation over the lateral side of their palm. Why is this?
8. Which muscles would be affected by an ulnar nerve injury in the mid-forearm?

➢ Dissection Video: Session 30
➢ Dissection Instructions: Available in the MTU and via Minerva in advance.

Aims and Objectives

1. Review the **key anatomical landmarks** of the carpus and hand.
2. Name the muscles of the **posterior compartment**, know they are arranged into two layers and know the general function of these muscles.
3. Know the locations, actions and innervations of the muscles of the posterior forearm.
4. Know where the **long extensor tendons** insert in the hand.
5. Describe the location of the **extensor expansion** and which muscles attach to it.
6. Describe the location, boundaries, contents and clinical importance of the **anatomical snuffbox**.
7. Describe the origin, course and distribution of **blood vessels** in the posterior forearm.
8. Review the **joints** of the upper limb; structure, movements and muscles.

Clinical points

- Lateral epicondylitis
- Radial head subluxation
- Wrist drop
- Injury to the extensor tendons
- Arthritis

In the MTU you will **dissect / study the**:

- posterior forearm muscles
- insertion points of the long extensor tendons in the hand
- anatomical snuffbox
- joints of the upper limb
Part 1 - Key Anatomical Landmarks: the carpus and hand
We looked at these in the last session, but they are important for today’s session too.

Part 2 – Muscles of the Posterior Compartment

Like the anterior compartment, the posterior compartment of the forearm contains lots of muscles with long names. However, in general they mirror the anterior compartment muscles, so your previous study should help you with this session!

We can make some general statements about the posterior forearm muscles as a group:

- they are arranged in **two** layers: superficial and deep
- most of them are **extensors** of the wrist, digits or thumb
- they are **all** innervated by the **radial** nerve

**Superficial Layer**

There are six superficial muscles. From lateral to medial, they are:

- **Brachioradialis**
- **Extensor carpi radialis longus**
- **Extensor carpi radialis brevis**
- **Extensor digitorum**
- **Extensor digiti minimi**
- **Extensor carpi ulnaris**

As a general rule, these muscles are attached proximally to the **lateral epicondyle** of the humerus – otherwise known as the ‘**common extensor origin**’.

**Brachioradialis** is an exception to some of the rules of posterior compartment muscles. It lies on the boundary between the posterior and anterior compartments. It originates from the humerus, proximal to the lateral epicondyle, and inserts on the distal radius. It acts as a **weak flexor** of the elbow joint and hence functions as an anterior compartment muscle. However, it is innervated by the **radial nerve**.

**Extensor carpi radialis longus** (ECRL) and **brevis** (ECRB) lie on the radial side of the posterior compartment. ECRL inserts onto the 2**nd** metacarpal and ECRB inserts onto the 3**rd** metacarpal, hence they extend and abduct the wrist.
**Extensor digitorum** (ED) extends the digits via four long tendons that insert onto the dorsal aspects of the fingers (digits 2-5). The tendons of ED are connected by fibrous bands – this makes it difficult to fully extend the middle or ring fingers independently.
Extensor digiti minimi (EDM) extends the little finger via its insertion onto the dorsum of the little finger.

Extensor carpi ulnaris (ECU) is the most medial of the superficial muscles. It extends and adducts the wrist via its insertion onto the 5th metacarpal.

At the wrist, the tendons of these muscles travel under a band of tissue, the extensor retinaculum. It prevents the tendons from bowing when the wrist is extended.
Deep Layer

There are five deep muscles. From lateral to medial they are:

- Supinator
- Abductor pollicis longus
- Extensor pollicis brevis
- Extensor pollicis longus
- Extensor indicis
Except for supinator, they attach proximally to the forearm bones and the interosseous membrane.

Two deep muscles are exceptions to the general rules as they are not extensors:

- **Supinator** supinates the forearm and hand and is attached proximally to the humerus. It wraps around the upper part of the radius.
- **Abductor pollicis longus** abducts the thumb. It inserts on the 1st metacarpal.

**Extensor pollicis brevis** (EPB) and **extensor pollicis longus** (EPL) extend the thumb. EPB inserts on the proximal phalanx, so extends the MCP joint. EPL inserts on the distal phalanx, so is the only muscle capable of extending the interphalangeal joint of the thumb.

Although their proximal muscle attachments are deep in the forearm, the tendons of EPB and APL lie superficially at the wrist as they wrap around the distal radius.

