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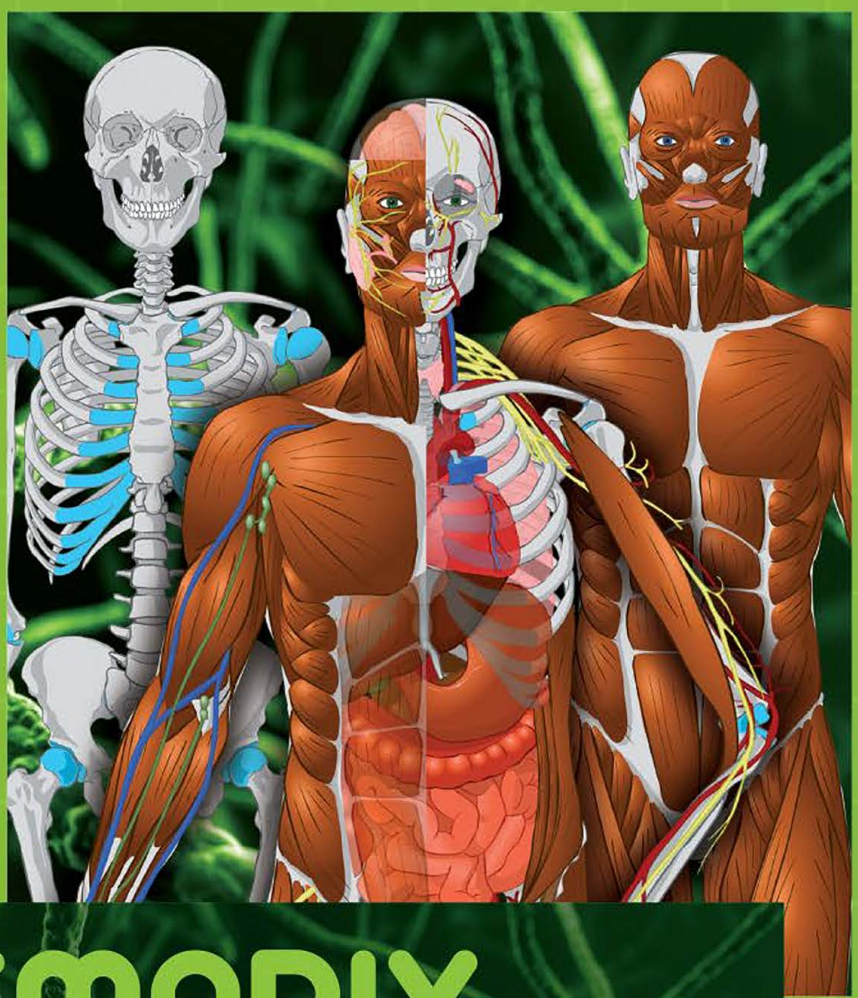
Radovan Hudák, David Kachlík
Ondřej Volný et al.



MEMORIX ANATOMY

Foreword by Bogdan Ciszek

Radovan Hudák
David Kachlík
Ondřej Volný
et al.

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Editors: Radovan Hudák, David Kachlík, Ondřej Volný et al.
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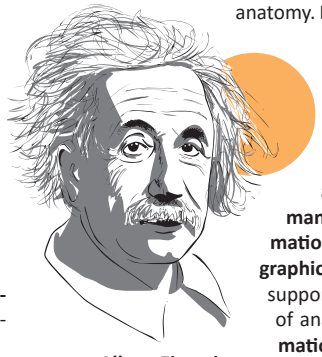
„**Anatomy**, albeit it is feminine, **has its own charm and logic,**“ said one professor of anatomy a long time ago. Although **anatomy is as old as humanity itself, its charm is immortal and its logic still maintained**. Owing to these characteristics, anatomy belongs among favorite subjects, which 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.



Albert Einstein

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.**"

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*), 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, August 20, 2015

