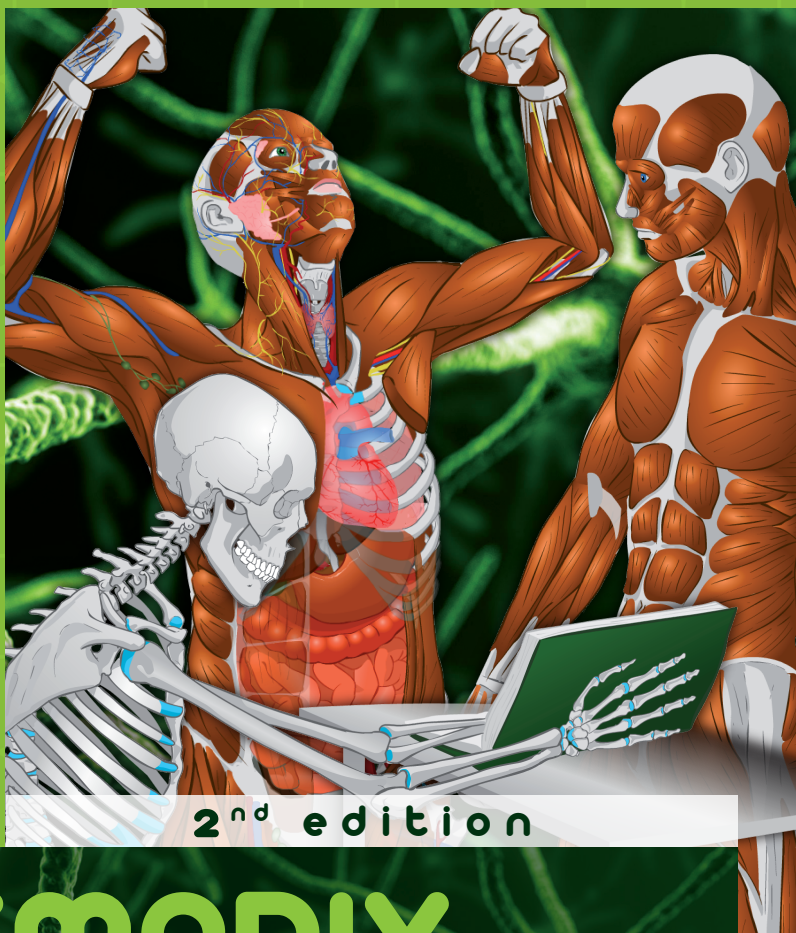


**Radovan Hudák, David Kachlík  
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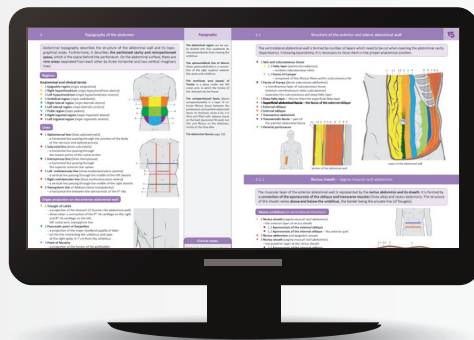
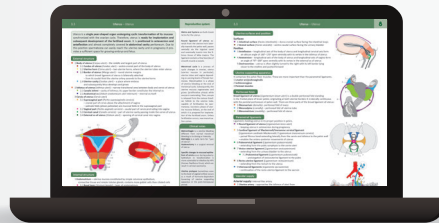
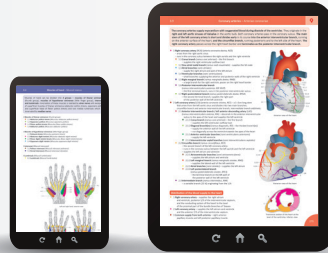
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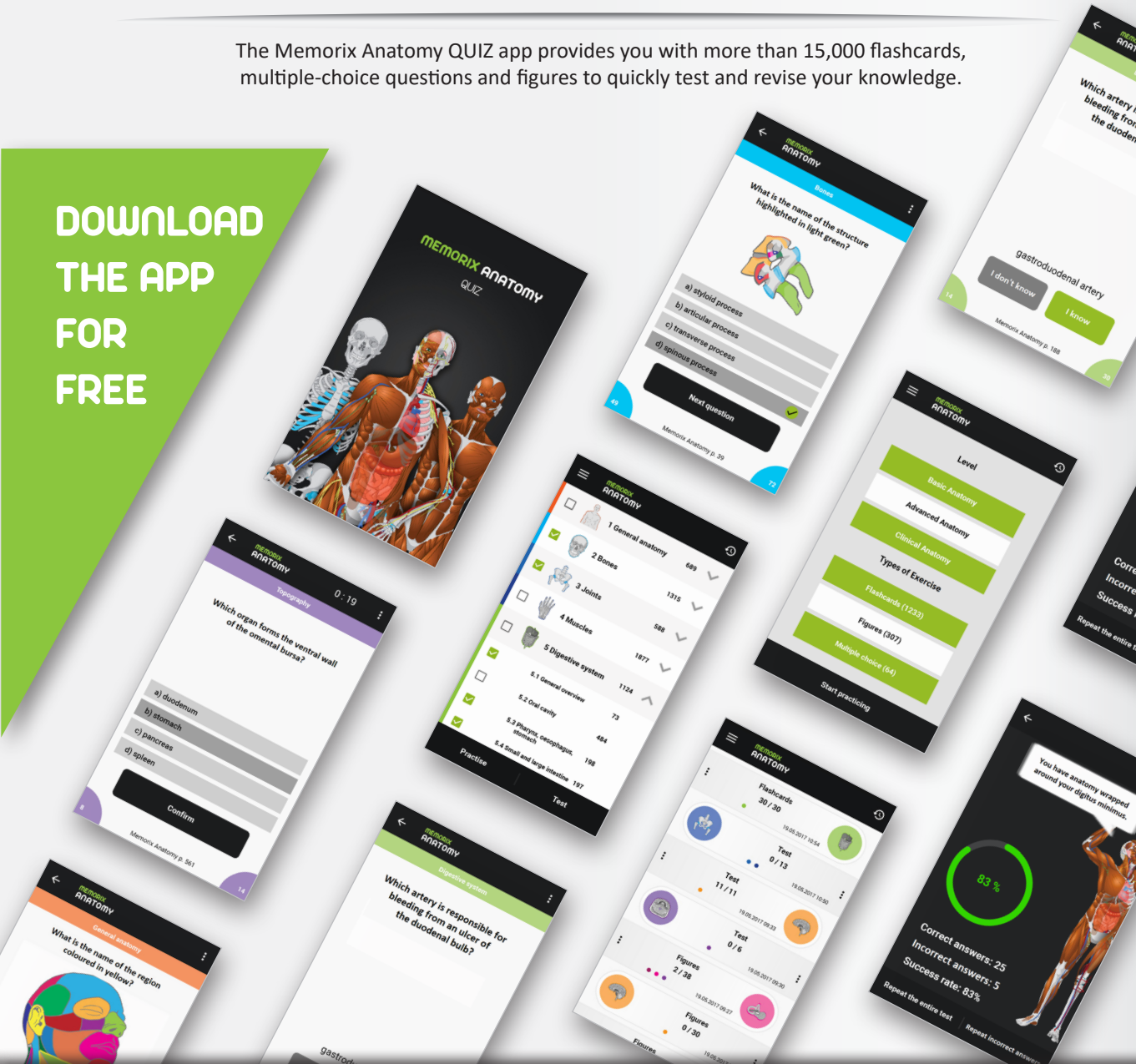
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- 1.1 Localizations and directions
- 1.2 Parts of human body
- 1.3 Planes and lines of human
- 1.4 Regions of human body


 2. Bones


 3. Joints


 4. Muscles



 5. Digestive system



 6. Respiratory system

 7. Urinary system

 8. Genital system

 9. Heart and blood vessels

  English term

  Latin term

Head	Caput
Forehead	Sinciput
Occiput	Occiput
Temple	Tempora
Ear	Auris
Face	Facies
Eye	Oculus
Cheek	Bucca
Nose	Nasus
Mouth	Os
Chin	Mentum
Neck	Collum; Cervix
Trunk	Truncus
Thorax	Thorax
Front of chest	Pectus
Abdomen	Abdomen
Pelvis	Pelvis
Back	Dorsum
Upper limb	Membrum superius
Pectoral girdle; Shoulder girdle	Cingulum pectorale; Cingulum membri superioris
Axilla	Axilla
Arm	Brachium
Elbow	Cubitus
Forearm	Antebrachium
Hand	Manus
Wrist	Carpus
Metacarpus	Metacarpus
Palm	Palma; Vola
Dorsum of hand	Dorsum manus
Fingers including thumb	Digitus manus
Lower limb	Membrum inferius
Pelvic girdle	Cingulum pelvium; Cingulum membri inferioris

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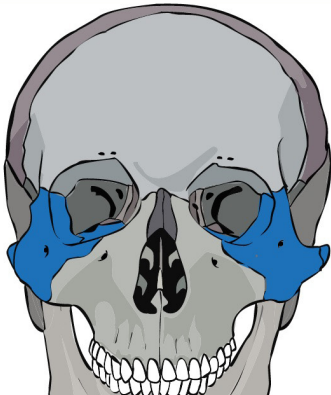
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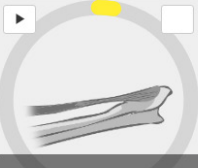
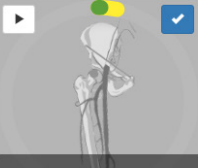
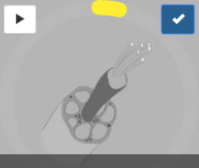




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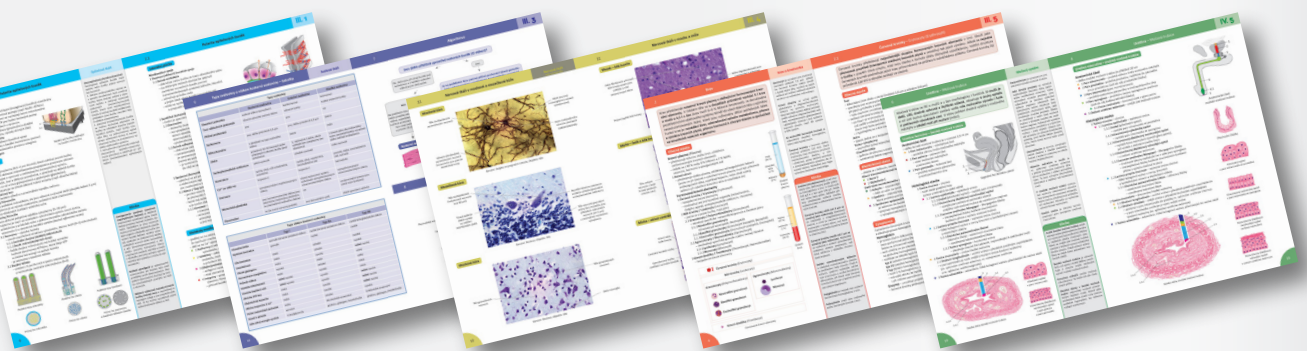
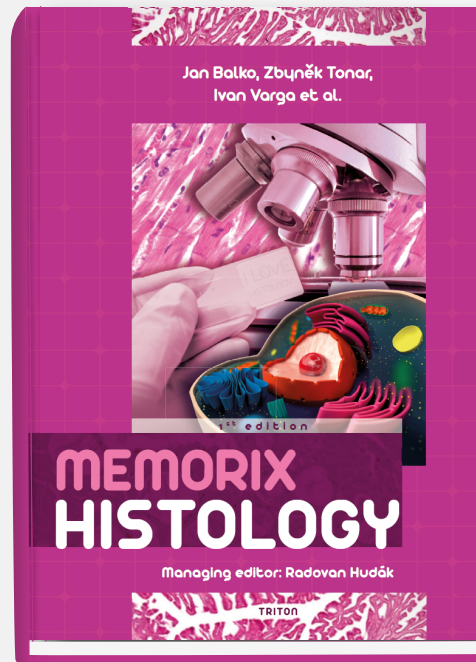
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# MEMORIX ANATOMY

Entire human anatomy in English and Latin

2<sup>nd</sup> edition

MEMORIX

Radovan Hudák, David Kachlík, Ondřej Volný  
**MEMORIX ANATOMY**

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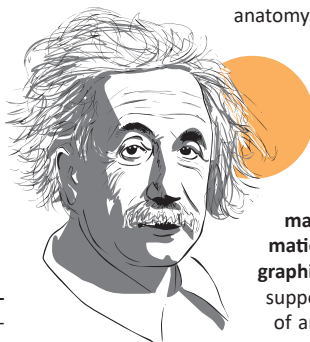
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„Anatomy, albeit it is feminine, has its own charm and logic,“ said one professor of anatomy a long time ago. Although **anatomy is as old as humanity itself, its charm is immortal and its logic still maintained.** Owing to these characteristics, anatomy belongs among favorite subjects, which students look forward to learning long before starting their university studies. However, **a great deal of specialized terms and information takes often smiles off students' faces** during their first week of school. Students usually don't give up and become devoted to studying, but the more they learn, the more they forget. They learn joints, but forget bones. When they manage to know the digestive system by heart, they in turn push out the muscles of the whole body. Forgetting things once learned brings them feelings of hopelessness and doubt whether they have what it takes to study medicine at all. The problem, though, is often not the amount of information, but rather their **way of learning and reviewing.** There are **many thousand-page anatomy textbooks** on the market comprising the immensity of anatomy, but there is just **a few of those that would provide information in a concise, clear, and understandable form.** And that is why **Memorix Anatomy** was created.

### Dissatisfaction as a reason for change

Even most of us (the authors of this book) had to study anatomy for the first time and pass our first year of medical school just a few years ago. Just like the vast majority of medical students, we too wished to own a big book of anatomy of our own. We wanted to take pride in its complexity, size, and infinity in front of every person we knew. We felt so proud that we were medical students that we bought **three volumes of an anatomy textbook from one author, several other books by other authors, with two more color atlases** on top of that. We had more books from one field than from any other subject altogether and a **beautiful (but naive) idea we would once know it all. Do you recognize that feeling?** The excitement that you will be able to know in detail the origins and insertions of 300 muscles, the passages of the fourteen branches of the maxillary artery, or all the nuclei, tracts, and circuits in the brain? **An amazing image!** Amazing until you realize what we all know, but are unwilling to admit: **the fact that our memory has a limited capacity and chooses only the information our brain evaluates as important.** However, this is often not necessarily the information that is truly important. There was relatively enough time for studying at the beginning and we devoured important information along with the less important. As the final exam was approaching, so was the schoolwork volume exponentially growing, and the time was growing less and less. It became **necessary to distinguish the importance of information, adjust one's system, and study effectively.** Our large textbooks didn't suit us anymore and we were looking for something more clear and concise. **We were seeking tables, schemes, structured text, and simple images.** But we just could not find a book that would meet our needs.

One of the editors of this book, **Radovan Hudák**, had thought already during his study of medicine that he could **initiate the creation of such book as a student.** He contacted an **experienced anatomist, associate professor David Kachlík, M.D.,** with a question whether he wanted to collaborate on the **creation of a comprehensive, yet easy-to-understand anatomy book.** He thought it over and agreed. This initiated the creation of **Memorix Anatomie** (the Czech forerunner of this book), which was in the spirit of **Albert Einstein's "Everything should be made as simple as possible – but not simpler."**



Albert Einstein

### The base of success lies in cooperation

Before we started to build a team of authors, we asked ourselves a question, **„Who is this textbook intended for? For students, anatomists, or perhaps clinicians?“** We came to the conclusion that it was for all. Where a quality textbook should arise, it was necessary to have **a collaboration not only with anatomists who would guarantee quality anatomical content of the book, students who would ensure its comprehensibility, but also physicians who would add clinically important information.** Thus, more than half of the team of authors has been formed by **students who have already spent several years teaching anatomy to younger students from the position of student tutors.** The second part of the team consisted of **anatomists and clinicians, who also significantly engaged themselves in anatomy.** Even our **three illustrators have come from medical school,**

so they knew very well what kind of pictures are best understood by students. The work of the Memorix team was also contributed to by **a large number of reviews by dozens of other anatomists, students, and physicians.**

The creation of this book cost us thousands of hours of hard work, but after 1.5 years we managed to finish it and get it to the students. **On a mere 600 pages, we have managed to summarize the most important anatomical information, which we have supplemented with more than 1,500 graphically uniform pictures.** The text and images are mutually supportive in order to significantly accelerate the understanding of anatomical structures. **Less important and interesting information were, together with clinical notes, set aside the main content** and placed in the middle column of each double

page.

The sorting of the chapters, structured text, and large number of pictures has made **Memorix Anatomie a clear, systematic, and concise textbook designed for the effective learning and rapid reviewing of anatomy.**

After the success in the Czech and Slovak Republic, one of the co-authors of the Czech version, **Ondřej Volný,** couldn't resist and immediately initiated **the creation of an English version.** Again, the work involved a large number of **students, anatomists, and clinicians, only this time, from around the world.** Apart from the aforementioned features of the book, the Memorix book will be helpful to many students by having **all the structures described with English and Latin terms** right next to each other.

With the Memorix Anatomy book, we want to contribute to a **better understanding of anatomy among students.** We don't want them to see learning anatomy as necessary evil, but actually the other way around – to learn it with affection. **We would also like to motivate all students not to be afraid to address teachers with their ideas for improving teaching.** They will certainly appreciate it. And if not, contact us ([anatomy@memorix.cz](mailto:anatomy@memorix.cz)), because we will gladly hear out your thoughts and opinions. Who knows, we may create another useful study material together.

On behalf of the Memorix team  
**Radovan Hudák, David Kachlík, Ondřej Volný**  
Prague, Czech Republic, July 1, 2017

**Anatomy can be learned very quickly. But it can also be quickly forgotten.** To keep the anatomical knowledge in your memory, it is necessary to study and repeat systematically. That is why we created the **Memorix Education System** with specialists in teaching psychology and andragogy (teaching of adults). We decided to use a **structured text** instead of a continuous one, as it is considered **more efficient in the process of studying, memorizing, and reviewing**. We separated **important anatomical information described in the main content from the less important**, which we put in the middle column. **Clinical correlations** have their place in the middle spread, as well. Special emphasis is put on **charts and schemes** serving as a tool for better memory consolidation and revision.

## Steps of the Memorix Education System

### 1. Chapter structure

- schedule your study time and plan your study process
- look through the chapter headings, its divisions and subdivisions
- study the introduction windows and briefly look at pictures and schemes

### 2. Study the chapter in detail

- go through the chapter step-by-step
- reread the main sentences, study the main text and pictures carefully and in more detail
- try to find all the answers to your questions
- highlight all information which you consider to be important, make notes, redraw pictures and create mind maps

### 3. Interesting things

- look through the less important but interesting anatomical information in the middle column

### 4. Clinical notes

- read the clinical notes and try to understand the correlations between anatomy and clinical medicine

### 5. Schemes and charts

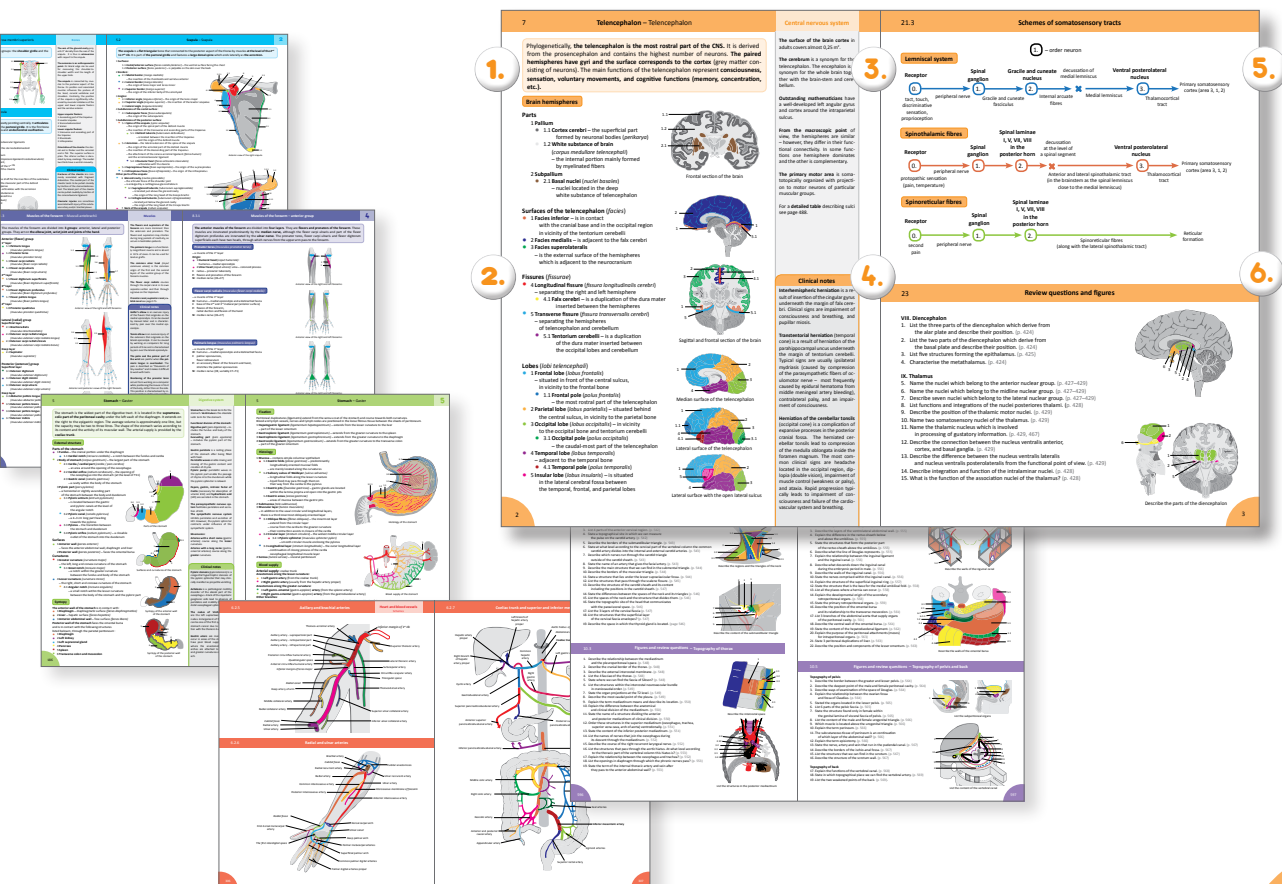
- use the schemes and charts for effective revision and quick orientation

### 6. Review questions and figures

- answer all the questions
- describe all the pictures presented in the revision part
- if you are not able to answer a question or describe a picture, return to the chapter and try to find it

### 7. Anatomy presenting

- present the information you have learnt to your classmates
- engage in discussions about the topics





**Designing a format, creating an outline, and building a quality team of authors, illustrators, and typesetters** was just a fraction of the work. **Writing and constant efforts to improve the texts, illustrations, and schemes followed.** The integral part of the process was the involvement of **dozens of anatomists, clinicians, students, proofreaders, and native speakers** whose reviews and input have significantly contributed to the quality of our book. Certainly, we could not have sailed through all of this on our own. That is why **we would like to acknowledge all** who have contributed to the emergence of this revolutionary and unique anatomy textbook.

Firstly, we appreciate all of the time and energy of all the co-authors: **Jakub Miletín, Matej Halaj, Ladislav Douda, Barbora Beňová, Martin Čepelík, Vojtěch Kunc, Petr Vaněk, and Adam Whitley.** We are thankful for this hardworking team that made the Memorix Anatomy dream a reality. It was a great pleasure for the main authors to work with all of you.

We are grateful for our stunning illustrators, whose illustrative drawings and schemes make anatomy easier to understand and also visually attractive. Many thanks to the brilliant **Jan Balko** and precise **Šárka Zavazalová** for thousands of hours spent with electronic paintbrush, their ubiquitous tablets, and enthusiasm for colorful anatomy. We really appreciate the carthorse work of our typesetters, who are responsible for time-consuming manual corrections of all arising comments and revisions – many thanks to the tireless **Vojtěch Kunc**, tenacious **Matej Halaj**, and diligent **Daniel Slovák.** We also value very much the help of our certified language proofreaders: **Zuzana Balážová, Pavel Filip,** and **Michal Vilimovský** led by the extraordinary **Petr Vaněk**, and the willing native speakers led by the outstanding **Adam Whitley**; their cooperation and detective work contributed to the high-quality English in Memorix Anatomy. We appreciate all the help of our andragogist, **Miroslava Dvořáková**, who helped us with building of the Memorix Education System and who precisely answered all questions related to the didactic value of this textbook.

We wish to express our gratitude to all **anatomic reviewers** from all over the world, led by reviewer-in-chief and excellent clinical anatomist **Václav Báča.** Many thanks to **Nihal Apaydin** (Turkey), **Marcela Bezdíčková** (Czech Republic/Wales), **Susana N. Biasutto** (Argentina), **Phil Blyth** (New Zealand), **Adriana Boleková** (Slovakia), **Stephen Carmichael** (USA), **Ayhan Cömert** (Turkey), **Hans J. ten Donkelaar** (Netherlands), **Lada Eberlová** (Czech Republic), **Georg Feigl** (Austria), **Quentin Fogg** (Australia), **Guiliana Gobbi** (Italy), **Marek Joukal** (Czech Republic), **Dzintra Kažoka** (Latvia), **Darina Kluchová** (Slovakia), **Květuše Lovásová** (Slovakia), **Veronica Macchi** (Italy), **Pavel Šnajdr** (Czech Republic), and **Trifon Totlis** (Greece). Their contribution to Memorix Anatomy was always constructive and anatomically and personally enriching, and we cannot possibly thank them enough for all of the advice and suggestions they provided.

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Our gratitude also goes out to dozens of students who went carefully over the contents of the book page after page. They helped us discover quite a number of flaws and errors, thus improving the understanding of the entire text.

We wish to thank to **Memorix Anatomy godfathers: Vladimír Komárek** (Dean of Second Faculty of Medicine, Charles University in Prague, professor of neurology and Head of Department of Paediatric Neurology, Second Faculty of Medicine, Charles University in Prague and Motol University Hospital) and **Martin Bareš** (Vice-Rector for Development of Masaryk University in Brno, professor of neurology at First Department of Neurology, St. Anne's Faculty Hospital and Faculty of Medicine, and professor of neurology at University of Minnesota).

And last but not least, we are immensely appreciative of all anatomists, clinicians, students, and members of the Memorix team, who participated in the creation of the Czech predecessor of this book: **Memorix Anatomie.**

Finally, we would like to sincerely thank to our families, friends, and loved ones for the continuous help, unconditional support, and endless motivation.

*Radovan Hudák, David Kachlík, Ondřej Volný*



**25** Anatomists



**56** Medical doctors



**94** Medical students



**36** Other people

**...worked hard creating MEMORIX ANATOMY for You!**

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*and further 52 medical students which reviewed the Czech edition of Memorix Anatomy*

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**The creation of the Czech and English version of  
Memorix Anatomy involved together over 200 people.  
We sincerely thank you from the depths  
of our anatomical hearts.**

## Acknowledgements to student organisations

**Student clubs bring together active students to work, create, and help with enthusiasm.** These organizations prepare unique projects that **educate students, elicit smiles on the faces of patients, and inform thousands of fellow citizens about health care.** Members of these organizations are not paid for their work, but **their reward is the feeling of a job well done, the gained experiences, and the possible appreciation from others.** I myself, as well as many co-authors, are grateful to many of these associations for what they have taught us about communication, time and projects management, teamwork and many other areas. If it weren't for student organizations and active students, this book would have never been created. We thank you.

**IFMSA Czech Republic (IFMSA CZ)**, the largest medical student organisation in the Czech Republic, is a part of IFMSA, a federation of medical student organisations spanning the world. Projects like Medicafé, Teddy Bear Hospital, World Health day and many others, provide medical students with first hand experience dealing with public health and many other topics. IFMSA CZ also holds successful fundraising events, that help various non-profit organisations. IFMSA CZ organises more than 300 clinical and research exchanges yearly. These exchanges are open to all our members, giving them an opportunity to travel, meet other cultures, whilst furthering their medical knowledge and experience. [www.ifmsa.cz](http://www.ifmsa.cz)

**Slovak Medical Student's Association (SloMSA)** connects 4 Local Medical Student's Associations in Slovakia and provides projects in public health, medical education, reproductive health and in many other fields of medicine. Our Association also provides more than 150 month exchange programs for medical students to more than 40 countries worldwide every year. [www.slomsa.sk](http://www.slomsa.sk)



### Radovan Huďák



I devoted my childhood to basketball, which I played at a professional level, but a **knee injury changed my life course towards medicine**. Sports have continued to stay in my heart and have shifted me to **medical disciplines related to the construction and movement of the human body**, such as **anatomy, kinesiology and orthopedics**. In medical school I was actively involved in **student organisations and the academic senate** and in the third year of my medical studies, **I started teaching anatomy**. My goal is to **teach students in both a fun and an easily understood manner**. I like active people and I try to be one of them. I guess **I'm a workaholic** but I love it.

### David Kachlík



During my medical studies at university, the true, **decisive and fatal crossroad of my life came into the picture: the dissection room**. That space destined my future life career and medical specialization. **Fascination by the hidden corners and nooks of the human body** led me to my future teaching and scientific way of life. The driving force of my effort was the desire to **mediate the knowledge to students in an easily accessible and gripping manner**. Whenever I saw a light of cognition in my students' eyes, my endeavor came to fruition. **The result of my effort is this book**. Although it pulled me away from my children a bit, **it became a kind of my child itself**.

### Ondřej Volný



I was born in Ostrava, where I have graduated from both elementary and high school. After that, my feet lead me to Brno to the Medical Faculty. **My big dream is to one day be on the world's stage**, though I haven't yet tried actual acting. Instead, every week I „perform“ **in front of students during anatomy classes**. I like challenges, which is why I chose **the brain and nervous system as a chapter in Memorix, as well as in my professional life**. I focused on neurology, anatomy, and research at **Hotchkiss Brain Institute at the University of Calgary**. Currently, I work as an assistant professor at the **First Department of Neurology in Brno**.

## Co-authors – nothing fascinates us more than the mysteries of human anatomy

### Barbora Beňová



**Starting as a young and eager book-loving student of medicine**, as soon as I could I **immersed myself into the complexity of anatomy** bringing it to today's young, eager and book-loving students. Working as an anatomy assistant I was offered a wonderful chance to co-author this amazing textbook. **The complexity of human anatomy strikes me every day in my practice**. Currently as a **resident of paediatric neurology and a PhD student in neuroscience**, I turn back to the very first edition of “Memorix Anatomie” to recall all the lost and newly regained knowledge of brain anatomy.

### Martin Čepelík



Since childhood as I remember I have always wanted to become a physician. I have also been **inclined to teaching and anatomy** united these two paths into one. Although I am now working as a **surgeon in the Department of Pediatric Trauma and Surgery in Prague**, I still gladly remember my days in the Department of Anatomy, and **my knowledge of anatomy helps me a lot in what I do now**. I am proud and thankful to be a part of such great team that worked hard on the Memorix Anatomy and I hope that **it will be as rewarding for you to read it as it was for us to create it**.

### Ladislav Douda



**The relationship between structure, function and clinical relevance is the main goal of studying and teaching anatomy**. The ability to explain, to answer frequently asked questions and anatomical difficulties, and simply to be closer to the readers and behave student-friendly, these are the rudiments of Memorix Anatomy. **This excellent textbook makes studying anatomy interesting and dynamic**. In this matter, it not only deserves an exceptional attention but also an exceptional humility of authors before their own work.

Matej Halaj

After years of hard work in judo, hockeyball and contemplating studying at lawschool, I decided to leave it all behind and **instead pursue medschool**. As a medical student I get the opportunity to **teach anatomy at our anatomy department in Brno**. It was something remarkable for me. That's the reason why I said: "Yes!" when Rado Hudák asked me, if I wanted to work on Memorix Anatomy. Currently I **work as a resident of Neurosurgery** in Olomouc and I **open Memorix almost every day**. I hope that anatomy with Memorix will soon become your passion.



Vojtěch Kunc



"Do you like it?" With this question one Georgian orthopedist **asked for my opinion after a complicated surgery**. I laughed. Why would an experienced surgeon ask a newbie, who was only seeing that operation for the first time? But it was not a joke. **The surgery was not finished until every member of the team verified that he or she was satisfied by it**. This humble attitude I have also found this humble attitude within the **Memorix team**. **Both are connected by the desire for perfection**. I hope this book will serve you well and I would also like to ask you: **do you like it?**

Jakub Miletín

I have been interested in surgery and anatomy since my first years at the university. Thanks to the friendly attitude of the department of anatomy, **I had almost unlimited options to study this wonderful discipline**. Its knowledge helps me a lot in my surgical profession, so I decided to continue teaching anatomy at the Third Faculty of Medicine. **I always try to transmit my knowledge to the students in as a comprehensible way as possible**. Memorix Anatomy was a **great challenge to be able to explain the topographical anatomy intelligibly, yet still thoroughly**.



Petr Vaněk



I am **ambitious** and have been since an early age. As a child, I grew up **dreaming of playing sports** in the pro-ranks and couldn't picture myself doing anything else. Later on, I moved to the United States and began to fulfill this dream. But there is one saying, "**We plan, God laughs**." And so, after a series of injuries, my sports career was over. This life lesson, which has taught me much about the importance of health, has brought me a new ambition: **restoring the health of others**, which after all, may be **more rewarding than anything else**. And it all begins with anatomy.

Adam Whitley

I was inspired to teach anatomy by the excellent student lecturers who taught me during the **dissection course in my first year of studies**. I grew up in England, and moved to Prague in 2010 **to study at the Second Faculty of Medicine at Charles University**. I have now been teaching anatomy for four years and I have taught students of both the second and first medical faculties. **I have enjoyed working on Memorix Anatomy and I believe it provides a unique way of presenting the complexities of human anatomy in a simple and concise format**.



## Illustrators – a drawing of the human body is a pleasure of our senses

Jan Balko



I have taken part in creation of Memorix Anatomy right before my graduation. It has been my task to **paint the majority of the pictures including the cardiovascular system, bones, joints etc**. Luckily, there were two co-workers, who helped me a lot. We have managed to **finish hundreds of pictures in just a single year**. It was our wish to **make them simple and colourful**. Simplicity makes it possible to **redraw the pictures by the students themselves** and the motley colours help distinguish all the **anatomical structures**. I hope you will be satisfied with our work.

Šárka Zavázalová

For a long time the **only partnership between me and medicine was an emergency room and an otorhinolaryngology ward**. At present, as a physician, I gain strength for **doing my job through my life-time hobby – drawing and painting**. I'm extremely happy that I was challenged to utilize my hobby by **making illustrations for this marvellous textbook – friendly not only to medical students but also to forgetful physicians** – as well as myself. I hope this book will accompany you on your journey through medical school and medical career.



"Everything should be made as simple as possible,  
but not simpler."

*Albert Einstein*



# Be an Anatomist at heart!

## Book contents:

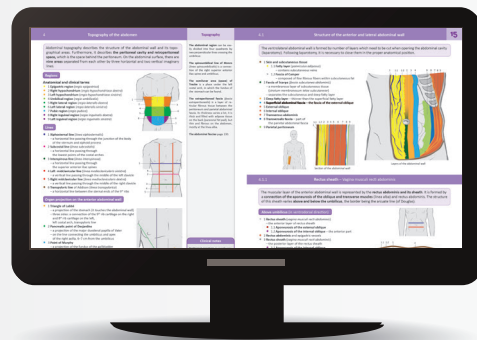
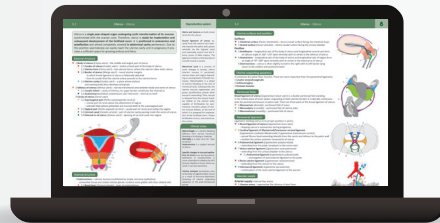
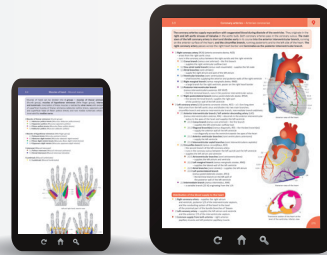
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This sample contains a free chapter

### 1. General anatomy.

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# Memorix Anatomy

## 2 Bones



Martin Čepelík  
David Kachlík  
Radovan Hudák  
Ondřej Volný  
Adam Whitley

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**Osteology** is the study of bone (osseous) tissue. Bone tissue is a type of connective tissue characterised by a **hard mineralised ground substance, collagen fibres and specialised cells**. Bone tissue has **structural, supportive and protective functions**. **Ossification** is the formation of new bone either from a fibrous or cartilaginous model.

