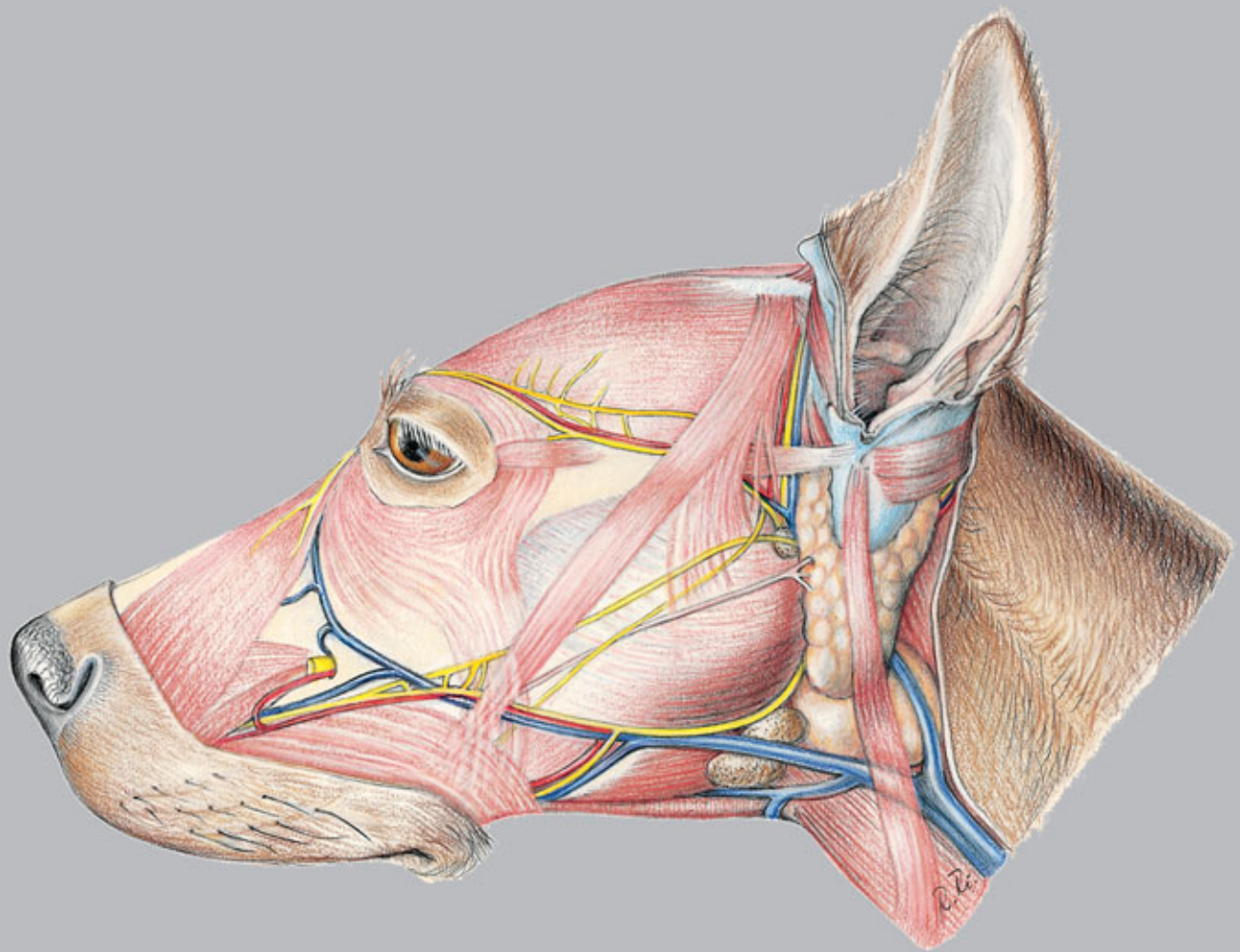


Klaus-Dieter Budras · Patrick H. McCarthy ·
Wolfgang Fricke · Renate Richter

Anatomy of the Dog

vet



with Aaron Horowitz and Rolf Berg

vet

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Fifth, revised edition

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The present volume of *Anatomy of the Dog* is based on the 8th edition of the highly successful German text-atlas of canine anatomy.

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Anatomy of the Dog

Fifth, revised Edition

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Table of Contents

References	vi
Introduction to Anatomy	1
Topographical Anatomy:	
Chapter 1: Surface of the Body and Axial Skeleton	
1. Division of the animal body	2
2. Skin (common integument)	4
3. Cutaneous glands, modifications of the skin, digital end-organs	6
4. Vertebral column and thorax	8
5. Articulations of the vertebral column and of the thorax; atlanto-occipital joint and atlanto-axial joints (A. WÜNSCHE and K.-D. BUDRAS)	10
Chapter 2: Neck and Chest Region (Cervical and Thoracic Region)	
1. Cutaneous muscles and cutaneous nerves of the neck and thoracic wall	12
2. Dorsal extrinsic limb muscles	12
3. Ventral extrinsic limb muscles	14
4. Nerves, vessels, and visceral organs of the neck	14
Chapter 3: Thoracic Limb	
1. The skeleton of the thoracic limb	16
2. Medial veins of the thoracic limb; medial shoulder and arm muscles and their nerve supply	18
3. Lateral veins of the thoracic limb; lateral shoulder and arm muscles and their nerve supply	20
4. Antebrachial (forearm) muscles and their nerve supply	22
5. Vessels and nerves of the thoracic limb	24
6. Synovial structures of the thoracic limb (A. WÜNSCHE and K.-D. BUDRAS)	26
Chapter 4: Thoracic and Abdominal Wall	
1. Muscles of the vertebral column, nuchal ligament and lumbar cutaneous nerves	28
2. Respiratory muscles	30
3. Body wall, prepuce, and mammary glands (<i>Mammae</i>)	32
4. Abdominal muscles, rectus sheath, prepubic tendon	34
5. Inguinal region, inguinal space (inguinal canal), neuromuscular and vascular lacunae	36
Chapter 5: Thoracic Cavity	
1. Lungs, tracheal bifurcation and bronchi	38
2. Blood vessels, nerves, and lymphatic system of the lungs; aortic arch; lymph nodes of the thoracic cavity, thymus	40
3. Thoracic cavity, pleura, and veins of the thoracic cavity	42
4. Heart, surface of the heart, heart wall and relationships in the interior of the heart	44
5. Heart, coronary vessels, heart valves, cardiac conduction system	46
6. Autonomic nervous system	48
Chapter 6: Abdominal Cavity	
1. Topography of the abdominal organs and relationships of the peritoneum	50
2. Peritoneal cavity, lymph nodes of stomach and intestine, <i>cisterna chyli</i> and spleen	52
3. Stomach and small intestine, pancreas	54
4. Large intestine, blood vessels of stomach and intestine	56
5. Liver and gall bladder (H. BRAGULLA and K.-D. BUDRAS)	58
6. Autonomic nervous system, abdominal aorta, caudal vena cava, sublumbar muscles and the lumbar plexus	60
Chapter 7: Urinary and Genital Organs, Pelvis	
1. Urinary organs	62
2. Urinary bladder and peritoneal relationships of the genital organs	64
3. Female genital organs	66
4. Male genital organs, lymphatic system of the lumbar and pelvic regions	68
5. Arteries, veins and nerves of the pelvic cavity, adrenal glands	70
6. Pelvic diaphragm, ischiorectal fossa; associated arteries, veins and nerves	72
7. Smooth muscle of the pelvic diaphragm and the bony pelvic girdle	74
Chapter 8: Pelvic Limb	
1. The skeleton of the pelvic limb	76
2. Muscles of the hip joint and their nerve supply	78
3. The medial saphenous vein, obturator nerve, femoral nerve, medial thigh muscles, femoral space (femoral canal)	80
4. The lateral saphenous vein, common peroneal nerve and tibial nerve; crural (leg) muscles and popliteus muscle	82
5. Arteries and accompanying vessels and nerves of the pelvic limb	84
6. Synovial structures of the pelvic limb (S. REESE and K.-D. BUDRAS)	86
Chapter 9: Head	
1. Skull, including the hyoid apparatus	88
2. Skull, paranasal sinuses	90
3. Lymphatic system, superficial veins of the head, facial nerve (VII)	92
4. Facial muscles and mandibular muscles	94
5. Internal (deep) muscles of mastication, trigeminal nerve (V), mandibular nerve (V3), maxillary nerve (V2)	96
6. Lacrimal apparatus, optic nerve (II), ophthalmic nerve (V1), nerves and muscles of the eye, and external nose	98
7. Nose, larynx, oral cavity and pharynx	100
8. Pharyngeal muscles, cranial nerves of the vagus group (IX, X, XI), autonomic nervous system of the head, arteries of the head, external acoustic meatus	102
9. Tongue, lingual muscles, hypoglossal nerve (XII), salivary glands, and dentition	104
10. Joints of the head (S. REESE and K.-D. BUDRAS)	106