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

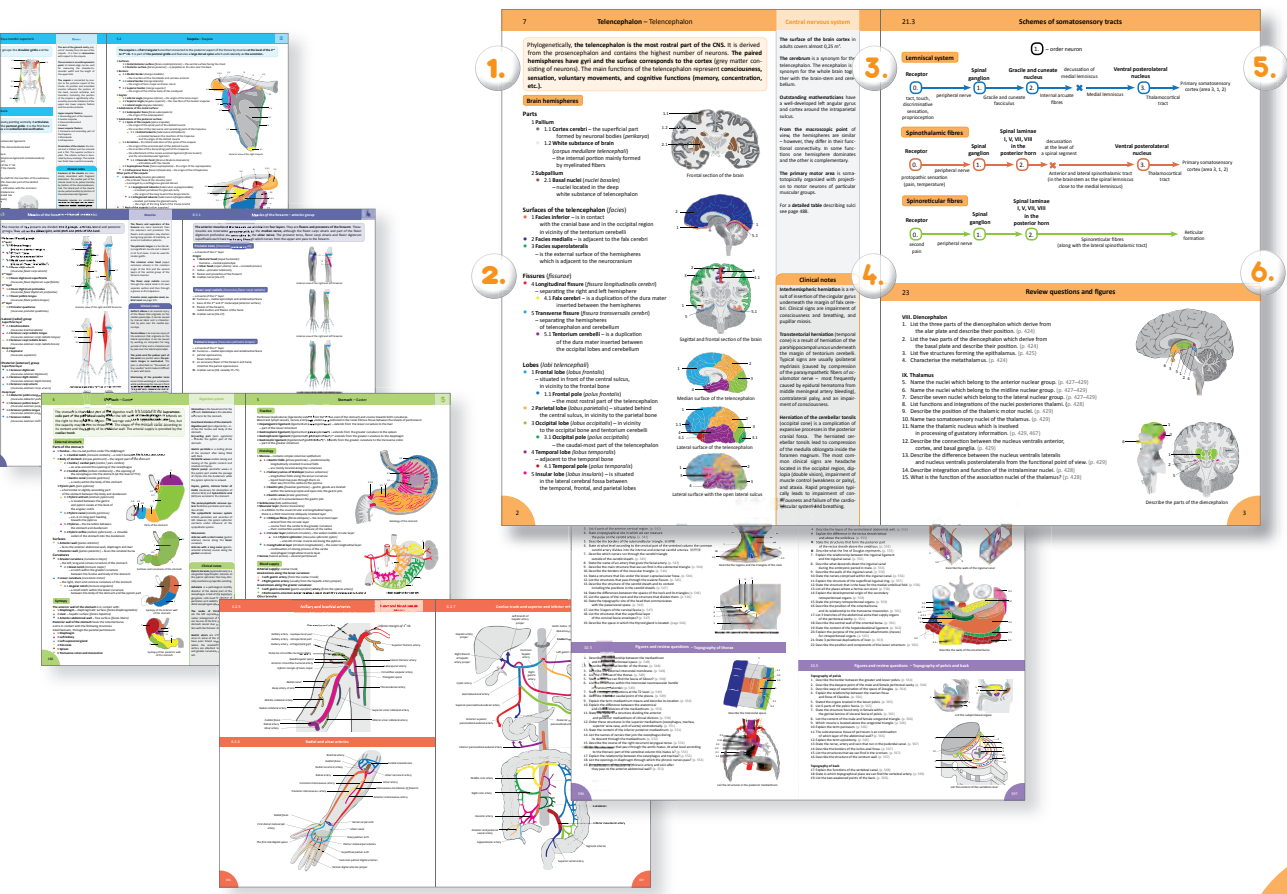
3. Interesting things
- look through the less important but interesting anatomical information in the middle column

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**, charming **Simona Felšőová**, 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 Apaydın** (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.

We very much value the help of **clinical reviewers**, who were able to contribute their precious time to Memorix Anatomy. Many thanks to physiotherapist **Zdeněk Čech** (Czech Republic), gynecologist **Andrej Černý** (Czech Republic), neuroradiologist **Christopher d'Esterre** (Canada), neurologist **Aravind Ganesh** (Canada), orthopedist **Vojtěch Havlas** (Czech Republic), cardiologist **Anna Chaloupka** (Czech Republic), gastroenterologist **Markéta Ječmenová** (Czech Republic), cardiosurgeon and vascular surgeon **Štepán Jelínek** (Czech Republic), internist **Dale Kalina** (Canada), neurologist **Robert Kuba** (Czech Republic), ophthalmologist **Helena Menšíková** (Czech Republic), urologist **Ivo Minárik** (Czech Republic), oncogynecologist **Lucie Mouková** (Czech Republic), internist **Jan Novák** (Czech Republic), neurologist **Eva Plaňanská** (Czech Republic), neurologist **Ondřej Strýček** (Czech Republic), and hematooncologist **Martin Štork** (Czech Republic). It was particularly their dedication, enthusiasm, and insight which has earned our frank gratitude and which has made this a better anatomy textbook with relevant and useful clinical notes.

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!

Anatomic reviewers

Assoc. prof. Václav Báča, MD, PhD – *chief reviewer*
Assoc. prof. Nihal Apaydın, MD
Marcela Bezdíčková, MD PhD
Prof. Susana N. Biasutto, MD
Assoc. prof. Adriana Boleková, MD, PhD
Emer. prof. Stephen Carmichael, PhD, DSc.
Assoc. prof. Ayhan Cömert, MD
Prof. Hans J. ten Donkelaar, MD, PhD
Lada Eberlová, MD, PhD
Dr.med.univ. Georg Feigl
Quentin Fogg, PhD
Prof. Guiliana Gobbi , MD
Marek Joukal, MD
Assoc. prof. Dzintra Kažoka, MD
Prof. Darina Kluchová, MD, PhD
Assoc. prof. Květuše Lovásová, VDM, PhD
Assoc. prof. Veronica Macchi, MD, PhD
Pavel Šnajdr, MD, PhD
Trifon Totlis, MD, PhD

and further 4 anatomists which reviewed the Czech edition of Memorix Anatomy

Clinical reviewers

Zdeněk Čech, MSc.
Andrej Černý, MD
Christopher d'Esterre, PhD
Aravind Ganesh, MD
Assoc. prof. Vojtěch Havlas, MD, PhD
Anna Chaloupka, MD
Markéta Ječmenová, MD
Štepán Jelínek, MD
Dale Kalina, MD
Prof. Robert Kuba, MD, PhD
Helena Menšíková, MD
Ivo Minárik, MD, FEBU
Lucie Mouková, MD, PhD
Jan Novák, MD
Eva Plaňanská, MD
Ondřej Strýček, MD
Martin Štork, MD

and further 33 clinicians which reviewed the Czech edition of Memorix Anatomy

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Max Cameron
Antonio Franca
Eva Fürstová
Therese George
Daniel Glanc
Monika Hejduková
Lucie Holubičková
Petr Kala
Linda Kašičková
Daanish Khorasani
Michal Klíma
Matěj Krchov
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Vojtěch Kunc
Adam Kubica
Miroslav Kyselica
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Lukáš Mach
Domenico Messina
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Sebastian Schmitz
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Petr Urban
Prokop Vodička
Christoph Wawoczny
Rachel White
Danil Yershov