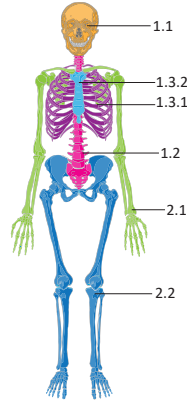
### Overview of the skeleton

#### 1 Axial skeleton (*skeleton axiale*)

- 1.1 **Skull** (*cranium*)
- 1.2 **Vertebral column** (*columna vertebralis*) – spine
- 1.3 **Thorax** (*skeleton thoracis*) – chest
  - 1.3.1 **Ribs** (*costae*)
  - 1.3.2 **Sternum** – breastbone

#### 2 Appendicular skeleton (*skeleton appendiculare*) – skeleton of the limbs

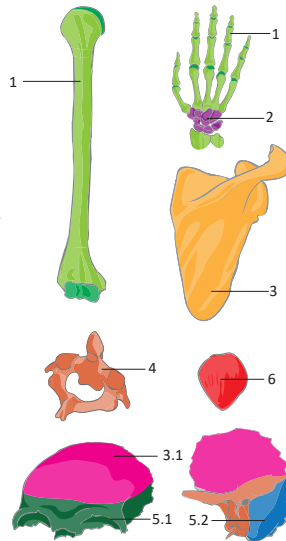
- 2.1 **Bones of upper limb** (*ossa membri superioris*)
- 2.2 **Bones of lower limb** (*ossa membri inferioris*)



Overview of the skeleton

### Types of bones

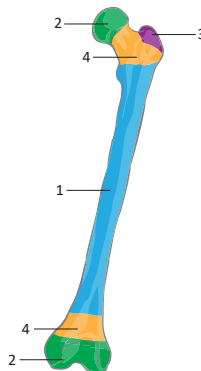
- 1 **Long bones** (*os longum*) – are characterised by a long shaft with articular facets on both ends – include the humerus, ulna, radius, femur, tibia, fibula, metacarpals, metatarsals and phalanges
- 2 **Short bones** (*os breve*) – are characterised by being roughly as long as they are wide – include the carpal bones and tarsal bones
- 3 **Flat bones** (*os planum*) – are characterised by being composed of two layers of compact bone with a layer of spongy bone in-between – include the sternum, scapula, ilium and several bones of the skull
  - 3.1 **Flat bones of the skull**
    - are composed of an internal table and external table composed of compact bone and a diploë composed of spongy bone
    - include the squamous part of the temporal, frontal and occipital bone
- 4 **Irregular bones** (*os irregulare*) – irregularly shaped bones that do not fit in any other category – include the temporal bone, vertebra, ischium and pubis
- 5 **Pneumatised bones** (*os pneumaticum*) – contain air-filled cavities
  - 5.1 include parts of the frontal bone, sphenoidal bone, ethmoidal bone and maxilla
  - 5.2 the tympanic cavity and mastoid air cells are pneumatised spaces in the temporal bone
- 6 **Sesamoid bones** (*os sesamoideum*) – are bones located inside tendons – include the patella and the sesamoid bones of the thumb and big toe



Types of bones

### Parts of long bones

- 1 **Diaphysis** – the middle part of a long bone where the primary ossification centre is located
- 2 **Epiphysis** – the distal end of a long bone where the secondary ossification center is located
- 3 **Apophysis** – part of a bone (usually a tubercle) that contains a secondary ossification centre but isn't an epiphysis
- 4 **Metaphysis** – is located between the epiphysis and diaphysis and has its own blood supply
  - 4.1 **Epiphyseal plate** (*lamina epiphysialis*)
    - contains growth cartilage (*cartilago epiphysialis*)
    - present only in children



Parts of long bones

**Os** is the Latin term for bone and **osteon** is the Greek term.

**Osteology** is a science concerned with the study of bones.

The **inorganic component** of bones is approximately 60 % of total bone weight in adults and approximately 48 % in children.

The **periosteum** adheres firmly to the bone, but can still be separated from the surface. It adheres significantly less in children.

In **clinical practice**, the metacarpals, metatarsals and phalanges are classified as short tubular bones. **Anatomically**, they are classified as long bones.

**Physis** is a clinical term used for the growth plate.

### Clinical notes

The **periosteum** is significantly firmer in children than in adults. It tears much less in fractures and helps to stabilise the bone fragments after reduction.

**Soft tissues** such as muscles and periosteum can be wedged (interposed) between bone fragments and can hinder closed reduction of a fractured bone. If the periosteum becomes wedged into the fracture line after reduction, the fracture will not heal and a pseudoarthrosis (false joint) may develop.

**Closed reduction, internal fixation (CRIF)** is reduction of a fractured bone with internal osteosynthesis (bone reconnecting) without performing a skin incision.

**Open reduction, internal fixation (ORIF)** is an open reduction of fracture fragments performed by incising the skin and surgically putting the fragments back into place.

**Fracture healing** occurs in several stages. First, a haematoma develops over the fracture site. The hematoma is then organised into granulation tissue. A fibrocartilaginous callus then takes form, which is later replaced by an osseous callus. The osseous callus is then remodelled and the fracture is finally healed.

## Histology

### 1 Bone/osseous tissue (*textus osseus*)

#### 1.1 Cells

- 1.1.1 **Osteoblasts** – synthesise the bone matrix
- 1.1.2 **Osteocytes** – mature osteoblasts that no longer synthesise bone matrix
  - reside in spaces in bone tissue called lacunae
  - participate in the regulation of the serum calcium level
- 1.1.3 **Osteoclasts** – bone-resorbing cells
- 1.1.4 **Osteoprogenitor cells / pre-osteoblasts**
  - mesenchymal stem cells that are located in the periosteum and endosteum

#### 1.2 The bone matrix

- 1.2.1 **Organic components** – consist of collagen fibres (ossein) and unmineralised ground substance that consists of proteins (osteocalcin, osteonectin, osteopontin etc.), glycosaminoglycans, lipids and carbohydrates
- 1.2.2 **Inorganic components** – include tricalcium phosphate, hydroxyapatite and calcium carbonate

#### 1.3 Type of bone tissue

##### 1.3.1 Primary bone / woven bone (*textus osseus fibroreticularis*)

- irregularly organised collagen fibres
- present in bone development
- in adults, primary bone is located in the wall of the bony labyrinth of the inner ear, around the sutures of the skull and at points of attachment of muscles and ligaments to bone
- present during bone healing after fractures

##### 1.3.2 Secondary bone / lamellar bone (*textus osseus lamellaris*)

- 1.3.2.1 **Osteon / Haversian system**
  - the fundamental structural unit of secondary bone
  - consists of a system of concentric bony lamellae surrounding a central canal called the Haversian canal
  - **The Haversian canal** (*canalis osteoni, canalis centralis*) contains nerves and vessels and communicates with the periosteum, medullary cavity, and other Haversian canals via the transverse Volkmann's canals

#### 1.4 Organisation of bone tissue

- 1.4.1 **Compact bone** (*substantia compacta*)
  - forms the superficial layer of bone under the periosteum
- 1.4.2 **Trabecular bone / cancellous bone / spongy bone** (*substantia spongiosa, substantia trabecularis*) – composed of a branching system of rods of bone tissue located under the bone cortex
  - found inside short bones and in the terminal ends of long bones
  - the diploë is trabecular bone located between two lamellae of compact bone in the flat bones of the skull

### • 2 Periosteum

- the fibrous covering of the entire external bone surface except for the articular surfaces, which are covered by cartilage
- has a rich innervation and blood supply
- bone grows in width by “periosteal apposition”
- **the periosteum consists of 2 layers:**
  - **the fibrous layer** (*stratum fibrosum*)
    - the external layer, composed of parallel collagen fibers
  - **the osteogenic layer** (*stratum osteogeneticum*)
    - the internal layer, made up of osteoprogenitor cells, which are active when the bone is growing in width and during healing of fractures

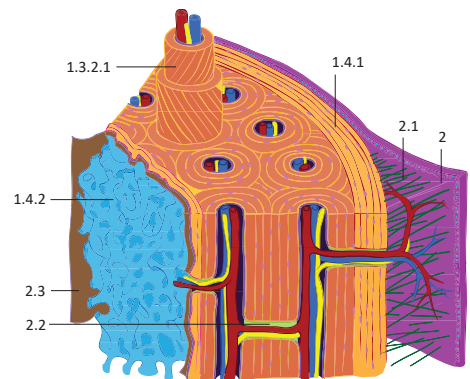
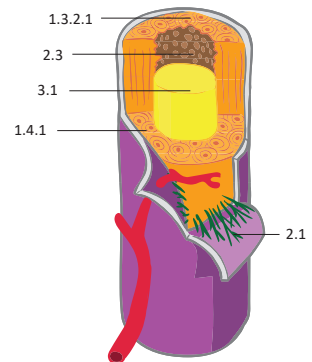
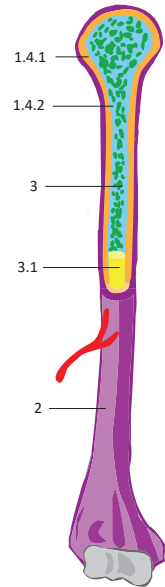
- 2.1 **Sharpey's fibres / perforating collagen fibre bundles** (*fasciculi collageni perforantes*) – strong collagen fibers connecting the periosteum to the bone surface

- 2.2 **Volkmann's canals / transverse canals** (*canales transversi*)
  - run transversely through the osteons and carry nerves and vessels from the periosteum to the Haversian canals

- 2.3 **Endosteum** – the internal fibrous layer similar to the periosteum
  - located between bone tissue and bone marrow

### • 3 Medullary cavity / medulla (*cavitas medullaris*)

- 3.1 **Bone marrow** (*medulla ossium*) – the tissue of the medullary cavity



### Bone marrow (*Medulla osium*)

Bone marrow is a tissue located inside the medullary (marrow) cavity of long bones and in the spaces between trabeculae.

- 1 **Red bone marrow** (*medulla ossium rubra*)
  - a haematopoietic organ
  - is composed of reticular connective tissue containing haematopoietic stem cells capable of differentiating into all types of blood cells
  - contains a network of sinusoids (thick capillaries with large pores)
  - haematopoiesis starts in the 2<sup>nd</sup>–3<sup>rd</sup> month of intrauterine life
  - from birth until adulthood haematopoiesis occurs in the medullary cavity of long bones
  - in adults, haematopoiesis takes place in the epiphyses of long bones, ribs, sternum, wing of the ilium and diploe of flat bones of the skull
- 2 **Yellow bone marrow** (*medulla ossium flava*)
  - is composed mostly of adipose tissue and has no haematopoietic function
  - is located in the medulla of long bones in adults
  - red marrow transforms is replaced by adipose tissue as it transforms into yellow marrow

### Development and bone ossification

- 1 **Intramembranous ossification** (*ossificatio membranacea, ossificatio desmialis*)
  - development of bone tissue from a fibrous model of embryonic connective tissue (mesenchyme)
  - osteoblasts differentiate directly from mesenchymal cells
  - occurs in the desmocranium, clavicle and sesamoid bones
- 2 **Endochondral ossification** (*ossificatio chondralis*)
  - development of bone from a hyaline cartilage model
  - mesenchymal tissue forms a hyaline cartilage model, which subsequently transforms into bone tissue
  - 2.1 **Perichondral ossification** (*ossificatio perichondralis*)
    - formation of new bone from the external surface of the bone
  - 2.2 **Endochondral ossification** (*ossificatio endochondralis*)
    - formation of new bone from the internal surface of the bone
    - both perichondral and endochondral ossification occur in long bones
    - only endochondral occurs in short bones
  - 2.3 **Ossification centres of long bones**
    - 2.3.1 **Primary ossification centres**
      - are located in diaphyses (shafts) of long bones
    - 2.3.2 **Secondary ossification centres**
      - are located in epiphyses and apophyses of long bones
- 3 **Bone growth**
  - 3.1 **Growth in width** – by periosteal ossification
  - 3.2 **Growth in length** – occurs in growth cartilage in children

### Innervation and vascular supply of bone

- 1 **Arteries**
  - periosteal vessels are thin but form a rich plexus in the periosteum
  - they supply the majority of both compact and trabecular bone via Volkmann's canals
  - 1.1 **Nutrient arteries** (*arteriae nutriciae*)
    - enter the diaphysis at an inclined angle and supply both the bone marrow and cortex
    - 1–2 nutrient arteries supply each diaphysis
    - the epiphysis is supplied by its own artery, which degenerates after growth arrest
    - after growth arrest, the epiphysis is supplied by vessels from the metaphysis
- 2 **Veins**
  - usually run parallel with the arteries
  - diploic veins (*venae diploicae*) are found inside the diploe of the flat skull bones and lack valves
- 3 **Nerves**
  - provide a rich somatosensory innervation to the periosteum,
  - Pacinian corpuscles are found in the periosteum
  - visceromotor nerves supply vessels in bones

The **splanchnocranium** is an obsolete term for the viscerocranium.

The **pericranium** is a synonym of the periosteum of the skull.

The **auditory ossicles** (*ossicula auditus*) are a part of the viscerocranium. For further details see page 506.

The **bones of the skull** develop from mesenchymal tissue surrounding the developing brain. According to their developmental origin and type of ossification, the bones of the skull are divided into three main groups: the **chondrocranium**, **desmocranium** and **viscerocranium**.

The **chondrocranium** includes the bones of the skull that develop by endochondral ossification. These bones are phylogenetically the oldest part of the skull.

The **desmocranium** includes the bones of the cranial vault that develop by intramembranous ossification.

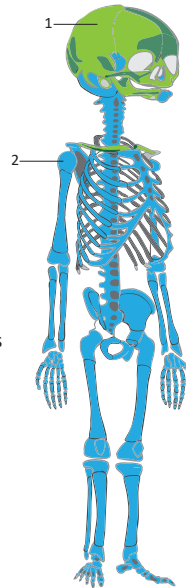
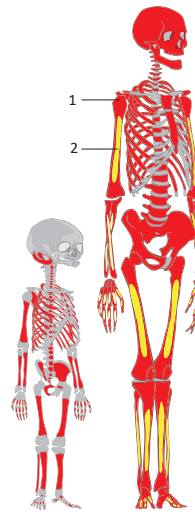
The **viscerocranium** includes the bones that make up the facial skeleton. It is phylogenetically the youngest part of the skull. The facial bones develop from mesenchyme of the pharyngeal arches by intramembranous ossification. The exceptions are the auditory ossicles and the hyoid bone, which develop by endochondral ossification.

The **desmocranium** includes the parietal bone, upper part of the squama of the occipital bone, frontal bone, squamous and tympanic part of the temporal bone, nasal bone, lacrimal bone, vomer, zygomatic bone, maxilla, mandible, palatine bone, inferior nasal concha and the medial plate of the pterygoid process of the sphenoidal bone.

**Long bones** ossify predominantly by endochondral ossification which begins at the primary ossification centre in the diaphysis and expands towards both epiphyses. The epiphyses ossify from a separate ossification center: the secondary ossification centre.

### Clinical notes

**Cleidocranial dysostosis** is a hereditary disorder of intramembranous ossification that affects the clavicles and flat bones of the skull. It may be associated with an impairment of ossification of the pelvis and bones of the limbs.





The **neurocranium**, or more colloquially the “**brain case**”, is a group of bones in the skull that encloses and protects the brain and its associated organs of vision, audition and balance. The neurocranium is divided into the **cranial vault** and the **cranial base**. The **viscerocranium** (facial skeleton) is a group of bones in the skull that surrounds and protects the proximal parts of the digestive and respiratory systems.

### Overview of the bones of the skull

#### 1 Neurocranium – brain box or brain case

##### Cranial vault / calvaria

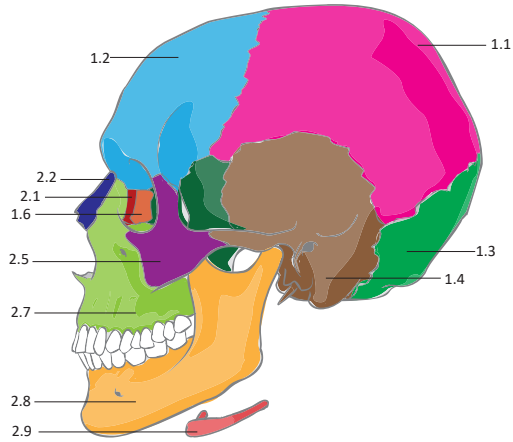
- 1.1 Parietal bone (*os parietale*)
- 1.2 Frontal bone (*os frontale*)
- 1.3 Occipital bone (*os occipitale*)

##### Cranial base (*basis cranii*)

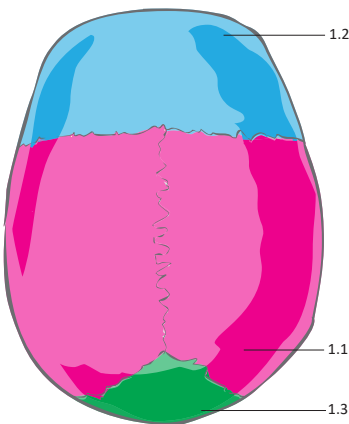
- 1.4 Temporal bone (*os temporale*)
- 1.5 Sphenoid bone (*os sphenoidale*)
- 1.6 Ethmoid bone (*os ethmoidale*)

#### 2 Viscerocranium – facial skeleton

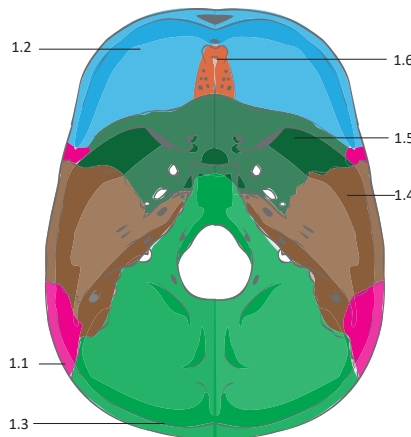
- 2.1 Lacrimal bone (*os lacrimale*)
- 2.2 Nasal bone (*os nasale*)
- 2.3 Vomer
- 2.4 Inferior nasal concha (*concha nasalis inferior*)
- 2.5 Zygomatic bone (*os zygomaticum*)
- 2.6 Palatine bone (*os palatinum*)
- 2.7 Maxilla
- 2.8 Mandible (*mandibula*)
- 2.9 Hyoid bone (*os hyoideum*)



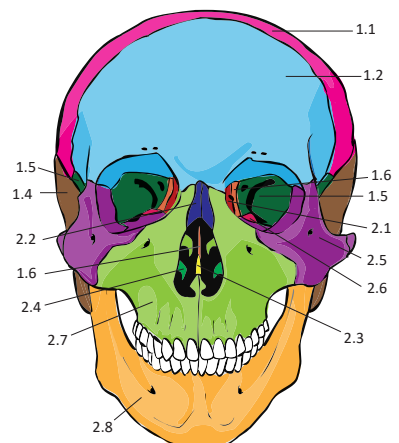
Lateral view (*norma lateralis*)



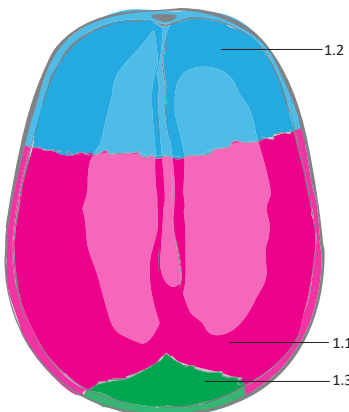
Superior view (*norma superior/verticalis*)



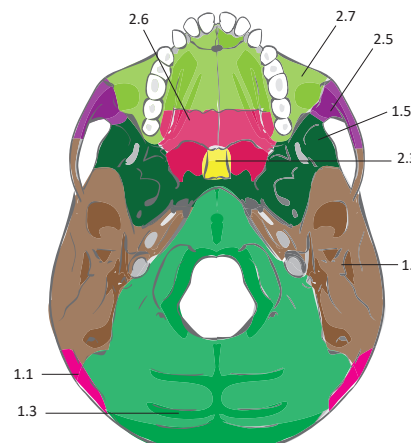
Superior view (*norma superior/verticalis*)



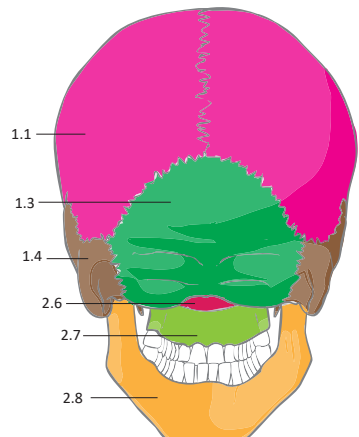
Anterior view (*norma facialis/frontalis*)



Inferior view (*norma inferior/basalis*)



Inferior view (*norma inferior/basalis*)



Posterior view (*norma occipitalis*)

Originally a paired bone of the cranial vault which develops by **intramembranous ossification**, the **frontal bone** is an unpaired **pneumatized bone** and contains a paranasal sinus: the **frontal sinus**. The frontal bone consists of a **squamous part**, a **nasal part** and **two paired orbital parts**.

### 1 Squamous part (*squama frontalis*)

#### External surface (*facies externa*)

- 1.1 **Frontal tuber** (*tuber frontale*) – paired large elevations containing ossification centers
- 1.2 **Superciliary arch** (*arcus superciliaris*) – paired arches located above the orbits
- 1.3 **Glabella** – a flattened area above the nasal root and between the superciliary arches
- 1.4 **Supra-orbital margin** (*margo supraorbitalis*) – the superior border of the orbit
  - 1.4.1 **Frontal notch/foramen** (*incisura/foramen frontale*)
    - a notch or foramen above the orbit that is only occasionally present
    - transmits the medial branch of the supra-orbital nerve
  - 1.4.2 **Supra-orbital notch/foramen** (*incisura/foramen supraorbitalis*)
    - a notch or foramen above the orbit that is always present
    - contains the supra-orbital vessels and the lateral branch of the supra-orbital nerve
- 1.5 **Zygomatic process** (*processus zygomaticus*)
  - connects to the zygomatic bone
- 1.6 **Temporal line** (*linea temporalis*)
  - the upper border of the origin of the temporalis muscle
  - continues on the parietal bone
- 1.7 **Parietal margin** (*margo parietalis*)
  - connects with the parietal bone to form the coronal suture

#### Internal surface (*facies interna*)

- 1.8 **Groove for superior sagittal sinus** (*sulcus sinus sagittalis superioris*)
  - contains the superior sagittal sinus
- 1.9 **Frontal crest** (*crista frontalis*)
  - the site of attachment of the falx cerebri
  - the anterior continuation of the groove for the superior sagittal sinus

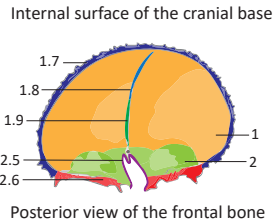
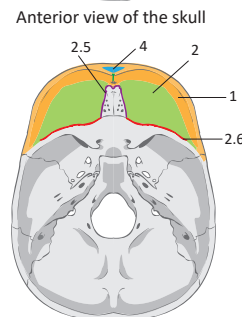
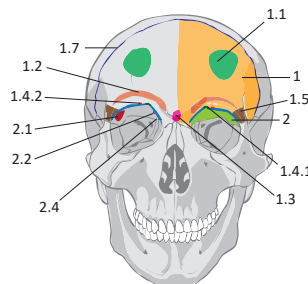
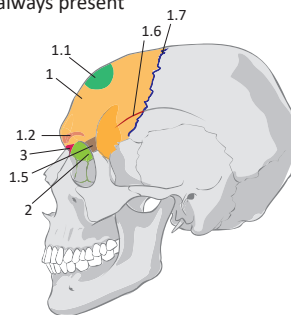
### 2 Orbital part (*pars orbitalis*)

- 2.1 **Lacrimal fossa** (*fossa glandulae lacrimalis*)
  - a fossa on the lateral part of the roof of the orbit for the lacrimal gland
- 2.2 **Trochlear fovea** (*fovea trochlearis*)
  - fossa containing the trochlear spine
- 2.3 **Trochlear spine** (*spina trochlearis*)
  - the attachment of the trochlea of the superior oblique muscle
- 2.4 **Anterior and posterior ethmoidal foramina** (*foramen ethmoidale anterius et posterius*)
  - formed by connection with the ethmoidal bone
  - transmit the anterior and posterior ethmoidal artery, vein and nerve
- 2.5 **Ethmoidal notch** (*incisura ethmoidalis*)
  - a notch for the ethmoidal bone
- 2.6 **Sphenoidal margin** (*margo sphenoidalis*)

### 3 Nasal part (*pars nasalis*)

- a small unpaired part of the bone located at the nasal root where the nasal spine and nasal margin are found

- 4 **Frontal sinus** (*sinus frontalis*) – a paired paranasal sinus
  - develops in children after the first year of life
  - the full volume is reached at the end of the growth period
  - opens into the middle nasal meatus
- 4.1 **Septum of the frontal sinuses** (*septum sinuum frontalem*)
  - separates the left and right frontal sinus
- 4.2 **Opening of the frontal sinus** (*apertura sinus frontalis*)
  - the entrance to the frontal sinus



The frontal foramen and the supra-orbital foramen (*foramina frontalis et supraorbitalis*) are variable openings which can replace the frontal and supraorbital notch (*incisura frontalis et supraorbitalis*).

**Gyrar impressions** (*impressions gyrarum*) are impressions of the cerebral gyri on the inner surface of the frontal bone. The **cerebral juga** are eminences between these impressions.

The **spheno-occipital synchondrosis** ossifies at the age of eighteen.

The **transverse occipital suture** lies in the upper part of the occipital squama and marks the boundary between the upper part of the occipital bone, which develops by intramembranous ossification, and the lower part of the occipital bone, which develops by endochondral ossification.

**Failure of fusion the transverse occipital suture** (*sutura occipitalis transversa*) gives rise to the **interparietal bones** (*Inca bones*). These bones occur in 30 % of the Native American population but only in 5 % of the European population.

The **sutura mendosa** is formed after incomplete fusion of the squamous part of the occipital bone. It projects medially or vertically from the lambdoid suture and is variable in length.

The **trochlear spine** is a cartilaginous pulley in the trochlear fovea which is ossified in less than 15 % of population.

The **orbitocranial canal** connects the orbit to the anterior cranial fossa. It opens into the anterior ethmoidal foramen.

The **orbitoethmoidal canal** connects the orbit to the ethmoidal air cells. It opens into the posterior ethmoidal foramen.

The **internal occipital crest** (*crista occipitalis interna*) is a vertical osseous crest. Sometimes it is replaced by the groove for the occipital sinus.

The **foramen caecum of the frontal bone** is a small hole on the cranial surface of the squama of the frontal bone. It represents a remnant of a foetal foramen and contains an emissary vein, which persists after birth in about 1 % of the population.

The occipital bone is an unpaired bone composed of four main parts: **the squamous part, the basilar part and the two lateral parts**. The basilar parts, the lateral parts and a portion of the squamous part contribute to **the cranial base**. These parts develop by **endochondral ossification**. A portion of the squamous part forms part of **the cranial vault** and develops by **intramembranous ossification**.

- 1 **Foramen magnum** – a large opening that contains the medulla oblongata as it changes into the spinal cord
  - contains the vertebral arteries, the anterior spinal artery, the paired posterior spinal arteries, the spinal root of the accessory nerve and the spinal vein
- 2 **Basilar part** (*pars basilaris*) – lies anterior to the foramen magnum and articulates with the sphenoid bone
  - 2.1 **Clivus** – a slope on the internal surface located beneath the brain stem, basilar artery and basilar venous plexus
  - 2.2 **Pharyngeal tubercle** (*tuberculum pharyngeum*) – an unpaired tubercle for the attachment of the pharyngeal raphe to the base of the skull
  - 2.3 **Groove for the inferior petrosal sinus** (*sulcus sinus petrosi inferioris*)
  - 2.4 **Spheno-occipital synchondrosis** (*synchondrosis sphenooccipitalis*) – a cartilaginous connection between the sphenoid and occipital bone
- 3 **Lateral parts** (*partes laterales*) – located laterally to the foramen magnum
  - 3.1 **Occipital condyles** (*condyli occipitales*) – protuberances for articulation with the atlas
  - 3.2 **Hypoglossal canal** (*canalis nervi hypoglossi*) – transmits the hypoglossal nerve and venous plexus of the hypoglossal canal
  - 3.3 **Condylar fossa** (*fossa condylaris*) – located behind the occipital condyle and may contain the condylar canal which transmits the condylar emissary vein
  - 3.4 **Jugular notch** (*incisura jugularis*) – forms the jugular foramen with the jugular notch of the temporal bone
    - 3.4.1 **Jugular process** (*processus jugularis*) – a prominence at the end of the jugular notch for the origin of the rectus capitis anterior
    - 3.4.2 **Intrajugular process** (*processus intrajugularis*) – is located inside the jugular notch and separates the jugular foramen into two compartments

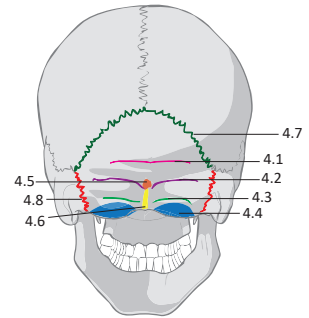
• 4 **Squamous part** (*squama occipitalis*)

**External surface** (*facies externa*)

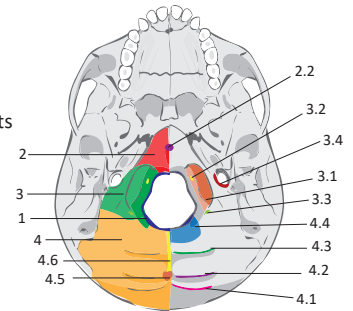
- 4.1 **Highest nuchal line** (*linea nuchalis suprema*) – the attachment of the nuchal fascia
- 4.2 **Superior nuchal line** (*linea nuchalis superior*) – the attachment of the trapezius and sternocleidomastoid
- 4.3 **Inferior nuchal line** (*linea nuchalis inferior*) – the attachment of the rectus capitis posterior major and minor
- 4.4 **Occipital plane** (*planum occipitale*) – the attachment of some back muscles
- 4.5 **External occipital protuberance** (*protuberantia occipitalis externa*) – a palpable tubercle on the posterior surface of the skull
- 4.6 **External occipital crest** (*crista occipitalis externa*) – a vertical crest for attachment of the nuchal ligament
- 4.7 **Lambdoid border** (*margo lambdoideus*) – forms the lambdoid suture with the parietal bone
- 4.8 **Mastoid border** (*margo mastoideus*) – connects to the temporal bone to form the occipitomastoid suture

**Internal surface** (*facies interna*)

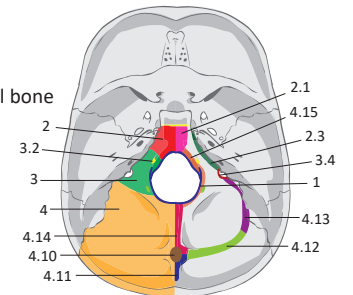
- 4.9 **Cruciform eminence** (*eminentia cruciformis*) – a cross-shaped prominence formed by the grooves for the occipital, superior sagittal and transverse sinuses
  - divides the occipital bone into two cerebral fossae and two cerebellar fossae
- 4.10 **Internal occipital protuberance** (*protuberantia occipitalis interna*) – contains the confluence of sinuses, which is the connection point of the transverse, straight, superior sagittal and occipital sinuses
- 4.11 **Groove for superior sagittal sinus** (*sulcus sinus sagittalis superioris*) – contains the superior sagittal sinus and the attachment of the falx cerebri
- 4.12 **Groove for transverse sinus** (*sulcus sinus transversi*) – contains the transverse sinus as well as the attachment of the tentorium cerebelli
- 4.13 **Groove for sigmoid sinus** (*sulcus sinus sigmoidei*) – contains the sigmoid sinus
- 4.14 **Groove for occipital sinus** (*sulcus sinus occipitalis*) – contains the occipital sinus and the attachment of the falx cerebelli
- 4.15 **Groove for marginal sinus** (*sulcus sinus marginalis*) – contains the marginal sinus and surrounds the foramen magnum
- 4.16 **Cerebral fossae** (*fossae cerebrales*) – contains the posterior part of the occipital lobes of the telencephalon
- 4.17 **Cerebellar fossae** (*fossae cerebellares*) – contains the cerebellar hemispheres
  - separated from the cerebral fossae by the tentorium cerebelli



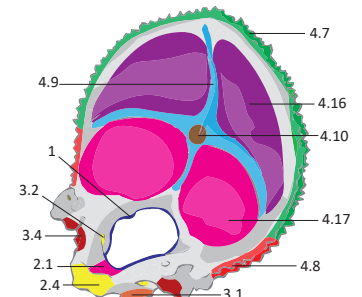
Posterior view of the skull



External surface of the cranial base



Internal surface of the cranial base



Oblique view of the occipital bone

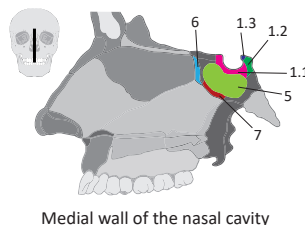
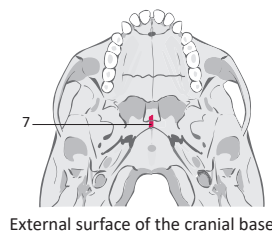
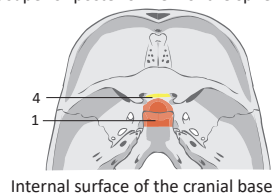
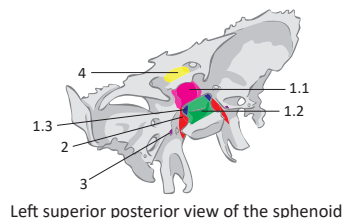
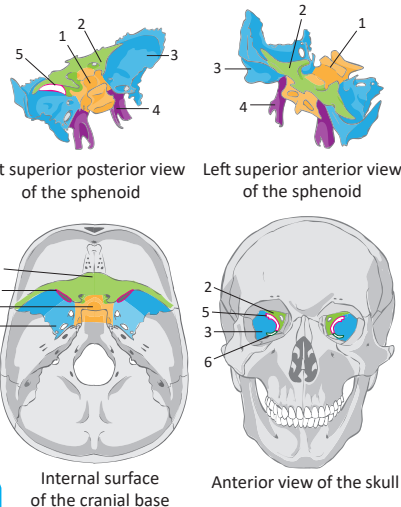
The **sphenoidal bone** is an unpaired bone of the base of the skull that develops predominantly by **endochondral ossification**. It consists of an unpaired **body** and **three paired projections: the greater wing, lesser wing and pterygoid process**. The sphenoidal bone connects the middle cranial fossa to several topographical spaces of the skull via various foramina. These topographical spaces are the infratemporal fossa, pterygopalatine fossa, tympanic cavity and the orbit. **The sphenoidal bone is an pneumatized bone** and contains a paired paranasal sinus: **the sphenoidal sinus**.