Chapter 10: Central Nervous System	
1. Spinal cord and meninges	108
2. Brain (<i>Encephalon</i>) and its meningeal coverings	110
3. Cerebrum (<i>Telencephalon</i>), brain stem and limbic system	112
4. Rhinencephalon, sites of egression of the cranial nerves, arterial supply of the brain	114
5. Cerebral veins, sinuses of the dura mater, cerebral ventricles and choroid plexuses	116
Chapter 11: Sense organs	
1. The eye (P. SIMOENS and K.-D. BUDRAS)	118
2. The ear (H. KÖNIG and K.-D. BUDRAS)	120
3. Olfactory and gustatory (chemical) senses; superficial, deep, and visceral sensibility	122
Tables, Special Anatomy	
1. Myology	124
2. Lymphology	134
3. Cranial nerves (C. HERRMANN and K.-D. BUDRAS)	136
General Anatomy	
1. Osteology: membranous and chondral ossification; growth of bones in length and diameter	140
2. Osteology: structure and form of bone and cartilage	142
3. Arthrology: the connections of bones and the form of joints	144
4. Myology: general myology	146
5. Myology: skeletal musculature and its accessory structures	148
6. Nervous system	150
7. Endocrine system	152
8. Cardiovascular system (R. HIRSCHBERG)	154
9. Lymphatic system (H.-G. LIEBICH and K.-D. BUDRAS)	156
10. Glands, mucous membranes, and serous membranes	158
Introduction to the physics of radiographic and ultrasound diagnostic techniques (C. POULSEN NAUTRUP)	160
Introduction to Computed Tomography and Anatomy of the CT Scan (C. NÖLLER)	176
Contributions to Clinical and Functional Anatomy	180
Index	212

How to use this book:

The framed introductions at the beginning of the text-pages dealing with topographical anatomy give information with respect to the dissection of the areas shown in the figures. At the same time, they can be used as abbreviated dissection instructions. Boldface terms of anatomical structures serve for emphasis and, insofar as they are identified by numbers, they are represented on the neighboring illustration-page where they are identified by the same number. Numbers on the margin of the text-pages refer to the 'Clinical and Functional Anatomy.' The numbers in the clinical anatomy part refer to the corresponding page in the topographical anatomy; *e.g.*, '8.2' refers to the part numbered '2' on page 8. The anatomical/medical terms and expressions occurring in the text are explained and interpreted in 'Anatomical Terms.' Abbreviations of anatomical terms follow the abbreviations as employed in the *Nomina Anatomica Veterinaria* (2005). Other abbreviations are explained in the appertaining text, and in the titles and legends for the illustrations. A few abbreviations that are not generally employed are listed here:

The **cranial nerves** (*Nervi craniales*) are designated with roman numerals I – XII.

Spinal nerves (*Nervi spinales*):

- n — Nervus spinalis
- nd — Ramus dorsalis n. spinalis
- ndl — Ramus dorsolateralis
- ndm — Ramus dorsomedialis
- nv — Ramus ventralis
- nvl — Ramus ventrolateralis
- nvm — Ramus ventromedialis
- nC — Nervus cervicalis (*e.g.*, nC1 – first cervical nerve)
- nCy — Nervus coccygeus s. caudalis
- nL — Nervus lumbalis
- nS — Nervus sacralis
- nT — Nervus thoracicus

Vertebrae

- vC — Vertebra cervicalis (*e.g.*, vC3 – third cervical vertebra)
- vL — Vertebra lumbalis
- vS — Vertebra sacralis
- vT — Vertebra thoracica

Preface to the Fifth Edition

The present revised and enlarged edition is published at a time of change, which is characterized by the new appointment of all anatomically oriented chairs in the German-speaking area. The tendency to shorten the time for anatomical education has existed for a longer time, which to a moderate degree seems to be acceptable and unavoidable for the creation of free space for new educational subjects. Because this trend now seems to assume excessive proportions, the danger exists of a partial or even total renunciation of the dissection of the animal body, which since the time of Leonardo da Vinci has been considered a very efficient and essential method of deepening our knowledge. The deficiency in practical exercises cannot be compensated by our offer of anatomical drawings but will mitigate its negative impact. Especially in the initial phase of the curriculum, our realistic figures in the atlas part of our textbook have the indisputable value that they provide the essential basis for understanding much used sketches and schematic representations. Beyond that, as an illustrated guide to dissection, they promote the proper initiative for an independent

dissection and contribute by that to the acquisition of a solid knowledge. For dissection and pictorial rendition, the topographical-anatomical procedure offers the enormous advantage that comprehensive subjects can be imparted with brevity in a natural reality. For the practicing veterinarian the topographical plates are suitable for orientation at surgical operations.

The consideration of computed tomography, which thanks to Dr Nöller was integrated into the current eighth edition, has the objective to safeguard an attractive field of activity for anatomy. The imparting of normal structure discoverable by computed tomography and supplemented by the presentation of clinical-functional cases creates a solid basis for the further development and application of imaging procedures in the clinical curriculum and later in the practice of veterinary medicine.

Berlin, in the summer of 2007

The Authors

Preface to the First German Edition (abridged)

The *Atlas of the Anatomy of the Dog* was conceived as a compendium and at the same time as an introduction to the topographical anatomical dissection as well as for teaching. The subject matter of anatomy was prepared from a topographical point of view with separation into systems. To do that, the osteology, myology, angiology, neurology and splanchnology of the different parts of the body were dealt with in sequence in their reciprocal relationship to one another and demonstrated by topographical colored plates with complementary schematic diagrams. The methods of presentation emphasize the mutual topographical relationships of the vessels and nerves considered, laying stress on their nomenclatural agreement. In that way, the concern for the multiplicity, the breadth, and the complexity of the material should be minimized. The concept chosen here, with its close relationship of content and apposition of illustration and pertinent description, has the advantage of being able to deal with the essential in the smallest space.

The present book offers to the students a clearly arranged illustrative material and an abbreviated reading supplementing textbook study and classroom material as well as an aid for review, especially for preparation for examinations. For the practising veterinarian, it is drawn up as a source of quick information and to refresh and deepen what was previously learned. The breadth, division and sequence of the subject matter according to the preceding are coordinated with the topographical dissection that is offered to the students at the Free University of Berlin as the teaching program in their first semester of study. Upon the foundation achieved, the subsequent study of comparative and clinically applied anatomy is continued. Topographical anatomy is the foundation and the key to understanding the associated medicine. It is of special value to the surgeon and pathologist.

Professor Fritz Preuss introduced the whole-animal topographical anatomy in Berlin, and his dissection instructions directed the way for teaching up to the drastic shortening and repositioning of the dissection exercises. The successful and exacting method of dissection with the short time available places high demands on the students and requires a multisided support by the instructors. With its true to nature rendition of areas of dissection with accompanying text, the present atlas should serve for this purpose also. Instructions for dissection of the illustrated preparation and guidance to the person carrying out the exercise were placed at the beginning of the described part. Structures to be dissected are specially emphasized in the text by boldface print. To keep the space limitations, anatomical variations are given less attention. The current *Nomina Anatomica Veterinaria* (HOLZHAUSEN, Vienna 1973) was utilized, which also holds in the main for the applied abbreviations. Moreover, in the written material only vertebrae and nerve branches were abbreviated (*e.g.*: VL 1 for the first lumbar vertebra; nL 1vl for the ventrolateral branch of the first lumbar nerve). In the legends of the figures and the tabular compositions, owing to the limitations of space even more extensive, otherwise uncommon, abbreviations had to be used. Suggestions and wishes of the students, for example with respect to preparing the tables for special myology and for anatomical terms were largely considered.

Dissections from the anatomical collection of the Department of Anatomy, Histology and Embryology (Institute for Veterinary Anatomy, Histology and Embryology) of the Free University of Berlin served as models for the figures. These specimens were prepared by the technical staff of the department, Mr. Seifert, Mr. Dressel, and Mr. Schneider.

Berlin, summer 1983

The Authors

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Introduction to Anatomy

The term anatomy stems from the Greek word, 'anatemnein' which means to dissect, to cut apart. The important anatomist Hyrtl spoke consistently also of the art of dissection. The original meaning is true even today; although the term has gained a wider meaning. Modern anatomy is not limited to mere description but emphasizes the interrelations between form and function as well as the application of anatomical knowledge in the clinic. Then as today the student gains most of his knowledge by dissection of the animal body in the laboratory, where he lays bare the 'naked truth' (Nudas veritas). This practice also serves to obtain a necessary finger-dexterity, which in later professional life, in the first place in surgery, is of immeasurable value. Beyond that there are hardly any limits to investigation by enthusiastic dissection. Even the very best anatomical collection of outstanding demonstration-dissections cannot replace practical work in the laboratory, but can however indeed make it easier and more efficient. The thorough study of anatomical preparations is indispensable like the industrious use of textbooks and atlases. All of these aids are more important today than ever since there is much less time available for practical work in the laboratory than formerly. Shortening the teaching time allotted to anatomy in favor of newer disciplines was unavoidable.

Anatomical study is, unlike any other basic discipline, important in learning the language of medicine, the **terminology**. Many terms for diseases and methods of treatment have their origin in anatomical terms. Centuries-long research and description brought an unforeseen abundance of synonyms. The function of the international nomenclature commission has been to thin out the jungle of terms and to publish a recognized list of official terms with useful synonyms.

In its entirety, anatomy is subdivided into macroscopic (gross) anatomy, microscopic anatomy and developmental anatomy. However, the areas of anatomy flow together without boundary, forming a unit, an understanding constantly and forcefully advocated by the important Berlin veterinary anatomist and, at an earlier time, the professorial chair of our department, Professor Preuss. The oldest and most encompassing area is macroscopic anatomy, often placed equal to the term anatomy. Where the accessories to observation in macroscopic anatomy, the bare eye and the dissection hand lens no longer reach, it passes over into the area of microscopic anatomy (histology and cytology), to which the microscope serves as accessory. The boundary between macroscopic and microscopic anatomy is also called mesoscopy, which is gaining more and more in significance. The latter area deals with the same material and pursues the same goals; it is only the technique that is different. The third area, embryology, is concerned with ontogenesis (development of the individual) before and after birth and, in addition to embryological methods, applies also macroscopic, microscopic and mesoscopic methods.