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

Others

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Prof. Martin Bareš, MD, PhD
Dr. Miroslava Dvořáková, Ph.D.
Stanislav Juhaňák, MD
Gabriela Holubová
Peter Magic
Helena Menšíková, MD
Michaela Pospěchová
Daniel Slovák
Prokop Vodička

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.

Editors – anatomy is our passion, anatomy is our life

Radovan Hudák

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**.

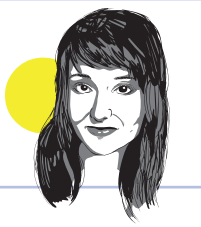
Illustrators – a drawing of the human body is a pleasure of our senses

Jan Balko

My name is Jan Balko and I work at the Department of Pathology in Prague. 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, muscles** 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.

Simona Felšőová

I have had a passion for drawing ever since I was a little girl. **I could spend upon hours and hours improving my sketches**. **I didn't think for another second when I was offered to draw illustrations for Memorix**. I like the fact that I could **combine medicine and art** while producing **something undoubtedly useful for young students to understand the basics of human anatomy**. I take a keen interest in illustrating and graphics and I want to take part in future graphical projects. My life's goal is to **help people every day by becoming an excellent and sensitive physician**.



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 lifetime 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.

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**.

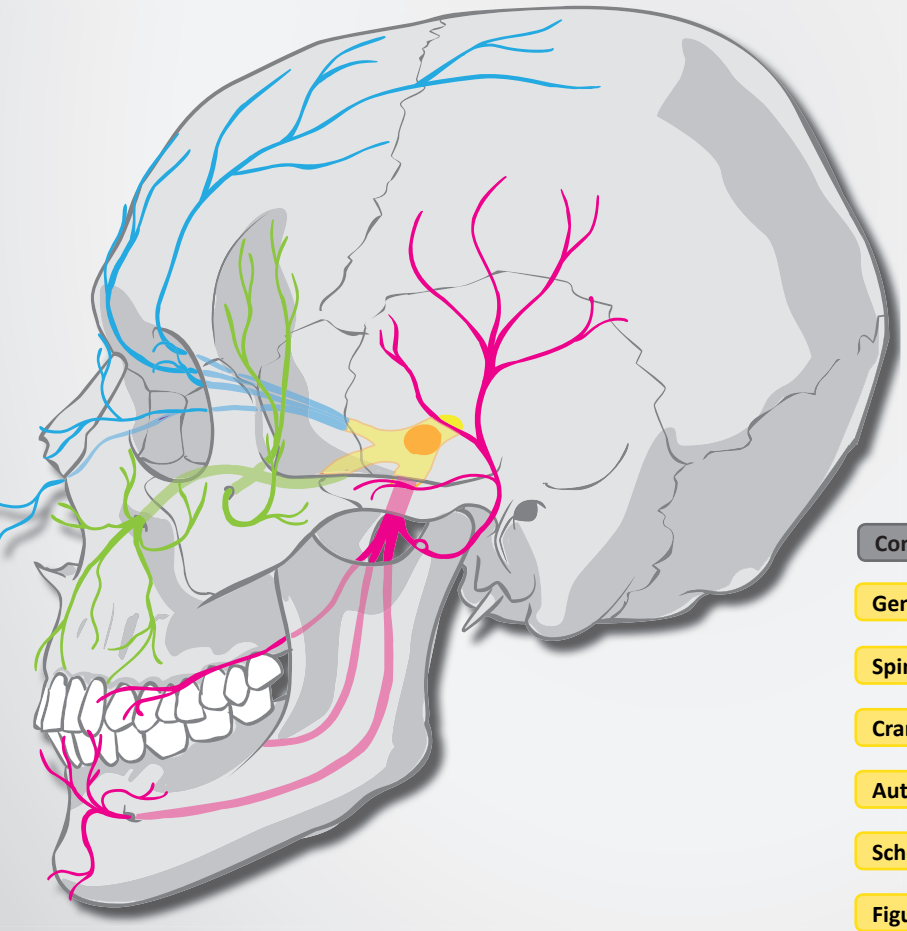
”Everything should be made as simple as possible,
but not simpler.“

Albert Einstein

Memorix Anatomy

11 Peripheral nervous system

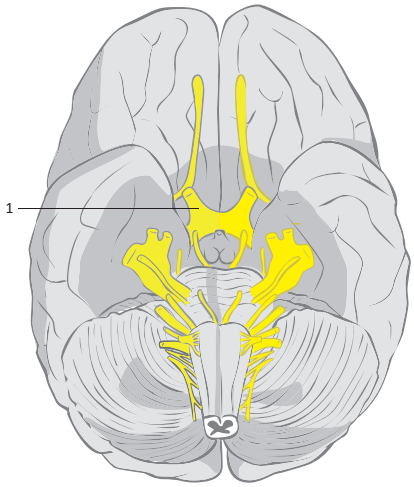
Ondřej Volný
Matej Halaj
David Kachlík
Radovan Hudák
Adam Whitley