**Extensor indicis** (EI) inserts on the dorsum of the index finger, allowing independent extension of this digit.

To summarise, all the posterior forearm muscles are:

- **extensors**, except for brachioradialis, supinator and abductor pollicis longus
- innervated by the **radial** nerve

The muscles that cross the wrist also contribute to **wrist extension**.

### Part 3 – The Dorsum of the Hand

The dorsum of the hand is far less complex than the palm in terms of muscles – only the four **dorsal interossei** are seen on the dorsal aspect. The metacarpal bones are palpable. The extensor tendons are often visible under the skin over the dorsum of the hand.

The **superficial veins** of the dorsum of the hand are often visible and palpable under the skin. They comprise the **dorsal venous network** but the pattern is variable between individuals. Veins of the dorsal venous network can be cannulated.

The dorsal venous network drains into the **cephalic vein** laterally and into the **basilic vein** medially.
**Extensor Expansion**

Also called the extensor hood, this fibrous structure overlies the dorsal aspect of the digits. It is attached to the base of the proximal phalanx and gives rise to a central slip and two marginal slips. The central slip inserts on the middle phalanx and the marginal slips converge on the distal phalanx.

- The tendons of ED, EI and EDM insert into the dorsal aspect of the extensor expansion. This helps keep the tendons fixed in the **midline** of the digits.
- The lumbricals and interossei insert into the sides of the proximal parts of the extensor expansion. Via this attachment, they contribute to **extension** of the **interphalangeal** joints of the fingers.
Anatomical Snuffbox

The anatomical snuffbox (ASB) is a triangular-shaped depression on the lateral aspect of the wrist, at the base of the thumb, seen when the thumb is extended.

The boundaries of the snuffbox are the tendon of EPL medially and the tendons of EPB and APL laterally. It is a clinically important region because:

- The scaphoid lies in the floor of the ASB. ASB tenderness on palpation may indicate a scaphoid fracture
- The radial artery travels through it
- The cephalic vein arises in the ASB; it can be cannulated here if necessary

The superficial branch of the radial nerve runs over the anatomical snuffbox to supply the skin over the lateral aspect of the dorsum of the hand.

Part 4 - Vessels and Nerves of the Posterior Forearm

Arteries and Veins

The posterior compartment is supplied by a branch of the ulnar artery. This artery is accompanied by deep veins.

The major superficial veins of the forearm – the cephalic and basilic – have been described in Session 28.

Blood from the dorsal venous network on the dorsum of the hand drains towards both the cephalic and basilic veins.

Nerves

The radial nerve innervates all the muscles of the posterior forearm. Proximal injuries to the radial nerve (e.g., in the arm) can therefore result in an inability to extend the wrist and fingers.

The superficial branch of the radial nerve innervates the skin over the lateral aspect of the dorsum of the hand, including the skin over the anatomical snuffbox and the skin over the dorsum of the lateral 3 ½ digits, as far as the DIP joint.
Part 5 – Joints of the Upper Limb

Your IMMS Anatomy Handbook contains an overview of the different types of joints and the movements that occur at them.

The Shoulder Joint

A synovial ball and socket joint formed by the articulation between the glenoid fossa of the scapula and the head of the humerus.

- The articular surfaces of the shoulder are a poor fit – this compromises the stability of the joint but increases range of movement.
- The joint capsule is lax, which allows mobility. It is reinforced by ligaments.
- The glenoid is deepened by a rim of fibrocartilage – the glenoid labrum.
- The rotator cuff is vital for stability at the shoulder joint.
- The tendon of the long head of biceps contributes to stability at the joint.

Complete the following tables:

1. Muscles that move the scapula

<table>
<thead>
<tr>
<th>Movement of the scapula</th>
<th>Muscles involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protraction</td>
<td></td>
</tr>
<tr>
<td>Retraction</td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td></td>
</tr>
<tr>
<td>Rotation</td>
<td></td>
</tr>
</tbody>
</table>
2. Muscles that move the shoulder joint

<table>
<thead>
<tr>
<th>Movement of the shoulder joint</th>
<th>Muscles involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td></td>
</tr>
<tr>
<td>Abduction</td>
<td></td>
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<tr>
<td>Adduction</td>
<td></td>
</tr>
<tr>
<td>Lateral rotation</td>
<td></td>
</tr>
<tr>
<td>Medial rotation</td>
<td></td>
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</tbody>
</table>

The Elbow Joint

A synovial hinge joint formed by articulations between the trochlea of the humerus and the trochlear notch of the ulna, and the capitellum of the humerus and the radial head.