### Basic parts

- 1 **Body of the sphenoid**  
(*corpus ossis sphenoidalis*)
- 2 **Lesser wings**  
(*alae minores ossis sphenoidalis*)
- 3 **Greater wings**  
(*alae majores ossis sphenoidalis*)
- 4 **Pterygoid processes**  
(*processus pterygoidei*)
- 5 **Superior orbital fissure**  
(*fissura orbitalis superior*)  
– an opening located between the greater and lesser wings
- 6 **Inferior orbital fissure**  
(*fissura orbitalis inferior*)  
– an opening between the greater wing and the maxilla

### Body of sphenoid (*corpus ossis sphenoidalis*)

- 1 **Sella turcica**
  - 1.1 **Hypophysial fossa** (*fossa hypophysialis*)  
– contains the hypophysis
  - 1.2 **Dorsum sellae** – the posterior wall
  - 1.3 **Posterior clinoid processes**  
(*processus clinoides posteriores*)  
– the attachment of the sellar diaphragm and tentorium cerebelli
- 2 **Carotid sulcus** (*sulcus caroticus*)  
– a groove for the internal carotid artery  
– located lateral to the sella turcica
- 3 **Sphenoidal lingula** (*lingula sphenoidalis*)  
– the lateral margin of the carotid sulcus
- 4 **Prechiasmatic sulcus**  
– a shallow groove located anterior to the optic chiasma
- 5 **Sphenoidal sinus** (*sinus sphenoidalis*)  
– a paired paranasal sinus located inside the sphenoid body and under the sella turcica
  - 5.1 **Septum of sphenoidal sinuses**  
(*septum sinuum sphenoidalium*)  
– separates the left and right sphenoidal sinuses
  - 5.2 **Opening of sphenoidal sinus**  
(*apertura sinus sphenoidalis*)  
– connects the sphenoidal sinus to the superior nasal meatus
  - 5.3 **Sphenoidal concha** (*concha sphenoidalis*)  
– a rudimentary paired nasal concha that narrows the opening of the sphenoidal sinus
- 6 **Sphenoidal crest** (*crista sphenoidalis*)  
– a vertical crest in the midline of the ventral surface of the sphenoid body that articulates with the perpendicular plate of the ethmoidal bone
- 7 **Sphenoidal rostrum** (*rostrum sphenoidale*)  
– a vertical crest on the inferior surface of the sphenoid body that articulates with the vomer



The majority of the sphenoidal bone develops by **endochondral ossification**. However, the greater wings and the medial plate of the pterygoid process develop by **intramembranous ossification**.

The **middle clinoid process** (*processus clinoides medius*) is a variable binate prominence situated medial to the carotid groove that serves for the insertion of the sellar diaphragm.

The **foramen of Arnold** and *canaliculus innominatus* are obsolete terms for the **foramen petrosum**.

The **foramen of Vesalius** is an obsolete term for the **foramen venosum**.

The **pterygospinous process of Civini** (*processus pterygospinosus*) is a variable feature located on the posterior aspect of the lateral plate of the pterygoid process. It is a sharp bony protuberance that serves as the attachment of the **pterygospinous ligament**. The pterygospinous ligament can ossify to create the **foramen of Hyrtl**, containing the motor root of the mandibular nerve.

The **vomerovaginal canal** (*canalis vomerovaginalis*) is a small canal without any content, formed between the vaginal process of the pterygoid process and the vomer.

The **cavernous sinus** is discussed on page 534.

### Clinical notes

The **pteron** is a **craniometric point** at the point where the greater wing of the sphenoid bone, the parietal bone and the frontal bone meet. It is the weakest point of the skull. The middle meningeal artery is located underneath it on the internal surface of the skull. Trauma to this region may result in bleeding of the middle meningeal artery, which results in an epidural hematoma.

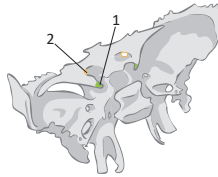
**From the developmental point of view**, the pterion is the location of the fibrous sphenoidal fontanelle.

The **pituitary gland** can be accessed via the sphenoidal sinus. This is known as the **transnasal transsphenoidal approach** and can be used to remove pituitary tumours.

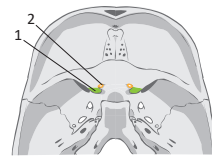


### Lesser wing (*ala minor ossis sphenoidalis*)

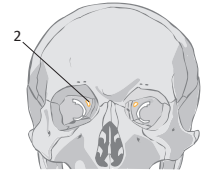
- 1 **Anterior clinoid process** (*processus clinoides anteriores*)
  - the attachment of the tentorium cerebelli
- 2 **Optic canal** (*canalis opticus*)
  - leads to the orbit
  - transmits the optic nerve and ophthalmic artery



Left superior posterior view of the sphenoid



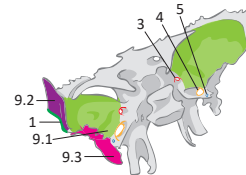
Cranial base



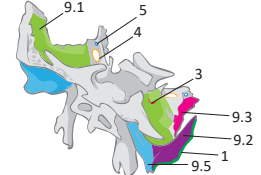
Anterior view of the skull

### Greater wing (*ala major ossis sphenoidalis*)

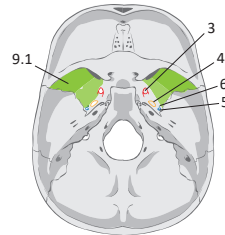
- 1 **Infratemporal crest** (*crista infratemporalis*)
  - forms the border between the temporal and infratemporal fossae
  - the origin of the superior head of the lateral pterygoid muscle
- 2 **Spine of sphenoidal bone** (*spina ossis sphenoidalis*)
  - the most dorsal part of the sphenoid
  - points downwards and is located near the foramen spinosum
  - the attachment of the sphenomandibular ligament, pterygospinous ligament and anterior ligament of the malleus
  - the origin of the tensor veli palatini
- 3 **Foramen rotundum** – transmits the maxillary nerve (n. V2)
- 4 **Foramen ovale** – transmits the mandibular nerve (n. V3) and the venous plexus of foramen ovale
- 5 **Foramen spinosum** – transmits the middle meningeal vessels and the meningeal branch of the mandibular nerve
- 6 **Petrosal foramen** (*foramen petrosum*)
  - a variable opening for the lesser petrosal nerve
- 7 **Sphenoidal emissary foramen / foramen venosum**
  - a variable opening for the sphenoidal emissary vein
- 8 **Sulcus of the auditory tube** (*sulcus tubae auditivae*)
  - contains the auditory tube (*tuba auditiva*), which connects the tympanic cavity to the nasopharynx
- 9 **Surfaces:**
  - 9.1 **Cerebral surface** (*facies cerebralis*)
  - 9.2 **Temporal surface** (*facies temporalis*)
  - 9.3 **Infratemporal surface** (*facies infratemporalis*)
  - 9.4 **Maxillary surface** (*facies maxillaris*)
  - 9.5 **Orbital surface** (*facies orbitalis*)
- 10 **Margins:**
  - 10.1 **Zygomatic margin** (*margo zygomaticus*)
  - 10.2 **Frontal margin** (*margo frontalis*)
  - 10.3 **Parietal margin** (*margo parietalis*)
  - 10.4 **Squamosal margin** (*margo squamosus*)



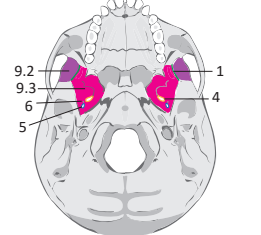
Left superior posterior view of the sphenoid



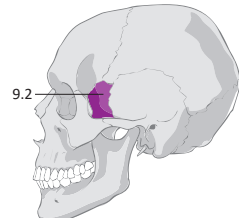
Left superior anterior view of the sphenoid



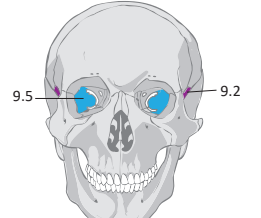
Internal view of the cranial base



External view of the cranial base



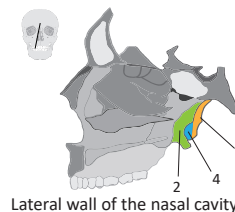
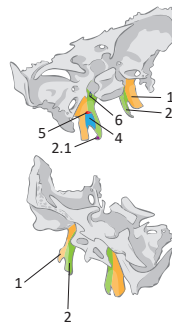
Lateral view of the skull



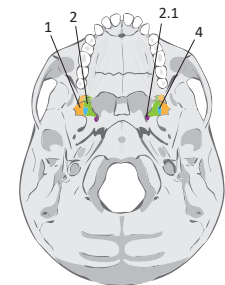
Anterior view of the skull

### Pterygoid process (*processus pterygoideus*)

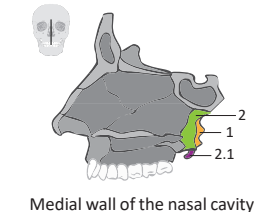
- 1 **Lateral plate** (*lamina lateralis*)
  - the origin of the inferior head of the lateral pterygoid muscle
- 2 **Medial plate** (*lamina medialis*) – the attachment of the pharyngobasilar fascia and superior constrictor of the pharynx
  - 2.1 **Pterygoid hamulus** (*hamulus pterygoideus*)
    - serves as a pulley for the tensor veli palatini tendon
- 3 **Pterygoid notch** (*incisura pterygoidea*)
  - a notch between the lateral and medial plates
- 4 **Pterygoid fossa** (*fossa pterygoidea*)
  - a fossa located between the lateral and medial plates
  - the origin of the medial pterygoid muscle
- 5 **Scaphoid fossa** (*fossa scaphoidea*)
  - is located cranial to the pterygoid fossa
  - the origin of the tensor veli palatini
- 6 **Pterygoid canal of Vidian** (*canalis pterygoideus*)
  - transmits the vessels and nerve of the pterygoid canal
- 7 **Vaginal process** (*processus vaginalis*)
  - a small prominence under the body of the sphenoid
  - forms the palatovaginal canal, which transmits the pharyngeal nerve and the pharyngeal branch of the maxillary artery



Lateral wall of the nasal cavity



Inferior aspect of the skull



Medial wall of the nasal cavity



The **parietal bone** is a paired bone in the cranial vault that develops by **intramembranous ossification**. It is square-shaped with an outward convexity formed by the **parietal eminence** (*tuber parietale*).

### 1 Surfaces

#### Internal surface (*facies interna*)

- 1.1 **Groove for the superior sagittal sinus** (*sulcus sinus sagittalis superioris*)  
– contains the superior sagittal sinus
- 1.2 **Groove for the middle meningeal artery** (*sulcus arteriae meningae mediae*)  
– contains the middle meningeal artery
- 1.3 **Grooves for arteries** (*sulci arteriosi*)  
– grooves for the branches of the middle meningeal artery

#### External surface (*facies externa*)

- 1.4 **Superior temporal line** (*linea temporalis superior*)  
– the attachment of the temporal fascia
- 1.5 **Inferior temporal line** (*linea temporalis inferior*)  
– the inferior margin of the origin of the temporalis muscle
- 1.6 **Parietal tuber** (*parietal eminence, tuber parietale*)  
– contains an ossification center  
– a thickened part of the bone with an outward convexity
- 1.7 **Groove for the sigmoid sinus** (*sulcus sinus sigmoidei*)  
– a short groove for the sigmoid sinus located over the mastoid angle

### 2 Parietal foramen (*foramen parietale*)

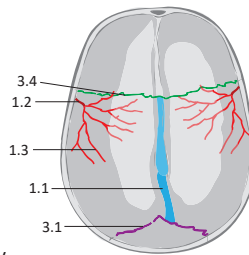
- transmits the parietal emissary vein
- located close to the sagittal border

### 3 Margins

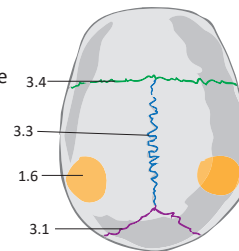
- 3.1 **Occipital border** (*margo occipitalis*)  
– connects to the occipital bone, forming the lambdoid suture (*sutura lambdoidea*)
- 3.2 **Squamous border** (*margo squamosus*)  
– connects to the temporal bone, forming the squamous suture (*sutura squamosa*)
- 3.3 **Sagittal border** (*margo sagittalis*)  
– connects to the contralateral parietal bone, forming the sagittal suture (*sutura sagittalis*)
- 3.4 **Frontal border** (*margo frontalis*)  
– connects to the frontal bone, forming the coronal suture (*sutura coronalis*)

### 4 Angles

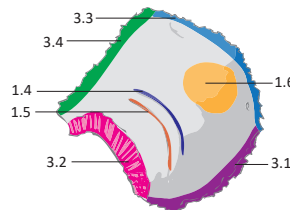
- 4.1 **Frontal angle** (*angulus frontalis*)
- 4.2 **Occipital angle** (*angulus occipitalis*)
- 4.3 **Mastoid angle** (*angulus mastoideus*)
- 4.4 **Sphenoidal angle** (*angulus sphenoidalis*)



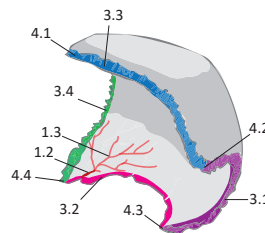
Internal view of the cranial vault



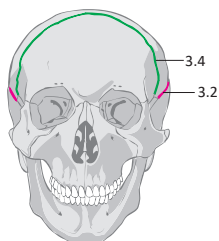
External view of the cranial vault



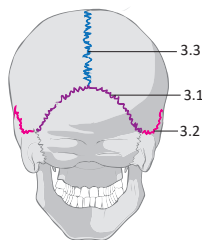
External view of the left parietal bone



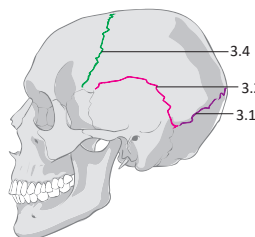
Internal view of the right parietal bone



Anterior view of the skull



Posterior view of the skull



Lateral view of the skull

The **granular foveolae** (*foveolae granulares*) are small depressions located adjacent to the groove for the superior sagittal sinus. They are impressions formed by arachnoid granulations.

**Arachnoid granulations / arachnoid villi** (*granulationes arachnoideae*) are pouches of arachnoid that project into the dural venous sinuses to allow cerebrospinal fluid to be absorbed into the blood. They are also known as **Pacchionian granulations**.

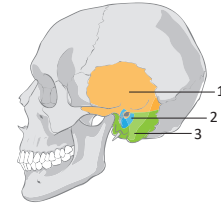
### Clinical notes

The **triangle of Macewan** is an eponym for the **suprameatal triangle** (*foveola suprameatica*). The suprameatal triangle can be used to approach the mastoid antrum, which lies 1.5–2 cm deep to the surface of the bone.

The **temporal bone** is a paired bone that consists of three main parts: the **squamous part**, the **tympanic part** and the **petrous part**. The squamous and tympanic parts of the temporal bone develop by **intramembranous ossification**. The petrous part and the styloid and mastoid process develop by **endochondral ossification**. The middle and inner ear are hidden inside the petrous bone. They open to the surroundings via the **internal and external acoustic openings**. The double-curved **facial canal**, housing the **facial nerve**, is located within the petrous part. The **mastoid process** is a pneumatized bony prominence containing small air filled cavities called **mastoid air cells**.

### Basic parts

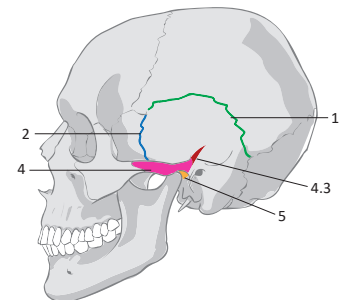
- 1 **Squamous part** (*pars squamosa*)
- 2 **Tympanic part** (*pars tympanica*)
  - forms the walls of the external acoustic meatus
  - has the shape of the letter “U”
- 3 **Petrous part** (*pars petrosa*)



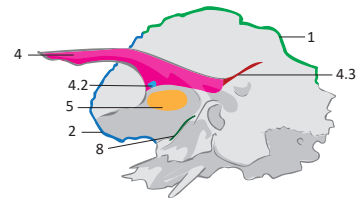
Basic parts of the temporal bone, lateral view of the skull

### Squamous part (*pars squamosa*)

- 1 **Parietal border** (*margo parietalis*) – connects to the parietal bone, forming the squamous suture (*sutura squamosa*)
- 2 **Sphenoidal margin** (*margo sphenoidalis*) – connects to the sphenoidal bone, forming the sphenosquamous suture (*sutura sphenosquamosa*)
- 3 **Groove for middle temporal artery** (*sulcus arteriae temporalis mediae*)
  - a shallow vertical groove on the internal surface of the bone
- 4 **Zygomatic process** (*processus zygomaticus*) – the origin of the masseter
  - the attachment of the lateral temporomandibular ligament and temporal fascia
  - forms the zygomatic arch with the temporal process of the zygomatic bone
- 4.1 **Articular surface** (*facies articularis*)
  - 4.2 **Articular tubercle** (*tuberculum articulare*)
    - a prominence in front of the mandibular fossa
    - forms part of the temporomandibular joint
  - 4.3 **Supramastoid crest** (*crista supramastoidea*)
    - part of the origin of the temporal muscle and temporal fascia
    - the dorsal continuation of the zygomatic process
- 4.4 **Suprameatal triangle** (*foveola suprameatica*)
  - a small fossa located above the external acoustic meatus
- 4.5 **Suprameatal spine** (*spina suprameatica*)
  - a variable osseous spine located under the suprameatal triangle
- 5 **Mandibular fossa** (*fossa mandibularis*)
  - the articular fossa for the temporomandibular joint



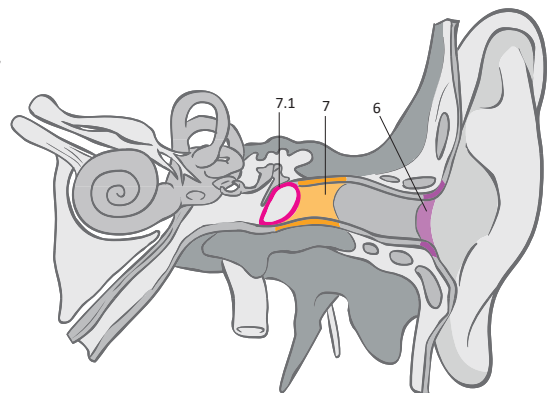
Lateral view of the skull



External oblique view of the left temporal bone

### Tympanic part (*pars tympanica*)

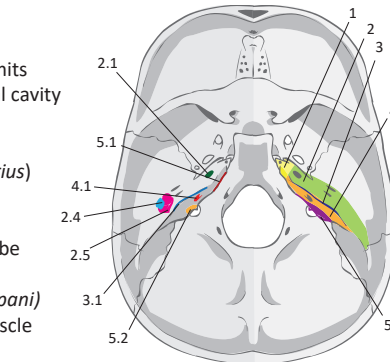
- 6 **External acoustic opening** (*porus acusticus externus*) – the opening of the ear canal
  - is composed of a bony part and a cartilaginous part
- 7 **Osseous external acoustic meatus** (*meatus acusticus externus osseus*)
  - the bony part of the external acoustic meatus
  - 7.1 **Tympanic ring** (*anulus tympanicus*)
    - a bony ring at the medial end of the external acoustic opening, covered by the tympanic membrane / eardrum
    - 7.1.1 **Tympanic sulcus** (*sulcus tympanicus*)
      - a groove in the tympanic ring for the attachment of the tympanic membrane
    - 7.1.2 **Tympanic notch** (*incisura tympanica*)
      - a notch in the upper part of the tympanic ring
      - contains the pars flaccida of the tympanic membrane
- 8 **Petrotympanic fissure** (*fissura petrotympanica*)
  - a fissure located between the tympanic and petrous parts of the temporal bone
  - transmits the chorda tympani, anterior tympanic vessels and anterior ligament of the malleus
- 9 **Tympanomastoid fissure** (*fissura tympanomastoidea*)
  - the end of the mastoid canaliculus
  - transmits the auricular branch of the vagus nerve
- 10 **Tympanosquamous and petrosquamous fissure** (*fissura tympanosquamosa et petrosquamosa*)



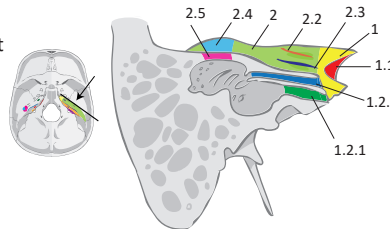
Frontal section of the principal parts of the ear

### Petrous part (*pars petrosa*)

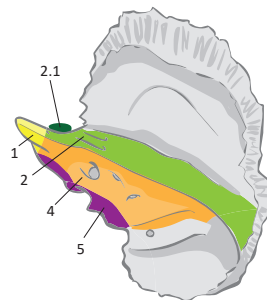
- 1 **Apex of the petrous part** (*apex partis petrosae*)
  - points ventromedially
  - 1.1 **Internal opening of the carotid canal** (*apertura interna canalis carotici*) – transmits the internal carotid artery into the cranial cavity
    - is located in the dorsal wall of the foramen lacerum
  - 1.2 **Musculotubal canal** (*canalis musculotubarius*)
    - 1.2.1 **Canal for auditory tube** (*semicanalis tubae auditivae*)
      - the bony part of the auditory tube
    - 1.2.2 **Canal for tensor tympani muscle** (*semicanalis muscoli tensoris tympani*)
      - contains the tensor tympani muscle
- 2 **Anterior surface** (*facies anterior*)
  - 2.1 **Trigeminal impression** (*impressio trigeminalis*)
    - a shallow fossa for the trigeminal ganglion (*ganglion trigeminale*)
    - located near the apex of the petrous part
  - 2.2 **Groove for greater petrosal nerve** (*sulcus nervi petrosi majoris*)
    - the continuation of the hiatus for the greater petrosal nerve
    - transmits the greater petrosal nerve
  - 2.3 **Groove for lesser petrosal nerve** (*sulcus nervi petrosi minoris*)
    - the continuation of the hiatus for the lesser petrosal nerve
    - transmits the lesser petrosal nerve from the tympanic cavity to the foramen ovale
  - 2.4 **Arcuate eminence** (*eminentia arcuata*)
    - a bulge formed by the anterior semicircular canal of the inner ear
  - 2.5 **Tegmen tympani** – the roof of the tympanic cavity, located anteromedial to the arcuate eminence
    - a weakened part of the skull
    - is perforated by the veins of the tympanic cavity
- 3 **Superior border** (*margo superior*)
  - the attachment of the tentorium cerebelli
  - contains the groove for the superior petrosal sinus
    - 3.1 **Groove for superior petrosal sinus** (*sulcus sinus petrosi superioris*)
- 4 **Posterior surface** (*facies posterior*)
  - 4.1 **Internal acoustic opening** (*porus acusticus internus*)
    - transmits the facial nerve, vestibulocochlear nerve and labyrinthine vessels from the posterior cranial fossa to the middle and internal ear
  - 4.2 **Subarcuate fossa** (*fossa subarcuata*)
    - a small depression that may contain a small residual vein from development
  - 4.3 **External opening of vestibular canaliculus** (*apertura externa canaliculi vestibuli*)
    - contains the endolymphatic sac
    - the location of endolymph resorption
    - 4.3.1 **Vestibular canaliculus** (*canaliculus vestibuli*)
      - contains the endolymphatic duct
- 5 **Posterior border** (*margo posterior*) – connects to the occipital bone
  - 5.1 **Groove for inferior petrosal sinus** (*sulcus sinus petrosi inferioris*)
  - 5.2 **Jugular notch** (*incisura jugularis*) – forms the jugular foramen (*foramen jugulare*) with the jugular notch of the occipital bone
  - 5.3 **Intrajugular process** (*processus intrajugularis*) – a projection inside the jugular notch that divides the jugular foramen into two compartments



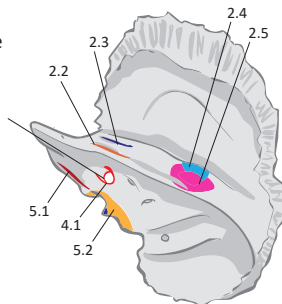
Internal view of the cranial base



A cross section of the right temporal bone viewed from the right



Internal oblique view of the right temporal bone



Internal oblique view of the right temporal bone,

The pyramid (*pyramis*) is an obsolete term for the petrous part of the temporal bone.

The pyramidal crest is an obsolete term for the superior border of the petrous part of the temporal bone.

The ventrobasal surface is an obsolete term for the portion of the petrous part of the temporal bone which forms most of the walls of tympanic cavity. It can be accessed after removal of tympanic part of the temporal bone.

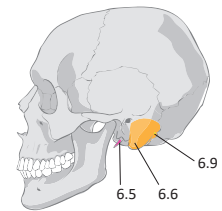
The facial nerve, see page 361.

The tympanic cavity, see page 506.

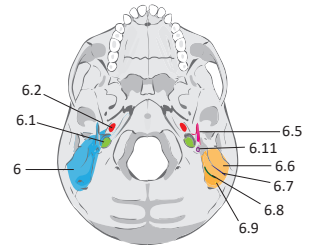
The internal acoustic meatus, see page 507.

### Petrous part (*pars petrosa*)

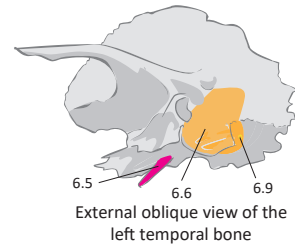
- 6 Inferior surface (*facies inferior*)
  - 6.1 **Jugular fossa** (*fossa jugularis*)
    - a fossa for the wide origin (superior bulb) of the internal jugular vein
    - 6.1.1 **Mastoid canaliculus** (*canaliculus mastoideus*)
      - transmits the auricular branch of the vagus nerve
  - 6.2 **External opening of the carotid canal** (*apertura externa canalis carotici*)
    - the entrance of the carotid canal (*canalis caroticus*)
    - transmits the internal carotid artery, the internal carotid plexus and the internal carotid venous plexus
  - 6.3 **Petrosal fossula** (*fossula petrosa*) – a little fossa between the jugular fossa and the external opening of the carotid canal
    - the entrance of the tympanic canaliculus
    - transmits the tympanic nerve and the inferior tympanic vessels to the tympanic cavity
  - 6.4 **External opening of the cochlear canaliculus** (*apertura externa canaliculi cochleae*) – is located between the jugular fossa and the external opening of the carotid canal
    - 6.4.1 **Cochlear canaliculus** (*canaliculus cochleae*)
      - contains the vein of the cochlear aqueduct
  - 6.5 **Styloid process** (*processus styloideus*)
    - the origin of the stylohyoid, styloglossus and stylopharyngeus
    - the attachment of the stylohyoid and stylomandibular ligaments
  - 6.6 **Mastoid process** (*processus mastoideus*)
    - a large pneumatized bony projection
    - the attachment of the sternocleidomastoid, splenius capitis and longissimus capitis
    - 6.6.1 **Mastoid cells** (*cellulae mastoideae*) – air filled cavities that communicate anteriorly with the mastoid antrum
  - 6.7 **Mastoid notch** (*incisura mastoidea*)
    - the origin of the posterior belly of the digastricus
  - 6.8 **Occipital groove** (*sulcus arteriae occipitalis*)
    - a groove for the occipital artery, located medial to the mastoid notch
  - 6.9 **Mastoid foramen** (*foramen mastoideum*) – transmits the mastoid emissary vein
  - 6.10 **Groove for sigmoid sinus** (*sulcus sinus sigmoidei*)
    - is located on the internal surface of the mastoid process
    - contains the internal entrance of the mastoid foramen
  - 6.11 **Stylomastoid foramen** (*foramen stylomastoideum*)
    - the external opening of the facial canal
    - transmits the facial nerve and the stylomastoid vessels



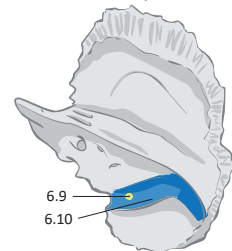
Lateral view of the skull



Inferior surface of the cranial base



External oblique view of the left temporal bone

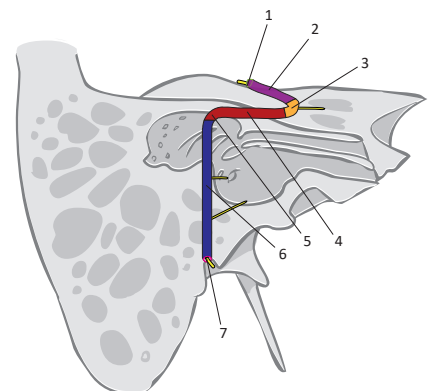


Internal oblique view of the right temporal bone

### Facial canal of Falloppio (*canalis nervi facialis*)

The facial canal is a double-curved canal located inside the petrous part of the temporal bone. It contains the facial nerve.

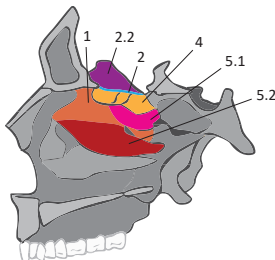
- 1. **The entrance** is the area facialis of the fundus of the internal acoustic meatus.
- 2. **The labyrinthine part** (*pars labyrinthica*) runs ventrolaterally above the cochlea at a right angle to the long axis of the petrous part of the temporal bone.
- 3. **The geniculum** houses the geniculate ganglion of the facial nerve. Here the canal makes a **90° turn laterocaudally**. The greater petrosal nerve leaves in a small canal that also contains the petrosal branch of the middle meningeal artery.
- 4. **The tympanic part** (*pars tympanica*) runs dorsolaterally and parallel to the long axis of the petrosal part of the temporal bone between the medial and upper walls of the tympanic cavity.
- 5. The canal reaches the posterior wall of the middle ear and makes a **90° turn downwards** forming the prominence of the facial canal (*prominentia canalis nervi facialis*) in the mastoid antrum.
- 6. **The mastoid part** (*pars mastoidea*) runs caudally in the posterior wall of the tympanic cavity. Two canals branch off here: the pyramidal eminence containing the nerve to the stapedius and the canaliculus of the chorda tympani which contains the chorda tympani and the posterior tympanic vessels.
- 7. **The exit** is the stylomastoid foramen, which transmits both the facial nerve and the stylomastoid vessels.



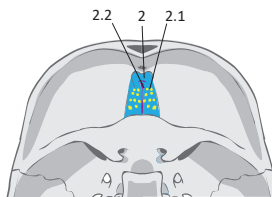
Section of the right temporal bone viewed from the right

The **ethmoidal bone** is an unpaired bone in the cranial base that develops by **endo-chondral ossification**. It consists of a **horizontal plate**, a **vertical plate** and the **ethmoidal labyrinth**. The ethmoidal bone is a **pneumatised bone** containing a paranasal sinus: the **ethmoidal air cells**.

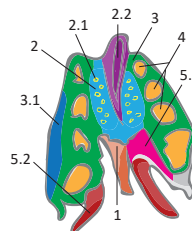
- 1 **Perpendicular plate** (*lamina perpendicularis*) – part of the nasal septum
- 2 **Horizontal/cribriform plate** (*lamina cribrosa*)
  - 2.1 **Cribriform foramina** (*foramina cribrosa*) – transmit the olfactory nerves (*fila olfactoria*)
    - 2.2 **Crista galli** – a bony plate located in the middle of the ethmoid bone, protruding above the cribriform plate
      - part of the attachment of the *falx cerebri*
- 3 **Ethmoidal labyrinths** (*labyrinthe ethmoidales*)
  - 3.1 **Orbital plate** (*lamina orbitalis*) – the outer wall of ethmoidal cells, facing the orbit
  - 3.2 **Anterior and posterior ethmoidal foramina** (*foramen ethmoidale anterius et posterius*)
    - are located between the ethmoidal and frontal bones
    - transmit the anterior and posterior ethmoidal artery, vein and nerve
- 4 **Ethmoidal cells** (*cellulae ethmoidales*)
  - 4.1 **Anterior and middle ethmoidal cells** (*cellulae ethmoidales anteriores et mediae*)
    - open into the middle nasal meatus via the ethmoidal infundibulum
  - 4.1.1 **Ethmoidal bulla** (*bulla ethmoidalis*) – a bulge in the lateral wall of the middle nasal meatus formed by the anterior ethmoidal cells
  - 4.2 **Posterior ethmoidal cells** (*cellulae ethmoidales posteriores*)
    - open into the superior nasal meatus
- 5 **Nasal conchae** (*conchae nasales*) – project medially into the nasal cavity
  - divide the nasal cavity into the nasal meati
  - 5.1 **Superior nasal concha** (*concha nasalis superior*)
  - 5.2 **Middle nasal concha** (*concha nasalis media*)
    - 5.2.1 **Uncinate process** (*processus uncinatus*) – a dorsolateral arched projection of the middle nasal concha caudally to the inferior nasal concha



Lateral wall of the nasal cavity



Internal view of the cranial base



Posterior oblique view of the ethmoidal bone

The **cerebral falx** (*falx cerebri*) is a fold of dura mater located between the two cerebral hemispheres.

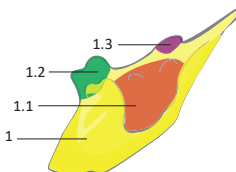
The **supreme nasal concha** (*concha nasalis suprema*) is a variable concha located on the roof of the nasal cavity.

**Lamina papyracea ossis ethmoidalis** is an obsolete term for the orbital plate of the ethmoid bone. As the name implies, this part of the ethmoid bone is very thin and liable to fracture.

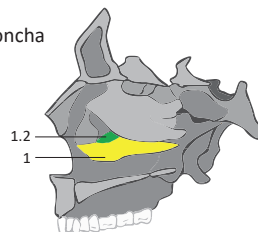
The **uncinate process of the middle nasal concha** (*processus uncinatus conchae nasalis mediae*) is connected to the ethmoidal process of the inferior nasal concha. These two processes form the semilunar hiatus, which lies within the maxillary hiatus.

Unlike the other conchae, the **inferior nasal concha** is an independent bone. The inferior nasal concha is connected to the maxilla and separates the **inferior nasal meatus** from the middle nasal meatus.

- 1 **Inferior nasal concha** (*concha nasalis inferior*)
  - 1.1 **Maxillary process** (*processus maxillaris*)
    - connects to the lateral wall of the nasal cavity
  - 1.2 **Lacrimal process** (*processus lacrimalis*) – connects to the lacrimal bone
  - 1.3 **Ethmoidal process** (*processus ethmoidalis*)
    - connects to the uncinate process of the middle nasal concha



Left anterior view of the left inferior nasal concha

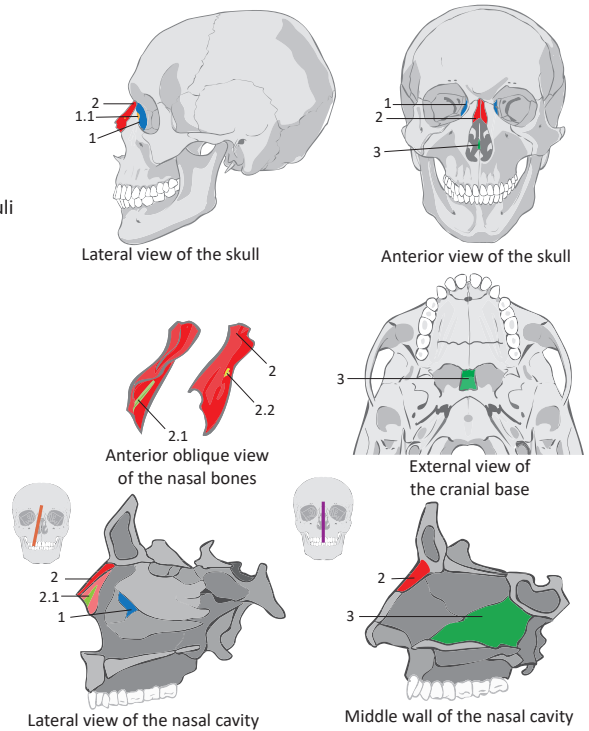


Inferior nasal concha viewed from the left



The **lacrimal bone** is a small paired bone that develops by **intramembranous ossification** and forms part of the medial wall of the orbit. The **nasal bone** is also a small paired bone that develops by **intramembranous ossification**. It is attached to the nasal part of the frontal bone. The **vomer** is a small unpaired sagittally oriented bone that develops by **intramembranous ossification** and forms the dorsal part of the nasal septum.