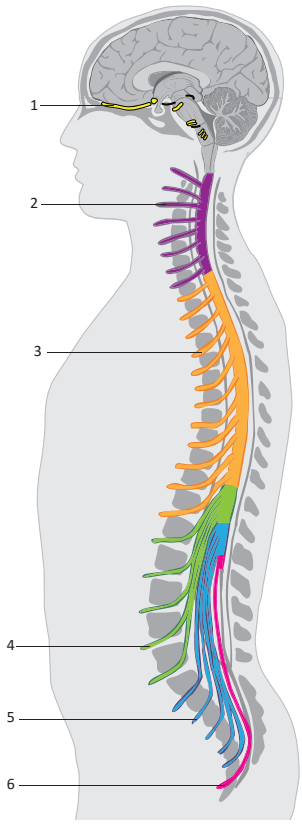


The **peripheral nervous system** (PNS) consists of **nerves** and neural **ganglia**. Nerves enable **bidirectional communication** between the central nervous system and the rest of the body (referred to as the periphery). There are **31 pairs of spinal nerves** originating from the spinal cord and **12 pairs of cranial nerves** from the brainstem. The **autonomic nervous system** (ANS) is a division of the PNS. It is subdivided into the **sympathetic, parasympathetic and enteric nervous systems**. Ganglia are groups of cell bodies of nerves, located outside of the CNS. **Spinal ganglia** contain the cell bodies of sensory nerves. **Autonomic ganglia** contain synapsing visceromotor neurones; they contain a preganglionic axon synapsing on the dendrites of the postganglionic neurone. The cell body of the postganglionic neurone is located in the ganglion. Nerve fibres are axons and are either **myelinated** or **non-myelinated**. They are grouped together into nerve fascicles, which are further grouped together to form a periphal nerve.

Classification

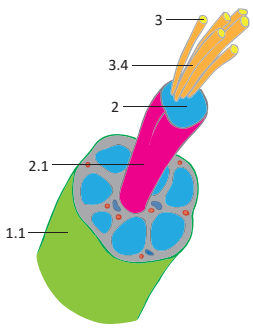
- 1 **Cranial nerves** (*nervi craniales*) – 12 pairs
- 2 **Cervical nerves** (*nervi cervicales*) – 8 pairs
- 3 **Thoracic nerves** (*nervi thoracici*) – 12 pairs
- 4 **Lumbar nerves** (*nervi lumbales*) – 5 pairs
- 5 **Sacral nerves** (*nervi sacrales*) – 5 pairs
- 6 **Coccygeal nerve** (*nervus coccygeus*) – 1 pair





Peripheral nerve

1 **Nerve** (*nervus*)
– the peripheral nerve is a bundle of axons surrounded by fibrous tissue and supplied by small vessels called the vasa nervorum
- 1.1 **Epineurium** – a sheath of fibrous tissue covering a peripheral nerve
  – emits septa into the nerve, dividing the fascicles
- 2 **Fascicle** (*fasciculus*) – a bundle of axons (nerve fibres)
  - 2.1 **Perineurium** – a fibrous sheath covering one fascicle
- 3 **Types of nerve fibres**
  - 3.1 **Axons of alpha motor neurones**
    - 3.1.1 **Schwann cells**
      – responsible for myelin production
  - 3.2 **Peripheral branches of pseudounipolar neurones**
  - 3.3 **Axons of autonomic neurones**
  - 3.4 **Endoneurium** – a fibrous sheath surrounding each myelinated nerve fibre



CNS is an abbreviation for the central nervous system.
PNS is an abbreviation for the peripheral nervous system.

A peripheral nerve does not contain any neuronal bodies (*perikarya*).

The nerve fibres travelling in a peripheral nerve are arranged in a wavy pattern. This prevents them from being harmed when they are stretched during limb movements.

Clinical notes

From the clinical point of view, there are two types of motor neurones. The upper motor neurone (UMN) is located in the cerebral cortex and the lower motor neuron (LMN) is located in the anterior horns of the spinal cord and in the nuclei of the cranial nerves.

Flaccid paralysis is caused by damage to the lower motor neurone. Muscle tone is decreased (hypotonia), partial or complete impairment of voluntary movement (paresis or plegia, respectively) and tendon reflexes are weakened or completely absent (hyporeflexia or areflexia, respectively). Viral poliomyelitis is an example of lower motor neuron disease. Spinal muscular atrophy (SMA) is a group of genetically determined diseases of the lower motor neurons.

Spastic paralysis is caused by damage to the upper motor neurone. It occurs as a result of lesions in the cerebral motor cortex or from damage to the axons of UMN that descend from the cortex to the spinal cord. This may arise after ischaemic insults such as occur in strokes and in periventricular perinatal hypoxia that can occur from complicated labour. Spastic paralysis manifests as partial or complete impairment of voluntary movements (paresis or plegia), increased muscle tone (hypertonia) and signs of spasticity (hyperreflexia and irritative pyramidal signs including the Babinski sign). Cerebral palsy is a classic example of an upper motor neurone disorder.