- The joint capsule is reinforced by medial (ulnar) and lateral (radial) collateral ligaments.

Complete the following table:

<table>
<thead>
<tr>
<th>Movement of the elbow joint</th>
<th>Muscles involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td></td>
</tr>
<tr>
<td>Extension</td>
<td></td>
</tr>
</tbody>
</table>
The Proximal and Distal Radioulnar Joints

Synovial, pivot-type joints between the radius and ulna.

- The radius rotates around the ulna when the forearm is pronated and supinated.
- The anular ligament of the radius is attached to the ulna and holds the radial head in place. The radial head rotates within it to produce pronation and supination.

Complete the following table:

<table>
<thead>
<tr>
<th>Movement of the radioulnar joints</th>
<th>Muscles involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pronation</td>
<td></td>
</tr>
<tr>
<td>Supination</td>
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</tbody>
</table>

Wrist Joint and Carpus

The wrist joint is a condyloid synovial joint formed by the articulation of the distal radius with the scaphoid and lunate.

- It is surrounded by a joint capsule which is reinforced by ligaments.
- The intercarpal joints between the carpal bones are synovial joints, which are also reinforced by ligaments.

Complete the following table:

<table>
<thead>
<tr>
<th>Movement of the wrist joint</th>
<th>Muscles involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
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<td>Extension</td>
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<tr>
<td>Abduction</td>
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<tr>
<td>Adduction</td>
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</tbody>
</table>
Joints of the Hand

- The joints of the hand are synovial.
- The first carpometacarpal (CMC) joint lies between the trapezium and the 1st metacarpal. It is a saddle joint and is key to the range of movement possible at the thumb.
- The metacarpophalangeal joints are condyloid joints.
- The interphalangeal joints are hinge joints.
- The CMC, MCP and IP joints are all reinforced by ligaments.

Part 6 – Clinical Relevance

Lateral epicondylitis

The attachments of the extensor muscles to the lateral epicondyle may become inflamed. Pain is felt over the region of the lateral epicondyle and may radiate down the forearm. It is caused by repetitive strain of the muscles and is also known as ‘tennis elbow’.

Radial head subluxation = ‘pulled elbow’

This is seen in young children and is caused by the child being suddenly pulled upwards by their arm. The anular ligament is partially torn and the radial head moves out of the ligament. It is painful and the child will not use their arm. The subluxed head is reduced and the tear heals.

Wrist drop

This describes an inability to extend the wrist (and fingers) due to weakness or paralysis of the posterior forearm muscles. It results from injury to the radial nerve proximal to the forearm. It is typically caused by a mid-shaft humeral fracture, as the radial nerve lies close to the bone here. Sensation is also impaired over the lateral aspect of the dorsum of the hand (i.e. in the regions of skin of the hand supplied by the radial nerve).

Injury to the extensor tendons

The tendons lie relatively superficially over the dorsum of the hand and are vulnerable to injury from lacerations.
Arthritis

**Osteoarthritis** is 'wear and tear' arthritis and is more common in older people. It affects large and small joints. In the hands, it predominantly affects the PIP and DIP joints and bony swellings are seen at the joints.

**Rheumatoid arthritis** is an autoimmune condition. It affects synovial joints and the small joints of the hands and feet are typically involved. The MCP and PIP joints are predominantly affected. Rheumatoid arthritis can destroy these joints causing significant deformity and functional impairment. Early treatment prevents these joint complications.

Other relevant pathology

In previous sections of this Handbook and in the Upper Limb – Part 1 Handbook we have looked at various pathologies affecting bones and joints. Review the following:

- fracture of the surgical neck of the humerus
- dislocation of the humeral head
- adhesive capsulitis
- rotator cuff injury
- fracture of the forearm bones
- carpal tunnel syndrome
- scaphoid fracture

Part 7 – Questions to Consolidate Learning

Aim to have a **serious** attempt at these and **discuss them** with your group in the session before checking your answers in Minerva. If you’re struggling with any of the questions, discuss them with a demonstrator in the class.

1. Which nerve supplies the muscles in the posterior forearm? Which region of skin in the hand does this nerve also innervate?
2. Which bone lies in the floor of the anatomical snuffbox?
3. Which neurovascular structures are associated with the anatomical snuffbox?
4. In a patient with a T1 nerve root injury, which muscles will be weak / paralysed? Which area of skin will be affected?
5. Which muscle of the upper limb is the most powerful supinator of the forearm? How does the position of the elbow joint affect the action of this muscle?
6. Which fingers have two extensor muscles and tendons?