Like the remaining disciplines, macroscopic anatomy can be presented from different points of view with emphasis on special areas of greater difficulty. In so doing, the basic facts remain of course unchanged.

Systematic, descriptive anatomy describes the animal body with all its parts as systems of structure and organ-systems, strictly divided from one another and therefore without attention to their natural interdependence. Expansive descriptions treat many particulars and allow some-times the view to the important to be missed; nevertheless they are a necessary prerequisite to the remaining, subsequent kinds of observations to which the descriptive anatomy has led.

Systematic anatomy can be subdivided further into general and special anatomy.

General anatomy treats of facts that are generally valid for the entire system of structure or the organ-system.

Special anatomy provides special data for these structure- and organ-systems that hold for individual structures, as for one bone.

Comparative anatomy emphasizes anatomical correlations, similarities and variations between the individual animal species and human beings. Comparisons of anatomy between the individual species are very often informative and helpful for homology and determining the function of anatomical structure. Already Goethe utilized principles of comparative anatomy to good advantage with the discovery of the incisor bone of human beings. This bone occurs regularly in our domestic animals and

only occasionally in human beings. With his study of the human skull he encountered a specimen with a developed incisor bone. It was by comparison with the animal skull that he was able to identify the bone and establish its homology.

Topographical anatomy emphasizes the varying position-relationship of anatomical structures and underlines the areas of application for clinical medicine. The relationship of anatomical structures is analyzed step by step and in doing so the whole structural plan of the body is regarded.

Applied anatomy is directed clinically and emphasizes the relationship of anatomical structures from which treatments or diseases of animals can be determined or explained. In that way not only interdisciplinary cooperation and interest for the veterinary profession are promoted but also the learning of anatomy is made easier.

The anatomy of the living dog is undoubtedly a significant part of the whole of anatomy. It presents the body in its natural condition. In that way a significant completion and an adjustment for unavoidable disadvantage becomes imperative in the remaining subjects of the whole of anatomy, which must tolerate postmortem changes such as variations in color, consistency and character as well as artificial changes resulting from fixation. Anatomy of the living dog cannot be given attention here for several reasons. It is adapted even less for rendering in a book, but can be offered to the students better and more successfully in an exercise under the instruction of a clinically experienced anatomist.

Radiographic anatomy and sonography are directly connected to the clinic. In the teaching of anatomy, the first experiences are obtained in analysis of radiographs of the normal animal body. This experience will be utilized and considerably supplemented in the total associated area of study. Presentations of abnormal or even pathological changes should awaken the interest and accordingly add 'spice' to the teaching of anatomy.

The atlas of anatomy presented here is adapted in special measure to significantly combine and coordinate the different methods of presenting anatomy and the manner of viewing it. The textual part can be presented in a very compressed form since the different anatomical circumstances can be 'read off' from time to time from the adjacent color-plate. Beyond that, a good topographical color-plate presents an ideal introduction for topographical dissection, which is then completed only by brief remarks. Also the requisites of comparative veterinary anatomy are taken into account in this atlas insofar as the simply structured (from many points of view) canine body is set out as the 'cornerstone.' Building upon this knowledge, the more complicated (from many points of view) anatomy of the remaining domestic animals can be comprehended from the aspect of comparative anatomy.

Art and anatomy with their mutual interrelations are forcefully impressed on us with each visit to a museum. The artist is inspired by the corporeal beauty, and teachers and students of anatomy enjoy and profit from the talent and painstaking detail in the artistic presentation. Gifted with genius were realized the claims of Leonardo da Vinci, whose abundant anatomical drawings came about after basic studies of anatomy. Aristotle published among other things an anatomical description of senile sexual reversal in the bird as well of the horse hoof in regard to founder. What fascination of anatomy passes over to art, Rembrandt immortalized in his work 'The anatomy lesson of Dr. Nicolaes Tulp.' The greats of world history gifted with genius like Aristotle, Leonardo da Vinci and Goethe show proof of their enthusiasm for anatomy with anatomical illustrations, descriptions and research results. To Goethe's credit was the promotion of educational art and the introduction of plastic wax models in Germany, to which he, himself, was inspired during his journey to Italy, especially in Florence. The good qualities of wax models, which is true to an equal measure for well done true-to-nature illustrations, Goethe expressed in his novel 'Wilhelm Meisters Wanderjahre' with the following excellent formulation: 'If you concede that most physicians and surgeons retain in their minds only a general impression of the dissected human body and believe that to satisfy the purpose; so such models will certainly suffice, which refresh in his mind again little by little pictures that are fading and actively retain for him just the necessary.' His investigative mind held Goethe, who with his discovery of the human incisor bone felt 'unspeakable joy.'

Topographical Anatomy

Chapter 1: Surface of the Body and Axial Skeleton

1. Division of the animal body

a) SUBDIVISION OF THE BODY

The longitudinal lines and planes of the body are useful for the orientation of the body and of the body surface. The **dorsal (a) and ventral midline (b)** are the dorsal and ventral median lines of the body, respectively.

The **median plane (A)** is the plane between the two lines mentioned above. It divides the body into right and left halves. **Sagittal (paramedian) planes (B)** are adjacent planes parallel and lateral to the median plane. They divide the body longitudinally, but into unequal parts. **Transverse planes (C)** are planes that divide the body transversely and are perpendicular to the median and sagittal planes. **Dorsal planes (D)** lie parallel to the dorsal body surface. They divide the body perpendicular to the longitudinal (median and paramedian planes) and transverse planes. In that view, two symmetrical body sides appear and it is for that reason that dorsal planes are also called bilateral planes.

b) TERMS THAT DESCRIBE THE DIRECTION AND TOPOGRAPHICAL RELATIONS OF ORGANS derive partially from body parts, *e.g.*, in direction toward the tail (**caudal —c**), partially from landmarks of the body surface, *e.g.*, parallel to the median plane (**sagittal —d**) or designate with respect to hollow organs *external* or *internal*. Furthermore terms are used as left (*sinister*) and right (*dexter*), short (*brevis*) and long (*longus*) or deep (*profundus*) and superficial (*superficialis*), longitudinal (*longitudinalis*) or transverse (*transversus*) as well as lateral (*lateralis*) and toward the median plane (*medialis*). The term **cranial (e)**, in a direction toward the head, cannot be applied in the head region. Here the term **rostral** is used (**f**, in a direction toward the tip of the nose). The term **dorsal (g)** relates to the 'back' or *dorsum* of the body. It may also be used with respect to the proximal parts of the limbs; but has

a different meaning on the limb extremities. The term **ventral**, in a direction toward the belly (*venter*), may be used on the proximal parts of the limb, but is not used on the free part of the limbs. The terms **proximal (i)**, toward the attached end) and **distal (m)**, toward the free end) are related to the axis of the body (vertebral column and spinal cord with the origin of spinal nerves). On the limbs, from the carpus distally, the term **palmar (l)**, the surface of the manus that faces caudally in the normal standing attitude) is employed; from the tarsus distally (**m**, the surface of the pes that faces caudally in the normal standing attitude of the animal), the term **plantar**. The term **dorsal** is utilized alike on the thoracic limb from the carpus distally and on the pelvic limb from the tarsus distally. It refers to surface of the manus and pes that is cranial in the normal standing attitude of the animal. Terms like **abaxial (n)**, away from the axis) and **axial (o)**, toward the axis) are related to the central axis of the hand (manus) or foot (pes), in which the axis lies between the third and fourth digits. In front (anterior), behind (posterior), above (superior) and below (inferior) are terms often used in human anatomy and refer to the human body in the normal upright attitude. To avoid misunderstanding, these terms are not applied to the quadruped animal body. Their use in veterinary anatomy is restricted to certain areas of the head; *e.g.*, upper and lower eyelids, anterior and posterior surfaces of the eye.

c) PARTS OF THE BODY AND BODY REGIONS subdivide the body, including the surface of the body. Parts of the body are head and trunk with neck, rump, and tail, as well as the limbs. The body regions divide the surface of the body and can be subdivided into subregions. In the latter case, they appear indented in the following table.