To suture nerves a special microsurgical technique is used to apply stitches to the perineurium of individual fascicles.

The **spinal nerve** is formed from an anterior and a posterior spinal root, which fuse and leave the vertebral canal through the intervertebral foramen. The **anterior root** consists of **efferent (motor) fibres** and the **posterior root** consists of **afferent (sensory) fibres**. The posterior root contains the **spinal ganglion** (*ganglion spinale*), containing the cell bodies of the afferent nerves entering the spinal cord. Outside the vertebral canal, the spinal nerve divides into a **posterior branch** (*ramus posterior*) and an **anterior branch** (*ramus anterior*). These branches contain **both afferent and efferent fibres**.

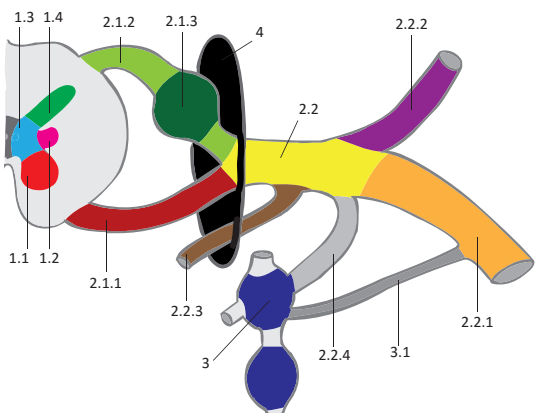
- 1 **Grey matter of the spinal segment**
  - 1.1 **Anterior horn** (*cornu anterius*) – the cell bodies (*perikarya*) of the somatomotor neurones
  - 1.2 **Lateral horn** (*cornu laterale*) – the cell bodies of the visceromotor neurones
  - 1.3 **Intermediate zone** (*zona intermedia*) – the cell bodies of the viscerosensory neurones
  - 1.4 **Posterior horn** (*cornu posterius*) – the cell bodies of the somatosensory neurones

  2 **Spinal nerve**

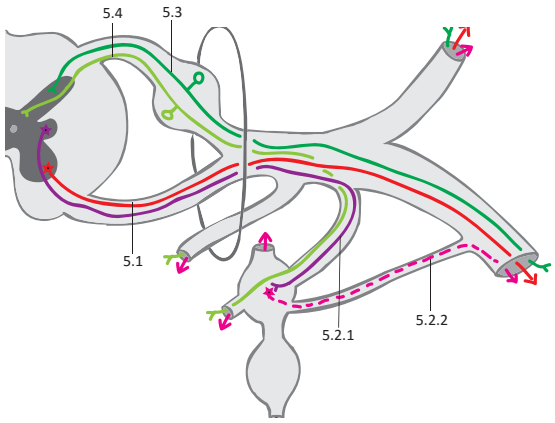
  2.1 **Rootlets** (*fila radicularia*)
  - 2.1.1 **Anterior root** (*radix anterior/ventralis*) – emerges from the anterolateral groove (*sulcus anterolateralis*)
  - 2.1.2 **Posterior root** (*radix posterior/dorsalis*) – emerges from the posterolateral groove (*sulcus posterolateralis*)
  - 2.1.3 **Spinal ganglion** (*ganglion sensorium nervi spinalis*) – a sensory ganglion within the posterior root

  2.2 **Trunk of spinal nerve** (*truncus nervi spinalis*)
  - 2.2.1 **Anterior branch** (*ramus anterior*) – innervates the anterior part of the trunk and limbs
  - 2.2.2 **Posterior branch** (*ramus posterior*) – innervates the back
  - 2.2.3 **Meningeal branch** (*ramus meningeus*) – innervates the spinal dura mater
  - 2.2.4 **White ramus communicans** (*ramus communicans albus*)
    – a branch of the spinal nerve going to the sympathetic ganglion
    – contains preganglionic and afferent fibres, which either transmit signals to other neurones and leave the ganglion as the grey ramus communicans (*ramus communicans griseus*), interganglionic branches or pass through the ganglion and continue as the splanchnic nerves (*nn. splanchnici*)
- 3 **Ganglion of sympathetic trunk** (*ganglion trunci sympathici*)
  – the synapse between pre and postganglionic neurons in the sympathetic ganglia
  – in contrast to parasympathetic ganglia, a significant amount of signal divergence occurs (as one preganglionic neuron connects to several postganglionic neurons)
  - 3.1 **Grey ramus communicans** – originates from the sympathetic ganglion and merges into the spinal nerve containing postganglionic fibers
- 4 **Intervertebral foramen** (*foramen intervertebrale*) – the exit for the spinal nerve

  5 **Fibres according to their function in the peripheral nerve**
  - 5.1 **Somatomotor fibres** – regulate movements and tension in skeletal muscles
  - 5.2 **Visceromotor fibres** – participate in the regulation of activity of smooth muscle cells, myocardial cells and glands
    - 5.2.1 **Preganglionic fibers** (C8–L3, S2–S4) – join the ganglia of the sympathetic trunk via the white rami communicantes
    - 5.2.2 **Postganglionic sympathetic fibers** (C8–L3) – emerge from the ganglia of the sympathetic trunk
      – rejoin the spinal nerves via the grey rami communicantes
      – other fibres give rise to the sympathetic trunk or leave the ganglia independently
    - 5.2.3 **Postganglionic parasympathetic fibers** (S2–S4)
      – do not synapse in the ganglia of the sympathetic trunk
  - 5.3 **Somatosensory fibers** – transfer information from mechanoreceptors, exteroreceptors, proprioceptors and termoreceptors on the body surface
  - 5.4 **Viscerosensory fibers** – transfer information from baroreceptors, chemoreceptors and receptors inside the internal organs (wall tension, special receptors for pain and chemical stimuli)