- 1 **Lacrimal bone** (*os lacrimale*)
  - 1.1 **Lacrimal groove** (*sulcus lacimalis*)
    - a rounded vertical groove
  - 1.1.1 **Fossa for the lacrimal sac** (*fossa sacci lacimalis*)
    - is formed by the lacrimal bone and maxilla
  - 1.1.2 **Posterior lacrimal crest** (*crista lacimalis posterior*)
    - the dorsal border of the lacrimal fossa
    - the attachment of the medial palpebral ligament and the origin of the deep part of the orbicularis oculi
  - 1.2 **Nasolacrimal canal** (*canalis nasolacrimalis*)
    - a bony canal that leads to the nasal cavity
    - contains the nasolacrimal duct
    - is bordered by the lacrimal hamulus
- 2 **Nasal bone** (*os nasale*)
  - 2.1 **Ethmoidal groove** (*sulcus ethmoidalis*)
    - a groove for the nasal branch of the anterior ethmoidal nerve
  - 2.2 **Nasal foramen** (*foramen nasale*)
    - transmits the external nasal branch of the anterior ethmoidal nerve
- 3 **Vomer**
  - forms the dorsal third of the nasal septum
  - divides at its cranial aspect into the paired alae of the vomer, which are connected to the rostrum of the sphenoidal bone
  - caudally connected to the nasal crest of the hard palate
  - ventrocranially connected to the perpendicular plate of the ethmoidal bone

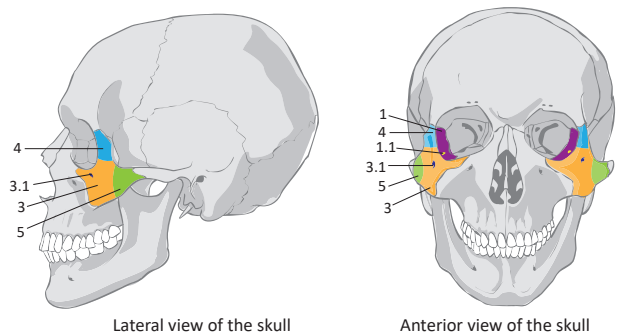


The **zygomatic bone** is a paired bone of the **viscerocranium** that develops by **intramembranous ossification**. Together with the **zygomatic process of the temporal bone** it forms the **zygomatic arch**. It contains the **zygomatic nerve**, which bifurcates inside the bone into two terminal branches that innervate the skin overlying the zygomatic bone and the temporal fossa.

- 1 **Orbital surface** (*facies orbitalis*)
  - forms the lateral and caudal walls of the orbit
  - 1.1 **Zygomatico-orbital foramen** (*foramen zygomaticoorbitale*)
    - the entrance for the zygomatic nerve
- 2 **Temporal surface** (*facies temporalis*)
  - forms the anterior wall of the temporal fossa
  - 2.1 **Zygomaticotemporal foramen** (*foramen zygomaticotemporale*)
    - transmits the zygomaticotemporal nerve
- 3 **Lateral surface** (*facies lateralis*)
  - forms the skeleton of the zygomatic region of the face
  - 3.1 **Zygomaticofacial foramen** (*foramen zygomaticofaciale*)
    - transmits the zygomaticofacial nerve

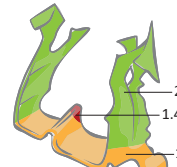
#### Projections

- 4 **Frontal process** (*processus frontalis*)
- 5 **Temporal process** (*processus temporalis*)
  - forms the zygomatic arch with the zygomatic process of the temporal bone
- 6 **Orbital tubercle** (*tuberculum orbitale*) – the attachment of the lateral palpebral ligament and the suspensory ligament of the eyeball

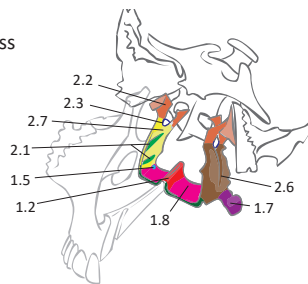


The **palatine bone** is a paired bone of the viscerocranium that develops by **intramembranous ossification**. It consists of two plates arranged perpendicularly to each other in an L-shape. These are the **horizontal plate** and the **perpendicular plate**. The horizontal plate articulates with the maxilla, forming the hard palate.

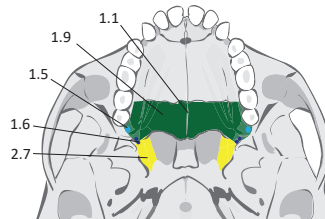
- **1 Horizontal plate** (*lamina horizontalis*)
  - 1.1 **Median palatine suture** (*sutura palatina mediana*)
    - connects the two palatine bones in the midline
  - 1.2 **Nasal crest** (*crista nasalis*) – a bony ridge adjacent to the median palatine suture and facing the nasal cavity
  - 1.3 **Palatine crest** (*crista palatina*) – a bony ridge adjacent to the median palatine suture and facing the oral cavity
  - 1.4 **Posterior nasal spine** (*spina nasalis posterior*)
    - the dorsal projection of the nasal crest
    - the origin of the musculus uvulae
  - 1.5 **Greater palatine foramen** (*foramen palatinum majus*)
    - an opening on the lateral surface near the connection with the maxilla
    - the terminal opening of the greater palatine canal, which transmits the greater palatine nerve and vessels
  - 1.6 **Lesser palatine foramina** (*foramina palatina minora*)
    - are located dorsal to the greater palatine foramen
    - the terminal openings of the lesser palatine canals, which transmit the lesser palatine nerves and vessels
  - 1.7 **Pyramidal process** (*processus pyramidalis*)
    - connects to the lateral plate of the pterygoid process
    - the origin of the medial pterygoid muscle
  - 1.8 **Nasal surface** (*facies nasalis*) – forms the dorsal part of the floor of the nasal cavity
  - 1.9 **Palatine surface** (*facies palatina*) – forms the dorsal part of the hard palate
- **2 Perpendicular plate** (*lamina perpendicularis*)
  - 2.1 **Ethmoidal crest and conchal crest** (*crista ethmoidalis et crista conchalis*)
    - projections for the attachment of the middle and inferior nasal conchae
  - 2.2 **Orbital and sphenoidal process** (*processus orbitalis et sphenoidalis*)
    - two cranial processes
    - form the sphenopalatine notch
  - 2.3 **Sphenopalatine foramen** (*foramen sphenopalatinum*) – an opening formed by the sphenoid bone and the sphenopalatine notch of the palatine bone
    - transmits the sphenopalatine artery and posterior superior lateral and medial nasal branches of the maxillary nerve
  - 2.4 **Greater palatine canal** (*canalis palatinus major*)
    - is located between the maxillary bone and a groove on the maxillary surface of the palatine bone
    - transmits the greater palatine nerve and vessels
  - 2.5 **Lesser palatine canals** (*canales palatini minores*)
    - branches of the greater palatine canal
    - transmit the lesser palatine nerves and vessels
  - 2.6 **Maxillary surface** (*facies maxillaris*)
    - points towards the maxilla
  - 2.7 **Nasal surface** (*facies nasalis*)
    - forms the dorsal part of the lateral wall of the nasal cavity



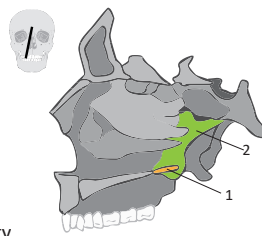
Anterior oblique view of the palatine bones



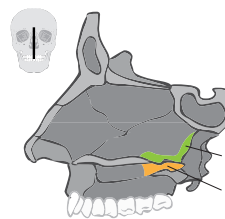
Anterior oblique view of the palatine bones



External view of the cranial base



Oblique section through the nasal cavity



Middle wall of the nasal cavity

**Invololution of the alveolar processes.** After loss of the teeth, the alveolar processes (*processus alveolaris*) of both the maxilla and mandible diminish in size.

**Palatine spines** (*spinae palatinae*) are longitudinal ridges on the inferior (palatal) surface of the maxilla.

**Palatine grooves** (*sulci palatini*) are grooves between the palatine spines for the branches of the greater palatine nerve and vessels (*nervus et vasa palatina majora*).

**The maxillary hiatus** is narrowed by the ethmoidal bulla, the uncinate process of the middle nasal concha and the palatine bone.

**The incisive fossa** (*fossa incisiva*) is an anatomical term that is used for two different structures:

1. A shallow pit above the first incisive tooth on the anterior surface of the maxilla. This is the origin of the depressor septi nasi muscle (*musculus depressor septi nasi*)
2. A pit behind the incisive teeth on the incisive bone where the incisive foramina and the lower ends of the incisive canals are situated.

The maxilla is a paired bone of the **viscerocranium** that develops by **intramembranous ossification**. It consists of a **body** with **four surfaces** and **four processes**. The maxilla is a **pneumatised bone** and contains the largest paranasal sinus: the **maxillary sinus**.

● **1 Body of maxilla** (*corpus maxillae*)

**Orbital surface** (*facies orbitalis*) – forms the floor of the orbit

1.1 **Infra-orbital groove** (*sulcus infraorbitalis*) – a groove for the infra-orbital nerve and vessels

● 1.2 **Infra-orbital canal** (*canalis infraorbitalis*)

– the extension of the infra-orbital groove through the maxilla to the anterior surface

● 1.3 **Infra-orbital margin** (*margo infraorbitalis*) – the caudal margin of the orbit

**Anterior surface** (*facies anterior*)

● 1.4 **Infra-orbital foramen** (*foramen infraorbitale*) – the anterior opening of the infra-orbital canal

1.5 **Canine fossa** (*fossa canina*) – is located lateral to the canine tooth root

– the origin of the levator anguli oris

1.6 **Nasal notch** (*incisura nasalis*) – forms the caudal border of the piriform aperture (the orifice of the nasal cavity)

**Infratemporal surface** (*facies infratemporalis*) – forms the anterior wall of the infratemporal fossa

● 1.7 **Maxillary tuberosity** (*tuber maxillae*)

1.8 **Alveolar foramina** (*foramina alveolaria*) – transmit the posterior superior alveolar branches of the maxillary nerve and the posterior superior alveolar vessels to the upper posterior teeth

**Nasal surface** (*facies nasalis*) – the medial surface of the maxilla

– forms part of the lateral wall of the nasal cavity

1.9 **Lacrimal notch** (*incisura lacrimalis*)

– borders the entrance of the nasolacrimal canal

1.10 **Lacrimal groove** (*sulcus lacrimalis*)

– forms the nasolacrimal canal with the inferior nasal concha

1.11 **Conchal crest** (*crista conchalis*)

– a projection for the attachment of the inferior nasal concha

1.12 **Maxillary hiatus** (*hiatus maxillaris*)

– the opening of the maxillary sinus into the middle nasal meatus

1.13 **Maxillary sinus / antrum of Highmore** (*sinus maxillaris*)

– a paranasal sinus that opens into the middle nasal meatus

**Processes:**

● **2 Frontal process** (*processus frontalis*)

2.1 **Anterior lacrimal crest** (*crista lacrimalis anterior*)

– together with the lacrimal bone forms a fossa for the lacrimal sac  
– the attachment of the medial palpebral ligament

2.2 **Ethmoidal crest** (*crista ethmoidalis*)

– a projection for the attachment of the middle nasal concha

● **3 Zygomatic process** (*processus zygomaticus*)

● **4 Palatine process** (*processus palatinus*) – forms the hard palate  
– connects to the contralateral palatine process, forming the median palatine suture

4.1 **Nasal crest** (*crista nasalis*) – an elevation projecting into the nasal cavity located above the median palatine suture

● 4.2 **Anterior nasal spine** (*spina nasalis anterior*)

– the ventral prominence of the nasal crest

● 4.3 **Incisive bone** (*os incisivum, premaxilla*)

– the ventral part of maxilla that holds the incisor teeth  
– develops as an independent bone (the primary palate)  
– is separated from the maxilla by the incisive suture, which is only present in some adults

● 4.3.1 **Incisive foramen** (*foramen incisivum*)

– a paired opening located in the midline on the median palatine suture

4.3.2 **Incisive canal** (*canalis incisivus*) – a paired canal connecting the nasal and oral cavities

– transmits the nasopalatine nerve and a branch of the sphenopalatine artery

● **5 Alveolar process** (*processus alveolaris*) – contains the dental alveoli (teeth sockets)

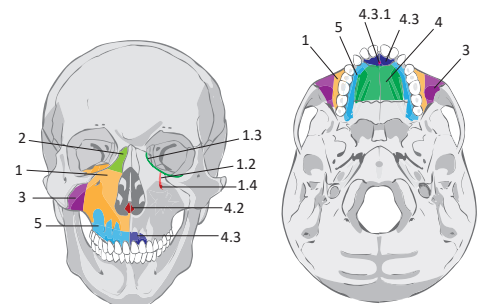
5.1 **Alveolar arch** (*arcus alveolaris*) – an ellipsoid arch of the dental alveoli

5.2 **Alveolar yokes** (*juga alveolaria*) – surround the dental roots

5.3 **Dental alveoli** (*alveoli dentales*) – spaces for the teeth

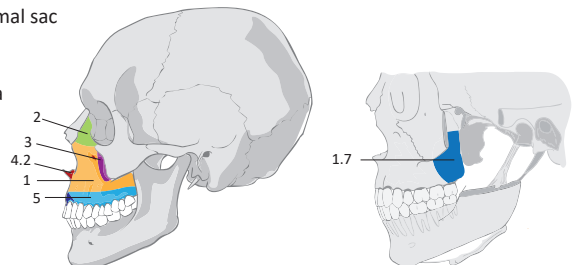
5.4 **Interalveolar septa** (*septa interalveolaria*) – septa between the teeth

5.5 **Interradicular septa** (*septa interradicularia*) – septa between roots of the teeth



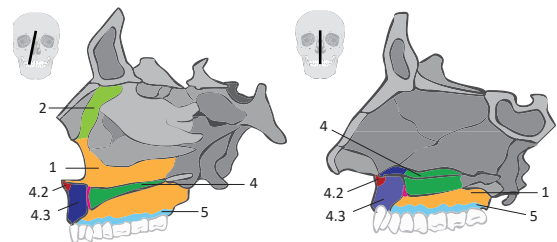
Anterior view of the skull

External view of the cranial base



Lateral view of the skull

Lateral view of the skull

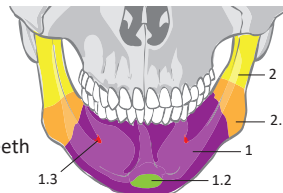


Lateral wall of the nasal cavity

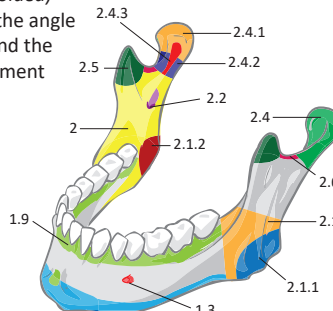
Medial wall of the nasal cavity

The **mandible** is an unpaired bone of the **viscerocranium** that develops as a paired bone by both **intramembranous** and **endochondral ossification**. It consists of a **body** and two broad **rami**. The mandible is the only skull bone that is connected with the rest of the skull by a synovial joint: the **temporomandibular joint**. It serves as a place of insertion for all the **masticatory muscles**.

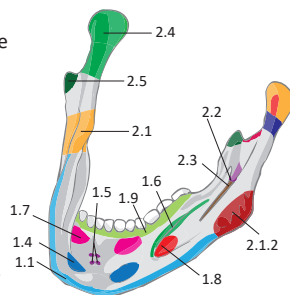
- **1 Body of mandible** (*corpus mandibulae*) – the unpaired central part of the bone
  - **1.1 Base of mandible** (*basis mandibulae*) – the rounded caudal margin of the mandible
  - **1.2 Mental protuberance** (*protuberantia mentalis*) – the unpaired prominence of the chin
    - **1.2.1 Mental tubercle** (*tuberculum mentale*) – is located on the mental protuberance
  - **1.3 Mental foramen** (*foramen mentale*) – the external opening of the mandibular canal – transmits the inferior alveolar nerve and vessels
  - **1.4 Digastric fossa** (*fossa digastrica*) – the attachment of the anterior belly of the digastricus
  - **1.5 Superior and inferior mental spines** (*spina mentalis superior et inferior*)
    - the genioglossus originates on the superior mental spine
    - the geniohyoid originates on the inferior mental spine
  - **1.6 Mylohyoid line** (*linea mylohyoidea*) – the origin of the superior constrictor of the pharynx and the mylohyoid and the attachment of the pterygomandibular raphe
  - **1.7 Sublingual fossa** (*fovea sublingualis*) – is located above the mylohyoid line
    - the location of the sublingual salivary gland
  - **1.8 Submandibular fossa** (*fovea submandibularis*) – is located below the mylohyoid line
    - the location of the submandibular salivary gland
  - **1.9 Alveolar part** (*pars alveolaris*) – houses the teeth
    - **1.9.1 Alveolar arch** (*arcus alveolaris*)
      - a parabolic arch of dental alveoli
    - **1.9.2 Alveolar yokes** (*juga alveolaria*)
      - woven bone surrounding the dental roots
    - **1.9.3 Dental alveoli** (*alveoli dentales*) – spaces for the teeth
- **2 Ramus of mandible** (*ramus mandibulae*)
  - **2.1 Angle of mandible** (*angulus mandibulae*)
    - **2.1.1 Masseteric tuberosity** (*tuberositas masseterica*)
      - a tuberosity on the external surface of the angle
      - the insertion of the masseter
    - **2.1.2 Pterygoid tuberosity** (*tuberositas pterygoidea*)
      - a tuberosity on the internal surface of the angle
      - the insertion of the medial pterygoid and the attachment of the stylomandibular ligament
  - **2.2 Mandibular foramen** (*foramen mandibulae*)
    - the entrance of the mandibular canal
  - **2.2.1 Mandibular canal** (*canalis mandibulae*)
    - runs through the ramus and body of the mandible
    - transmits the inferior alveolar nerve and inferior alveolar vessels
  - **2.3 Mylohyoid groove** (*sulcus mylohyoideus*)
    - a groove for the mylohyoid nerve and vessels
  - **2.4 Condylar process** (*processus condylaris*)
    - **2.4.1 Head of mandible** (*caput mandibulae*)
      - the articular head of the temporomandibular joint
    - **2.4.2 Neck of mandible** (*collum mandibulae*)
      - the attachment of the lateral temporomandibular ligament
    - **2.4.3 Pterygoid fovea** (*fovea pterygoidea*)
      - the insertion of the lateral pterygoid muscle
  - **2.5 Coronoid process** (*processus coronoideus*)
    - the attachment of the temporal muscle
  - **2.5.1 Temporal crest** (*crista temporalis*)
    - is located between the anterior border of the coronoid process and the external surface of the body of the mandible
    - the insertion of the temporal muscle
  - **2.6 Mandibular notch** (*incisura mandibulae*) – a notch located between the condylar and coronoid process that transmits the masseteric artery and vein



Anterior view of the skull



Anterior oblique view of the mandible



Posterior oblique view of the mandible

The **retromolar triangle** (*trigonum retromolare*) is a triangular space located behind the third molar.

The **retromolar fossa** (*fossa retromolaris*) is a depression located in the retromolar triangle.

The **lingula of the mandible** (*lingula mandibulae*) delimits the mandibular foramen anteriorly and serves as the attachment for the sphenomandibular ligament.

The **oblique line** (*linea obliqua*) is a line on the outer surface of the mandible leading to the mental tubercle and separating the base of the mandible (*basis mandibulae*) from the alveolar part (*pars alveolaris*). It serves as an origin for some of the facial muscles.

**Small and independent centres of ossification** may occur in certain fontanelles. This leads to formation of some small accessory skull bones. Such bones include the **bregmatic bone** (*os bregmaticum*) in the anterior fontanelle and the **epipteric bone** (*os epiptericum*) in the sphenoidal fontanelle.

**Sutural bones** (*ossa suturarum*) are also known as **Wormian bones**. They are variable small irregular bones located within the cranial sutures, most frequently around the parietal bones.

### Clinical notes

The **hyoid bone** is sensitive to palpation in disorders of the infrahyoid and suprahyoid muscles (especially the digastric muscle).

**Venepuncture** can be performed through the anterior fontanelle to get a sample of dural venous blood.

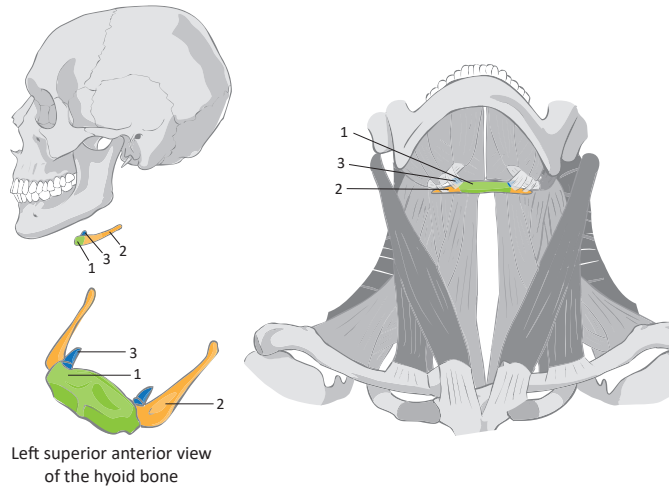
**Premature closure of the sutures of the newborn skull** results in a condition called **craniosynostosis** and can result in a misshaped skull, intellectual disability and hydrocephalus.

The **brain of newborns and infants** may be viewed by ultrasound through the anterior fontanelle.

The **anterior and posterior fontanelles** help orientate the head of the baby during delivery.

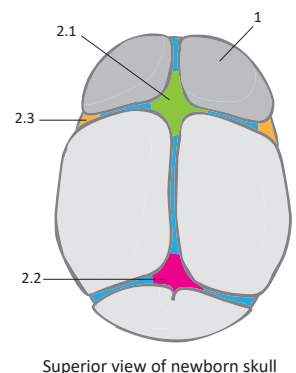
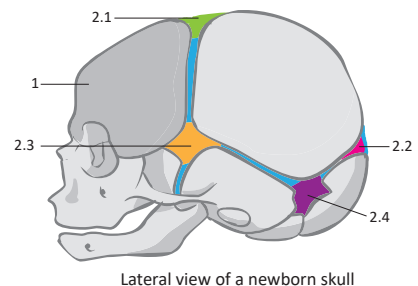
The hyoid bone is an unpaired bone located between the muscles of neck **at the level of C2–C3**. The hyoid bone develops by **enchondral ossification**. It has muscular attachments for the larynx, pharynx, tongue and floor of the mouth.

- **1 Body of hyoid bone** (*corpus ossis hyoidei*)
  - the unpaired central portion of the bone
  - the insertion of the geniohyoid, mylohyoid, stylohyoid, sternohyoid and superior belly of the omohyoid
  - the attachment of the thyrohyoid membrane and the thyoepiglottic ligament
- **2 Greater horn** (*cornu majus*)
  - paired lateral parts of the bone
  - projects dorsally from the body
  - the origin of the middle constrictor of the pharynx
  - the attachment of the thyrohyoid membrane
  - the insertion of the thyrohyoid muscle
  - the attachment of a fibrous sling that pulls the intermediate tendon of the digastricus towards the hyoid bone
- **3 Lesser horn** (*cornu minus*)
  - a paired short projection from the body
  - projects dorsocranially from the lateral part of the body
  - the origin of the middle constrictor of the pharynx
  - the attachment of the stylohyoid ligament



In contrast to the skull of an adult, **the skull of a newborn** has a large neurocranium and a small viscerocranium. **The dorsoventral diameter is 11.5 cm, the transverse dimension is 9.5 cm and the circumference is 34 cm. Fontanelles** are gaps in the infant skull located at the junctions of two or more sutures and are covered by fibrous membranes.

- **1 Frontal bone** (*os frontale*) – a paired bone connected by the frontal suture
- **2 Fontanelles** (*fonticuli cranii*) – gaps between skull bones covered by fibrous membranes
  - **2.1 Anterior fontanelle** (*fonticulus anterior*) – is diamond shaped
    - is located at the junction between the coronal and sagittal suture
    - closes by the 2<sup>nd</sup> year of life
  - **2.2 Posterior fontanelle** (*fonticulus posterior*) – is triangle-shaped
    - is located at the junction between the sagittal and lambdoid suture
    - closes by the 3<sup>rd</sup> month of life and sometimes is not even palpable at birth
    - an orientation point for obstetricians
  - **2.3 Sphenoidal fontanelle** (*fonticulus sphenoidalis*)
    - has an irregular square shape
    - is located on the medial wall of the temporal fossa between the parietal bone, frontal bone, the squamous part of the temporal bone and the greater wings of the sphenoid bone
    - closes by the 6<sup>th</sup> month of life
  - **2.4 Mastoid fontanelle** (*fonticulus mastoideus*)
    - closes by 6<sup>th</sup>–18<sup>th</sup> month of life
    - is located between the mastoid process, parietal bone and occipital bone
- **3 Mandible** (*mandibula*) – has a very small body and rami
  - the mandibular symphysis is located in the midline of the body and closes by the first year of life
  - has no alveolar process
  - has an obtuse angle between the body and rami
  - the shape of the newborn mandible allows significant protraction during breastfeeding
- **4 Paranasal sinuses** – are not developed or are just slightly implied
- **5 Hard palate** – the incisive suture is present between the maxilla and the incisive bone
- **6 Tympanic part of the temporal bone** – forms an opened ring
- **7 Cranial sutures** – are not fused in the newborn skull, which makes the skull more flexible during delivery





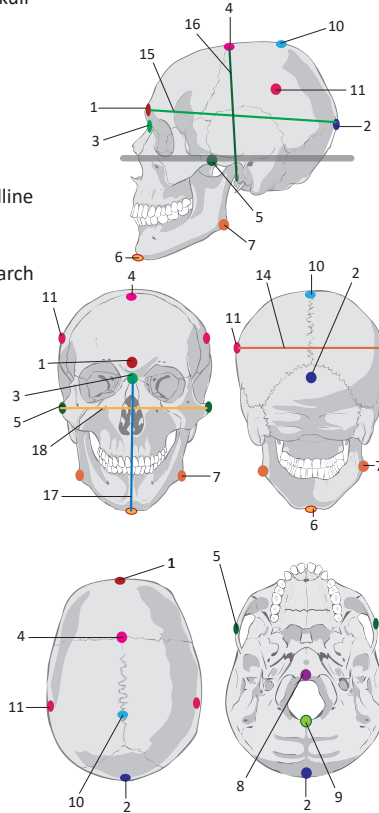
**Craniometric landmarks** are used for measuring the dimensions of the skull. They can be applied to determine the sex of the skull. Outside of clinical medicine, **craniometry** is used in **forensic pathology, biological anthropology and archaeology**.

### The basic anthropometric plane

- **Auriculo-orbital plane** – is also known as Frankfurt's (horizontal) plane
  - traverses the lower margin of the orbit and upper margin of the external acoustic meatus
  - establishes the anatomical position of the human skull

### Craniometric landmarks

- 1 **Glabella** – a flattened area above the nasal root
- 2 **Opisthocranium** – a point located on the posterior part of the skull
  - the most distant landmark from the glabella
- 3 **Nasion** – lies on the nasofrontal suture in the midline
- 4 **Bregma** – is found at the intersection of the coronal and sagittal sutures
- 5 **Zygion** – the most lateral point on the zygomatic arch
- 6 **Gnathion** – the most caudal point in the midline of the mandible
- 7 **Gonion** – is located at the angle of the mandible
- 8 **Basion** – is located in the middle of the ventral margin of the foramen magnum
- 9 **Opisthion** – is located in the middle of the dorsal margin of the foramen magnum
- 10 **Vertex** – the highest point of the skull
- 11 **Euryon** – the most lateral point on the skull
  - is usually located on the parietal bone
- 12 **Pterion** – the intersection of the temporal, frontal and sphenoidal bones
  - is located over the sphenoidal fontanelle in the skull of a newborn
- 13 **Asterion** – is located on the mastoid fontanelle

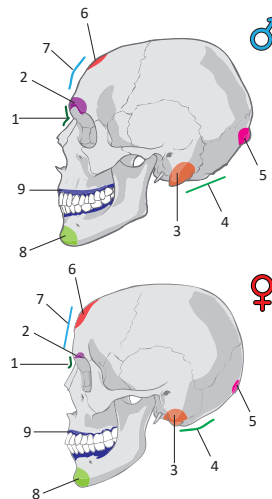


### Craniometric measurement

- 14 **Width of skull**: euryon to euryon
- 15 **Length of skull**: glabella to opisthocranium
- 16 **Height of skull**: basion to bregma
- 17 **Height of face**: nasion to gnathion
- 18 **Width of face**: zygion to zygion

### Sex differences in the skull

- 1 **Nasofrontal transition**
  - is distinct in men but continuous in women
- 2 **Superciliary arches**
  - are distinct in men but discrete in women
- 3 **Mastoid processes**
  - is distinct in men but discrete in women
- 4 **Occipital plane**
  - is flat in men but curved in women
- 5 **External occipital protuberance**
  - is distinct in men but discrete in women
- 6 **Frontal tubers**
  - is discrete in men but distinct in women
- 7 **Shape of the forehead**
  - is sloped in men but steep in women
- 8 **Shape of the chin**
  - is square-shaped in men but round in women
- 9 **Alveolar processes**
  - protrude further outwards in men



**Sclerotomes** are formed from mesenchymal cells from the paraxial mesoderm. They are situated bilaterally to the neural tube and notochord. Their medial parts give rise to the vertebral bodies. Their lateral parts surround the neural tube and give rise to the vertebral arches. **The complete vertebra** is formed by fusion of two halves of two adjacent sclerotomes: the caudal half of the more cranial sclerotome and the cranial half of the more caudal sclerotome.

**Kyphoses** of the vertebral column are partially developed at birth. **Lordoses** are formed after birth when the baby activates and fully uses the muscles of the back. This occurs through lifting the head, which forms the **cervical lordosis**, and by erecting the trunk and walking, which forms the **lumbar lordosis**.

**Abbreviations** used for transitions points in the vertebral column:  
**AO** – atlanto-occipital joint  
**CT** – cervicothoracic transition  
**TL** – thoracolumbar transition  
**LS** – lumbosacral transition

**Movements of the vertebral column** are discussed on page 75.

### Clinical notest

**Pain in CT and TL transitions** can occur as a result of changes in the curvatures of the vertebral column.

**Scoliosis** is a sideways curvature of the spine. It occurs most often during the growth spurt just before puberty.

**Hyperlordosis and hyperkyphosis** are pathological conditions caused by excessive anteroposterior curvatures of the vertebral column. Loss of the natural lower curvature of the spine is called flat back or flat back syndrome.

**The spinous processes** are sensitive to palpation in muscular disorders, particularly in disorders affecting the erector spinae muscles.

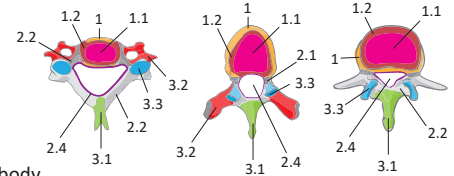
**The advantage of vertebral column** is its ability to help treat orthopaedic conditions of the distal parts of the body. **The disadvantage** is its capability to develop problems that originate in distal parts of the body.

**The individual segments of the spine** are often hypomobile. By contrast transitions of the vertebral column (AO, CT, TL, LS) are hypermobile and have a tendency to become overloaded.

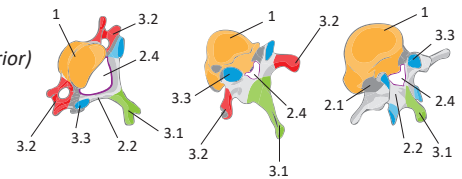
The **vertebral column** is derived from the sclerotomes. The **vertebrae** are the individual bony units of the vertebral column. We differentiate **7 cervical vertebrae**, **12 thoracic vertebrae**, **5 lumbar vertebrae**, **5 fused sacral vertebrae** and **4–5 fused coccygeal vertebrae**. The vertebral column has four ventrodorsal curves (two kyphoses and two lordoses) and a slight lateral curve (a physiological scoliosis).

### Vertebra – general organisation

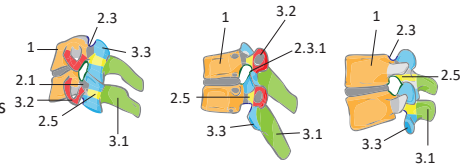
- **1 Vertebral body** (*corpus vertebrae*)
  - the large ventral part of the vertebrae
  - **1.1 Intervertebral surface** (*facies intervertebralis*)
    - connects to the intervertebral disc
  - **1.2 Anular epiphysis** (*epiphysis anularis*) – a ring of compact bone on the external margin of the upper and lower surface of the vertebral body
    - contains a secondary ossification centre
- 2 Vertebral arch** (*arcus vertebrae*) – attaches to the dorsal surface of the vertebral body
  - **2.1 Pedicle** (*pediculus arcus vertebrae*) – the anterior part of the vertebral arch
    - the narrowest part of the arch
    - connect to the vertebral body
  - **2.2 Lamina** (*lamina arcus vertebrae*) – the posterior part of the vertebral arch
  - **2.3 Superior and inferior vertebral notch** (*incisura vertebralis superior et inferior*)
    - paired notches located on the anterior part of the vertebral arch
    - the superior notch is shallow and the inferior notch is deep
    - **2.3.1 Intervertebral foramen** (*foramen intervertebrale*)
      - is formed by connection of the notches of adjacent vertebrae
      - transmits the spinal nerve with some small vessels
  - **2.4 Vertebral foramen** (*foramen vertebrale*) – is bordered by the body and arch
    - 2.4.1 Vertebral canal** (*canalis vertebralis*)
      - contains the spinal cord with its meninges and vessels
      - is formed by connection of adjacent vertebral foramina
  - **2.5 Isthmus** (*isthmus arcus vertebrae / pars interarticularis vertebrae*)
    - a small, thin segment between the superior and inferior articular process
- 3 Processes**
  - **3.1 Spinous process** (*processus spinosus*) – an unpaired palpable process
  - **3.2 Transverse process** (*processus transversus*)
    - a paired process, palpable only on the cervical vertebrae
  - **3.3 Superior and inferior articular process** (*processus articularis superior et inferior*)
    - paired articular processes pointing cranially and caudally respectively



Superior view of cervical, thoracic and lumbar vertebrae



Posterior oblique view of cervical, thoracic and lumbar vertebrae



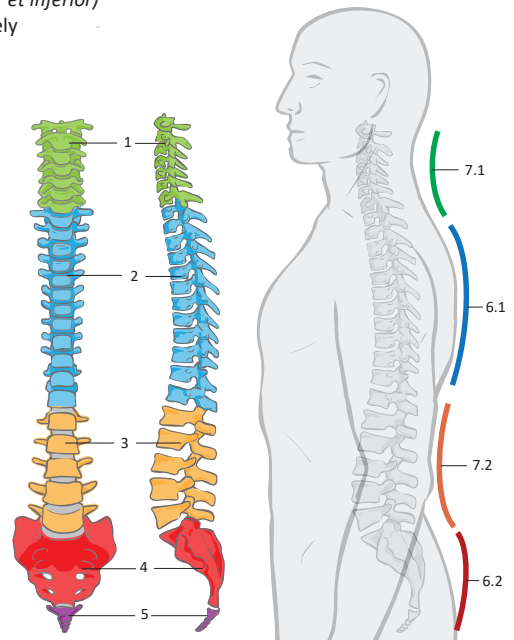
Lateral view of cervical, thoracic and lumbar vertebrae

### Basic classification of vertebrae

- **1 Cervical vertebrae (C)** – 7 vertebrae of the neck
- **2 Thoracic vertebrae (T)** – 12 vertebrae of the thorax
- **3 Lumbar vertebrae (L)** – 5 vertebrae of the loin
- **4 Sacrum (S)** – is formed from 5 fused vertebrae
- **5 Coccyx (Co)** – is formed from 4–5 fused rudimentary vertebrae

### Curvatures of the vertebral column

- 6 Primary curvatures** (*curvaturae primariae*)
  - are kyphoses, which are curves with a dorsal convexity
  - **6.1 Thoracic kyphosis** (*kyphosis thoracica*)
  - **6.2 Sacral kyphosis** (*kyphosis sacralis*)
- 7 Secondary curvatures** (*curvaturae secundariae*)
  - are lordoses, which are curves with a ventral convexity
  - **7.1 Cervical lordosis** (*lordosis cervicalis*)
    - develops as the child starts to use the muscles of the neck and raise his/her head
  - **7.2 Lumbar lordosis** (*lordosis lumbalis*)
    - develops when the child stands-up and learns to walk
- 8 Scoliosis**
  - is a lateral curve of the vertebral column, pathologic when distinct
  - is characterised by wedging and rotation of vertebrae
  - C-type and S-type
  - **8.1 Physiological scoliosis** – is a lateral curve at the level of T3 without rotation of the vertebrae



Anterior and lateral view of the vertebral column

The **cervical vertebral column** consists of 7 vertebrae and forms the **cervical kyphosis**. The cervical vertebrae share similar morphological features. The **atlas (C1)** greatly differs from the basic structure of the vertebrae as it does not have a vertebral body. During development, its body fuses with the dens and becomes part of C2. The cervical vertebral column is **connected to the skull** and thus participates in **skull movements**.