REGIONS OF THE BODY

Regions of the cranium

- 1 Frontal region
- 2 Parietal region
- 3 Occipital region
- 4 Temporal region
- 5 Auricular region

Regions of the face

- 6 Nasal region
- 6' Dorsal nasal region
- 6'' Lateral nasal region
- 6''' Region of the naris
- 7 Oral region
- 7' Superior labial region
- 7'' Inferior labial region
- 8 Mental region
- 9 Orbital region
- 9' upper palpebral
- 9'' lower palpebral
- 10 Zygomatic region
- 11 Infraorbital region
- 12 Region of the temporomandibular articulation
- 13 Masseteric region
- 14 Buccal region
- 15 Maxillary region
- 16 Mandibular region
- 17 Intermandibular region

Regions of the neck

- 18 Dorsal neck region
- 19 Lateral neck region
- 20 Parotid region
- 21 Pharyngeal region
- 22 Ventral neck region
- 22' Laryngeal region
- 22'' Tracheal region

Regions of the dorsum

- 23 Thoracic vertebral region
- 23' Interscapular region
- 24 Lumbar region

Pectoral regions

- 25 Presternal region
- 26 Sternal region
- 27 Scapular region
- 28 Costal region
- 29 Cardiac region

Regions of the abdomen

- 30 Cranial abdominal region
- 30' Hypochondriac region
- 30'' Xiphoid region
- 31 Middle abdominal region
- 31' Lateral abdominal region
- 31'' Paralumbar fossa
- 31''' Umbilical region
- 32 Caudal abdominal region
- 32' Inguinal region
- 32'' Pubic region and preputial region

Pelvic regions

- 33 Sacral region
- 34 Gluteal region
- 35 Region of the tuber coxae
- 36 Ischiorectal fossa
- 37 Region of the tuber ischiadicum
- 38 Caudal region (tail region)
- 38' Region of the root of the tail
- 39 Perineal region
- 39' Anal region
- 39'' Urogenital region
- 40 Scrotal region

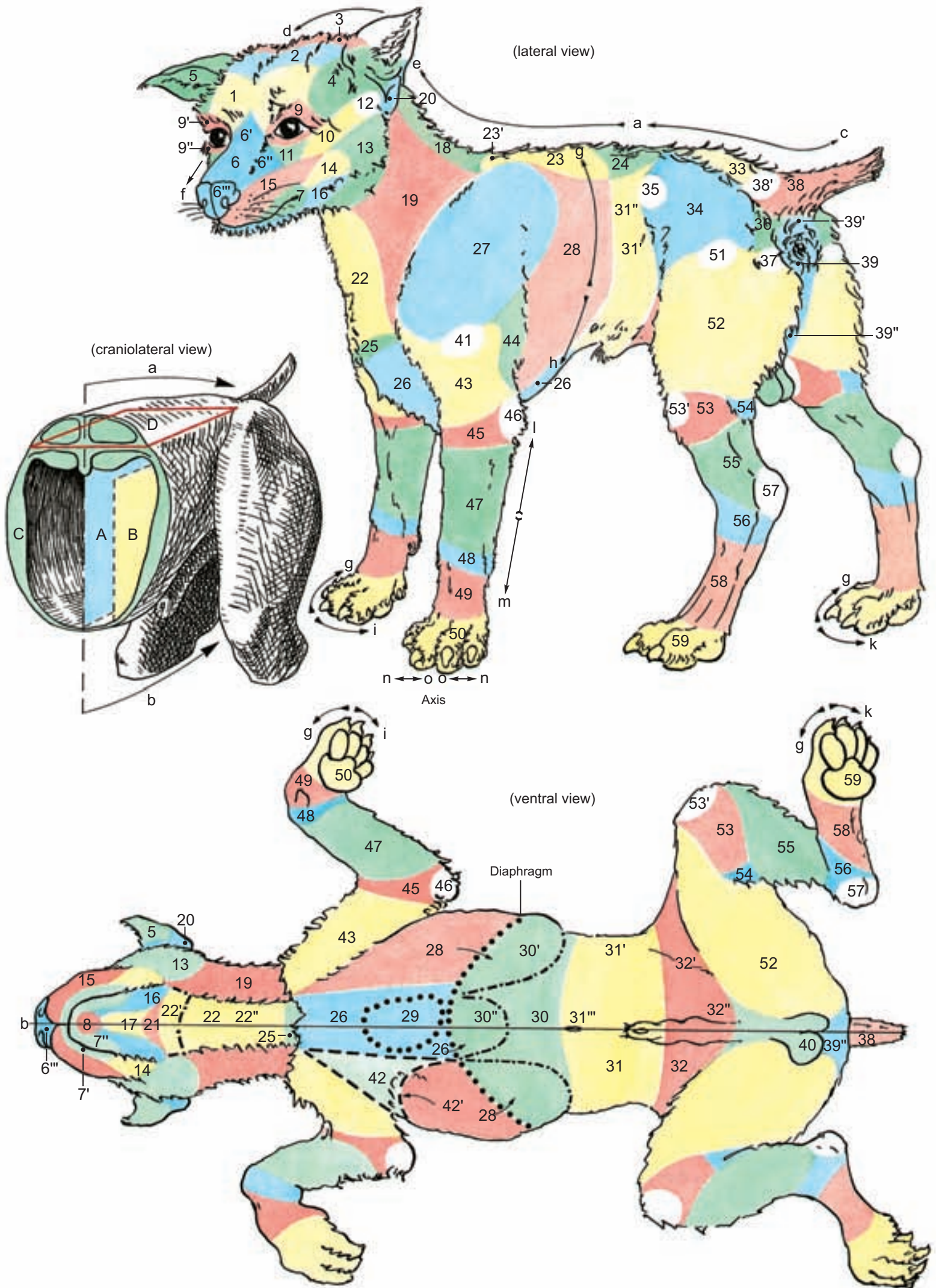
Regions of the thoracic limb

- 41 Region of the humeral joint
- 42 Axillary region
- 42' Axillary fossa
- 43 Brachial region
- 44 Tricipital region
- 45 Cubital region
- 46 Region of the olecranon
- 47 Antebrachial region
- 48 Carpal region
- 49 Metacarpal region
- 50 Phalangeal region (region of the digits, digital region)

Regions of the pelvic limb

- 51 Region of the hip joint
- 52 Region of the thigh
- 53 Genual region (region of the knee, region of the stifle joint)
- 53' Patellar region
- 54 Popliteal region
- 55 Region of the crus (region of the leg)
- 56 Tarsal region
- 57 Calcaneal region
- 58 Metatarsal region
- 59 Phalangeal region (region of the digits, digital region)

Body regions and terms of site and direction in relation to parts of the body indicated



2. The Skin (Common Integument)

- 1 a) The **SKIN** forms the external surface of the body and consists of two layers: I. an epithelial layer designated *epidermis* and II. a connective tissue layer designated *dermis* or *corium*. The dermis rests upon an underlying layer of connective tissue, the subcutaneous layer or *subcutis* (*Tela subcutanea*). The latter consists of a fatty part, the *panniculus adiposus*, and a supporting fibrous part that, together, constitute the superficial fascia.

I. The **epidermis** (1) is made up of a stratified squamous epithelium that is cornified (keratinized) at its surface. Thickness and degree of keratinization depend on the mechanical stress to which this layer is subject. The epidermis is composed of a deep, still living, layer, (**stratum germinativum = basal layer**, —27) which, by mitotic division, furnishes cell replacement, a **spinous layer** (26), a cornifying, dying layer (**stratum granulosum**, —25) as well as cornified cell layers, **stratum lucidum** (24) and **stratum corneum** (23). In addition to the epidermal cells, there are melanocytes, LANGERHANS' cells, and MERKEL'S tactile discs, especially in the stratum germinativum.

'Horn' is cornified epidermis and is of varying quality in the different regions of the body. On the pads and in other regions of the skin there is soft horn. Hard horn is found at the claw. In the skin and at the pads, the cornified cells are shed as scales owing to reduced adhesion of membrane coating materials. At the same time, because of good adhesion as a solid mass, the **horn of the claws** remains restored by distal growth **conical**. The individual horn cell of the claw is distinctly harder than that of the skin. In areas where soft horn is formed, the epidermis exhibits a stratum granulosum between the stratum spinosum and the cornified layers. The stratum granulosum is so-named because of the keratohyalin granules that it contains. The proteins within this layer of cells coat and 'glue' the keratin filaments together. At individual sites additionally a stratum lucidum occurs. It consists of young, not yet differentiated, cornifying cells, the cytoplasm of which appears somewhat transparent when examined under the microscope, hence the name stratum lucidum. In the areas of formation of hard horn, these layers are absent, so that the cells of the stratum spinosum cornify directly without intervening strata granulosum and lucidum.

The **function of the epidermis** consists of the replacement of cornified cells as a protection from radiation (radiation absorbing pigments; see histology), from the loss and entrance of water into the body, from the entrance of parasites and for protection against trauma. With traumatic injury to the skin, healing is furthered by covering the exposed dermis by epidermal cells as soon as possible.

- 3 II. The **dermis or corium** (6) consists of a thin, loosely arranged **papillary layer** (2), the papillae of which are seated in corresponding depressions of the epidermis, and a dense **reticular layer** (7). The papillary layer contains mainly loosely arranged collagenous fibrils. The reticular layer consists of a plexus of coarse nondistensible collagenic fibers with a predominant course direction. Elastic fibers are present in both layers and function to restore the typical texture of the tissue following lacerations or other distortion of the skin (with respect to the cells that are found here, especially fibrocytes, fibroblasts, mast cells, plasma cells, macrophages and pigment cells, see histology).
- 4 The **subcutis** (10) (*Tela subcutanea*) consists mainly of loose connective and adipose tissue. It is penetrated by connective tissue cords that fix the skin to the underlying fascia or periosteum. The panniculus adiposus is the layer of fat tissue within the subcutis.

Functionally, the subcutis with its subcutaneous fat tissue serves as a cushioning tissue, serves for the storage of calories and water as well as thermoregulation. Its loose connective tissue functions as a gliding layer. Where the subcutis is lacking (lips, cheeks, and eyelids) this gliding function is lacking and the striated musculature ends here directly in the dermis.