Scheme of the spinal nerve



Scheme of the spinal nerve

The nervous system **constantly monitors changes of external and internal environments**. **A reflex is a physiological phenomenon** that occurs in response to a change in the **internal or the external environment**. The reflex arc provides the anatomical basis for a reflex. It consists of a peripheral receptor, which transmits a signal to the CNS, where the signal is processed and a command is given to an effector organ. Reflex arcs may contain a **various number of synapses**. The simplest reflex arc is the monosynaptic reflex, which consists of two neurones: an afferent sensory neurone and a efferent motor neurone.

Receptors

– react to changes in the external and internal environments
– transduce these changes to action potentials, which pass information to the CNS

Division according to the location of the stimulus:

1 **Exteroreceptors** – receptors that react to stimuli in the external environment
2 **Interoreceptors** – receptors that react to stimuli in the internal environment
  2.1 **Proprioceptors** – receptors located in muscles, tendons and joint capsules that provide information about the location of different parts of the body
  2.2 **Visceroreceptors** – receptors located in the internal organs and vessels

Division according to the nature of the stimulus:

1 **Mechanoreceptors** – react to mechanical stimuli (touch, pressure, vibration, stretch)
2 **Chemoreceptors** – react to chemical stimuli
3 **Thermoreceptors** – react to temperature
4 **Photoreceptors** – react to light

Afferent (centripetal) pathways

– conduct signals from receptors to the CNS
– are formed by axons of sensory neurons
– their cell bodies are located outside the CNS in the dorsal root ganglia
1 **Somatosensory** (somatic sensory) – transfer signals from receptors in the skin and structures of the locomotor system
2 **Viscerosensory** (visceral sensory) – transfer signals from visceroreceptors in the internal organs
3 **Special sensory** – carry signals from the special sense organs (vision, hearing, motion and balance, smell and taste)

Efferent (centrifugal) pathways

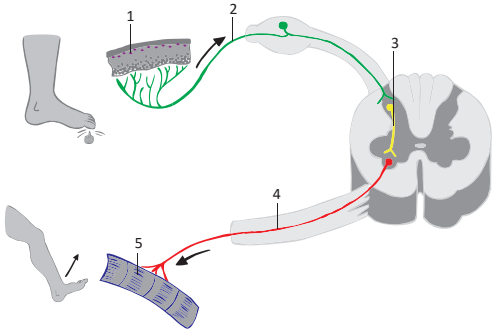
– transmit impulses from the CNS to effector organs in the periphery through efferent neurones
– the efferent neurone is the (somatomotor or visceromotor) lower motor neuron
– the cell body of the efferent neuron is located in the spinal cord, its axon leaves the CNS to form the motor part of the peripheral nerve
1 **Somatomotor tracts** – innervate striated muscle
2 **Visceromotor tracts** – innervate smooth muscles and glandular cells

Effectors

– an organ or a tissue executing the commands of the CNS
1 **Muscle cells** – contraction of skeletal muscles (somatomotor / somatic motor) myocardial and smooth muscles (visceromotor / visceral motor)
2 **Glands** – secretion (sweat, saliva, tears and glands of hollow organs)

The reflex arc

- 1 **Receptor**
- 2 **Afferent branch**
- 3 **Neurons within the CNS**
- 4 **Efferent branch**
- 5 **Effector**



A mixed nerve (*nervus mixtus*) contains several different types of nerve fibres. Most nerves are mixed nerves and contain somatomotor, somatosensory, visceromotor and viscerosensory fibres.

Examples of purely sensory cutaneous nerves: saphenous nerve, sural nerve and lateral cutaneus nerve of the forearm.

The stretch (myotatic) reflex is a monosynaptic reflex. The afferent limb originates in the muscle spindle, travels in the spinal nerve and posterior root, enters the spinal cord and synapses on an alpha motor neurone in the anterior horn. The efferent limb (the alpha motor neurone) travels to the neuromuscular junction and synapses on a muscle. Transection of a peripheral nerve will abolish its corresponding reflex, resulting in areflexia. Damage to the spinal cord above a reflex arc results in destruction of inhibiting impulses from higher neuronal centres, resulting in hyper-reflexia.

Polysynaptic reflex arcs contain one or more interneurons between the afferent and efferent limbs.

Muscles originate from the segmentally organised somites. Each somite gives rise to muscle tissue (myotome), part of the skeleton (sclerotome) and an area of skin and subcutaneous tissue (dermatome). Each somite is innervated by one segment of the spinal cord. The structures that the somite differentiates into retain this innervation as they mature and migrate to form different parts of the body. The myotome divides into an epaxial and a hypaxial division. The epaxial muscles are located posterior to the vertebral column and are innervated by the posterior branches of the spinal nerves. The hypaxial muscles are located ventral to the vertebral column and are innervated by the anterior branches of the spinal nerves. The musculature of the limbs originates from the hypaxial division; thus, all plexuses are derived from the anterior branches of the spinal nerves

Sensory radicular area (*area radicularis sensoria*) is the area of the skin (dermatome) innervated by one posterior spinal root.