### Cervical vertebra (*vertebra cervicalis*)

- **1 Body** – is small and oval to kidney-shaped
  - **1.1 Uncus of body (*uncus corporis*)** – a paired eminence on the lateral sides of the body
- **2 Vertebral foramen** – is triangular-shaped
- **3 Spinous process** – is bifid (with the exception of C1 and C7)
- **4 Transverse process**
  - **4.1 Transverse foramen (*foramen transversarium*)** – transmits the vertebral artery (C6–C1) and the vertebral vein (C1–C7)
  - **4.2 Anterior tubercle (*tuberculum anterius*)** – a remnant of the cervical rib
  - **4.3 Posterior tubercle (*tuberculum posterius*)** – the embryological derivative of the transverse process
  - **4.4 Groove for spinal nerve (*sulcus nervi spinalis*)** – the continuation of the intervertebral foramen
- **5 Articular process** – is located between the transverse and frontal planes
  - superior articular process points dorsocranially
  - inferior articular process points ventrocaudally

### Atlas (C1)

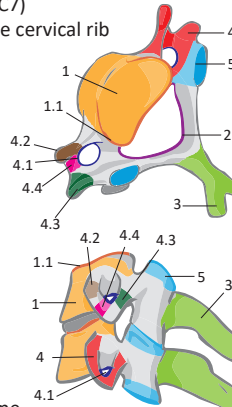
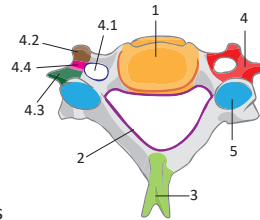
#### Specific features of the atlas:

- **1 Lateral mass (*massa lateralis*)**
  - **1.1 Superior articular surface (*facies articularis superior*)** – articulates with the occipital condyle on the occipital bone – is concave and kidney-shaped
  - **1.2 Inferior articular surface (*facies articularis inferior*)** – is flat with a rotund surface for articulation with the axis
- **2 Anterior arch (*arcus anterior atlantis*)**
  - the attachment of the anterior atlanto-occipital membrane and anterior atlanto-axial ligament
  - **2.1 Facet for dens (*fovea dentis*)** – articulates with the dens – is located on the dorsal surface of the anterior arch
  - **2.2 Anterior tubercle (*tuberculum anterius*)** – the attachment of the longus colli and anterior longitudinal ligament – is located on the ventral surface of the anterior arch
- **3 Posterior arch (*arcus posterior atlantis*)**
  - the attachment of the posterior atlanto-occipital membrane
  - **3.1 Groove for vertebral artery (*sulcus arteriae vertebralis*)** – paired grooves located on the cranial aspect of the posterior arch for the vertebral artery and vein and the suboccipital nerve
  - **3.2 Posterior tubercle (*tuberculum posterius*)** – the embryological remnant of the spinous process – the origin of the rectus capitis posterior minor and the attachment of the nuchal ligament

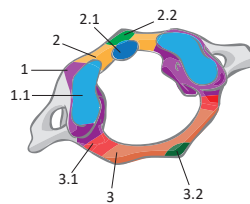
### Axis (C2)

#### Specific features of the axis:

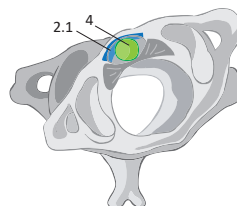
- **4 Dens (*dens axis*)** – the embryological remnant of the body of the atlas
  - articulates with the anterior arch of the atlas
  - **4.1 Anterior articular facet (*facies articularis anterior*)** – articulates with the atlas
  - **4.2 Posterior articular facet (*facies articularis posterior*)** – articulates with the transverse ligament of the atlas
  - **4.3 Apex (*apex dentis*)** – the embryological remnant of the body of the occipital vertebra



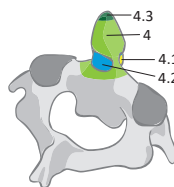
Superior, oblique superior and lateral view of the cervical vertebrae



Superior view of the atlas



Reciprocal movements of C1 and C2



Posterior oblique view of the axis

The **weakest spot on the axial skeleton** is the T5 vertebra.

**Vertebra prominens** is the clinical term for vertebra C7. It has an accentuated non-bifurcated spinous process with a spherical end. It is an orientation point used during palpation of the vertebral column.

**Accentuated spinous processes** can also be found on vertebra C6 and even T1. When palpating spinous processes the patient's head must be in dorsiflexion. The first palpable vertebra going in a craniocaudal direction is C7. The other cervical spinous processes are not palpable.

The **apex of the dens axis** is originally a defunct body of the occipital vertebra.

**Epistropheus** is an obsolete term for the vertebra C2 (axis).

The **atlas** is named after the Greek god atlas who held the celestial sphere on his shoulders. The atlas mountain range in North Africa also bear his name.

The **groove for the vertebral artery** can be changed into a canal by an osseous bridge.

### Clinical notes

**Disorders of the cervical spine** can lead to compression of the vertebral artery which results in reduced blood supply to the brain. This causes a syndrome called **vertebrobasilar insufficiency**, which is characterised by a constellation of various symptoms. Symptoms include fatigue, headache, vertigo, tinnitus and unconsciousness. The disorder is most commonly caused by atherosclerosis of the vertebral arteries.

The **transverse processes of the atlas and axis** may be sensitive to touch and pressure. This is typically caused by a **hypertonic levator scapula**, which typically occurs in people with sedentary lifestyles or from carrying heavy weights.

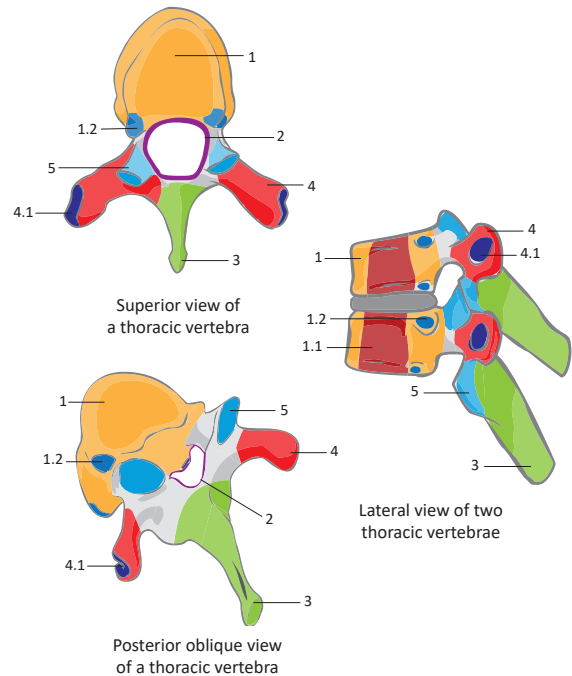
**Rupture of the ligaments between the atlas and axis**, the ligaments of the dens axis and fractures of the dens axis with dorsal displacement lead to immediate death due to damage of the medulla oblongata. This is the mechanism of death by hanging.

**Sandberg projection** is the X-ray picture of the dens axis taken from the front with an open mouth. The dens axis is **approached surgically** through the posterior pharyngeal wall.

The thoracic vertebral column consists of **12 vertebrae** that share morphological characteristics and form the **thoracic kyphosis**. The **connections of the ribs** to the thoracic vertebrae restrict the movements of the thoracic vertebral column.

### Thoracic vertebrae (*vertebrae thoracicae*)

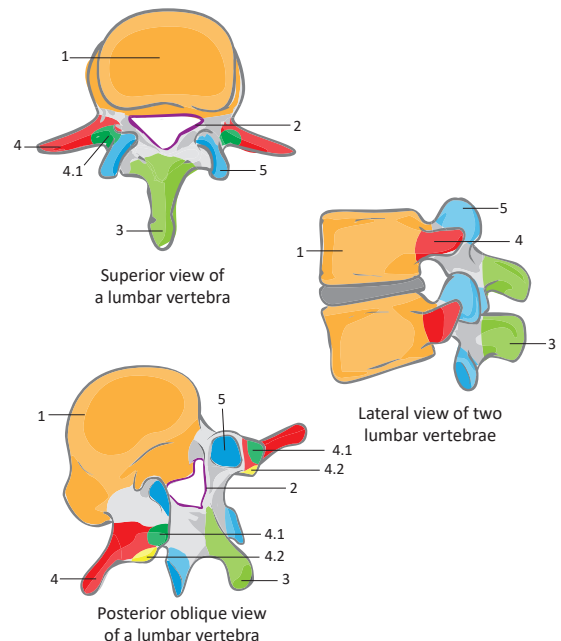
- **1 Body** – is heart-shaped and roughly as tall as it is wide
  - **1.1 Aortic impression** (*impressio aortica*)
    - a shallow impression for the descending aorta
    - is found on the vertebral bodies T4–T9
  - **1.2 Superior and inferior costal facets** (*fovea costalis superior et inferior*)
    - articular facets for articulation with the head of the rib
    - vertebrae T1–T9 have two pairs of facets
    - vertebrae T10–T12 have only one pair of facets
- **2 Vertebral foramen** – is round or diamond-shaped
- **3 Spinous process** – are long and point caudally
- **4 Transverse process**
  - **4.1 Transverse costal facet** (*fovea costalis processus transversi*)
    - articulates with the costal tubercle of the rib
    - are not present on T11 and T12
- **5 Articular processes**
  - project in the frontal plane
  - the superior articular facets point dorsally
  - the inferior articular facets point ventrally
  - the exception is vertebra T12 which has caudal facets in sagittal plane



The lumbar vertebral column consists of **5 large vertebrae** that share morphological characteristics and form the **lumbar lordosis**. Transverse processes are less well developed on the lumbar vertebrae. With respect to their embryological origin, **the costal processes** are the lumbar equivalents of the ribs.

### Lumbar vertebrae (*vertebrae lumbales*)

- **1 Body** – is tall, wide and kidney-shaped
  - is taller ventrally than it is dorsally
  - the body of L5 is wedge-shaped
- **2 Vertebral foramen** – is triangular
- **3 Spinous process** – is flat and quadrate-shaped when viewed from the side
- **4 Costal process** (*processus costalis*)
  - the embryological remnant of the lumbar rib
  - **4.1 Mammillary process** (*processus mammillaris*)
    - the embryological remnant of the transverse process
  - **4.2 Accessory process** (*processus accessorius*)
- **5 Articular process** – is in the sagittal plane
  - the cranial facets points medially
  - the caudal facets points laterally



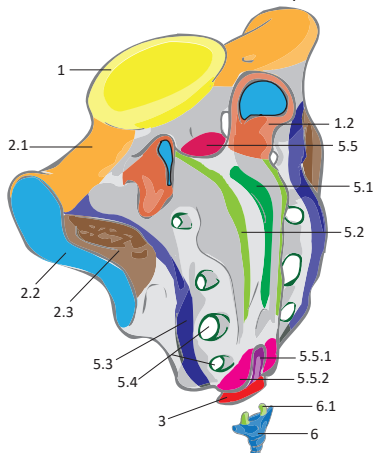
The **sacrum** is formed by fusion of the 5 sacral vertebrae. It forms a ventral concavity known as the **sacral kyphosis**. The **sacral canal** runs through the entire bone and contains the **cauda equina**. The cranial border of the sacrum, called the **promontory**, projects ventrally. The **coccyx** consists of 4–5 fused rudimentary vertebrae.

### Sacrum (*os sacrum*)

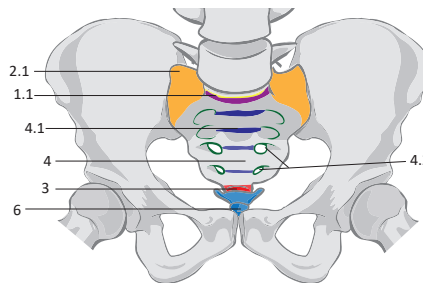
- 1 **Base** (*basis ossis sacri*) – the cranial part of the sacrum
  - 1.1 **Promontory** (*promontorium*) – a ventral bulging on the cranial margin – a part of the linea terminalis, which is the borderline between the greater and lesser pelvis
  - 1.2 **Superior articular process** (*processus articulares superiores*) – articulates with the corresponding inferior articular process of the 5<sup>th</sup> lumbar vertebra
- 2 **Lateral parts** (*partes laterales ossis sacri*) – paired lateral parts formed by fusion of remnants of the sacral ribs
  - 2.1 **Wing** (*ala ossis sacri*) – the cranial surface of the lateral part of the sacrum
  - 2.2 **Auricular surface** (*facies auricularis*) – articulates with the ilium
  - 2.3 **Sacral tuberosity** (*tuberositas ossis sacri*) – the attachment of the interosseous and posterior sacro-iliac ligament interosseum et posterius
- 3 **Apex** (*apex ossis sacri*) – connects to the coccyx via an intervertebral disc
- 4 **Pelvic surface** (*facies pelvica*) – the smooth ventral surface of the sacrum – forms the dorsal wall of the lesser pelvis
  - 4.1 **Transverse ridges** (*lineae transversae*) – lines of fusion of the vertebrae – the origin of the piriformis
  - 4.2 **Anterior sacral foramina** (*foramina sacralia anteriora*) – 4 pairs of openings – transmit the anterior rami of the sacral spinal nerves and spinal branches of vessels
- 5 **Dorsal surface** (*facies dorsalis*) – a roughened surface – the origin of the muscles of the back, septa and fasciae
  - 5.1 **Median sacral crest** (*crista sacralis mediana*) – fused spinous processes
  - 5.2 **Medial sacral crest** (*crista sacralis medialis*) – fused articular processes
  - 5.3 **Lateral sacral crest** (*crista sacralis lateralis*) – fused transverse processes
  - 5.4 **Posterior sacral foramina** (*foramina sacralia posteriora*) – 4 pairs of openings – transmit the posterior branches of the sacral spinal nerves S1–S4
  - 5.5 **Sacral canal** (*canalis sacralis*) – the extension of the vertebral canal
    - 5.5.1 **Sacral hiatus** (*hiatus sacralis*) – the caudal end of the sacral canal – transmits spinal nerves S5 and Co
    - 5.5.2 **Sacral cornua/horns** (*cornua sacralia*) – lateral borders the of sacral hiatus – remnants of the articular processes

### Coccyx (*os coccygis*) – tailbone

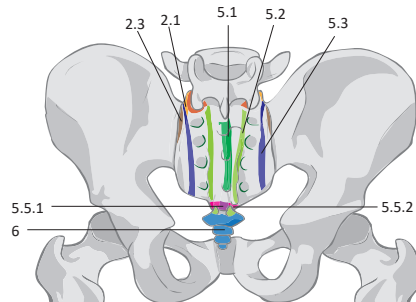
- 6 **Coccyx** (*os coccygis*)
  - 6.1 **Coccygeal cornua** (*cornua coccygea*) – horns pointing cranially – remnants of the articular processes



Posterior oblique view of the sacrum and coccyx



Anterior view of the pelvis



Posterior view of the pelvis

The **intercostal spaces** (*spatia intercostalia*) are filled with intercostal muscles. The intercostal neurovascular bundle courses along the lower border of the rib – see Page 549.

A **thoracocentesis** (also known as a pleural tap) is performed above the upper edge of a rib in order to prevent injury of intercostal vessels and nerves running in the costal groove.

The **ribs** are lifted up during **inspiration**, which expands the intrathoracic volume. During **expiration**, the ribs are lowered and the intrathoracic volume is reduced.

### Clinical notes

**Coccygeal syndrome** is caused by shortening of the muscles that insert on the coccyx. These muscles are the levator ani and the ischio-coccygeus. This leads to a variety of symptoms that develop in various other parts of body such premenstrual pain, headache, neck pain and pain during walk.

A **sternal puncture** is performed by sticking a needle into the bone marrow cavity of the sternum. It is typically used for the diagnosis of haematological disorders.

**Single rib fractures** may be very painful but usually do not require treatment. **Multiple rib fractures** lead to a condition called flail chest, which is characterised by paradoxical breathing. In **paradoxical breathing**, the fracture fragments move in the opposite direction to the normal movements of the chest. Multiple rib fractures require intensive treatment.

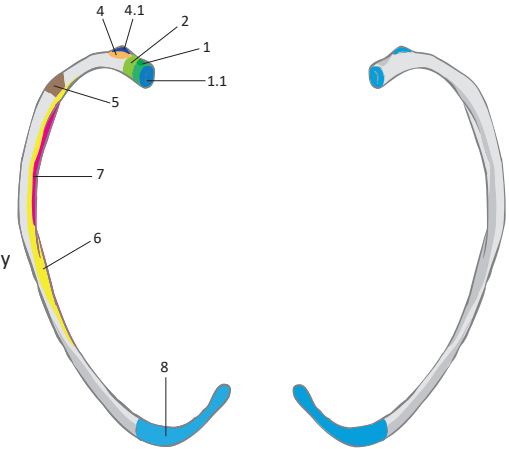
**Cervical ribs** are an anatomical abnormality occurring unilaterally or bilaterally on vertebra C7. Although cervical ribs are usually asymptomatic, they may encroach on the surrounding structures. Compression of the brachial plexus and subclavian artery is a cause of **thoracic outlet syndrome**, which is characterised by sensory disturbances in the ipsilateral arm.



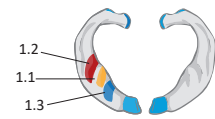
The **thorax** consists of the **sternum** and **twelve pairs of ribs**. The first seven pairs of ribs are the **true ribs** (*costae verae*), attached by cartilage directly to the sternum. The 8<sup>th</sup> to 10<sup>th</sup> ribs are called **false ribs** (*costae spuriae*) and they are connected by cartilage to the ribs directly above them. The 11<sup>th</sup> and 12<sup>th</sup> ribs are **floating ribs** (*costae fluctuantes*) with sharp ventral ends that terminate freely between the abdominal muscles. In general, the ribs belong to the flat bones.

### Rib (*costa*)

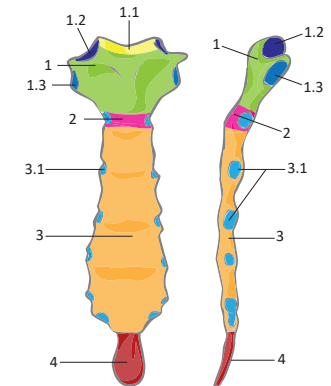
- 1 **Head** (*caput costae*) – articulates with the vertebral body
  - 1.1 **Articular facet** (*facies articularis capitis costae*) – articulates with the costal facets on the thoracic vertebral bodies
  - 1.2 **Crest** (*crista capitis costae*) – divides the articular facet into an upper and lower facet – not present on the 1<sup>st</sup> and 10<sup>th</sup>–12<sup>th</sup> ribs
- 2 **Neck** (*collum costae*)
- 3 **Body** (*corpus costae*) – the shaft of the rib
- 4 **Tubercle** (*tuberculum costae*) – is located behind the neck and points dorsally
  - 4.1 **Articular facet of tubercle** (*facies articularis tuberculi costae*) – articulates with the transverse process of the vertebra – is not present on the 11<sup>th</sup> and 12<sup>th</sup> rib
- 5 **Angle** (*angulus costae*) – a curvature of a rib in its dorsal third or quarter
- 6 **Costal groove** (*sulcus costae*) – a groove on the caudal margin of the dorsal surface of a rib – transmits the intercostal vein, intercostal artery and intercostal nerve (in this cranio-caudal order)
- 7 **Crest** (*crista costae*) – covers the costal groove from the ventral side
- 8 **Costal cartilage** (*cartilago costalis*) – a cartilaginous extension on the ventral end of the ribs – the costal cartilage of the true ribs articulates with the sternum – the costal cartilages of the false ribs articulate with the next rib above – is not present in floating ribs



Superior view of a rib



Superior view of the first and second ribs



Anterior and lateral view of the sternum

### First and second rib (*costa prima et secunda*) – unique features

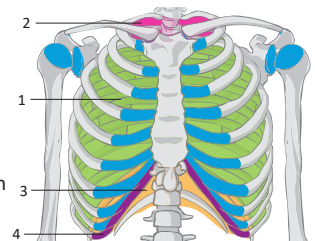
- 1 **First rib** (*costa prima*) – is short and flat
  - the costal cartilage usually ossifies, transforming the sternocostal synchondrosis into a synostosis
  - 1.1 **Scalene tubercle** (*tuberculum musculi scaleni anterioris*) – the insertion of the scalenus anterior
  - 1.2 **Groove for subclavian artery** (*sulcus arteriae subclaviae*) – is located behind the scalene tubercle
  - 1.3 **Groove for subclavian vein** (*sulcus venae subclaviae*) – is located in front of the scalene tubercle
- 2 **Second rib** (*costa secunda*)
  - 2.1 **Tuberosity for serratus anterior** (*tuberositas musculi serrati anterioris*) – the origin of one of the digitations of the serratus anterior

### Sternum – breast bone

- 1 **Manubrium of sternum** (*manubrium sterni*) – the cranial part of the sternum
  - the origin of the sternohyoid, sternothyroid and the sternal part of the sternocleidomastoid
  - 1.1 **Jugular notch** (*incisura jugularis*) – forms a skin depression above the sternum called the jugular fossa
  - 1.2 **Clavicular notch** (*incisura clavicularis*) – articulates with the clavicle
  - 1.3 **Costal notch** (*incisura costalis*) – articulates with the 1<sup>st</sup> rib
- 2 **Sternal angle of Louis** (*angulus sternalis Ludovici*) – articulates with the 2<sup>nd</sup> rib – an obtuse angle between the manubrium and body of the sternum
- 3 **Body of sternum** (*corpus sterni*)
  - 3.1 **Costal notches** (*incisurae costales*) – articulate with the 3<sup>rd</sup>–7<sup>th</sup> rib
- 4 **Xiphoid process** (*processus xiphoideus*) – a process of variable length and shape – can be bifurcated and may be partially or fully composed of cartilage

### Thorax – chest

- 1 **Thoracic cage** (*cavitas thoracis*) – is bordered by the ribs, sternum and thoracic vertebral column
- 2 **Superior thoracic aperture** (*apertura thoracis superior*) – the thoracic inlet
- 3 **Inferior thoracic aperture** (*apertura thoracis inferior*) – the thoracic outlet
- 4 **Right and left costal margin** (*arcus costalis dexter et sinister*) – the costal arches



The bones of the upper limb are divided into two groups: the **shoulder girdle** and the **free part of the upper limb**.

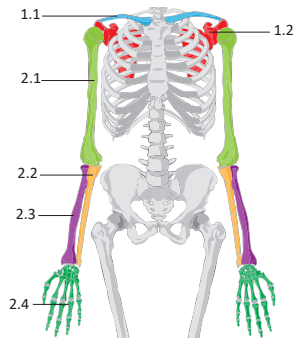
**1 Pectoral girdle** (*cingulum pectorale*) – shoulder girdle

- 1.1 **Clavicle** (*clavicula*) – collar bone
- 1.2 **Scapula** – shoulder blade

**2 Free part of upper limb**

(*pars libera membri superioris*)

- 2.1 **Humerus**
- 2.2 **Ulna** – elbow bone
- 2.3 **Radius** – radial bone
- 2.4 **Bones of hand** (*ossa manus*)
  - 2.4.1 **Carpal bones** (*ossa carpi*) – wrist bones
  - 2.4.2 **Metacarpals** (*ossa metacarpi*) – bones of the palm
  - 2.4.3 **Phalanges** – bones of the fingers

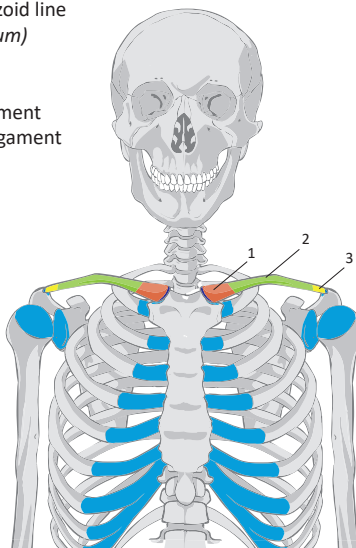
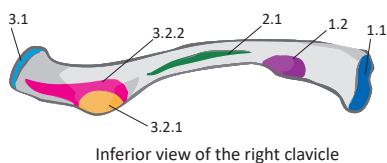
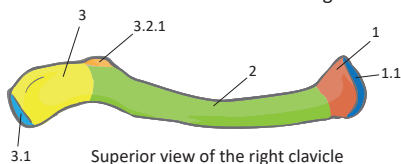


5.1

**Clavicle – Clavicula**

The **clavicle** is a **S-shaped** bone with a medial convexity pointing ventrally. It **articulates with the scapula and the sternum** and is part of the **pectoral girdle**. It is the first bone to ossify, which it does by both **intramembranous** and **endochondral ossification**.

- **1 Sternal end** (*extremitas sternalis*)
  - the attachment of the anterior and posterior sternoclavicular ligaments and the interclavicular ligament
  - the origin of the sternohyoid and clavicular part of the sternocleidomastoid
  - 1.1 **Sternal facet** (*facies articularis sternalis*)
    - articulates with the manubrium of the sternum
  - 1.2 **Impression for costoclavicular ligament** (*impressio ligamenti costoclavicularis*)
    - the attachment of the costoclavicular ligament, which connects the clavicle to the cartilage of the 1<sup>st</sup> rib
- **2 Body of clavicle** (*corpus claviculae*) – the shaft of the clavicle
  - the origin of the clavicular part of pectoralis major
  - 2.1 **Subclavian groove** (*sulcus musculi subclavii*)
    - a shallow groove on the caudal surface of the shaft for the insertion of the subclavius
- **3 Acromial end** (*extremitas acromialis*) – the origin of the clavicular part of the deltoid and the insertion of the descending part of the trapezius
  - 3.1 **Acromial facet** (*facies articularis acromialis*) – articulates with the acromion
  - 3.2 **Coracoclavicular tuberosity** – a large bony protuberance
    - has two parts: the conoid tubercle and trapezoid line
    - 3.2.1 **Conoid tubercle** (*tuberculum conoideum*)
      - the attachment the conoid ligament
    - 3.2.2 **Trapezoid line** (*linea trapezoidea*)
      - the attachment of the trapezoid ligament
      - the conoid ligament and trapezoid ligament form the coracoclavicular ligament



The **axis of the glenoid cavity** projects 9° dorsally from the axis of the scapula. It is thus in **retroversion** with respect to the scapula.

The **acromion** is an anthropometric point. Its lateral edge can be used for measuring the shoulder-to-shoulder width and the length of the upper limb.

The **scapula** is connected by muscles to the posterior aspect of the thorax. Its position and associated muscles influence the posture of the head, cervical vertebrae and shoulders. Contrarily, the position of the scapula is significantly influenced by muscular balance of the upper and lower scapular fixators.

**Upper scapular fixators:**

- 1 Trapezius (descending part)
- 2 Levator scapulae

**Lower scapular fixators:**

- 1 Serratus anterior
- 2 Trapezius (transverse and ascending part)
- 3 Rhomboids

**Orientation of the clavicle:** the sternal end is thicker and the acromial end is flat. The superior surface is smooth. The inferior surface is decorated by bony markings. The medial two thirds have a ventral convexity.

**Clinical notes**

**Fractures of the clavicle** are commonly associated with fragment dislocation. The medial part of the clavicle tends to be pulled cranially by the sternocleidomastoid. The lateral part of the clavicle can become caudally displaced by the coracoclavicular ligament.

**Clavicular injuries** are sometimes associated with injury of the subclavian artery and/or brachial plexus.

**Fractures of the scapula** occur very rarely and are almost always a consequence of direct violence or a fall.

The **superior angle of the scapula** is a common area of tenderness found by palpation in a physical examination. This pain can be caused by overuse of the levator scapulae.

A **winged scapula** is an out of place scapula. In **medial winging**, the scapula moves upward and medially. This can be caused by weakening of the lower fixators or injury to the long thoracic nerve. In **lateral winging**, the scapula moves downwards and laterally. This can be caused by damage to the accessory nerve.

The **scapula** is a **flat triangular** bone that connects to the posterior aspect of the thorax by muscles **at the level of the 2<sup>nd</sup> to 7<sup>th</sup> rib**. It is part of the **pectoral girdle** and features a **large dorsal spine**, which ends laterally as the **acromion**.

### 1 Surfaces:

- 1.1 **Costal/anterior surface** (*facies costalis/anterior*) – the ventral surface facing the chest
- 1.2 **Posterior surface** (*facies posterior*) – is palpable on the skin over the back

### 2 Borders:

- 2.1 **Medial border** (*margo medialis*)  
– the insertion of the rhomboids and serratus anterior
- 2.2 **Lateral border** (*margo lateralis*)  
– the origin of teres major and teres minor
- 2.3 **Superior border** (*margo superior*)  
– the origin of the inferior belly of the omohyoid

### 3 Angles:

- 3.1 **Inferior angle** (*angulus inferior*) – the origin of the teres major
- 3.2 **Superior angle** (*angulus superior*) – the insertion of the levator scapulae
- 3.3 **Lateral angle** (*angulus lateralis*)

### 4 Subdivisions of the costal surface:

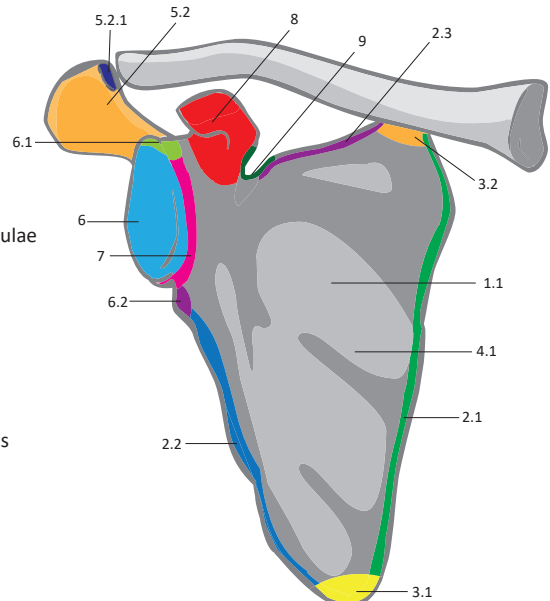
- 4.1 **Subscapular fossa** (*fossa subscapularis*)  
– the origin of the subscapularis

### 5 Subdivisions of the posterior surface:

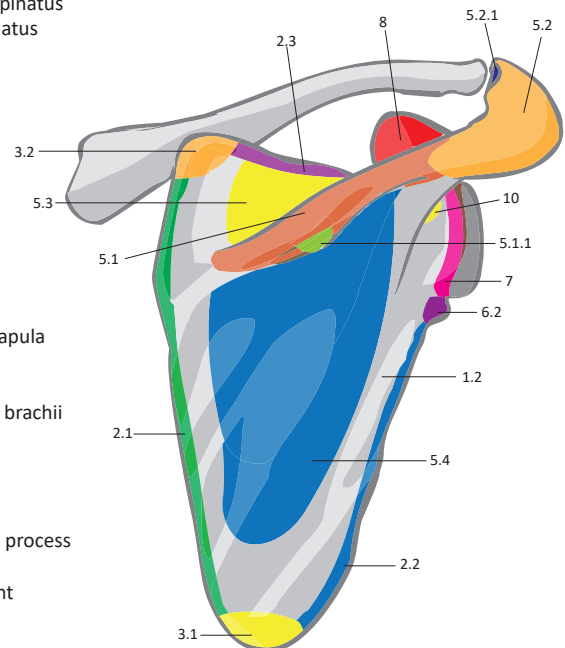
- 5.1 **Spine of scapula** (*spina scapulae*)  
– the origin of the spinal part of the deltoid muscle  
– the insertion of the transverse and ascending parts of the trapezius
  - 5.1.1 **Deltoid tubercle** (*tuberculum deltoideum*)  
– is located between the insertion of the trapezius and the origin of the deltoid muscle
- 5.2 **Acromion** – the lateral extension of the spine of the scapula  
– the origin of the acromial part of the deltoid muscle  
– the insertion of the descending part of the trapezius  
– the attachment of the coraco-acromial ligament (*fornix humeri*) and the acromioclavicular ligament
  - 5.2.1 **Clavicular facet** (*facies articularis clavicularis*)  
– articulates with the clavicle
- 5.3 **Supraspinous fossa** (*fossa supraspinata*) – the origin of the supraspinatus
- 5.4 **Infraspinous fossa** (*fossa infraspinata*) – the origin of the infraspinatus

### Other parts of the scapula:

- 6 **Glenoid cavity** (*cavitas glenoidalis*)  
– the articular fossa of the shoulder joint  
– is enlarged by a cartilaginous glenoid labrum
  - 6.1 **Supraglenoid tubercle** (*tuberculum supraglenoidale*)  
– is located just above the glenoid cavity  
– the origin of the long head of the biceps brachii
  - 6.2 **Infraglenoid tubercle** (*tuberculum infraglenoidale*)  
– located just below the glenoid cavity  
– the origin of the long head of the triceps brachii
- 7 **Neck of scapula** (*collum scapulae*)  
– a narrowed area between the glenoid cavity and the rest of the scapula  
– the attachment of the articular capsule of the shoulder joint
- 8 **Coracoid process** (*processus coracoideus*)  
– the origin of the coracobrachialis and the short head of the biceps brachii  
– the insertion of the pectoralis minor  
– the attachment of the coraco-acromial ligament, coracoclavicular ligament and coracohumeral ligament
- 9 **Suprascapular notch** (*incisura scapulae*)  
– a notch on the superior border of the scapula next to the coracoid process  
– covered by the superior transverse scapular ligament  
– the suprascapular nerve runs through the notch under the ligament  
– the suprascapular artery and vein pass over the ligament
- 10 **Spinoglenoid notch** (*incisura spinoglenoidalis*)  
– a notch between the glenoid cavity and the spine of the scapula  
– covered by the inferior transverse scapular ligament  
– transmits the suprascapular nerve and vessels



Anterior view of the right scapula



Posterior view of the right scapula

The humerus is a long bone of the free upper limb. It is divided into a head, a shaft and a condyle. The **head of the humerus** is a component of the shoulder joint. Two projections, the greater and lesser tubercle, are located on the head and serve as insertion sites for the rotator cuff muscles. The **radial nerve and the deep brachial artery** run around the **shaft of the humerus** in a groove on the posterior surface called the **radial groove**. The distal end of the humerus is called the **condyle of the humerus**. It is a component of the elbow joint. It possesses a **medial and lateral epicondyle**, which serve as origin sites for the muscles of the forearm.