The **blood supply** of the skin is provided by larger arteries and veins of the subcutis that, owing to the mobility of the skin, have a tortuous course. They send branches to the dermis that form here two networks. The **arterial network of the dermis** (9) is located at the boundary with the subcutis and the **subpapillary network** (3) lies between the papillary and reticular layers and gives off subepidermal capillary loops into the papillary body. The corresponding venous plexuses have a comparable location. A further subfascial vascular plexus joins the blood supply of the subcutis. The blood flow can be cut short by **arteriovenous anastomoses** (4), thus avoiding the capillary bed, and in this way the vascularization of the skin is regulated. The papillary layer is especially well supplied with blood. These vessels dilate in order to give off heat and constrict to conserve body temperature. In this way they function like the sweat glands in thermoregulation. The venous plexuses also function as a place to store blood.

The **lymphatic supply** is by lymph capillary networks that begin subepidermally and invest the hair follicles and skin glands.

The **nerve supply** is by sensory and sympathetic neurons (sympathetic nerve plexuses invest the blood vessels and function to regulate the blood pressure and in thermoregulation). The skin can be considered as the largest sensory organ of the body. Numerous **nerve terminals** (16) and terminal end corpuscles (e.g., **MEISSNER'S tactile discs**, —17, and **VATER-PACINIAN lamellar corpuscles**, —22) serve as receptors for sensory stimuli. With loss of their myelin sheaths, free nerve endings penetrate the epidermis at particular sites of the body and serve to mediate the sensation of pain.

b) The **HAIRS** cover nearly the entire body surface, except the *planum nasale*, anus, vulvar lips and limb pads. Hairs are cornified filiform structures that are formed by the skin. The hair is subdivided into the **shaft** (15), which projects beyond the surface of the skin, the **root** (21), which is obliquely oriented within the dermis and has at its proximal end an expanded part, the **hair bulb** (8). Hair root and hair bulb are in a divided epithelial root sheath (*Vagina epithelialis radicularis*). The outer part of the sheath is continuous with the superficial epidermis. Its inner part cornifies above the mouth of the **sebaceous gland** (18) and will be shed. The connective tissue root sheath (*Vagina dermalis radicularis*) is continuous with the surrounding connective tissue. The epidermal and dermal root sheaths together with the bulb of the hair constitute the hair follicle. The parts of the hair are **medulla** (12), the **cortex** (13) and the **superficial hair cuticle** (14), which consists of thin scale-like cornified cells and, the same as the medulla, is used for forensic species identification and individual diagnostic procedures. The **arrector pili muscle** (5) terminates below the mouth of the sebaceous gland, attaching obliquely to the dermal sheath of the root of the hair. Its contraction results in erection of the hair (in human beings, this brings about the phenomenon of 'goose pimples'). Contraction of the arrector pili muscle compresses the sebaceous glands and, in erecting the hair, increases the air space between the hairs and the skin surface for thermo-isolation.

The **hair coat** depends on the breed and is characterized by the individual and group-like arrangement of the hairs, the different portions of the individual hair types (lead hairs, guard hairs, wool hairs) as well as by the density, length and color of the hairs. There are basically three types of hairs:

The '**lead**' hair or '**main**' hair is long, stiff, and slightly curved. It is independent of other hairs and in the dog occurs only rarely. **Guard hairs** are shorter than the lead hair, arched near the tip and thickened. Both lead and guard hair types form the **hair coat** (**Capilli**). The third and shortest type of hair is the wool hair. It is very thin, pliable and in its course slightly or strongly undulated. Guard and wool hairs pass in a bundle or tuft together from a compound hair follicle, in which case one guard hair is surrounded by the six to twelve wool hairs that accompany it.

The **wool hairs** (11) predominate in the coat of the puppy. In most canine breeds they lie under the hair coat and only in a few breeds such as the Puli and Comodore, do they project above the hair coat and form a superficial 'wool coat.'

Sinus or tactile hairs (19) are remarkably long, special forms of hair in the vicinity of the opening of the mouth (*Rima oris*). To receive tactile stimuli, the root of the hair is ensheathed by a **blood sinus** (20) that is contacted by numerous sensory nerve endings. Owing to the great lever action of this long hair even the finest tactile stimuli result in stimulation of this receptor.

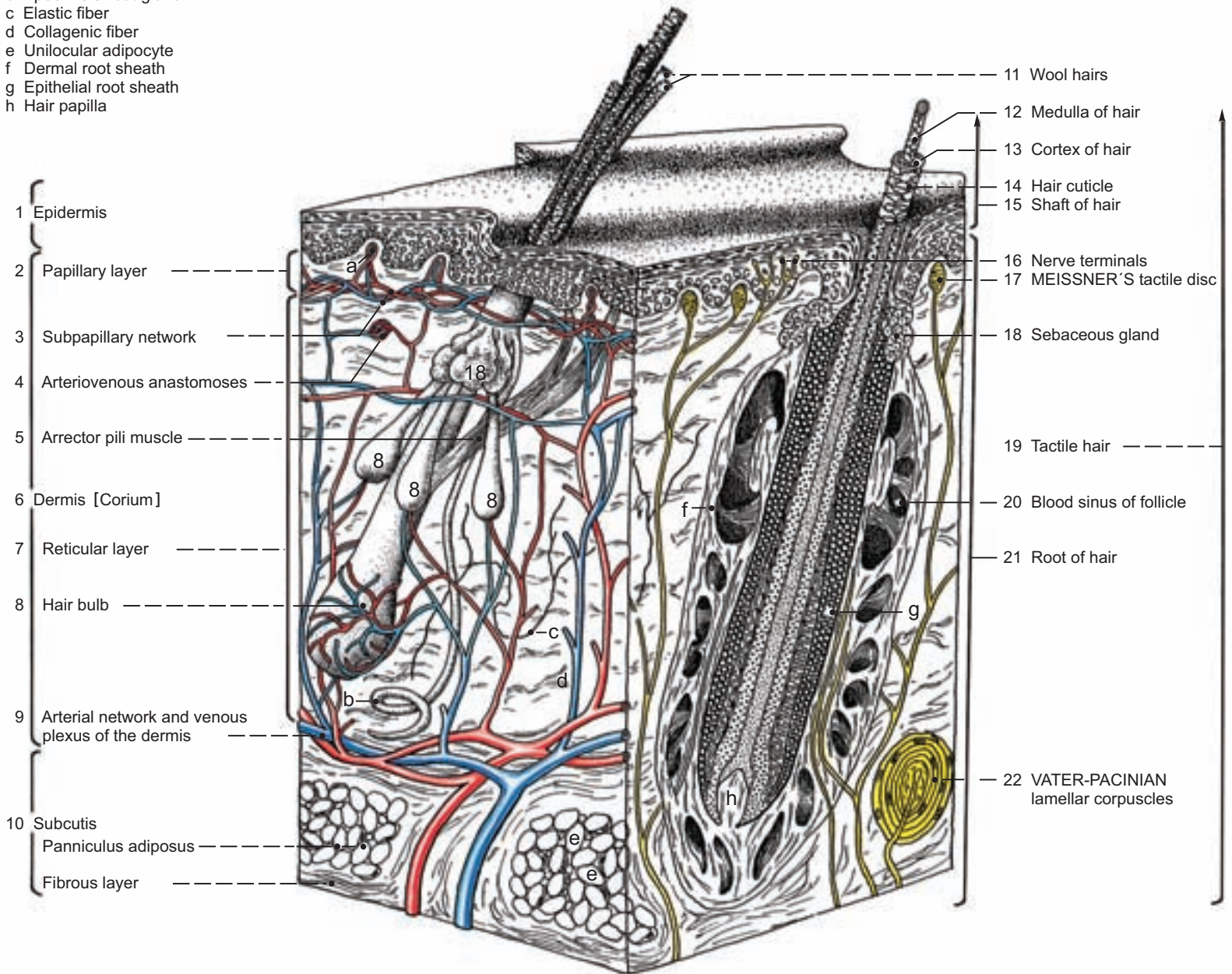
The length of the hairs varies considerably and is dependent on breed. In the ancestors of the dog, who lived in the wild, the longest hairs are found on the dorsum and the shorter ones on the belly and head. But this pattern is mostly lost with domestication. In wild Canidae, the thickness of the hairs increases toward the belly (thickness is about 0.1 mm). The color of the hair is effected by the melanin content of the cornified cells as well as the inter- and intracellular air bubbles, especially of the medullary cells.

The **direction of the hairs** characterizes the coat. That part of the coat in which the hairs have a uniform direction is called the *Flumina pilorum*. In a *vortex*, the hairs are arranged divergently or convergently with respect to a central point. By the crossing of converging lines of hairs, hair 'crosses' are formed.