Motor radicular area (*area radicukaris motoria*) is the muscles (myotome) that are innervated by one anterior spinal root.

Dermatome (*area nervina*) is the area (peripheral nerve field) innervated by one peripheral nerve.

There are 31 pairs of spinal nerves. After leaving the intervertebral foramen, the spinal nerve divides into **two main branches: the posterior branch** (*ramus posterior*) **and the anterior branch** (*ramus anterior*). Both branches contain afferent and efferent fibres. The **posterior branches** retain segmental organisation and provide motor innervation of the epaxial muscles of the back and the sensory innervation of the nape, back and buttocks. The **anterior branches form plexuses** (*plexus nervosi*) for the limbs and retain **segmental organisation** only in the **thoracic nerves** (*nervi thoracici*).

Spinal nerves

1 **Cervical nerves** (*nervi cervicales*) C1 to C8
– 8 pairs of cervical nerves, which innervate the skin and muscles of the upper limbs, head and neck
2 **Thoracic nerves** (*nervi thoracici*) T1 to T12
– 12 pairs of thoracic nerves, which innervate the intercostal muscles, skin and muscles of the back and thorax
3 **Lumbar nerves** (*nervi lumbales*) L1 to L5
– 5 pairs of lumbar nerves, which innervate the muscles and skin of the abdomen, thighs and skin of the genital organs
4 **Sacral nerves** (*nervi sacrales*) S1 to S5
– 5 pairs of sacral nerves, which innervate the skin and muscles of the lower extremities
5 **Coccygeal nerve** (*nervus coccygeus*) Co
– 1 pair, rudimentary in humans

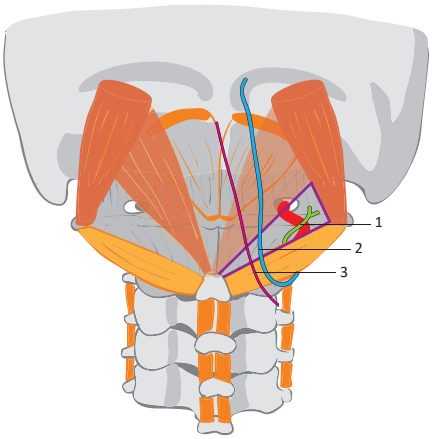
Posterior branches of the spinal nerves

– are thinner and shorter than the anterior branches
– innervate the posterior (epaxial) part of the trunk
– provide motor innervation for the epaxial muscles of the back
– provide sensory innervation for the skin of the nape, back and buttocks
– retain segmental organisation

- 1 **Suboccipital nerve** (*nervus suboccipitalis*) – the posterior branch of C1
  – a purely motor nerve for the suboccipital muscles and the semispinalis capitis
- 2 **Greater occipital nerve** (*nervus occipitalis major*)
  – the posterior branch of C2
  – a purely somatosensory nerve for the skin posterior to the interauricular line (a line joining the auricles in the frontal plane)
- 3 **Third occipital nerve** (*nervus occipitalis tertius*)
  – the posterior branch of C3
  – a purely somatosensory nerve innervating a narrow area of the skin medial to the greater occipital nerve

4 **Superior clunial nerves** (*nervi clunium superiores*)
– the posterior branches of L1 to L3
– provides somatosensory innervation of the superior gluteal region

5 **Middle clunial nerves** (*nervi clunium medii*)
– the posterior branches of S1 to S3
– provides somatosensory innervation of part of the gluteal region



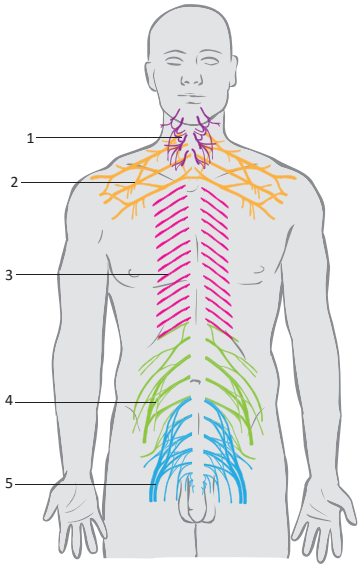
Suboccipital triangle and occipital nerves, posterior view

Anterior branches of the spinal nerves

– are longer and thicker branches than the posterior branches
– provide both motor and sensory innervation of the limbs and the hypaxial part of the trunk
– provide motor innervation of the muscles of the anterior abdomen, thorax and neck (except for the suprahyoid muscles)
– provide sensory innervation of the skin on the anterior aspect of the abdomen and thorax

- 1 **Cervical plexus** (*plexus cervicalis*) – C1 to C4
- 2 **Brachial plexus** (*plexus brachialis*) – C4 to T1
- 3 **Thoracic nerves** (*nervi thoracici*) – T1 to T12
- 4 **Lumbar plexus** (*plexus lumbalis*) – T12 to L4
- 5 **Sacral plexus** (*plexus sacralis*) – L4 and L5 and S1 to S4