● **1 Head (*caput humeri*)** – the articular head of the shoulder joint

- **1.1 Anatomical neck (*collum anatomicum*)**
  - the attachment of the articular capsule of the shoulder joint
- **1.2 Greater tubercle (*tuberculum majus*)**
  - projects dorsolaterally from the head
  - the insertion of the supraspinatus, infraspinatus and teres minor
  - the attachment of the coracohumeral ligament and transverse humeral ligament
  - **1.2.1 Crest of greater tubercle (*crista tuberculi majoris*)**
    - the insertion of the pectoralis major
- **1.3 Lesser tubercle (*tuberculum minus*)**
  - projects ventromedially from the head
  - the insertion of the subscapularis
  - the attachment of the glenohumeral ligaments and transverse humeral ligament
  - **1.3.1 Crest of lesser tubercle (*crista tuberculi minoris*)**
    - the insertion of the teres major and latissimus dorsi
- **1.4 Intertubercular sulcus (*sulcus intertubercularis*)**
  - the bicipital groove
  - a groove between the greater and lesser tubercles
  - the long head of the biceps runs through it in a tendinous sheath

● **2 Surgical neck (*collum chirurgicum*)**

- a narrow part of the humerus located below the head

● **3 Shaft of humerus (*corpus humeri*)**

- the body of the humerus
- **3.1 Deltoid tuberosity (*tuberositas deltoidea*)**
  - the insertion of the deltoid muscle
- **3.2 Radial groove (*sulcus nervi radialis*)**
  - an oblique groove for the radial nerve and the deep brachial vessels
  - is located on the posterior surface of the shaft
  - is bordered by the medial and lateral heads of the triceps brachii, which form the radial canal
- 3.3 Nutrient foramen (*foramen nutricium*)**
  - the entrance of vessels into the medullary cavity
  - points distally

**Surfaces:**

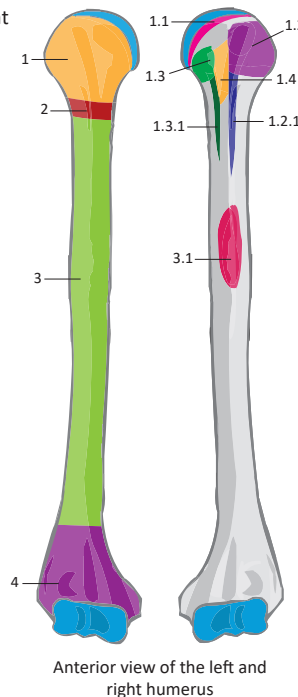
- 3.4 Anteromedial surface (*facies anteromedialis*)**
- 3.5 Anterolateral surface (*facies anterolateralis*)**
- 3.6 Posterior surface (*facies posterior*)**

**Margins:**

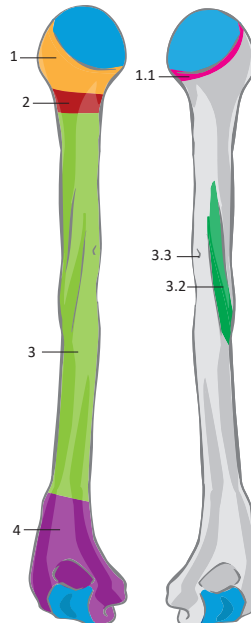
- 3.7 Medial border (*margo medialis*)**
- 3.8 Lateral border (*margo lateralis*)**

● **4 Condyle of humerus (*condylus humeri*)**

- the widened distal end of the humerus



Anterior view of the left and right humerus



Posterior view of the left and right humerus

The **angle of inclination of the humerus** is the angle between the head and body and is about 130°.

In children, the **proximal epiphyseal cartilage** contributes to 80 % of the growth of the humerus.

The **ulnar nerve** is located superficially as it runs through the groove for the ulnar nerve. Hitting the ulnar nerve at this point causes a tingling feeling spreading down the arm, hence the colloquial term for this region: “the funny bone”.

### Clinical notes

**Fractures of the distal humerus** can cause injury to the ulnar nerve.

The **surgical neck of the humerus** is an area of frequent fractures in adults. Injury to the anterior and posterior circumflex arteries can occur causing ischaemia and necrosis of the head of the humerus.

**Injuries of the diaphysis of the humerus** can damage the radial nerve and deep brachial artery, which are located in the groove for the radial nerve.

The **muscles of the rotator cuff** are inserted on the greater and lesser tubercles. They are responsible for the stability of the shoulder joint. During shoulder joint replacement operations these muscles and their insertions must be preserved.

**Pain over the greater tubercle** occurs when excessive internal rotation ruptures the rotator cuff muscles. **Pain over the lesser tubercle** can be caused by an overuse injury of internal rotation.

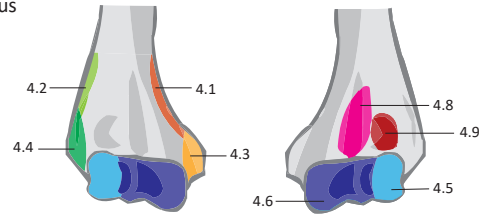
The osseous plate between the olecranon fossa and coronoid fossa may contain a hole called the **supratrochlear foramen**. This can cause hypermobility of the elbow joint, capable of hyperextension.

“**Golfer’s elbow**” is an overuse injury of the flexor group of muscles that attach to the medial epicondyle. The symptoms are precipitated by striking a golf club on the ground, which stretches the flexor origin on the medial epicondyle and causes pain located in this region.

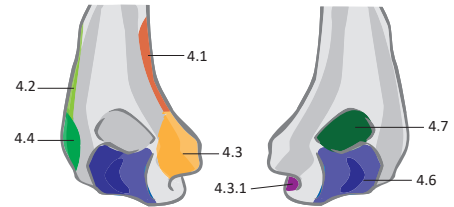
“**Tennis elbow**” is an overuse injury of the common extensor tendon attachment on the lateral epicondyle. It is typically caused by backhand strokes in tennis and working on computers for long periods of time. It is characterised by pain over the lateral epicondyle of the humerus.

#### 4 Condyle of the humerus (*condylus humeri*) – the widened distal end of the humerus

- 4.1 **Medial supraepicondylar ridge** (*crista supraepicondylaris medialis*)
  - the origin of the humeral head of the pronator teres
- 4.2 **Lateral supraepicondylar ridge** (*crista supraepicondylaris lateralis*)
  - the origin of the brachioradialis and extensor carpi radialis longus
- 4.3 **Medial epicondyle** (*epicondylus medialis*)
  - the common origin of the flexor muscles of the hand
    - 4.3.1 **Groove for ulnar nerve** (*sulcus nervi ulnaris*)
- 4.4 **Lateral epicondyle** (*epicondylus lateralis*)
  - the origin of the common extensor tendon and the anconeus
- 4.5 **Capitulum** (*capitulum humeri*)
  - the articular head of the humeroradial joint
- 4.6 **Trochlea** (*trochlea humeri*)
  - the articular head of the humeroulnar joint
- 4.7 **Olecranon fossa** (*fossa olecrani*)
  - is located dorsally on the condyle of the humerus
  - contains the olecranon of the ulna when the forearm is extended
- 4.8 **Coronoid fossa** (*fossa coronoidea*)
  - is located ventromedially on the condyle of the humerus
  - contains the coronoid process of the ulna when the forearm is flexed
- 4.9 **Radial fossa** (*fossa radialis*)
  - is located ventrolaterally on the condyle of the humerus
  - contains the head of the radius when the forearm is flexed



Anterior view of the distal end of the right and left humerus



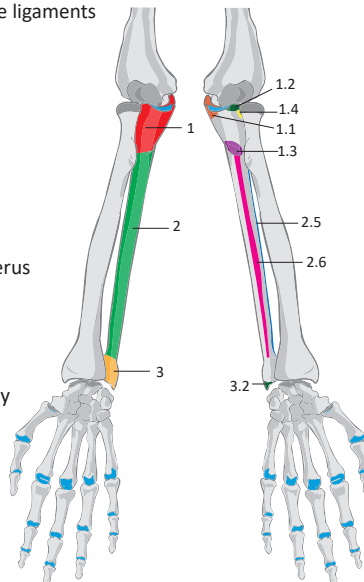
Posterior view of the distal end of the right and left humerus

#### 5.4

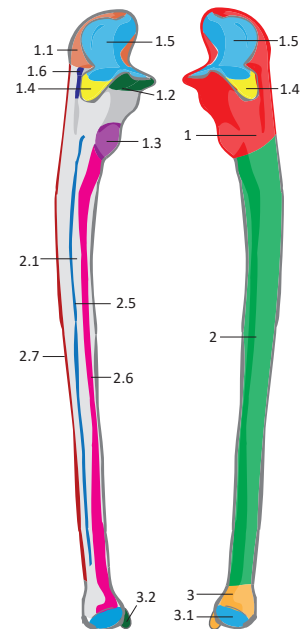
#### Ulna – Ulna

The ulna is a long bone located on the **medial aspect of the forearm**. It acts as a **rotary axis for the radius** during pronation and supination of the forearm.

- 1 **Proximal end** – is widened
    - 1.1 **Olecranon** – the insertion of triceps brachii and the attachment of the olecranonohumeral and oblique ligaments
    - 1.2 **Coronoid process** (*processus coronoideus ulnae*)
      - the ventral border of the trochlear notch
      - the attachment of the humerocoronoid and oblique ligaments
    - 1.3 **Tuberosity of ulna** (*tuberositas ulnae*)
      - the insertion of the brachialis
    - 1.4 **Radial notch** (*incisura radialis*)
      - the articular fossa for the head of the radius
    - 1.5 **Trochlear notch** (*incisura trochlearis*)
      - the articular cavity for the trochlea of the humerus
    - 1.6 **Supinator crest** (*crista musculi supinatoris*)
      - the origin of the supinator muscle
  - 2 **Shaft** (*corpus ulnae*) – the body of the ulna
    - 2.1 **Nutrient foramen** (*foramen nutricium*)
      - the entrance of vessels into the medullary cavity
      - points proximally
- Surfaces:**
- 2.2 **Anterior surface** (*facies anterior*)
  - 2.3 **Posterior surface** (*facies posterior*)
  - 2.4 **Medial surface** (*facies medialis*)
- Borders:**
- 2.5 **Interosseous border** (*margo interosseus*)
    - the attachment of the interosseous membrane of the forearm
  - 2.6 **Anterior border** (*margo anterior*)
  - 2.7 **Posterior border** (*margo posterior*) – is palpable in its entire course
- 3 **Head** (*caput ulnae*) – the distal narrow end
    - 3.1 **Articular circumference** (*circumferentia articularis*) – the annular articular facet around the head
      - an articular surface in the distal radio-ulnar joint
    - 3.2 **Ulnar styloid process** (*processus styloideus ulnae*) – a palpable projection on the dorsal side of the distal forearm
      - the attachment of the palmar ulnocarpal ligament and ulnar collateral ligament of the wrist joint



Anterior view of the right and left ulna situated in the forearm

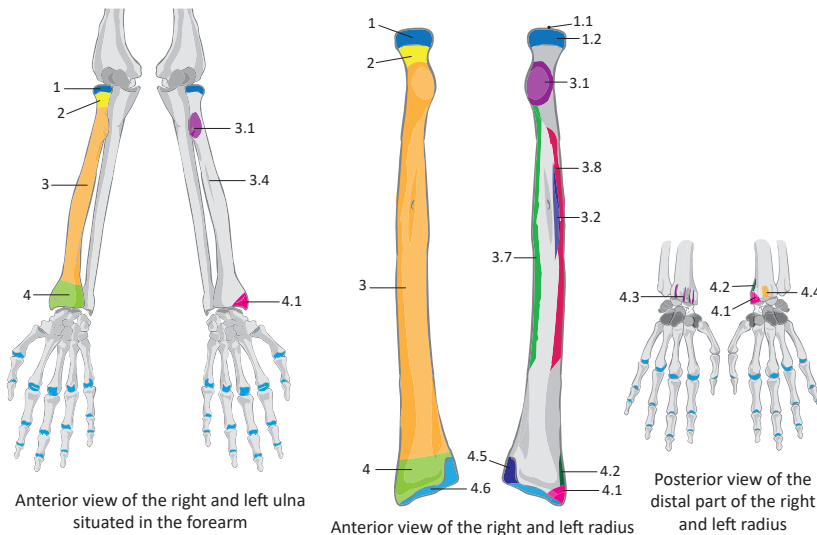


Anteriolateral view of the right and left ulna



The radius is a long bone located on the **lateral aspect of the forearm**. During pronation and supination, the radius rotates around the ulna.

- 1 **Head of radius** (*caput radii*) – is located on the proximal end of the bone
    - 1.1 **Articular facet** (*fovea articularis*) – the articular fossa for the capitulum of the humerus
    - 1.2 **Articular circumference** (*circumferentia articularis*)
      - an annular articular facet around the head of the humerus
      - the articular head of the proximal radio-ulnar joint
  - 2 **Neck** (*collum radii*) – the attachment of the articular capsule
  - 3 **Shaft** (*corpus radii*) – the body of the radius
    - 3.1 **Radial tuberosity** (*tuberositas radii*) – a tuberosity on the proximal part of the radius
      - the insertion of the biceps brachii
    - 3.2 **Pronator tuberosity** (*tuberositas pronatoria radii*)
      - a tuberosity in the middle of the radial shaft
      - the insertion of the pronator teres
    - 3.3 **Nutrient foramen** (*foramen nutricium*)
      - the entrance of vessels into the medullary cavity, points proximally
- Surfaces:**
- 3.4 **Anterior surface** (*facies anterior*)
  - 3.5 **Posterior surface** (*facies posterior*)
  - 3.6 **Lateral surface** (*facies lateralis*)
- Borders:**
- 3.7 **Interosseous border** (*margo interosseus*)
    - the attachment of the interosseous membrane of the forearm and the oblique cord
  - 3.8 **Anterior border** (*margo anterior*)
  - 3.9 **Posterior border** (*margo posterior*)
- 4 **Distal end** – is widened
    - 4.1 **Radial styloid process** (*processus styloideus radii*)
      - a palpable projection on the lateral side of the distal forearm
      - the attachment of the palmar radiocarpal ligament
      - the attachment of the radial collateral ligament of the wrist joint
    - 4.2 **Suprastyloid crest** (*crista suprastyloidea*) – the insertion of the brachioradialis
    - 4.3 **Grooves for tendons of extensors** (*sulci tendinum musculorum extensorum*)
      - grooves for the tendons of the extensor muscles: extensor pollicis longus, extensor carpi radialis longus, extensor carpi radialis brevis, extensor digitorum and extensor indicis
    - 4.4 **Dorsal tubercle of Lister** (*tuberculum dorsale*)
      - the attachment of the dorsal radiocarpal ligament
      - the most prominent tubercle between the grooves for the extensor tendons
    - 4.5 **Ulnar notch** (*incisura ulnaris*) – the articular fossa of the distal radio-ulnar joint
    - 4.6 **Carpal articular surface** (*facies articularis carpalis*)
      - the articular fossa for articulation with the scaphoid and lunate



In children, the distal epiphyseal cartilage contributes to 75–80 % of forearm growth.

**Ossification of the carpal bones** proceeds in a circle starting with the capitate. It serves as an X-ray marker of bone age.

The obsolete term “**navicular bone of the hand**” is often used in clinical practice for the scaphoid bone.

The **pisiform** (*os pisiforme*) develops as a sesamoid bone enclosed in the tendon of the flexor carpi ulnaris (*musculus flexor carpi ulnaris*).

The **greater and lesser multangular bones** (*os multangulum majus et minus*) are obsolete terms for the trapezium and trapezoid (*os trapezium et trapezoidum*) respectively.

### Clinical notes

**Pain around the head of the radius** develops in overuse of supination.

The **radial styloid process** (*processus styloideus radii*) becomes painful after excessive forearm flexion and in overuse of flexion of the digits when the forearm is in a position halfway between supination and pronation.

**Colles' fracture** is an extra-articular fracture of the distal radius with dorsal dislocation of the fragments. It is caused by falling on an extended wrist. It is the most common type of fracture.

**Smith's fracture** is an extra-articular fracture of the distal radius with ventral dislocation of the fragments. It is caused by falling on a flexed wrist.

**Fractures of the scaphoid** are the most common fractures of the carpal bones. They are characterised by pain over the anatomical snuff box.

The **blood supply of the scaphoid enters its distal end**. Fractures of the scaphoid neck can lead to impairment of the blood supply of the proximal fragment. This causes avascular necrosis.

The **most common type of injury to the lunate** is dislocation.

The bones of the hand consist of **8 carpal bones**, **5 metacarpals** and **14 phalanges**. The carpal bones are short bones arranged in **two transverse rows**. The metacarpals and phalanges are long monoepiphyseal bones arranged in 5 longitudinal lines, corresponding to the 5 fingers.

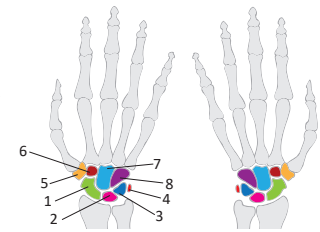
### Carpal bones (*ossa carpi*) – wrist bones

#### Proximal row:

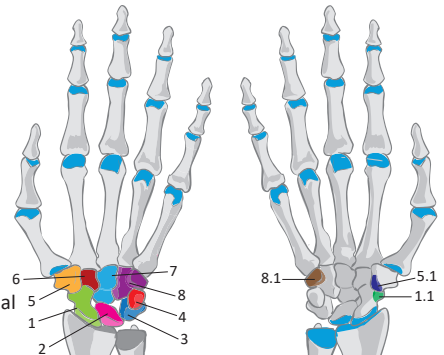
- 1 **Scaphoid** (*os scaphoideum*) – has a facet on its proximal surface for articulation with the radius
  - has a facet on its distal surface for articulation with the trapezium
  - has a semilunar-shaped facet on its medial surface for articulation with the lunate
  - forms an articular fossa with the lunate that articulates with the head of the capitate
- 1.1 **Tubercle** (*tuberculum ossis scaphoidei*) – contributes to the radial carpal eminence
- 2 **Lunate** (*os lunatum*) – has a facet on its proximal surface for articulation with the radius
  - has a concave fossa on its distal surface for articulation with the capitate
  - has a semilunar facet on its distal surface for articulation with the scaphoid
  - has a quadrate facet on its medial surface for articulation with the triquetrum
- 3 **Triquetrum** (*os triquetrum*) – has an oval-shaped facet on its distal surface for articulation with the pisiform
  - has a quadrate-shaped facet on its lateral surface for articulation with the lunate
  - has a facet on its distal surface for articulation with the hamate
- 4 **Pisiform** (*os pisiforme*) – forms part of the ulnar carpal eminence
  - is attached to the triquetrum
  - the origin of the abductor digiti minimi and the insertion of the flexor carpi ulnaris
  - the attachment of the pisohamate and pisometacarpal ligaments

#### Distal row:

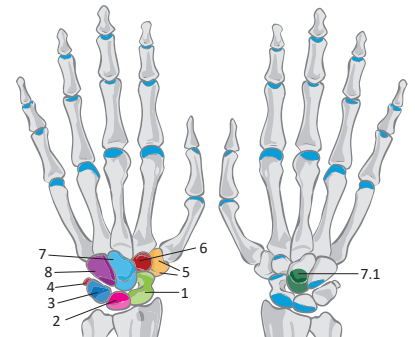
- 5 **Trapezium** (*os trapezium*)
  - has a saddle-shaped facet on its distal surface for articulation with the 1<sup>st</sup> metacarpal
  - has a small facet for articulation with the 2<sup>nd</sup> metacarpal
  - the facets on its medioproximal surface articulate with the scaphoid and trapezoid
  - has a groove on its ventral surface for the tendon of the flexor carpi radialis
- 5.1 **Tubercle** (*tuberculum ossis trapezii*) – contributes to the radial carpal eminence
- 6 **Trapezoid** (*os trapezoideum*)
  - has a facet on its proximal surface for articulation with the scaphoid
  - has a roof-shaped facet on its distal surface for articulation with the 2<sup>nd</sup> metacarpal
  - has a facet on its lateral surface for articulation with the trapezium
  - has a facet on its medial surface for articulation with the capitate
- 7 **Capitate** (*os capitatum*)
  - has a facet on its proximal surface for articulation with the scaphoid and lunate
  - has a facet on its lateral surface for articulation with the trapezoid
  - has a facet on its medial surface for articulation with the hamate
  - has a facet on its distal surface for articulation with the 3<sup>rd</sup> metacarpal
- 7.1 **Head of capitate** (*caput ossis capitati*) – the centre of the wrist
  - the attachment of the radiate carpal ligament
  - articulates with an articular fossa formed by the scaphoid and lunate
- 8 **Hamate** (*os hamatum*)
  - has a facet on its lateral surface for articulation with the capitate
  - has a facet on its medioproximal surface for articulation with the triquetrum
  - has two facets on its distal surface for articulation with the 4<sup>th</sup> and 5<sup>th</sup> metacarpals
- 8.1 **Hook of hamate** (*hamulus ossis hamati*)
  - part of the ulnar carpal eminence
  - the attachment of the pisohamate ligament
  - the origin of the flexor digiti minimi and opponens digiti minimi



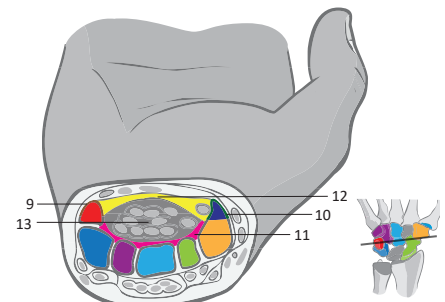
Anterior view of the bones of the left and right hand



Anterior view of the bones of the left and right hand



Posterior view of the bones of the left and right hand



Proximal view of a cross section through the right wrist

### Wrist (*carpus*)

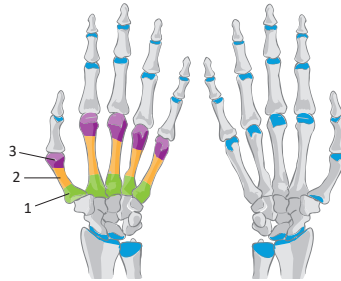
- 9 **Ulnar carpal eminence** (*eminentia carpi ulnaris*)
  - the medial border of the carpal groove
  - is composed of the pisiform and the hook of the hamate
  - the origin of the hypothenar muscles
- 10 **Radial carpal eminence** (*eminentia carpi radialis*) – the lateral border of the carpal groove
  - is composed of the scaphoid tubercle and the tubercle of the trapezium
  - the origin of the thenar muscles
- 11 **Carpal groove** (*sulcus carpi*) – a deep concave groove formed by the carpal bones for the tendons of the flexor muscles of the hand
- 12 **Flexor retinaculum** (*retinaculum musculorum flexorum*) – covers the carpal groove, stretched between the carpal eminences
- 13 **Carpal tunnel** (*canalis carpi*) – a space between the two carpal eminences, the carpal groove and the flexor retinaculum

Each **metacarpal** possesses only one growth cartilage, which is located in the distal end of the bone. The metacarpals are thus known as **monoepiphyseal bones**. The growth cartilages are located in the distal part of the bone, with the exception of the 1<sup>st</sup> metacarpal, which has its growth cartilage in the proximal part. **The thumb has a proximal and distal phalanx. The other digits have three phalanges: a proximal, medial and distal phalanx.**

### Metacarpals (*ossa metacarpi*)

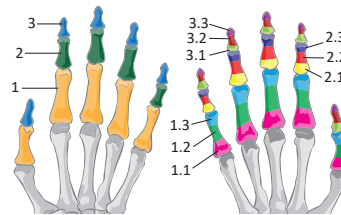
#### General organization

- 1 **Base** (*basis ossis metacarpi*)
- 2 **Shaft** (*corpus ossis metacarpi*)
- 3 **Head** (*caput ossis metacarpi*)
  - I 1<sup>st</sup> **metacarpal** (*os metacarpi primum*)
    - has a saddle-shaped facet on its base for articulation with the trapezium
  - II 2<sup>nd</sup> **metacarpal** (*os metacarpi secundum*)
    - the longest metacarpal
    - has a roof-shaped facet on its base for articulation with trapezoid
    - has a figure of eight shaped facet on its medial surface for articulation with the 3<sup>rd</sup> metacarpal
  - III 3<sup>rd</sup> **metacarpal** (*os metacarpi tertium*) – has a facet on its base for articulation with the capitate
    - has a figure of eight-shaped facet on its lateral surface for articulation with the 2<sup>nd</sup> metacarpal
    - has two facets on its medial surface for articulation with the 4<sup>th</sup> metacarpal
  - IV 4<sup>th</sup> **metacarpal** (*os metacarpi quartum*)
    - has a facet on its base for articulation with the hamate
    - has two facets on its lateral surface for articulation with the 3<sup>rd</sup> metacarpal
    - has a facet on its medial surface for articulation with the 5<sup>th</sup> metacarpal
  - V 5<sup>th</sup> **metacarpal** (*os metacarpi quintum*) – has a facet on the base for articulation with the hamate
    - has a facet on its lateral surface for articulation with 4<sup>th</sup> metacarpal
    - the tubercle of the 5<sup>th</sup> metacarpal is located on the medial aspect of the bone and is the insertion of the extensor carpi ulnaris and the attachment of the pisometacarpal ligament



### Phalanges (*ossa digitorum*)

- 1 **Proximal phalanx** (*phalanx proximalis*)
  - 1.1 **Base** (*basis*) – has an oval-shaped articular fossa for articulation with the metacarpal
  - 1.2 **Shaft** (*corpus*) – body
  - 1.3 **Head** (*caput*) – is pulley-shaped
- 2 **Middle phalanx** (*phalanx media*)
  - 2.1 **Base** (*basis*) – has an articular fossa with a ridge
  - 2.2 **Shaft** (*corpus*) – body
  - 2.3 **Head** (*caput*) – is pulley-shaped
- 3 **Distal phalanx** (*phalanx distalis*)
  - 3.1 **Base** (*basis*) – has an articular fossa with a ridge
  - 3.2 **Shaft** (*corpus*) – body
  - 3.3 **Tuberosity of distal phalanx** (*tuberositas phalangis distalis*)



The **axis of the hand** passes through the third finger.

The **sesamoid bones of the hand** (*ossa sesamoidea manus*) are located in the tendons of the flexor pollicis brevis over the metacarpophalangeal joint.

The **bones of the limbs** develop from mesenchymal tissue in the limb buds. The bones of the upper limb begin to develop at the beginning of the 2<sup>nd</sup> month of intrauterine life, a few days before the bones of the lower limb start to develop.

During birth, the pelvic ligaments and joints become loosened by the effect of the hormone relaxin, which is produced in the corpus luteum and placenta. This allows the pubic symphysis to be mildly expanded and the coccyx to be dorsally displaced during delivery.

#### Sex differences of the pelvis:

The **promontory** sticks out less in women.

The **pelvic inlet** has a transverse oval shape in women and a heart-shape in men.

The **wings of the ilium** are more widely open in women.

The **pubic symphysis** is shorter in women.

The **inferior pubic rami** form an angle termed the pubic arch in women. In men, they form an acute angle called the pubic angle.

The **sacrum** is shorter and wider in women. The angle between the base and anterior surface is sharper and the size of the auricular surface is smaller.

The **coccyx** is shorter and more mobile in women.

The **preauricular groove** is present in women only.

The **bispinal distance** (*distantia bispinalis*) is an obsolete term for the interspinous distance.

The **bicristal distance** (*distantia bicristalis*) is an obsolete term for the intercrystal distance.

### Clinical notes

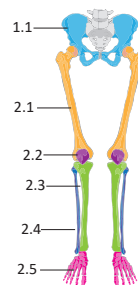
The **Boxer's Fracture** is a fracture of one of the metacarpal bones of the hand (the 5<sup>th</sup> metacarpal is the most common one). Classically, the fracture occurs transversely between the head and shaft of the bone, after the patient strikes an object with a closed fist.

**Traumatic pelvic fractures** are complex injuries with many bone fragments. Injury of the pelvic organs and vascular plexuses leads to large blood loss (3–4 liters) and hypovolemic shock.

## Bones of the lower limb – Ossa membri inferioris

The bones of the lower limb are divided into the **pelvic girdle** and the **free part of the lower limb**.

- 1 **Pelvic girdle** (*cingulum pelvicum*)
  - 1.1 **Hip bone** (*os coxae*) – pelvic bone
- 2 **Free part of lower limb** (*pars libera membri inferioris*)
  - 2.1 **Femur** – thigh bone
  - 2.2 **Patella** – kneecap
  - 2.3 **Tibia** – shinbone
  - 2.4 **Fibula** – calf bone
  - 2.5 **Bones of foot** (*ossa pedis*)
    - 2.5.1 **Tarsal bones** (*ossa tarsi*)
    - 2.5.2 **Metatarsals** (*ossa metatarsi*)
    - 2.5.3 **Phalanges** – bones of the toes



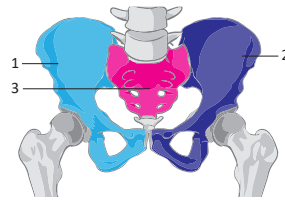
The pelvis consists of the **left and right hip bones** and the **sacrum**. The **linea terminalis** divides pelvis into the **greater pelvis**, which contains the small and large intestine, and the **lesser pelvis**, which contains the urinary bladder, the male and female internal genital organs and the rectum.

### Bony pelvis

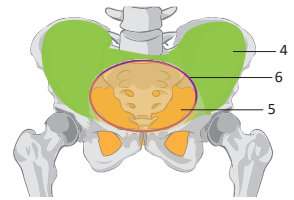
- 1 Right hip bone (*os coxae dextrum*)
- 2 Left hip bone (*os coxae sinistrum*)
- 3 Sacrum

### General organization

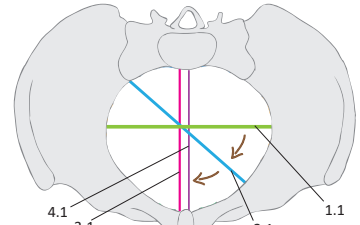
- 4 Greater pelvis (*pelvis major*)
- 5 Lesser pelvis (*pelvis minor*)
- 6 Linea terminalis – forms the pelvic inlet
  - the borders of linea terminalis:
    - 6.1 Promontory (*promontorium*) – the dorsocranial border
    - 6.2 Arcuate line (*linea arcuata*) – the lateral border
    - 6.3 Pecten pubis (*pecten ossis pubis*) – the lateral border
    - 6.4 Pubic symphysis (*symphysis pubica*) – the ventrocaudal border



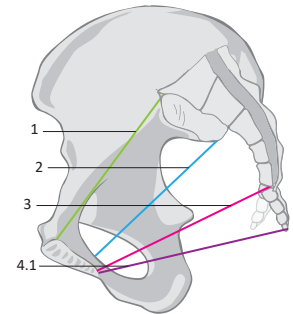
Anterior view of the pelvis



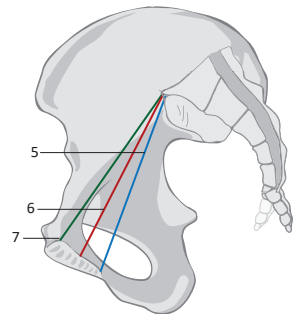
Anterior view of the pelvis



Internal pelvic diameters in planes



Sagittal section of the pelvis showing the pelvic diameters



Internal pelvic diameters

### Pelvic planes and internal pelvic diameters

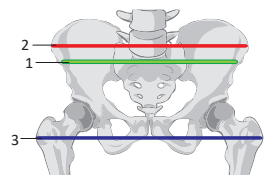
- 1 Pelvic inlet (*apertura pelvis superior, aditus pelvis*)
  - 1.1 Transverse diameter (*diameter transversa*) – 13 cm
    - the longest diameter of the pelvic inlet
- 2 Amplitudo pelvis – the pelvic plane with the largest dimensions
  - bordered by S2–S3, the acetabulum and the pubic symphysis
    - 2.1 Oblique diameter (*diameter obliqua*) – 13.5 cm
      - the longest diameter of amplitudo pelvis
- 3 Angustia pelvis – the pelvic plane with the smallest dimensions
  - is bordered by the apex of the sacrum, the margin of the ischial spine and the caudal margin of the pubic symphysis
    - 3.1 Median conjugate (*conjugata mediana, diameter recta*) – 11 cm
      - the distance between caudal margin of pubic symphysis and the sacrococcygeal symphysis
      - the longest diameter of angustia pelvis
- 4 Pelvic outlet (*apertura pelvis inferior, exitus pelvis*) – consists of two planes
  - is bordered by the caudal end of the coccyx, the ischial tuberosities and the caudal margin of the pubic symphysis
  - is made up of two triangles: the urogenital triangle and the anal triangle
    - 4.1 Straight diameter (*diameter recta*) – 9.5 cm
      - the distance between the caudal end of the coccyx and the caudal margin of the pubic symphysis
      - during delivery the foetus pushes the coccyx dorsally, increasing this diameter to 11.5 cm

### Other internal diameters

- 5 Diagonal conjugate (*conjugata diagonalis*) – 12.5–13 cm
  - the distance between the promontory and the caudal margin of the pubic symphysis
- 6 True conjugate (*conjugata vera, conjugata obstetrica*) – 10.5–11 cm
  - the distance between promontory and retropubic eminence, which is the most dorsal point on the pubic symphysis
- 7 Anatomical conjugate (*conjugata anatomica, diameter recta aperturæ pelvis superioris*) – 12 cm
  - the distance between the promontory and the upper margin of pubic symphysis

### External pelvic diameters

- 1 Interspinous distance (*distantia interspinosa*) – 25–26 cm
  - the distance between both anterior superior iliac spines
- 2 Intercrestal distance (*distantia intercrystalis*) – 28–29 cm
  - the distance between both iliac crests
- 3 Intertrochanteric distance (*distantia intertrochanterica*) – 31–32 cm
  - the distance between both greater trochanters
- 4 External conjugate of Baudelocque (*conjugata externa, diameter*) – 18–20 cm
  - the distance between the upper margin of pubic symphysis and the spinous process of L5



Anterior and posterior view of the pelvis

The hip bone consists of 3 fused bones: the ilium, ischium and pubis. These three bones articulate at the acetabulum to form the articular cavity of the hip joint. Two hip bones together with the sacrum form the bony pelvis.