Common integument

Legend:

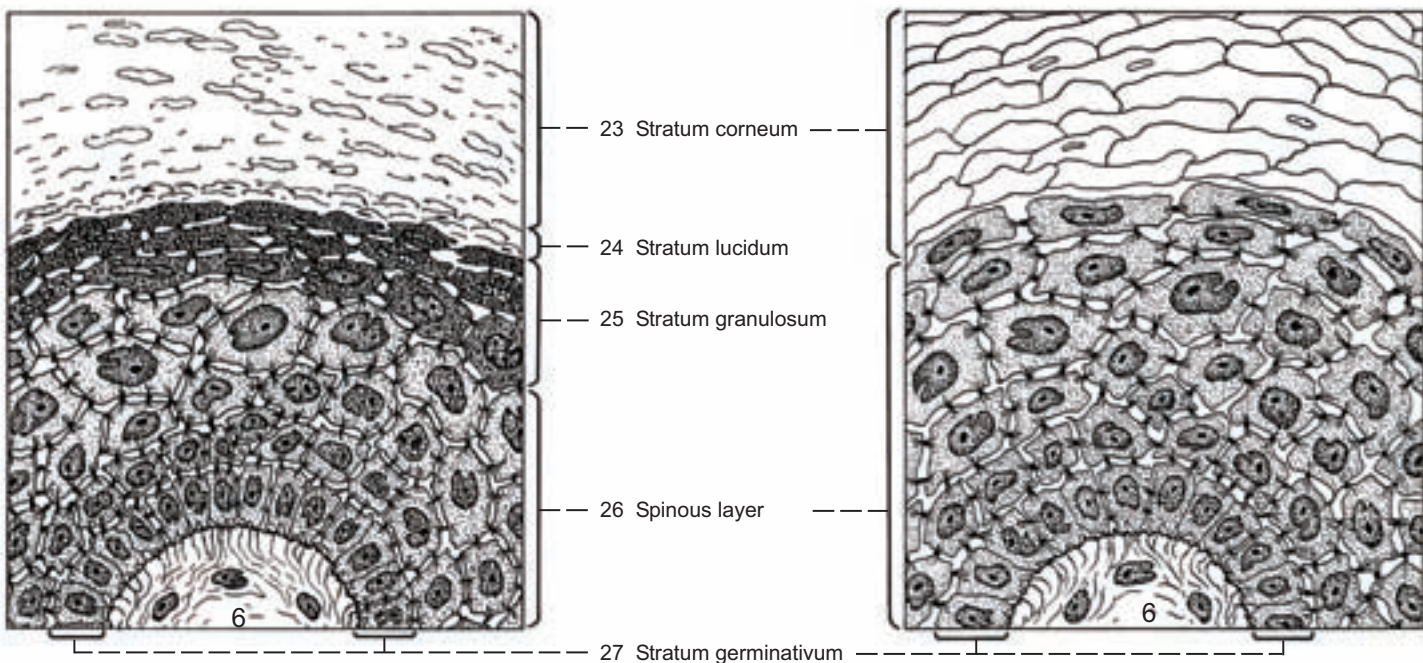
- a Intrapapillary capillary loop
- b Apocrine sweat gland
- c Elastic fiber
- d Collagenic fiber
- e Unilocular adipocyte
- f Dermal root sheath
- g Epithelial root sheath
- h Hair papilla



Epidermis

Epidermis of digital pad

Epidermis of wall of claw



3. Cutaneous Glands, Modifications of the Skin, Digital End-organs

a) The **CUTANEOUS GLANDS** comprise sebaceous and sweat glands as well as the mammary gland, which is a modified sweat gland.

1 I. The **sebaceous glands** (see p. 4) open into the hair follicles and are present at a few sites of the body independent of the presence of hairs as at the transition of the skin to the cutaneous mucous membrane (lips, anus). Sebaceous glands are lobular. The peripheral cells have a high rate of mitosis and the daughter cells are pushed centrally to the lumen of the gland. Here the enlarged and aging cells break down (holocrine secretion) and the sebum thus liberated reaches the lumen of the gland. It passes by way of a short excretory duct to the lumen of the hair follicle and thus to the skin. Sebum makes the skin soft and pliable and gives the hairs a natural sheen.

II. The **sweat or sudoriferous glands** are classified as merocrine (eccrine) and apocrine glands (odor glands). This classification was based on a supposed apocrine secretion of the (apocrine) odor glands; however, this was subsequently disproven. Both types of sweat glands secrete according to the merocrine (eccrine) manner of secretion (see histology).

The **merocrine sweat glands** are usually coiled, unbranched, tubular glands. They occur in the dog only on the pads of the limbs (see below; some authors consider these glands to be apocrine sweat glands). In human beings, real merocrine (eccrine) sweat glands are present in large areas of the skin surface.

Apocrine sweat glands or odor glands (see p. 4) are present over wide areas of the skin surface, but they are comparatively underdeveloped. These tubular glands open usually into the hair follicle. Their thick secretion has an alkaline reaction and is responsible for the individual species odor. In man, the glands are well developed but limited to a few regions of the body: anus, vulva, axilla.

III. **Special modifications of the skin** occur as the glands of the external acoustic meatus, the circumanal glands, glands of the paranal sinus ('anal sac') and glands of the dorsal tail organ, glands of the eyelids and the mammary glands.

2 The **ceruminal glands** of the external acoustic meatus are mainly sebaceous glands with fewer apocrine sweat glands. Their brown, oily secretion is called cerumen.

3 The **circumanal glands** surround the anus in the hairless or nearly hairless region of the anal cutaneous area. In the dog, we are dealing with modified sebaceous glands; in other domesticated animals, with modified apocrine sweat glands. Superficially located individual glands open into the hair follicles. Deep glands are also called hepatoid glands as their secretory cells appear similar to hepatocytes. The glands lack an excretory duct and their function is unclear.

4 The **glands of the wall of the paranal sinus** (see clinical-functional anatomy, 56.5) are apocrine sweat glands and sebaceous glands. The paranal sinus is commonly termed the 'anal sac.'

5 The **dorsal caudal (tail) organ** is composed of sebaceous and apocrine glands and is described more fully in the clinical-functional anatomy (6.5).

Glands of the eyelids are described in the clinical-functional anatomy (see also 118.1)

Mammary gland; see p. 32.

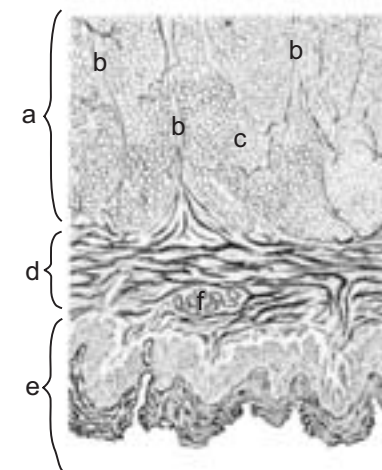
b) **SKIN MODIFICATIONS** are the nasal plane and the limb pads: carpal pad, metacarpal/metatarsal pad, digital pads.

I. The **nasal plane** (see p. 98), depending on breed, varies from unpigmented to its being strongly pigmented. The dermis forms distinct papillae. The epidermis is strikingly thin, and its superficial, cornified layer (stratum corneum) consists of hard 'horn' (hard cornified epidermis) that exhibits a polygonal pattern. The surface pattern is individually specific and for this reason serves to identify the individual animal. Glands are absent. The nose of the dog is kept moist by lacrimal fluid (see p. 98) and the secretion of the lateral nasal gland, which is located deeply in the maxillary recess of the nasal cavity. The evaporation of the fluid lowers the temperature of the nasal plane, which ordinarily feels cold to the touch (hence the saying, 'cold as a dog's nose').

6 II. The **pads of the dog** are the **digital pads** (14) at the level of the distal interphalangeal joints, the **metacarpal** (13) or **metatarsal pad** at the level of the metacarpophalangeal and metatarsophalangeal joints and the **carpal pad** (12) that is laterodistal at the carpus. The thick subcutis of the pads has much fat tissue and contains sweat glands. It is subdivided into compartments by radiating strands of collagenous and elastic fibers and is very sensitive (painful) if swollen due to increased tissue pressure when inflamed. The connective tissue strands radiate from the dermis of the pad into the

subcutis and fix the pad to the underlying fascia and to the skeleton. Well-developed **connective tissue bands** (**Tractus tori —15**) are present in the metacarpal and metatarsal pads. They fix the pads proximally to the metacarpal or metatarsal bones, respectively. The dermis has very firm connective tissue bundles and forms a very high papillary body with conical papillae. The epidermis of the pad is up to 2 mm in thickness and forms corresponding depressions in the soft horn (soft cornified epidermis). The pads are richly supplied with blood and lymph vessels as well as nerves.

Cutis of pad



Legend :

- a Subcutaneous tissue of pad [digital cushion] :
- b Retinacula
- c Panniculus adiposus
- d Dermis [Corium] of pad
- e Epidermis of pad
- f Merocrine sweat gland

c) The **DIGITAL END-ORGAN** is the bony end of the digit invested by a highly modified cutis (skin). Except for the digital pad, a subcutis is lacking. The dermis is developed in the form of papillae, villi or laminae or it has a smooth surface. The inner surface of the epidermis has a corresponding configuration: depressions that seat the papillae and villi, narrow furrows adapted to the laminae, or a smooth surface where it contacts the smooth surface of the dermis.

The cornified epidermis of the **claw (Unguicula)** is conical in form and invests the **unguicular process** (11). Dermis and epidermis are segmentally similarly differentiated as on the fingernail of the human being and on the equine hoof. Both, dermis and epidermis, are adapted to one another like the patrix (stamp = dermis) to the matrix (impression = epidermis).

The bony unguicular crest is overlain basally by a prominence of the skin, the **vallum** (7). The external lamina of the vallum is haired; the un haired inner lamella is comparable to the limbus (periole) of the horse. It forms a soft horn (**Eponychium, —1**) over the hard cornified epidermis of the claw. The eponychium corresponds to the periole of the horse and, like the periole, is worn off far proximal to the distal end of the claw. (On the human fingernail, the soft eponychium is removed at the manicure.)