6 **Coccygeal plexus** (*plexus coccygeus*) – S5 and Co



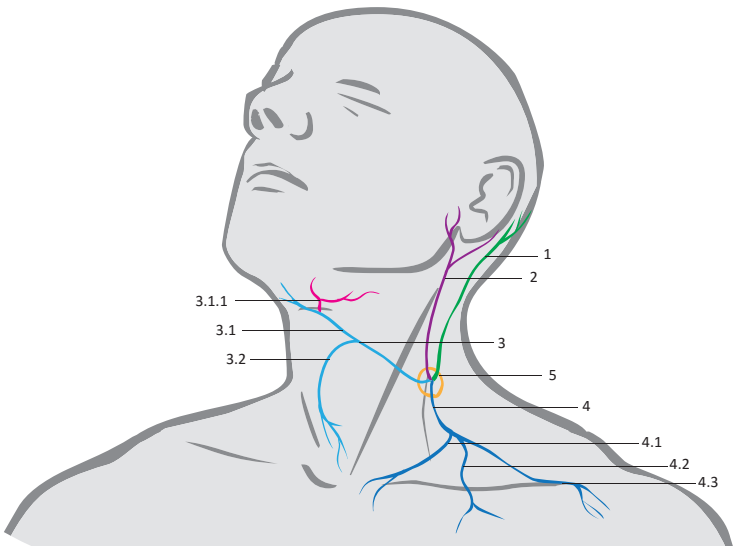
Anterior branches of the spinal nerves

The **cervical plexus** consists of spinal nerves **C1 to C4** and is located in the lateral cervical region. It produces both sensory and motor nerves. The sensory nerves reach the skin through the **the nerve point** (*punctum nervosum*), a gap in the superficial cervical fascia located approximately half-way along the posterior margin of the sternocleidomastoid. **The motor nerves** innervate the **anterior group** of cervical muscles. **The phrenic nerve** passes through the mediastinum and innervates the diaphragm.

Somatosensory branches

- 1 **Lesser occipital nerve** (*nervus occipitalis minor*) – C2 to C3
  - – a somatosensory nerve, which travels along the posterior margin of the sternocleidomastoid in a cranial direction
  - – innervates the lateral part of the nape region
- 2 **Great auricular nerve** (*nervus auricularis magnus*) – C2 to C3
  - – a somatosensory nerve, which travels along the sternocleidomastoid muscle in a cranial direction
  - 2.1 **Anterior branch** (*ramus anterior*) – innervates the skin over the anterior part of the auricle of the inferior part in the parotideomasseteric region
  - 2.2 **Posterior branch** (*ramus posterior*) – innervates the skin of the posterior part of the auricle and the mastoid region
- 3 **Transverse cervical nerve** (*nervus transversus colli*) – C3
  - – runs ventrally across the sternocleidomastoid muscle
  - 3.1 **Superior branch** (*ramus superior*) – innervates the skin of the suprahyoid region
    - 3.1.1 **Superficial ansa cervicalis** (*ansa cervicalis superficialis*)
      - – a loop forming a connection with the cervical branch of the facial nerve (*ramus colli nervi facialis*), which carries motor fibres for the platysma
  - 3.2 **Inferior branch** (*ramus inferior*) – innervates the skin of the infrahyoid region
- 4 **Supraclavicular nerves** (*nervi supraclaviculares*) – C3 to C4
  - – three groups of sensory nerves
  - – pass superficially over the clavicle giving off branches in a caudal direction
  - 4.1 **Medial supraclavicular nerves** (*nervi supraclaviculares mediales*)
    - – innervate the skin over the manubrium
  - 4.2 **Intermediate supraclavicular nerves** (*nervi supraclaviculares intermedii*)
    - – innervate the skin of the infraclavicular region (*regio infraclavicularis*)
  - 4.3 **Lateral supraclavicular nerves** (*nervi supraclaviculares laterales*)
    - – innervate the skin of the acromial region (*regio acromialis*)

- 5 **Nerve point** (*punctum nervosum*) – the point where the sensory cervical nerves pass through the superficial layer of the cervical fascia, emerging dorsally to the sternocleidomastoid muscle



Somatosensory branches of the cervical plexus

The hypoglossal nerve joins and travels with the superior root of the deep ansa cervicalis *(radix superior ansae cervicalis profundae)*. However, it does not participate in the motor innervation of the infrahyoid muscles.

Clinical notes

Surgical procedures in the area of the carotid bifurcation require very careful precision not to injury the motor branches of the cervical plexus.

The phrenic nerve must not be harmed when opening the pericardium during heart surgery.

Phrenic nerve irritation results in twitches of the diaphragm causing hiccups (singultus).

Unilateral damage to the phrenic nerve leads to ipsilateral paresis of the diaphragm and unilateral respiratory impairment.

Transverse lesions of the spinal cord above C4 often lead to respiratory arrest. This is common in vertebral column trauma.

The **Memorix Anatomy** is a very comprehensive and dependable source of anatomical information. The main use of this textbook is to help in self-preparation for laboratory courses, lectures and quick revision for students' exams or as anatomical dictionary for clinicians. Topographical context of presented data makes this book very practical. All the systems and structures necessary during the gross anatomy course are presented. Illustrations precisely support the text and constitute an independent value of this publication. Limited format makes this book very useful in all academic or clinical situations. Graphic concept of anatomical data makes this book a real "friend" of all medical people.

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