### General organisation

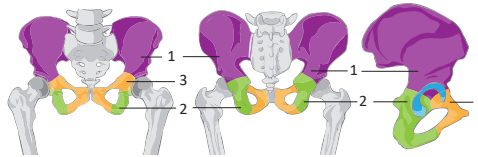
- 1 Ilium (*os ilium*)
- 2 Ischium (*os ichii*)
- 3 Pubis (*os pubis*)

### Ilium (*os ilium*)

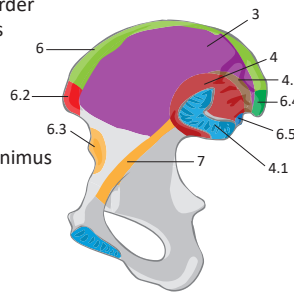
- 1 **Body of ilium** (*corpus ossis ilii*) – the smaller caudal part of the ilium
  - forms the upper third of the acetabulum
  - 1.1 **Supra-acetabular groove** (*sulcus supraacetabularis*)
    - the origin of the reflected head of the rectus femoris
- 2 **Ala of ilium** (*ala ossis ilii*) – the wing of the ilium, the larger cranial part of the ilium

#### Components of the ala of the ilium:

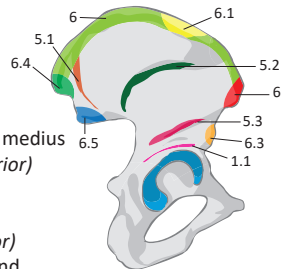
- 3 **Iliac fossa** (*fossa iliaca*) – a ventromedial concave fossa, the origin of the iliacus
- 4 **Sacropelvic surface** (*facies sacropelvica*) – the medial surface behind and below the iliac fossa
  - 4.1 **Auricular surface** (*facies auricularis*) – articulates with the sacrum
  - 4.2 **Iliac tuberosity** (*tuberositas iliaca*)
    - the attachment of the posterior interosseous sacro-iliac ligament
- 5 **Gluteal surface** (*facies glutea*) – the dorsolateral surface, the origin of the gluteal muscles
  - 5.1 **Posterior gluteal line** (*linea glutea posterior*) – the border between origins of the gluteus maximus and medius
  - 5.2 **Anterior gluteal line** (*linea glutea anterior*)
    - the border between the origins of the gluteus medius and minimus
  - 5.3 **Inferior gluteal line** (*linea glutea inferior*)
    - the caudal borderline of the origin of the gluteus minimus
- 6 **Iliac crest** (*crista iliaca*) – has three lips (lines) for attachment of the abdominal wall muscles
  - **outer lip** (*labium externum*): the origin of the latissimus dorsi, the tensor fasciae latae, and the gluteus maximus and medius, the insertion of the external oblique and the attachment of the fascia lata
  - **intermediate zone** (*linea intermedia*): the origin of the internal oblique
  - **inner lip** (*labium internum*): the origin of the transversus abdominis, the attachment of the thoracolumbar fascia and the insertion of the quadratus lumborum
  - 6.1 **Tuberculum of iliac crest** (*tuberculum iliacum*)
    - a bony projection formed by the origin of the gluteus medius
  - 6.2 **Anterior superior iliac spine** (*spina iliaca anterior superior*)
    - the origin of the sartorius and tensor fasciae latae and the attachment of the inguinal ligament
  - 6.3 **Anterior inferior iliac spine** (*spina iliaca anterior inferior*)
    - the origin of the straight head of the rectus femoris and the attachment of the iliofemoral ligament
  - 6.4 **Posterior superior iliac spine** (*spina iliaca posterior superior*)
  - 6.5 **Posterior inferior iliac spine** (*spina iliaca posterior inferior*)
- 7 **Arcuate line** (*linea arcuata*) – part of linea terminalis



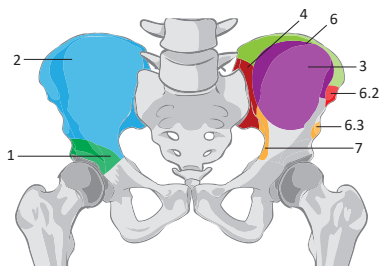
Anterior, posterior and lateral views of the pelvis



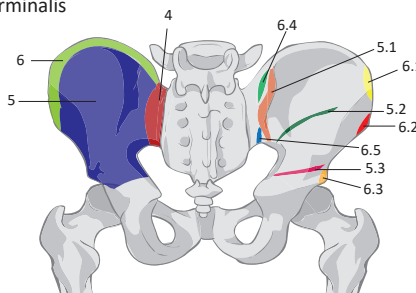
The medial side of the right hip bone



The lateral side of the right hip bone



Anterior view of the pelvis



Posterior view of the pelvis

The **preauricular groove** (*sulcus preauricularis*) is a groove at the transition between the hip bone and sacrum. It is a typical feature of the female pelvis.

In children, the individual parts of the pelvis are separated by cartilage at the acetabulum. This cartilage has a shape of a letter Y (*cartilago ypsilonformis*) and ossifies between the 14<sup>th</sup> and 16<sup>th</sup> year of life.

The appearance of the **symphyseal surface** (*facies symphysealis*) can be used in forensic medicine to estimate age.

The groove for the dorsal nerve of the penis/clitoris (*sulcus nervi dorsalis penis/clitoridis*) is a shallow and narrow groove situated on the inferior pubic ramus and on the frontal surface of the pubic bone. It is present in 90 % of cases.

### Clinical notes

The dorsal aspect of the iliac crest (*crista iliaca*) can become sensitive to touch in the presence of a hypertonic or spastic quadratus lumborum.

The superior part of the pubis becomes sensitive in the presence of a hypertonic rectus abdominis. This can occur in patients with an inguinal hernia and after surgical repair of such hernias.

The pubic bone can become sensitive in hypertonicity of the thigh adductors.

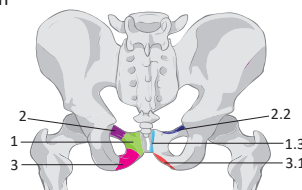
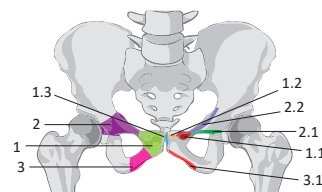
The ala of the ilium is used for harvesting spongy bone grafts for the treatment of complicated fractures in orthopaedics and traumatology.

A trephine biopsy is a procedure in which a cylindrically shaped core of bone is obtained for histopathological evaluation. Samples are drawn from the hip bone, usually from the area of the posterior superior iliac spine and occasionally from the anterior superior iliac spine.



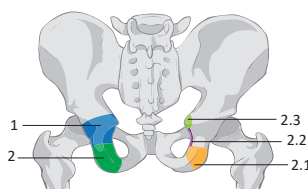
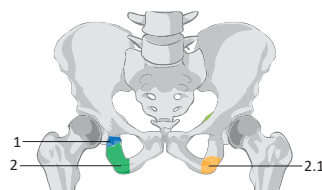
### Pubis (*os pubis*)

- 1 **Body** (*corpus ossis pubis*) – connects to the pubic symphysis
  - 1.1 **Pubic tubercle** (*tuberculum pubicum*)
    - the attachment of the inguinal ligament and superior pubic ligament
  - 1.2 **Pubic crest** (*crista pubica*) – the insertion of the rectus abdominis
    - the origin of the pyramidalis
  - 1.3 **Symphysial surface** (*facies symphysialis*)
    - the medial surface articulates at the pubic symphysis
- 2 **Superior pubic ramus** (*ramus superior ossis pubis*) – forms the ventral one third of the acetabulum
  - 2.1 **Obturator crest** (*crista obturatoria*)
    - is located between the pubic tubercle and acetabular notch
    - the attachment of the pubofemoral ligament
  - 2.2 **Pecten pubis** (*pecten ossis pubis*) – forms part of the linea terminalis
    - the origin of the pectineus
    - the attachment of the inguinal falx and the lacunar and pectineal ligaments
- 3 **Inferior pubic ramus** (*ramus inferior ossis pubis*)
  - forms the ischiopubic ramus with the ramus of the ischium
  - 3.1 **Phallic crest** (*crista phallica*) – origin of the erectile bodies of the penis and clitoris



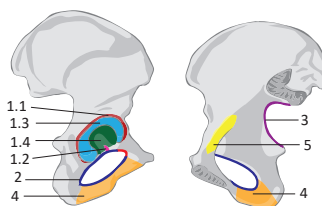
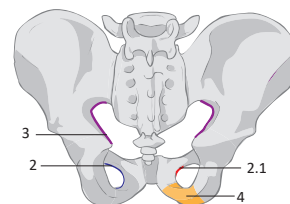
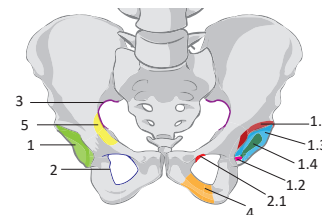
### Ischium (*os ischii*)

- 1 **Body** (*corpus ossis ischii*) – the thicker dorsal part that forms the dorsal third of the acetabulum
- 2 **Ramus** (*ramus ossis ischii*) – runs ventrally from the body
  - forms the ischiopubic ramus with the inferior pubic ramus
  - 2.1 **Ischial tuberosity** (*tuber ischiadicum*)
    - the origin of the semimembranosus, semitendinosus, biceps femoris, adductor magnus, gemellus inferior, quadratus femoris, superficial transverse perineal muscle and ischiocavernosus
    - the attachment of the sacrotuberous and ischiofemoral ligaments
    - is palpable when the thigh is flexed at the hip joint
  - 2.2 **Lesser sciatic notch** (*incisura ischiadica minor*)
    - forms the lesser sciatic foramen with the sacrospinous and sacrotuberous ligaments
  - 2.3 **Ischial spine** (*spina ischiadica*)
    - the border between the greater and lesser sciatic notches
    - the insertion of the iliococcygeus, ischiooccygeus and the origin of gemellus superior
    - the attachment of sacrospinous ligament



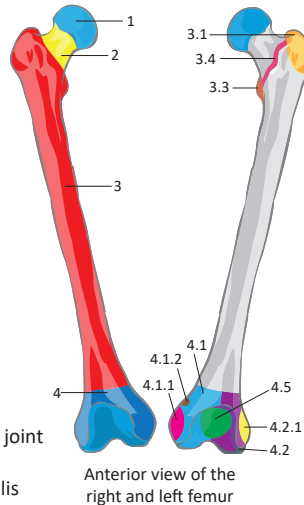
### Common features of the hip bone

- 1 **Acetabulum** – the articular fossa of the hip joint composed of all 3 hip bones
  - is enlarged by a fibrocartilaginous acetabular labrum
  - 1.1 **Acetabular margin** (*limbus acetabuli*) – an elevated ridge around the acetabulum
  - 1.2 **Acetabular notch** (*incisura acetabuli*)
    - a caudal notch on the acetabular margin
  - 1.3 **Lunate surface** (*facies lunata*) – the articular surface of the acetabulum
    - ends caudally at the acetabular notch
  - 1.4 **Acetabular fossa** (*fossa acetabuli*) – is filled with a fat pad (*pulvinar acetabuli*)
- 2 **Obturator foramen** (*foramen obturatum*)
  - is surrounded by the ischium and pubis
  - is almost fully closed by the obturator membrane
  - the origin of the obturator externus and internus
  - 2.1 **Obturator groove** (*sulcus obturatorius*)
    - is located on the internal side of the superior pubic ramus
    - forms the obturator canal with the obturator membrane
    - transmits the obturator nerve and vessels
  - 2.2 **Anterior and posterior obturator tubercle** (*tuberculum obturatorium anterius et posterius*)
    - variable bony projections
- 3 **Greater sciatic notch** (*incisura ischiadica major*) – together with the sacrospinous and sacrotuberous ligaments forms the greater sciatic foramen
- 4 **Ischiopubic ramus** (*ramus ischiopubicus*) – the caudal border of the obturator foramen formed by the ramus of the ischium and the inferior pubic ramus
- 5 **Iliopubic ramus** (*eminentia iliopubica*) – the insertion of the psoas minor
  - the transition of the arcuate line into the pecten pubis

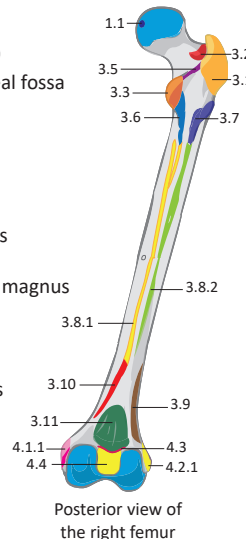


The femur is the longest bone of the human body. It is covered by a thick layer of muscles and therefore only a small proportion is palpable from the skin.

- 1 **Head** (*caput femoris*) – forms the articular head of the hip joint
  - 1.1 **Fovea of head of femur** (*fovea capitis femoris*) – the site of attachment of the ligament of the head of the femur
- 2 **Neck** (*collum femoris*) – the articular capsule of the hip joint attaches to the dorsal 2/3 of the neck
- 3 **Shaft of the femur** (*corpus femoris*) – the body of the femur
  - 3.1 **Greater trochanter** (*trochanter major*) – the insertion of the gluteus medius, gluteus minimus, piriformis, obturator internus, gemellus superior and gemellus inferior
  - 3.2 **Trochanteric fossa** (*fossa trochanterica*) – the insertion of the obturator externus
  - 3.3 **Lesser trochanter** (*trochanter minor*) – a dorsomedial prominence – the insertion of the iliopsoas
  - 3.4 **Intertrochanteric line** (*linea intertrochanterica*) – a ventral line connecting both trochanters – the attachment of the articular capsule of the hip joint – the attachment of the iliofemoral ligament – the origin of the vastus medialis and vastus lateralis
  - 3.5 **Intertrochanteric crest** (*crista intertrochanterica*) – a dorsal crest connecting both trochanters
    - 3.5.1 **Quadrato tubercle** (*tuberculum quadratum*) – the insertion of the quadratus femoris
  - 3.6 **Pectineal line** (*linea pectinea*) – the insertion of the pectineus – is located below the lesser trochanter
  - 3.7 **Gluteal tuberosity** (*tuberositas glutea*) – the insertion of the gluteus maximus – is located below the greater trochanter
  - 3.8 **Linea aspera** – an attachment site for many muscles of the thigh and also for the intermuscular septa
    - 3.8.1 **Medial lip** (*labium mediale*) – the attachment of the medial femoral intermuscular septum – the origin of the vastus medialis and the insertion of the adductor longus, adductor brevis and adductor magnus
    - 3.8.2 **Lateral lip** (*labium laterale*) – the attachment of the lateral femoral intermuscular septum – the origin of the short head of the biceps femoris and vastus lateralis
  - 3.9 **Lateral supracondylar line** (*linea supracondylaris lateralis*) – the origin of the plantaris
  - 3.10 **Medial supracondylar line** (*linea supracondylaris medialis*)
  - 3.11 **Popliteal surface** (*facies poplitea*) – the floor of the popliteal fossa
- 4 **Condyles of femur** (*condyli femoris*) – the distal end of the femur – articular surfaces that articulate with the tibia
  - 4.1 **Medial condyle** (*condylus medialis femoris*)
    - 4.1.1 **Medial epicondyle** (*epicondylus medialis*) – the attachment of the tibial collateral ligament – the origin of the medial head of the gastrocnemius
    - 4.1.2 **Adductor tubercle** (*tuberculum adductorium*) – the insertion of the extensor part of the adductor magnus
  - 4.2 **Lateral condyle** (*condylus lateralis femoris*)
    - 4.2.1 **Lateral epicondyle** (*epicondylus lateralis*) – the attachment of the fibular collateral ligament – the origin of the lateral head of the gastrocnemius
    - 4.2.2 **Groove for the popliteus** (*sulcus popliteus*) – the origin of the popliteus
  - 4.3 **Intercondylar line** (*linea intercondylaris*) – the attachment of the oblique popliteal ligament
  - 4.4 **Intercondylar fossa** (*fossa intercondylaris*) – the attachment of the cruciate ligaments of the knee joint
  - 4.5 **Patellar surface** (*facies patellaris*) – the ventral surface for articulation with the patella



Anterior view of the right and left femur



Posterior view of the right femur

The angle of inclination of the femur is formed between the neck and the body. It measures approximately 125°.

Torsion of the femur is measured by a line running between the condyles and a line through the neck of the femur. It is approximately 10°.

The greater and lesser trochanter are apophyses and have their own ossification centres.

The third trochanter (*trochanter tertius*) is an alternative term for the gluteal tuberosity in case it is very prominent.

Tubercle of Gerdy is a clinical term for the tuberosity of the iliotibial tract.

In children, the proximal epiphyseal cartilage of the tibia and fibula contributes 55 % of the growth of these bones. The distal epiphyseal cartilages contribute 45 %.

The pilon (or pylon) is a clinical term for the distal part of the tibia.

The tibial plateau is a clinical term for the proximal part of the tibia.

The internal and external supracondylar tubercles are variable tubercles found on the femoral condyles. They serve as the places of origin for the two heads of the gastrocnemius.

The greater trochanter is always palpable. In obese it is marked by the shallow skin depression.

### Clinical notes

The greater trochanter may become sensitive in a radiculopathy of the spinal root L5. It is sometimes sensitive to touch in disorders of the hip.

Limited mobility of the patella can be caused by a hypertonic quadriceps femoris.

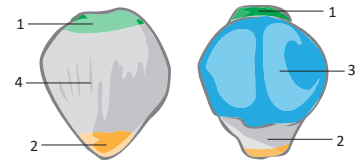
Pain provoked by pressure on the patella can occur in knee joint disorders.

Intra-osseous access to the tibia can be used in critical care medicine for application of infusions and medications. The bone marrow is accessed by a puncture approximately 1 cm below the tuberosity of the tibia.

Overload of the quadriceps femoris insertion on the tibial tuberosity can lead to disruption.

The **patella** is a sesamoid bone located in the **tendon of the quadriceps femoris**. It is part of the knee joint.

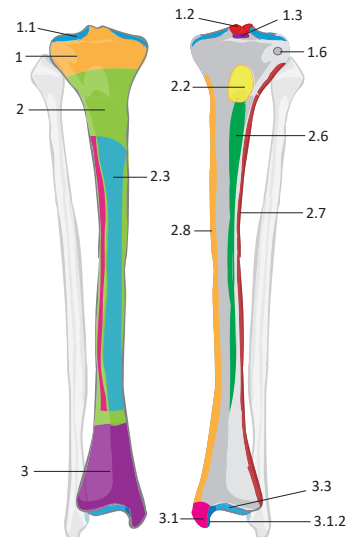
- 1 **Base of patella** (*basis patellae*) – the wide proximal part
- 2 **Apex of patella** (*apex patellae*) – the pointy distal end
- 3 **Articular surface** (*facies articularis*) – the dorsal surface
  - is divided into a lateral and a medial facet
  - the medial facet is smaller than the lateral facet
- 4 **Anterior surface** (*facies anterior*) – the roughened ventral surface
  - incorporates part of the tendon of the quadriceps femoris



Anterior and posterior view of the right patella

The **tibia** is a **weight bearing bone of the leg** which forms the **shin**. It is a long bone. The distal end of the tibia forms the **medial malleolus**. The **anterior margin** and the **medial surface** are not covered by muscles and are therefore **palpable** in their entire course.

- 1 **Condyles of tibia** (*condyli tibiae*) – form the widened proximal end of the bone
  - the tibia has two condyles: the medial condyle and the lateral condyle
  - the sartorius, gracilis and semitendinosus are attached to the medial condyle as a common tendon called the pes anserinus
- 1.1 **Superior articular surface** (*facies articularis superior*)
  - an articular surface for articulation with the femoral condyles
- 1.2 **Intercondylar eminence** (*eminentia intercondylaris*)
  - an eminence located in the middle of the superior articular surface
  - comprises the medial and lateral tubercle
- 1.3 **Anterior intercondylar area** (*area intercondylaris anterior*)
  - the attachment of the anterior cruciate ligament and menisci
- 1.4 **Posterior intercondylar area** (*area intercondylaris posterior*)
  - the attachment of the posterior cruciate ligament and menisci
- 1.5 **Fibular articular facet** (*facies articularis fibularis*)
  - articulates with the head of the fibula
- 1.6 **Tuberosity for iliotibial tract** (*tuberositas tractus iliotibialis*)
  - a small prominence for the attachment of the iliotibial tract
- 2 **Shaft** (*corpus tibiae*) – the body of the tibia
  - 2.1 **Soleal line** (*linea musculi solei*)
    - the origin of the soleus muscle
  - 2.2 **Tibial tuberosity** (*tuberositas tibiae*)
    - the insertion of the quadriceps femoris (as the patellar ligament)



Anterior view of the left and right tibia

#### Surfaces:

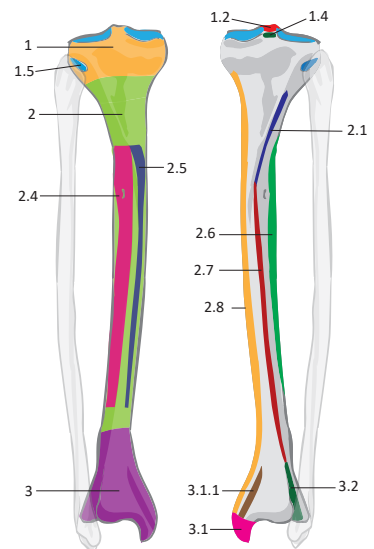
- 2.3 **Medial surface** (*facies medialis*)
  - is palpable as it is not covered by muscles
- 2.4 **Lateral surface** (*facies lateralis*)
- 2.5 **Posterior surface** (*facies posterior*)

#### Borders:

- 2.6 **Anterior border** (*margo anterior*)
  - is palpable as it is not covered by muscles
- 2.7 **Interosseous border** (*margo interosseus*)
  - the attachment of the interosseous membrane of the leg
- 2.8 **Medial border** (*margo medialis*)

#### 3 Distal end

- 3.1 **Medial malleolus** (*malleolus medialis*) – the medial side of the ankle
  - 3.1.1 **Malleolar groove** (*sulcus malleolaris*)
    - forms the malleolar canal together with the flexor retinaculum
    - tendons of the tibialis posterior and flexor digitorum longus pass through it
  - 3.1.2 **Articular facet** (*facies articularis malleoli medialis*)
    - articulates with the talus
- 3.2 **Fibular notch** (*incisura fibularis*) – forms part of the tibiofibular syndesmosis
- 3.3 **Inferior articular surface** (*facies articularis inferior*)
  - articulates with the trochlea of the talus



Posterior view of the left and right tibia

The **fibula** is a long bone located on the **lateral aspect of the leg**. It does not bear any weight of the body and serves only for attachments of muscles. The distal end of the fibula forms the **lateral malleolus**.

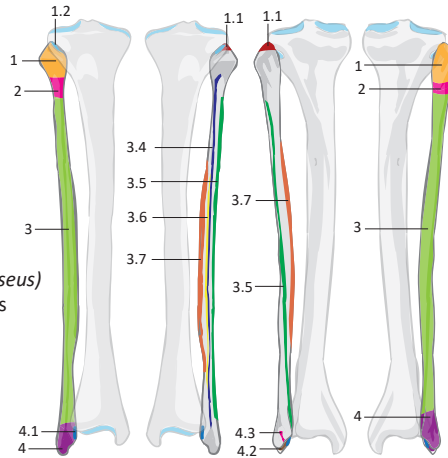
- 1 **Head** (*caput fibulae*)
  - the insertion of the biceps femoris
  - the attachment of the fibular collateral ligament, arcuate popliteal ligament and anterior and posterior ligaments of the head of the fibula
  - the origin of the soleus and fibularis longus
  - 1.1 **Apex of head of fibula** (*apex capitis fibulae*)
  - 1.2 **Articular facet** (*facies articularis capitis fibulae*)
    - articulates with the tibia
- 2 **Neck** (*collum fibulae*) – the common fibular nerve runs around the neck
- 3 **Shaft** (*corpus fibulae*)
 

**Surfaces:**

  - 3.1 **Lateral surface** (*facies lateralis*)
  - 3.2 **Medial surface** (*facies medialis*)
  - 3.3 **Posterior surface** (*facies posterior*)

**Borders:**

  - 3.4 **Anterior border** (*margo anterior*)
  - 3.5 **Posterior border** (*margo posterior*)
  - 3.6 **Interosseous border** (*margo interosseus*)
    - the attachment of the interosseous membrane of the leg
  - 3.7 **Medial crest** (*crista medialis*)- 4 **Lateral malleolus** (*malleolus lateralis*)
  - 4.1 **Articular facet** (*facies articularis malleoli lateralis*)
    - articulates with the talus
  - 4.2 **Malleolar fossa** (*fossa malleoli lateralis*)
    - for the posterior talofibular ligament
  - 4.3 **Malleolar groove** (*sulcus malleolaris*)
    - transmits the tendons of the fibularis longus and brevis in a common tendon sheath under the superior fibular retinaculum



Anterior and posterior view of the right and left fibulae

Almost 60 % of the surface area of the **talus** is covered by cartilage. It receives blood only from areas that are not covered by cartilage. Its blood supply is very liable to compromise in trauma.

The **calcaneus** is made up of a large proportion trabecular bone. It has a thicker compact layer close to the insertion of the calcaneal tendon.

**Astragalus** is a Greek term for talus.

**Perone** is a Greek term for fibula. **Peroneus** is often used synonymously with fibularis.

The **tuberosity above the articular facet of the lateral malleolus** (*facies articularis malleoli lateralis*) serves for the attachment of the tibiofibular syndesmosis.

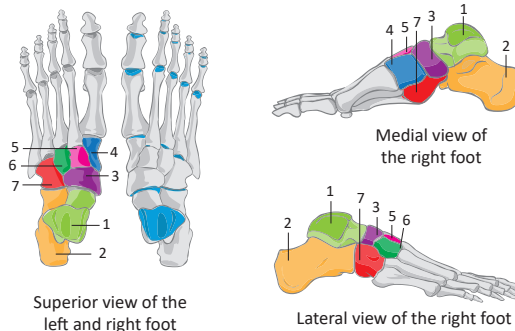
A **groove for the tendon of the flexor hallucis longus** is located on both the talus and calcaneus. Together they form a canal for this tendon in its tendinous sheath.

The **tarsal sinus** (*sinus tarsi*) is situated between the talar sulcus (*sulcus tali*) and calcaneal sulcus (*sulcus calcanei*). It is filled with the interosseous talocalcaneal ligament.

The bones of the foot consist of **7 tarsal bones**, **5 metatarsal bones** and **14 phalanges**. The tarsal bones form the **longitudinal and transverse arch of the foot**. The longitudinal arch is divided into a medial and lateral arch. The **lateral arch** consists of the calcaneus, cuboid and the 5<sup>th</sup> metatarsal. The **medial arch** consists of the calcaneus, talus, navicular bone, the three cuneiform bones and the 1<sup>st</sup> metatarsal. The general organisation of the **metatarsals and phalanges of the foot** is similar to the organisation of the metacarpals and phalanges of the hand.

#### Tarsal bones (*ossa tarsi*)

- 1 **Talus** – ankle bone
- 2 **Calcaneus** – heel bone
- 3 **Navicular** (*os naviculare*)
- 4 **Medial cuneiform** (*os cuneiforme mediale*)
- 5 **Intermediate cuneiform** (*os cuneiforme intermedium*)
- 6 **Lateral cuneiform** (*os cuneiforme laterale*)
- 7 **Cuboid** (*os cuboideum*)



Superior view of the left and right foot

Lateral view of the right foot

#### Clinical notes

The **common fibular nerve** (*nervus fibularis communis*) runs superficially behind the head and neck of the fibula. It can be injured by trauma or by an incorrectly positioned cast compressing the nerve.

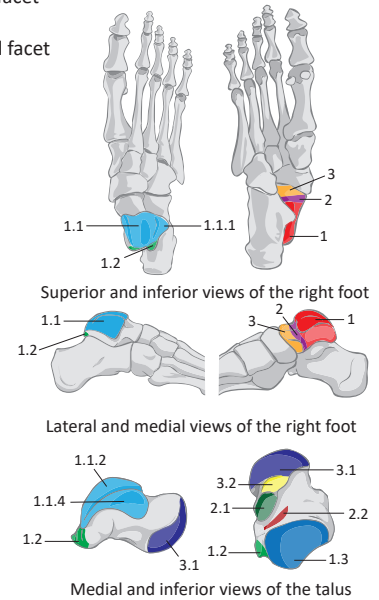
The **calcaneus** is the most frequently injured bone of the tarsus.

A **calcaneal spur** (*calcar calcanei*) is an osseous projection formed inside the ligament and muscle attachments on the calcaneal tuberosity (its plantar surface) or less often at the attachment of the calcaneal tendon. It forms due to repeated stress on the calcaneus and can cause pain during walking.

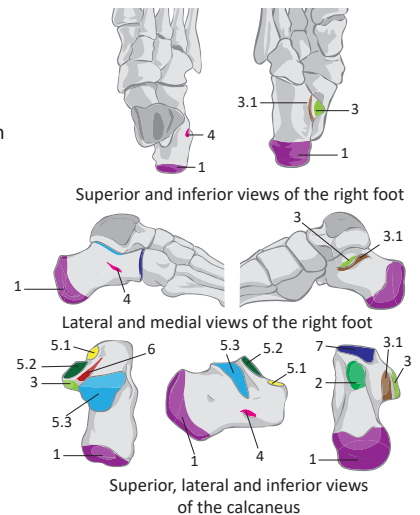
**Pain in the calcaneus** can develop in the presence of calcaneal spurs, in hypertonicity of the triceps surae and quadratus plantae, in overload of the plantar aponeurosis and in depression of the transverse arch of the foot.

**Talus**

- **1 Body** (*corpus tali*)
  - **1.1 Trochlea of talus** (*trochlea tali*) – the articular head of the ankle (talocrural) joint
    - 1.1.1 **Lateral process** (*processus lateralis tali*) – the attachment of the lateral talocalcaneal ligament**Articular facets:**
    - 1.1.2 **Superior facet** (*facies articularis superior*) – articulates with the inferior surface of the tibia
    - 1.1.3 **Lateral malleolar facet** (*facies articularis malleolaris lateralis*) – a large lateral facet
      - articulates with the articular facet of the lateral malleolus of the fibula
    - 1.1.4 **Medial malleolar facet** (*facies articularis malleolaris medialis*) – a small medial facet
      - articulates with the articular facet of the medial malleolus of the tibia
  - **1.2 Posterior process** (*processus posterior tali*)
    - 1.2.1 **Groove for tendon of flexor hallucis longus** (*sulcus tendinis musculi flexoris hallucis longi*)
    - 1.2.2 **Lateral tubercle** (*tuberculum laterale*)
      - the attachment of the posterior talofibular ligament
    - 1.2.3 **Medial tubercle** (*tuberculum mediale*)
      - the attachment of the medial talocalcaneal ligament
  - **1.3 Posterior calcaneal articular facet** (*facies articularis calcanea posterior*)
    - articulates caudally with the calcaneus
- **2 Neck** (*collum tali*) – the attachment of the articular capsule, anterior talofibular ligament and talonavicular ligament
  - **2.1 Middle calcaneal articular facet** (*facies articularis calcanea media*)
    - articulates with the calcaneus caudally
  - **2.2 Sulcus tali** – a groove located between the posterior articular facet and the middle and anterior articular facets
- **3 Head** (*caput tali*) – the head of the talonavicular joint
  - **3.1 Navicular articular surface** (*facies articularis navicularis*)
    - articulates with the navicular bone
  - **3.2 Anterior calcaneal articular facet** (*facies articularis calcanea anterior*)
    - articulates caudally with the calcaneus

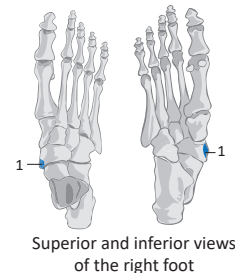
**Calcaneus**

- **1 Calcaneal tuberosity** (*tuber calcanei*) – is located the dorsal surface of the calcaneus
  - the insertion of the triceps surae (as the Achilles tendon) and the plantaris
  - the attachment of the plantar aponeurosis
  - 1.1 **Medial process** (*processus medialis*) – the attachment of the flexor retinaculum
    - the origin of the abductor hallucis and flexor digitorum brevis
  - 1.2 **Lateral process** (*processus lateralis*) – the origin of the abductor digiti minimi
- **2 Calcaneal tubercle** (*tuberculum calcanei*) – is located on the plantar surface
  - the attachment of the plantar calcaneocuboid ligament and part of the long plantar ligament
- **3 Sustentaculum tali** – the talar shelf, projects medially
  - the attachment of the tibiocalcaneal part of the medial collateral ligament, medial talocalcaneal ligament and plantar calcaneonavicular ligament
  - **3.1 Groove for tendon of flexor hallucis longus** (*sulcus tendinis musculi flexoris hallucis longi*)
- **4 Fibular trochlea** (*trochlea fibularis*)
  - a bony projection, under which runs the tendon of the fibularis longus
- **5 Talar articular surfaces** (*facies articulares talaris*) – articulates with the talus
  - **5.1 Anterior articular talar surface** (*facies articularis talaris anterior*)
  - **5.2 Middle articular talar surface** (*facies articularis talaris media*)
  - **5.3 Posterior articular talar surface** (*facies articularis talaris posterior*)
- **6 Calcaneal sulcus** (*sulcus calcanei*) – forms the tarsal sinus with the sulcus tali
  - a groove between the posterior articular facet and the middle and anterior articular facets
- **7 Articular surface for cuboid** (*facies articularis cuboidea*) – a facet on the ventral surface of the bone

**Navicular** (*os naviculare*)

- has a proximal articular cavity for articulation with the talus
- has 3 distal facets for articulation with the cuneiform bones
- has a laterodistal facet for articulation with the cuboid

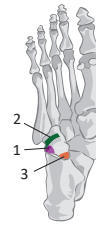
- **1 Tuberosity** (*tuberositas ossis navicularis*) – a palpable tuberosity located on the medial side of the foot
  - the insertion of the tibialis posterior
  - the attachment of the tibionavicular part of the medial collateral ligament and the plantar calcaneonavicular ligament





**Cuboid (*os cuboideum*)**

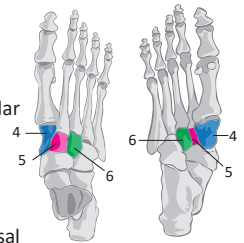
- has a facet on its medial surface for articulation with the lateral cuneiform
- has a narrow facet for articulation with the navicular
- has a facet on its proximal surface for articulation with the calcaneus
- has two facets on its distal surface for articulation with the 4<sup>th</sup> and 5<sup>th</sup> metatarsals
- **1 Tuberosity of cuboid (*tuberositas ossis cuboidei*)** – is located lateroplantarly
  - the attachment of the deep fibres of the long plantar ligament
- **2 Groove for tendon of fibularis longus (*sulcus tendinis musculi fibularis longi*)** – a groove on the plantar surface
- **3 Calcaneal process (*processus calcaneus*)**
  - is located proximally and points towards the calcaneus



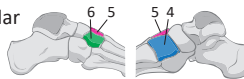
Inferior view of the right foot

**Cuneiform bones (*ossa cuneiformia*)**

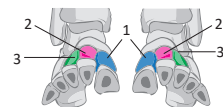
- **4 Medial cuneiform (*os cuneiforme mediale*)** – the largest cuneiform
  - is wedge-shaped with a dorsal facing apex
  - has a facet on its proximal surface for articulation with the navicular
  - has a kidney-shaped facet for articulation with the 1<sup>st</sup> metatarsal
- **5 Intermediate cuneiform (*os cuneiforme intermedium*)**
  - the smallest cuneiform
  - is wedge-shaped with a plantar facing apex
  - has a triangular-shaped facet for articulation with the 2<sup>nd</sup> metatarsal
- **6 Lateral cuneiform (*os cuneiforme laterale*)**
  - is wedge shaped with a plantar facing apex
  - has a facet on its proximal surface for articulation with the navicular
  - has an oval-shaped facet for articulation with the cuboid



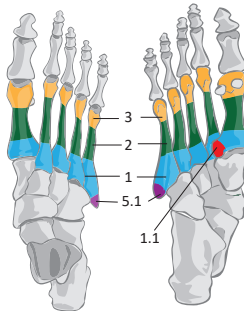
Superior and inferior views of the right foot



Lateral and medial views of the right foot



Anterior view of cross sections through the metatarsals of the right and left foot



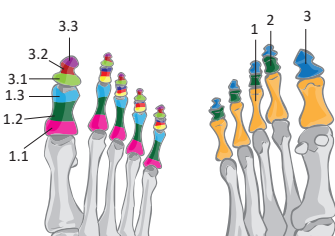
Superior and inferior view of the right foot

**Metatarsals (*ossa metatarsi*)****General organization**

- **1 Base (*basis ossis metatarsi*)**
- **2 Shaft (*corpus ossis metatarsi*)**
- **3 Head (*caput ossis metatarsi*)**
- I **1<sup>st</sup> metatarsal (*os metatarsi primum*)** – the thickest metatarsal
  - has a kidney-shaped facet for articulation with the medial cuneiform
  - **1.1 Tuberosity of 1<sup>st</sup> metatarsal (*tuberositas ossis metatarsi primi*)** – the insertion of the muscles of the big toe
- II **2<sup>nd</sup> metatarsal (*os metatarsi secundum*)** – the longest metatarsal
  - has a triangular facet for articulation with the intermediate cuneiform
  - articulates with the medial and lateral cuneiform bones
- III **3<sup>rd</sup> metatarsal (*os metatarsi tertium*)** – has a triangular facet on its proximal surface for articulation with lateral cuneiform bone
- IV **4<sup>th</sup> metatarsal (*os metatarsi quartum*)** – has a quadrate-shaped facet on its proximal surface for articulation with the cuboid
- V **5<sup>th</sup> metatarsal (*os metatarsi quintum*)**
  - has a facet on its proximal surface for articulation with the cuboid
  - **5.1 Tuberosity of 5<sup>th</sup> metatarsal bone (*tuberositas ossis metatarsi quinti*)**
    - the insertion of the fibularis brevis
    - the origin of the abductor digiti minimi

**Phalanges (*ossa digitorum*) – bones of the toes**

- **1 Proximal phalanx (*phalanx proximalis*)**
  - **1.1 Base (*basis*)** – has an oval-shaped articular fossa
  - **1.2 Shaft (*corpus*)** – body
  - **1.3 Head (*caput*)** – is pulley-shaped
- **2 Middle phalanx (*phalanx media*)**
  - **2.1 Base (*basis*)** – forms an articular fossa
  - **2.2 Shaft (*corpus*)** – body
  - **2.3 Head (*caput*)** – is pulley-shaped
- **3 Distal phalanx (*phalanx distalis*)**
  - **3.1 Base (*basis*)** – forms an articular fossa
  - **3.2 Shaft (*corpus*)** – body
  - **3.3 Tuberosity of distal phalanx (*tuberositas phalangis distalis*)**



Superior and inferior view of the right foot

The **tuberosity of the fifth metatarsal bone** has its own centre of ossification.