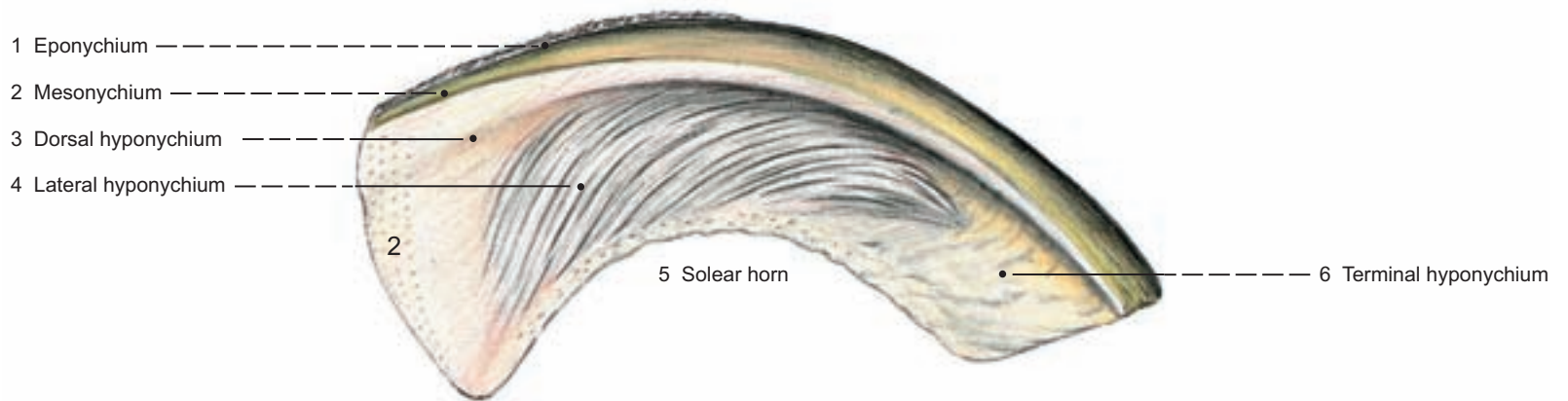
In the depth of the unguicular groove is the fold that corresponds to the coronary part of the equine hoof. Its dermis bears **papillae** (10). Its covering epidermis produces a tubular horn that, as a **mesonychium** (2), provides a considerable part of the claw. Dorsal on the unguicular process there is a smooth **dorsal swelling of the dermis (Dorsum dermale —8)**, that is particular to the digital end-organ of the dog and that, according to our investigations, is not comparable to the coronary part of the equine hoof. On the epidermis covering it, the **dorsal horn of the wall (dorsal hyponychium —3)** is formed. In the lateral region of the unguicular process lamellae are present, **dermal lamellae** (9) and correspondingly formed non-cornified epidermal lamellae that form the lateral wall horn (**Hyponychium laterale, —4**), which is simply layered and forms the internal lining of the conical claw horn.

Palmar (plantar) on the unguicular process is the solear part on which the dermis bears distinct villi. Here, tubular **solear horn** (5) is formed, the cells of which undergo substantial desquamation.

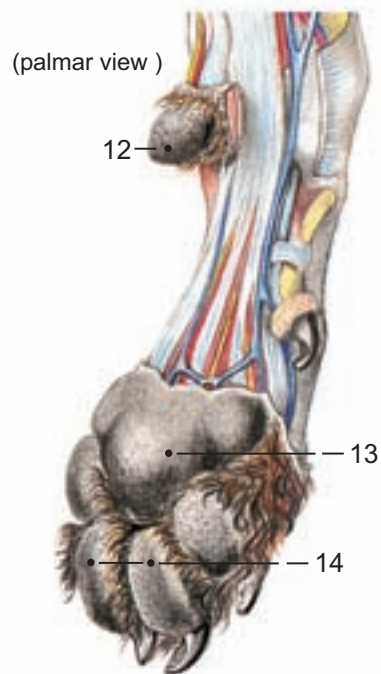
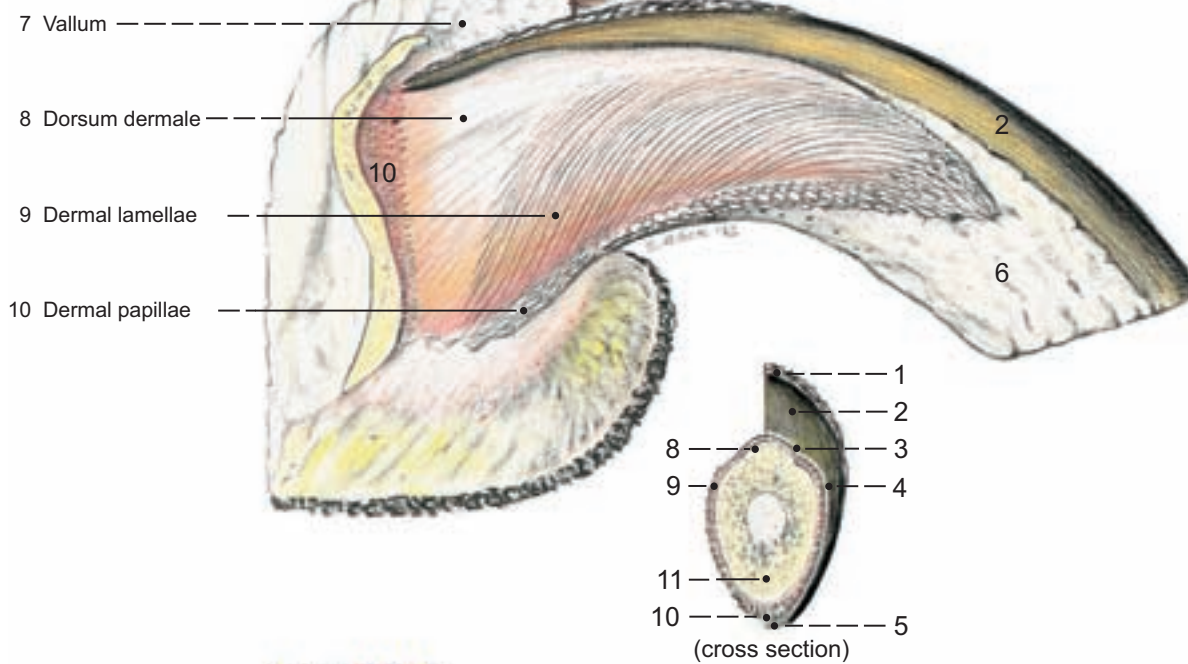
Around the tip of the unguicular process there is present a soft **terminal horn (Hyponychium terminale, —6)** that fills out the distal part of the conical claw horn and serves thus as a 'filling' horn.

Claw and digital pad

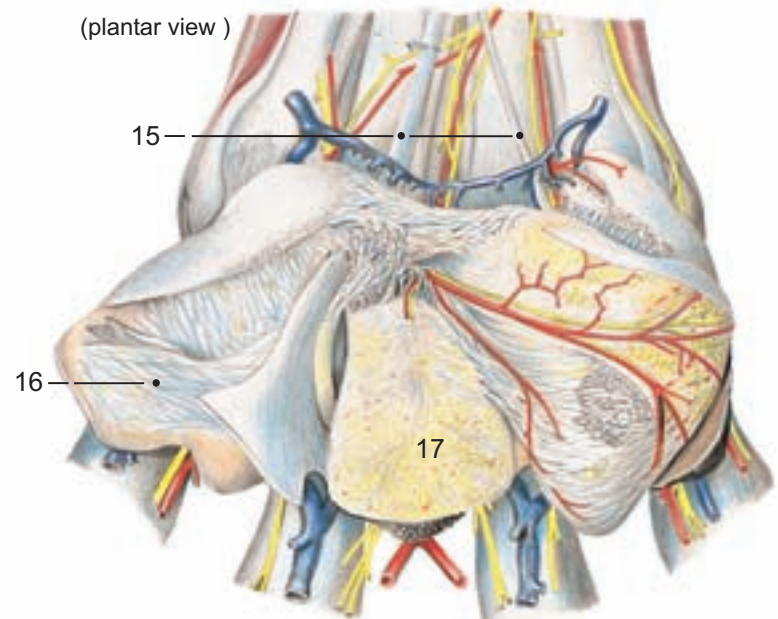
Epidermis:



Dermis [Corium]:



Digital pad



Metatarsal pad

Legend :

11 Unguicular process
 12 Carpal pad
 13 Metacarpal pad

14 Digital pads
 15 Tractus of metatarsal pad

Subcutaneous tissue of pad:
 16 Retinacula
 17 Panniculus adiposus (Fat pad)

(see pp. 19, 81, 83)

4. Vertebral Column and Thorax

The vertebrae are studied individually and on the mounted skeleton to obtain a total overview of the normal S-shaped curvature with its lordoses (ventral convexities) and kyphoses (ventral concavities). From a forensic view, particular attention is placed on the identification of individual vertebrae, for which reason comparison of the different segments of the vertebral column is done.

- 1 a) The **VERTEBRAL COLUMN** encloses and protects the spinal cord. It has a supporting function with respect to the statics and dynamics of the animal's body. For that, stability is assured by the individual vertebrae, and elasticity as well as pliability by the intervertebral symphyses and the vertebral joints.

The vertebral column consists of seven cervical vertebrae (vC 1 – 7), thirteen thoracic (vT 1 – 13), seven lumbar (vL 1 – 7), three sacral (vS 1 – 3), which are fused to form the sacrum, and about twenty caudal (coccygeal) vertebrae (vCy 1 – 20).