The **sesamoid bones of foot (*ossa sesamoidea pedis*)** are located in the flexor hallucis brevis tendons over the first metatarsophalangeal joint.

**Os peroneum** is a small accessory bone (present in 25 %) located at the lateral plantar aspect of the cuboid within the tendon of the fibularis longus as it arches around the cuboid.

**Clinical notes**

**March fractures** are a form of fatigue fractures that affect the second and third metatarsal bone after prolonged periods of marching or running. They occur most frequently in firm shoes with hard soles.

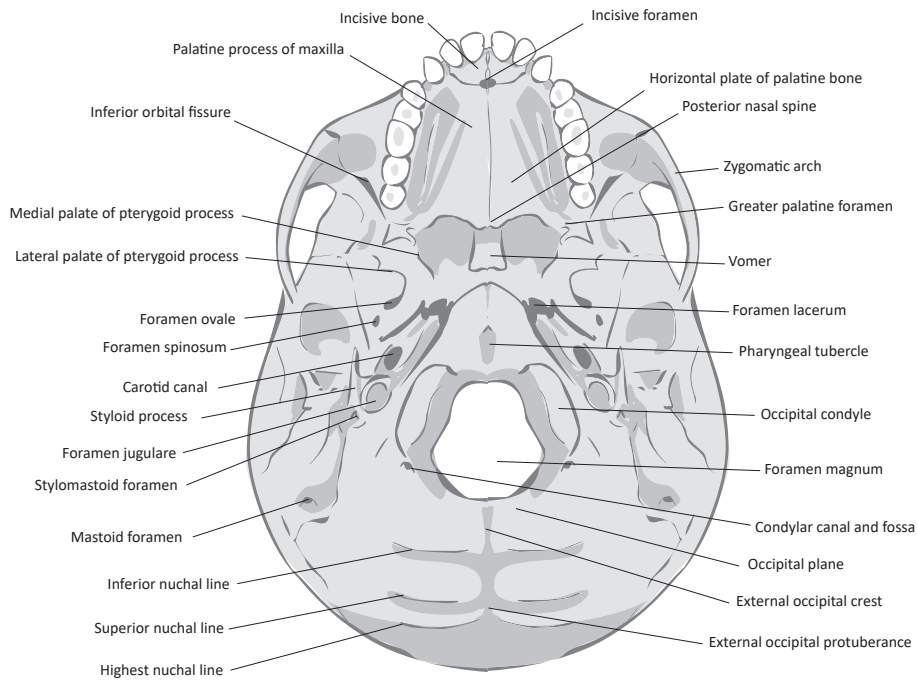
**Avulsion fractures** can occur on the tuberosity of the fifth metatarsal by traction at the fibularis brevis attachment.

**Pain and swelling around the heads of the metatarsals** develop in depression of transverse arch of the foot and insufficient foothold of calcaneus.

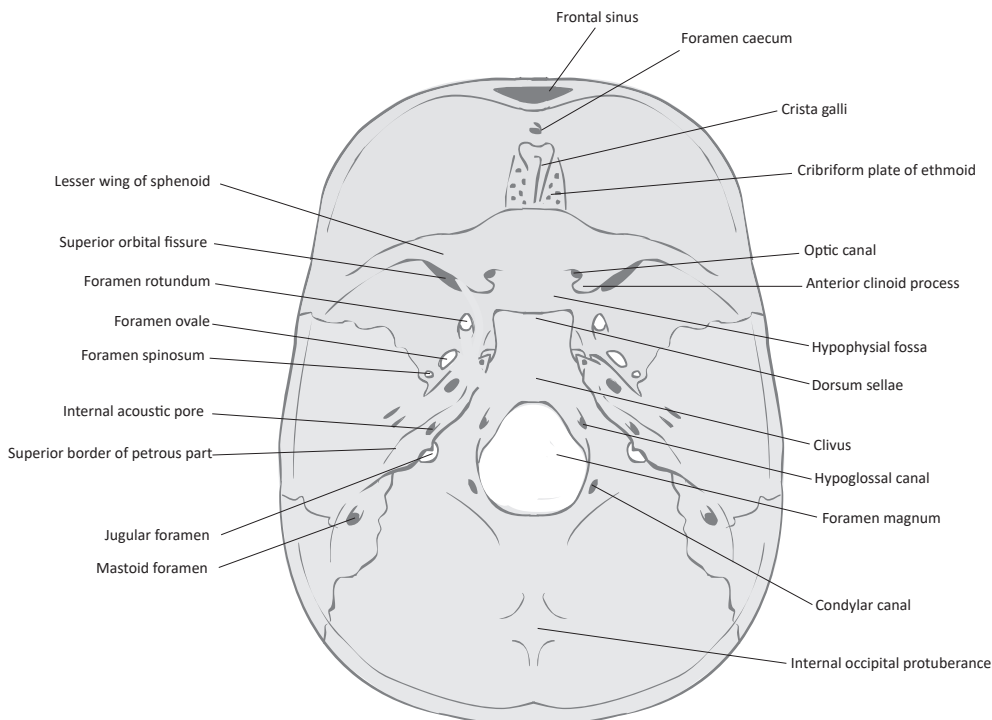
**Metatarsalgia of Morton** is a painful disorder caused by compression of nerves in the intermetatarsal spaces.

**Hammer toe (*digitus malleus*)** is a common foot deformity. It is caused by a disbalance between the short and long foot muscles. It is characterised by flexion at the proximal interphalangeal joint and hyperextension in the distal interphalangeal joint. The most common cause is wearing of ill-fitting shoes, which puts pressure on the proximal phalanges and cause blisters and painful corns (*clavi*).

A **bunion (*hallux valgus*)** is a foot deformity, characterised by lateral deviation of the big toe. A bulge can develop in the area of the first metatarsophalangeal joint. This disorder is more common in women who wear shoes with stiletto heels.



External view of the cranial base (*basis cranii externa*)



Internal view of the cranial base (*basis cranii interna*)

From	Through	To	Content
Alveolar canals of the maxilla	<b>Alveolar canals of the maxilla</b>	Dental alveoli of the maxilla	Posterior superior alveolar branches (nerves) Posterior superior alveolar artery
Diploë	<b>Diploic canals</b>	Diploë	Diploic veins
Hard palate	<b>Incisive canals</b>	Nasal cavity	Nasopalatine nerves and posterior septal branches of sphenopalatine artery
Greater palatine canal	<b>Lesser palatine canals</b>	Lesser palatine foramina on the hard palate	Lesser palatine nerve, artery and vein
Carotid canal	<b>Caroticotympanic canaliculi</b>	Carotid wall of the tympanic cavity	Caroticotympanic arteries and nerves
Scala tympani of the cochlea of the bony labyrinth	<b>Cochlear canaliculus</b>	Inferior surface of the petrous part of the temporal bone on the external surface of the cranial base	Cochlear aqueduct Vein of cochlear aqueduct
Mastoid part of the facial canal	<b>Canaliculus for chorda tympani</b>	Tympanic cavity	Chorda tympani Posterior tympanic artery and vein
Jugular fossa	<b>Mastoid canaliculus</b>	Tympanomastoid fissure	Auricular branch of vagus nerve
Petrosal fossula	<b>Tympanic canaliculus</b>	Jugular wall of the tympanic cavity	Tympanic nerve Inferior tympanic artery and vein
Vestibule of the bony labyrinth	<b>Vestibular canaliculus</b>	Posterior surface of the petrous part of the temporal bone on the internal surface of the cranial base	Endolymphatic duct
External opening of the carotid canal on the external surface of the cranial base in the foramen lacerum	<b>Carotid canal</b>	Internal opening of carotid canal in the middle cranial fossa	Internal carotid artery Internal carotid venous plexus Internal carotid plexus (sympathetic nerves)
Posterior cranial fossa	<b>Condylar canal</b>	External surface of cranial base	Condylar emissary vein Meningeal branch of the ascending pharyngeal artery
Infra-orbital groove	<b>Infra-orbital canal</b>	Infra-orbital foramen	Infra-orbital nerve Infra-orbital artery and vein
Mandibular foramen	<b>Mandibular canal</b>	Mental foramen	Inferior alveolar artery and vein Inferior alveolar nerve
External surface of cranial base	<b>Canal for tensor tympani</b> (part of the musculotubal canal)	Carotid wall of the tympanic cavity	Tensor tympani
External surface of cranial base	<b>Canal for auditory tube</b> (part of the musculotubal canal)	Carotid wall of the tympanic cavity	Auditory tube (Eustachian tube)
Geniculum of facial canal	<b>Canal for greater petrosal nerve</b>	Hiatus for greater petrosal nerve	Greater petrosal nerve Petrosal branch of middle meningeal artery
Tegmental wall of the tympanic cavity	<b>Canal for lesser petrosal nerve</b>	Hiatus for lesser petrosal nerve	Lesser petrosal nerve Superior tympanic artery and vein
Fossa for lacrimal sac	<b>Nasolacrimal canal</b>	Inferior nasal meatus	Nasolacrimal duct
Internal acoustic meatus	<b>Facial canal</b>	Stylomastoid foramen	Facial nerve Stylomastoid artery and vein
Posterior cranial fossa	<b>Hypoglossal canal</b>	External surface of the cranial base	Hypoglossal nerve Venous plexus of hypoglossal canal Meningeal branch of ascending pharyngeal artery
Middle cranial fossa	<b>Optic canal</b>	Apex of the orbit	Ophthalmic artery Ophthalmic plexus Optic nerve
Pterygopalatine fossa	<b>Greater palatine canal</b>	Greater palatine foramen	Greater palatine nerve Greater palatine artery and vein
Pterygopalatine fossa	<b>Palatovaginal canal</b>	External surface of cranial base	Pharyngeal nerve Pharyngeal branch of the maxillary artery
External surface of the cranial base	<b>Pterygoid canal of Vidian</b>	Pterygopalatine fossa	Nerve of pterygoid canal (formed from greater petrosal nerve and deep petrosal nerve) Artery and vein of the pterygoid canal

From	Through	To	Content
Anterior cranial fossa	<b>Foramen caecum</b>	Nasal cavity	Emissary vein of the foramen caecum
Medial wall of the orbit	<b>Anterior ethmoidal foramen</b> (origin of the orbitocranial canal)	Cribriform plate (anterior cranial fossa)	Anterior ethmoidal nerve Anterior ethmoidal artery and vein
Medial wall of the orbit	<b>Posterior ethmoidal foramen</b> (origin of the orbitoethmoidal canal)	Posterior ethmoidal cells	Posterior ethmoidal nerve Posterior ethmoidal artery and vein
Supra-orbital margin of orbit	<b>Frontal foramen / notch</b>	Facial aspect	Medial branch of the supra-orbital nerve
Posterior cranial fossa	<b>Jugular foramen</b>	External surface of cranial base	Internal jugular vein (the superior bulb is located above the foramen and is formed by the sigmoid sinus and inferior petrosal sinus) Glossopharyngeal nerve Vagus nerve Accessory nerve Posterior meningeal artery Ramus meningeus arteriae occipitalis
Middle cranial fossa	<b>Foramen lacerum</b>	External surface of cranial base	Internal carotid artery Internal carotid plexus Internal carotid venous plexus Deep petrosal nerve Greater petrosal nerve Lesser petrosal nerve Recurrent branch of the foramen lacerum
Groove for sigmoid sinus (posterior cranial fossa)	<b>Mastoid foramen</b>	Occipital aspect	Mastoid emissary vein Meningeal branch of the occipital artery
Posterior cranial fossa	<b>Foramen magnum</b>	External surface of cranial base	Transition of the medulla oblongata to the spinal cord Vertebral arteries Anterior spinal artery Posterior spinal arteries Emissary veins Spinal roots of accessory nerves Tectorial membrane Longitudinal bands of the cruciate ligament of the atlas Apical ligament of the dens
Middle cranial fossa	<b>Foramen ovale</b>	Infratemporal fossa	Mandibular nerve Venous plexus of the foramen ovale Accessory meningeal artery
Internal surface of calvaria	<b>Parietal foramen</b>	External surface of calvaria	Parietal emissary vein
Middle cranial fossa	<b>Foramen petrosum</b>	Infratemporal fossa	Lesser petrosal nerve
Middle cranial fossa	<b>Foramen rotundum</b>	Pterygopalatine fossa	Maxillary nerve
Pterygopalatine fossa	<b>Sphenopalatine foramen</b>	Nasopharyngeal meatus of nasal cavity	Sphenopalatine artery and vein Posterior superior lateral and medial nasal branches of the maxillary nerve
Middle cranial fossa	<b>Foramen spinosum</b>	Infratemporal fossa	Middle meningeal artery Middle meningeal artery and vein Meningeal branch of the mandibular nerve
Middle cranial fossa	<b>Foramen squamosum</b>	Temporal region	Squamous emissary vein
Supra-orbital margin of the orbit	<b>Supra-orbital foramen / notch</b>	Forehead	Lateral branch of the supra-orbital nerve Supra-orbital artery and vein
Middle cranial fossa	<b>Foramen venosum of Vesalius</b>	Foramen venosum	Emissary vein of the foramen venosum
Lateral wall of the orbit	<b>Zygomatico-orbital foramen</b>	Zygomaticofacial and zygomaticotemporal foramen	Zygomatic nerve which divides in the canal into the zygomaticotemporal branch and zygomaticofacial branch

From region	Through	To region	Content
Pterygopalatine fossa	Inferior orbital fissure	Orbit	Zygomatic nerve, Infra-orbital nerve and artery Inferior ophthalmic vein Orbital muscle (covers most of its lateral part)
Middle cranial fossa	Superior orbital fissure	Orbit	Oculomotor nerve, Trochlear nerve, Abducent nerve Ophthalmic nerve (nasociliary nerve, frontal nerve and lacrimal nerve) Superior ophthalmic vein
Temporal region	Petrotympenic fissure	Carotid wall of the tympanic cavity	Chorda tympani Anterior tympanic artery and vein Anterior ligament of malleus
Infratemporal fossa	Pterygomaxillary fissure	Pterygopalatine fossa	Maxillary artery Venous tributaries to the pterygoid plexus
Middle cranial fossa	Petrosphenoidal fissure	External surface of the cranial base	Lesser petrosal nerve
Middle cranial fossa	Hiatus for lesser petrosal nerve	Tegmental wall of the tympanic cavity	Lesser petrosal nerve Superior tympanic artery and vein
Anterior cranial fossa	Cribriform plate (via cribriform foramina)	Nasal cavity	Olfactory nerves Anterior meningeal artery and vein Anterior ethmoidal nerve
Posterior cranial fossa	Internal acoustic opening (in the internal acoustic meatus)	Facial canal and the bony labyrinth of the temporal bone	Facial nerve Vestibulocochlear nerve Labyrinthine artery and vein
Middle cranial fossa	Tegmen tympani	Tegmental wall of the tympanic cavity	Tympanic veins

Structure	Muscle – origin (O), insertion (I)	Ligament, articular capsule
<b>Scapula</b>		
Subscapular fossa	O: subscapularis	
Spine of scapula	O: deltoid (spinal part) I: trapezius (transverse and ascending part)	Inferior transverse scapular ligament
Supraspinous fossa	O: supraspinatus	
Infraspinous fossa	O: infraspinatus	
Acromion	O: deltoid, I: trapezius (transverse part)	Coraco-acromial ligament, acromioclavicular ligament
Medial border of scapula	I: levator scapulae, rhomboid major and minor, serratus anterior	
Lateral border of scapula	O: teres minor, teres major	
Superior border of scapula	O: omohyoid (inferior belly)	
Suprascapular notch		Superior transverse scapular ligament
Spinoglenoid notch		Inferior transverse scapular ligament
Inferior angle of scapula	O: teres major	
Superior angle of scapula	I: levator scapulae	
Supraglenoid tubercle	O: biceps brachii (long head)	
Infraglenoid tubercle	O: triceps brachii (long head)	
Neck of scapula		Articular capsule
Coracoid process	O: biceps brachii (short head), coracobrachialis I: pectoralis minor	Coracoacromial ligament, coracohumeral ligament, coracoclavicular ligament



Structure	Muscle – origin (O), insertion (I)	Ligament, articular capsule
<b>Clavicle</b>		
Sternal end	O: sternohyoid	Anterior and posterior sternoclavicular ligament, Interclavicular ligament
Body of clavicle	O: sternocleidomastoid O: pectoralis major (clavicular head)	
Subclavian groove	I: subclavius	
Acromial end	O: deltoid (clavicular part) I: trapezius (descending part)	Acromioclavicular ligament
<b>Humerus</b>		
Anatomical neck		Inferior glenohumeral ligament, articular capsule
Greater tubercle	I: supraspinatus, infraspinatus, teres minor	Transverse humeral ligament, coracohumeral ligament
Lesser tubercle	I: subscapularis	Transverse humeral ligament, glenohumeral ligaments
Crest of greater tubercle	I: pectoralis major	
Crest of lesser tubercle	I: teres major, latissimus dorsi	
Intertubercular sulcus (bicipital groove)	tendon of the long head of the biceps brachii	
Deltoid tuberosity	I: deltoid	
Medial supraepicondylar ridge	O: pronator teres (humeral head)	
Lateral supraepicondylar ridge	O: brachioradialis, extensor carpi radialis longus	
Lateral epicondyle	Common origin of the extensors of the hand, anconeus	Radial collateral ligament
Medial epicondyle	Common origin of the flexors of the hand	Humerocondylar ligament, olecranon ligament
<b>Radius</b>		
Neck of radius		Articular capsule
Radial tuberosity	I: biceps brachii	
Pronator tuberosity	I: pronator teres	
Interosseous border of radius		Radio-ulnar syndesmosis (interosseous membrane of forearm, oblique cord)
Dorsal tubercle		Dorsal radiocarpal ligament
Radial styloid process		Palmar radiocarpal ligament, radial collateral ligament of the wrist joint
Suprastyloid crest	I: brachioradialis	
<b>Ulna</b>		
Olecranon	I: triceps brachii	Olecranon ligament and oblique ligament
Coronoid process		Humerocondylar ligament and oblique ligament
Tuberosity of ulna	I: brachialis	
Interosseous border of ulna		Radio-ulnar syndesmosis (interosseous membrane of the forearm, oblique cord)
Supinator crest	O: supinator	
<b>Bones of the hand – Ossa manus</b>		
Tubercle of scaphoid	O: abductor pollicis brevis	
Tubercle of trapezium	O: abductor pollicis brevis, opponens pollicis, superficial head of flexor pollicis brevis	
Pisiform	I: flexor carpi ulnaris O: abductor digiti minimi	Pisohamate ligament, pisometacarpal ligament
Hook of the hamate	O: flexor digiti minimi brevis, opponens digiti minimi	Pisohamate ligament

Structure	Muscle – origin (O), insertion (I)	Ligament, capsule
<b>Hip bone – Os coxae</b>		
Acetabular notch		Transverse acetabular ligament
Outer lip of iliac crest	O: tensor fasciae latae, latissimus dorsi I: external oblique	Fascia lata
Intermediate zone of iliac crest	O: internal oblique	
Inner lip of iliac crest	O: transversus abdominis, quadratus lumborum, erector spinae	Thoracolumbar fascia
Anterior superior spina iliaca	O: sartorius, tensor fasciae latae	Inguinal ligament
Anterior inferior spina iliaca	O: rectus femoris (straight head)	Iliofemoral ligament
Posterior inferior spina iliaca	O: piriformis (small part)	
Iliac fossa	O: iliacus	
Gluteal surface	O: gluteus maximus, medius, minimus	
Supra-acetabular groove	O: rectus femoris (reflected head)	
Iliac tuberosity		Posterior and interosseous sacro-iliac ligament
Ischial tuberosity	O: semimembranosus, semitendinosus, biceps femoris, adductor magnus, gemellus inferior, quadratus femoris, superficial transverse perineal muscle, ischiocavernosus	Sacrospinous ligament, ischiofemoral ligament
Ischial spine	O: gemellus superior I: iliococcygeus, ischiococcygeus	Sacrospinous ligament
Iliopubic ramus	I: psoas minor	Pubofemoral ligament
Pubic tubercle		Inguinal ligament, superior pubic ligament
Pubic crest	I: rectus abdominis, pyramidalis	
Pecten pubis	O: pectineus, I: psoas minor	Lacunar ligament, inguinal falx, pectineal ligament
Obturator crest		Pubofemoral ligament
Phallic crest		Crus of penis/clitoris
Obturator groove		Passage of obturator nerve and vasa
<b>Femur</b>		
Fovea for ligament		Ligament of head of femur
Neck of femur		Capsule of the hip joint (dorsal side)
Greater trochanter	I: gluteus medius, minimus, piriformis, superior and inferior gemelli, obturatorius internus	
Lesser trochanter	I: iliopsoas	
Trochanteric fossa	I: obturatorius externus	
Intertrochanteric line	O: vastus medialis and lateralis	Iliofemoral ligament, capsule of the hip joint
Intertrochanteric crest	I: quadratus femoris	
Medial lip of linea aspera	O: vastus medialis, adductor longus, adductor brevis, adductor magnus	Medial intermuscular septum
Lateral lip of linea aspera	O: short head of biceps femoris, vastus lateralis	Lateral intermuscular septum
Pectinal line	A: pectineus	
Gluteal tuberosity	A: gluteus maximus	

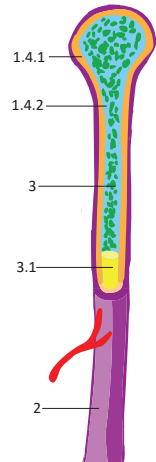
Structures	Muscle – origin (O), insertion (I)	Ligament, capsule
<b>Femur</b>		
Adductor tubercle	I: adductor magnus	
Lateral supracondylar line	O: plantaris	
Groove for popliteus	O: popliteus	
Intercondylar fossa		Anterior and posterior cruciate ligament
Intercondylar line		Oblique popliteal ligament, articular capsule
Medial epicondyle	O: gastrocnemius – medial head	Tibial collateral ligament
Lateral epicondyle	O: gastrocnemius – lateral head	Fibular collateral ligament
<b>Tibia</b>		
Anterior intercondylar area		Anterior cruciate ligament, lateral meniscus
Posterior intercondylar area		Posterior cruciate ligament, medial meniscus
Tibial tuberosity	I: quadriceps femoris (patellar ligament)	
Iliotibial tract tuberosity		Iliotibial tract (thickened part of fascia lata)
Soleal line	O: soleus (part of triceps surae)	
Interosseus border of tibia		Interosseous membrane
Malleolar groove of tibia	The tendon of tibialis posterior and the tendon of the flexor digitorum longi run through this groove	
Fibular notch		Tibiofibular syndesmosis
<b>Fibula</b>		
Head of fibula	O: soleus, fibularis longus I: biceps femoris	Fibular collateral ligament, arcuate popliteal ligament, anterior and posterior ligament of the fibular head
Interosseus border of fibula		Interosseous membrane of the leg
Fibular malleolar groove	The tendons of fibularis longus and brevis run through this groove	
Lateral malleolar fossa		Posterior talofibular ligament
<b>Bones of the foot – Ossa pedis</b>		
Neck of talus		Anterior talofibular ligament, talonavicular ligament
Sulcus tali and calcaneal sulcus		Talocalcaneal interosseous ligament
Lateral process of talus		Lateral talocalcaneal ligament
Groove for tendon of flexor hallucis longus and calcaneal sulcus	Flexor hallucis longus runs through this groove	
Medial tubercle of posterior process of talus		Medial talocalcaneal ligament
Lateral tubercle of posterior process of talus		Posterior talofibular ligament
Calcaneal tuberosity	I: triceps surae, plantaris	
Medial process of calcaneal tuberosity	O: abductor hallucis, flexor digitorum brevis	Flexor retinaculum
Lateral process of calcaneal tuberosity	O: abductor digiti minimi	
Sustentaculum tali		Tibiocalcaneal part of the medial ligament, medial talocalcaneal ligament, plantar calcaneonavicular ligament
Groove for tendon of fibularis longus	Tendon of fibularis longus runs through this groove	
Tuberosity of navicular	I: tibialis posterior	Tibionavicular part of the medial ligament, plantar calcaneonavicular ligament
Tuberosity of cuboid		Long plantar ligament
Tuberosity of the fifth metatarsal	O: abductor digiti minimi, A: fibularis brevis	

### I. General osteology

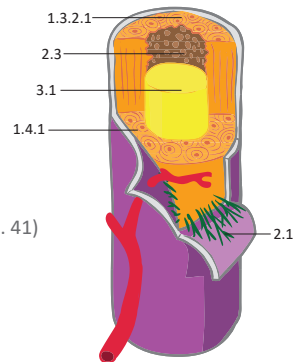
1. Explain the term "apophysis". Give at least two examples of apophyses. (p. 18)
2. Explain the term "Haversian system". Specify where we can find it. (p. 19)
3. State where we can find red bone marrow in adults. (p. 20)

### II. Bones of the skull

4. State the circumference and dorsoventral diameter of the skull of a newborn. (p. 35)
5. Name three bones of the skull that develop by endochondral ossification and three bones that develop by intramembranous ossification. (p. 20)
6. State at least three openings of the greater wing of the sphenoidal bone and list their contents. (p. 25)
7. Name two bones of the skull that feature an impression for the sigmoid sinus. (p. 23, 29)
8. Name three bones of the skull that feature an impression of the superior sagittal sinus. (p. 22, 23, 26)
9. Name the bone that possesses the superior nuchal line and describe its purpose. (p. 23)
10. Name the two bones of the skull that form the jugular foramen. (p. 23, 28)
11. State 5 dural venous sinuses that form impressions on the occipital bone. (p. 23)
12. List the borders of both the superior and inferior orbital fissure. (p. 24)
13. Name the two processes of the ramus of the mandible and state what they are for. (p. 34)
14. State at least 5 differences between the male and female skull. (p. 36)
15. Explain the term "premaxilla". (p. 33)
16. Specify at which vertebral level we can find the hyoid bone. (p. 35)



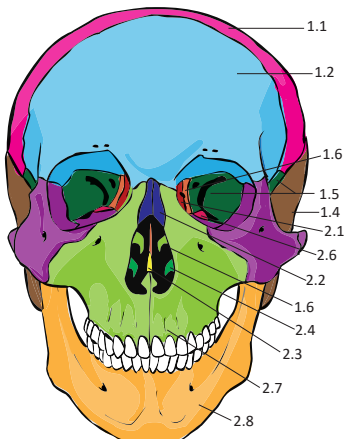
Describe general structure of bone



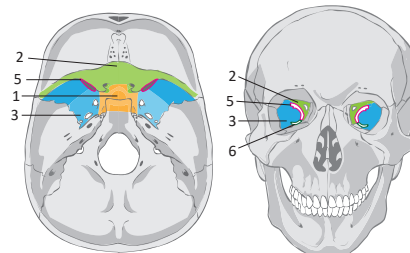
Describe general structure of bone

### III. Bones of the thorax and vertebral column

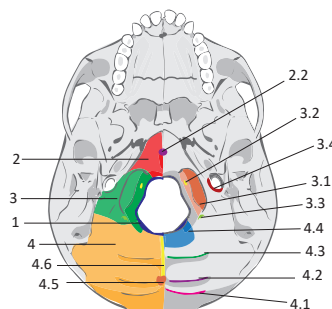
17. List 5 typical features of cervical vertebrae. (p. 38)
18. State the two cervical vertebrae that differ from the general structure of cervical vertebrae and describe their differences. (p. 38)
19. Describe the differences of vertebra T12 from the general structure of the thoracic vertebrae. (p. 39)
20. State the 5 subdivisions of the vertebral column and specify the number of vertebrae that form them. (p. 37)
21. Describe the sacral promontory and explain its significance. (p. 40)
22. List the curvatures of the vertebral column and specify the ages in which they develop. (p. 37)
23. State the term used for the 11<sup>th</sup> and 12<sup>th</sup> ribs and explain how they are different from the other ribs. (p. 41)
24. List the 3 structures that run in the costal groove and state the order in which they run. (p. 41)
25. Name the rib number of the rib that connects to the sternum at the level of the sternal angle. (p. 41)
26. Specify the location by ribs of the scapula. (p. 43)



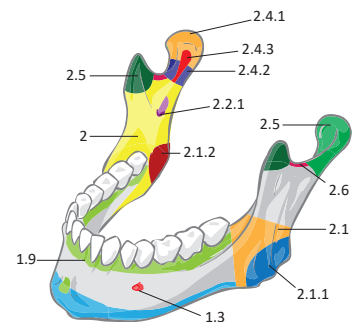
Name the bones of the skull



List the parts of the sphenoid bones



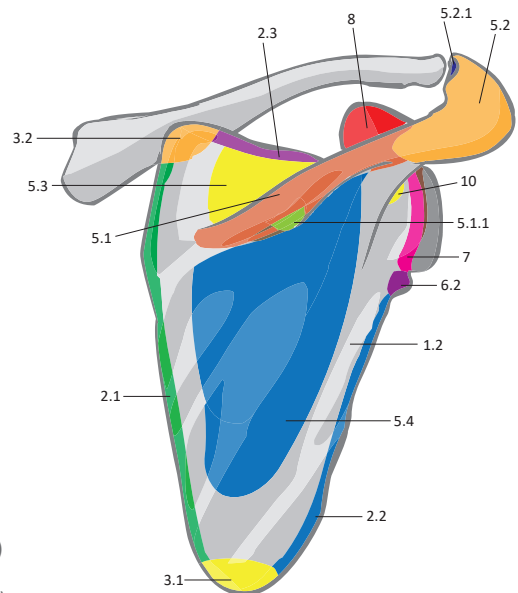
List the parts of the occipital bone



Name the parts of the mandible

#### IV. Bones of the upper limb

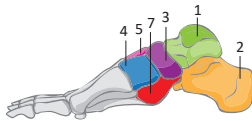
27. Name the ligament that bridges the suprascapular notch and the structures that run above and below this ligament. (p. 43)
28. Name the structure that is located between the greater and lesser tubercles of the humerus. (p. 44)
29. Name the nerve that forms a bony marking on the body of the humerus. (p. 44)
30. List the two articular surfaces of the condyle of the humerus. (p. 45)
31. Give the name of the muscle that inserts on the radial tuberosity. (p. 46)
32. Name the muscle that inserts on the ulnar tuberosity. (p. 45)
33. List three palpable parts of the ulna. (p. 45)
34. Name the bone that is the functional centre of the carpus. (p. 47)
35. List 4 bones that articulate with the lunate (p. 47)
36. List two carpal bones that articulate with the hamate. (p. 47)
37. Describe the difference between the 2<sup>nd</sup> metacarpal and other metacarpals. (p. 48)



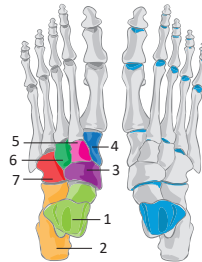
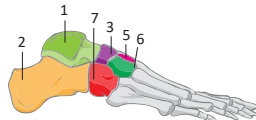
Describe the parts of the scapula

#### V. Bones of the lower limb

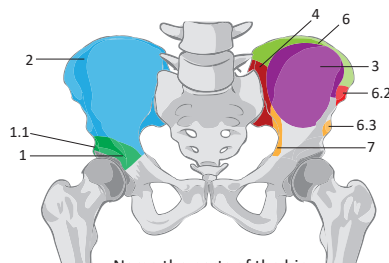
38. List the three bones that form the hip bone. (p. 49)
39. List the 3 parts of the pubis and specify how these parts are connected together. (p. 51)
40. Describe where the intertrochanteric crest and intertrochanteric line can be found and specify their purpose. (p. 52)
41. Explain the term "angle of inclination of the femur". (p. 52)
42. Specify where on the tibia the cruciate ligaments of the knee attach. (p. 53)
43. Specify where the tibial tuberosity can be found and which structure inserts on it. (p. 53)
44. Name the bone that forms the medial malleolus (p. 53)
45. Name the bone that forms the lateral malleolus. (p. 54)
46. List 2 bones that articulate with the medial cuneiform bone. (p. 56)
47. Describe the difference of the 5<sup>th</sup> metatarsal from the other metatarsals (p. 56)



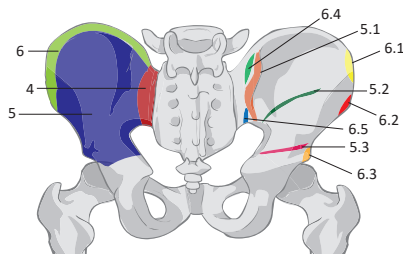
Name the tarsal bones



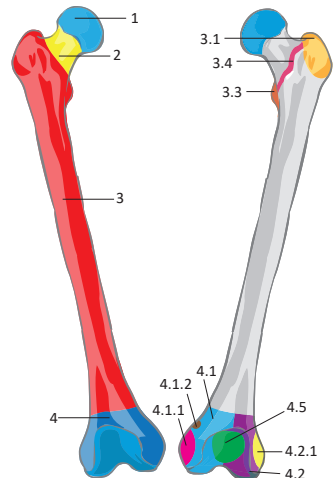
Name the tarsal bones



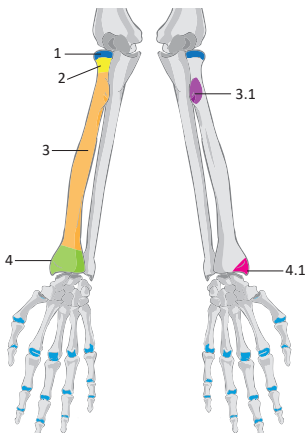
Name the parts of the hip



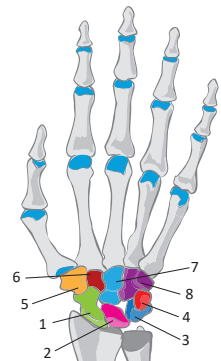
Name the parts of the hip



Describe the parts of the femur



List the parts of the radius



Name the carpal bones



We would like to **thank the following anatomists, physicians and medical students** for their invaluable help, devotion and feedback in the preparation of this chapter.

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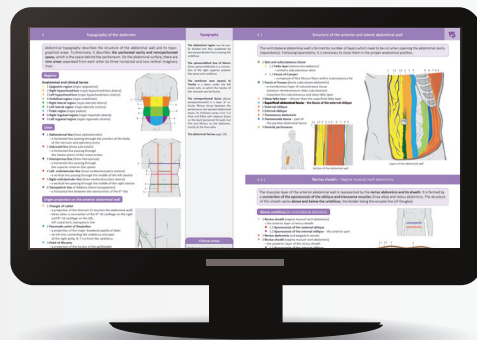
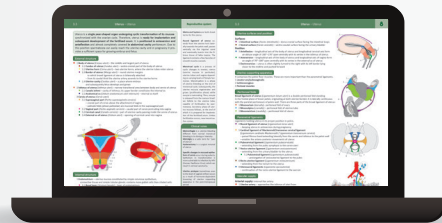
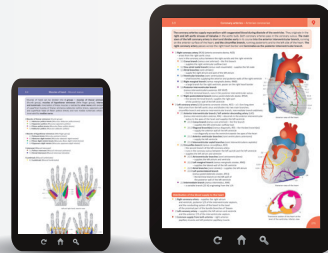
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