- 2 I. The **vertebrae** (see text-illustration) consist of three basic constituents: body and its parts, arch and processes, that are modified in different ways according to the functional requirements of the particular region.
- 3 The **body of the vertebra** (1) has a **ventral crest** (2), (distinct in the region of the cervical vertebral column) and **cranial** (3) and **caudal** (4) extremities. On the thoracic vertebrae, both the **caudal** (5) and **cranial costal foveae** (6) form a common articular facet for the head (*Capitulum*) of the rib (see below). The **vertebral foramen** (7) is the space enclosed by the body and arch. The vertebral canal is formed by the serial vertebral foramina and the soft tissues extending between adjacent vertebral arches and bodies. It contains the spinal cord with its cauda equina.
- 5 The **arch of the vertebra** (8) is made up of a pedicle basally and a flattened lamina dorsally. The **intervertebral foramina** (9) are bounded by the **cranial** (10) and **caudal** (11) vertebral notches of the vertebra of the same and preceding segments. Excepting the first cervical nerve (see below), these foramina are passages for the spinal nerves.

Of the processes of the vertebrae, the **spinous process** (12) is most distinct (exceptions are the first cervical vertebra and the caudal vertebrae). The **transverse processes** (13) are well developed on the cervical and lumbar vertebrae. On the thoracic vertebrae, they have a **costal fovea** (14) that bears an articular facet for the costal tubercle (see below). From the first to the sixth cervical vertebrae there are **transverse foramina** (15) at the base of the transverse processes, which altogether form the transverse canal that transmits the vertebral artery, vein and nerve. The **cranial articular processes** (16) and the **caudal articular processes** (17) form synovial joints between the vertebrae. A **costal process** (18) is present on the 3rd – 6th cervical vertebrae as the ventrocranial extremity of the transverse process, which is bifurcate in this region. In the lumbar vertebral column the ends of the transverse processes represent costal processes that are remnants of the ribs, and can develop to form lumbar 'ribs.' An **accessory process** (19) is lacking or poorly developed in the caudal part of the lumbar vertebral column. In the cranial lumbar region it is developed as an independent process. At the transition to the thoracic vertebral column, it passes onto the caudal contour of the transverse process and no longer stands independently. The **mamillary process** (20) of the lumbar vertebrae is expressed on the cranial articular process (mamiloarticular process) and changes its position at the transition to the thoracic vertebral column, passing onto the transverse process, actually to the cranial contour of the transverse process.

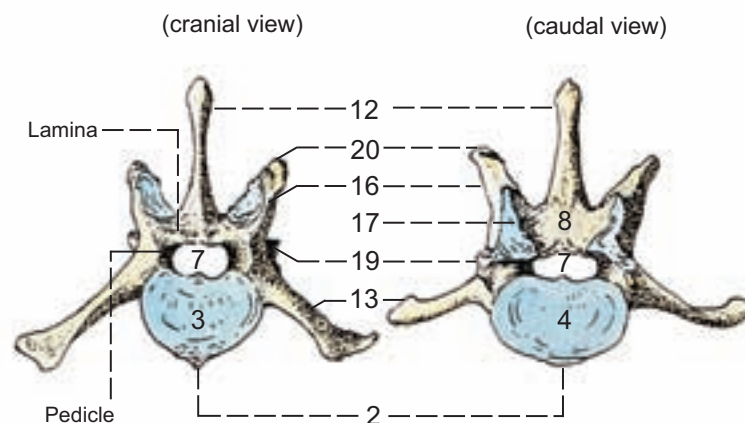
7 **Hemal processes** (21) are developed from the 4th caudal vertebra and become gradually indistinct caudally. On the 4th to the 7th or 8th caudal vertebra, they may unite to form a **hemal arch** (22).

The interarcuate spaces are dorsal and, in life, closed off by the interarcuate ligaments. The **lumbosacral space** (23) and the **sacrococcygeal (sacro-caudal) space** (24) are especially wide and of significance in performing epidural anesthesia. The atlanto-occipital space is suitable for tapping the subarachnoid space, which is filled with cerebrospinal fluid.

Special features are present on the following cervical vertebrae: The **first cervical vertebra** (atlas, —25) has a broad-surfaced **lateral process** (26), also designated the wing of the atlas (*Ala atlantis*). The **alar notch** (27) (alar foramen of other domestic mammals) is cranial at the attachment of the wing of the atlas to the lateral mass (see below) and is occupied by the ventral branch of the first cervical nerve. Contrary to the other spinal nerves, the first cervical nerve does not exit the vertebral canal by an intervertebral foramen but by the **lateral vertebral foramen** (28). The vertebral foramen of the atlas is also different in that it is bounded dorsally by a **dorsal arch** (29), ventrally by a **ventral arch** (30). The two arches are joined laterally by bone designated the lateral mass (*Massa lateralis*). The atlas is the only vertebra to have a ventral arch (30) in the place of the body. This is due to the caudal shift of a great part of the embryonal primordium of its vertebral body to form the dens of the axis. The **second cervical vertebra**, the axis

(31), for this reason contains in its **dens** (32) the displaced part of the body of the atlas. The last cervical vertebra differs from the other cervical vertebra by its large spinous process, its caudal costal foveae for the first ribs and by the absence of the transverse foramen.

Lumbar vertebra

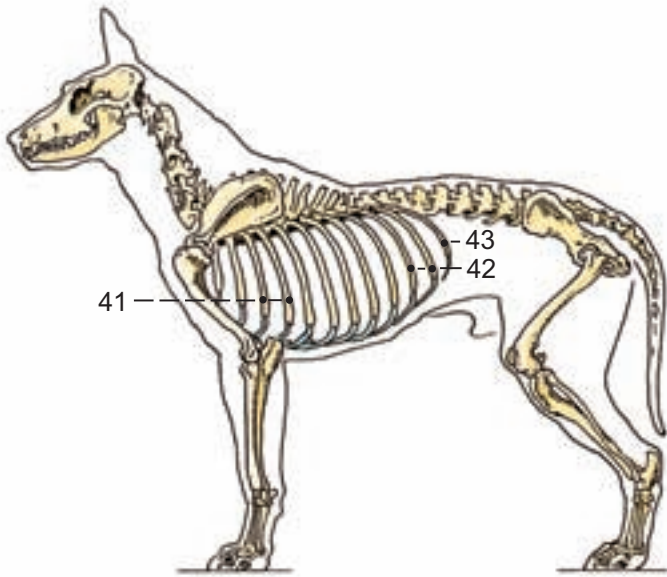


II. The **sacrum** is formed by the fusion of the three sacral vertebrae. Laterally, it bears the **sacral wing** (33), whose **auricular surface** (34) forms a synovial joint with the auricular surface of the ilium. The **median sacral crest** (35) is formed by an incomplete fusion of the spinous processes. The lateral ends of the fused lateral (transverse) processes form the **lateral sacral crest** (36). The **intermediate sacral crest** (37) results from the sequential arrangement of the fused mamilloarticular processes. The **promontory** (38) forms the cranioventral contour of the sacral bone and takes part in the limiting terminal line of the pelvic inlet. From the vertebral canal, the sacral nerves enter intervertebral foramina and leave the vertebral column after dividing into dorsal and ventral branches that emerge from the **dorsal** (39) and **ventral sacral foramina** (40), respectively, that proceed from each intervertebral foramen.

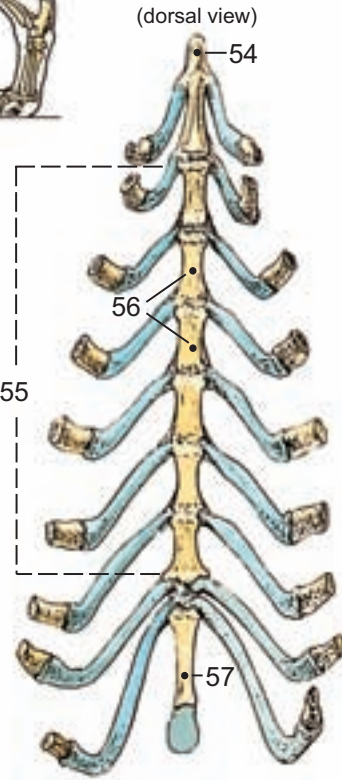
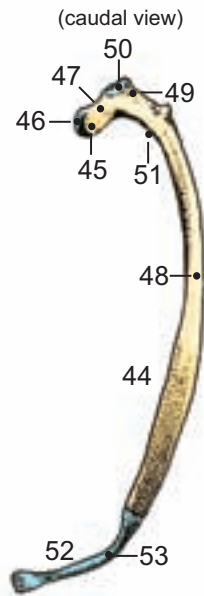
b) Of the 13 **RIBS (COSTAE)**, the first through the ninth are **sternal ribs** (41), connected to the sternum by synovial articulation. Ribs 10 – 12 are the freely moveable, 'breathing' **asternal ribs** (42). By the overlapping of the cartilaginous parts of the asternal ribs, a costal arch is formed on both sides of the body. The last rib does not regularly participate in the formation of the arch. It usually terminates freely in the musculature of the abdominal wall as a 'floating' **rib** (43). Ribs, sternum and thoracic vertebral column form the thorax, the inlet of which is bounded by the first pair of ribs and the outlet by the costal arches. The dorsal part of the rib is osseous (*Os costae*, —44). Its **head** (45) bears cranial and caudal **articular facets** (46). The two articular facets are separated by a rough crest that, in most ribs, is indirectly in contact with the intervertebral disc by means of the intercapitulum ligament (see illustration, p. 11). An indistinct **neck of the rib** (47) connects the head to the **body of the rib** (48). The proximodorsally located **costal tubercle** (49) bears an **articular surface** (50) for articulation with the costal fovea of the transverse process. The **angle of the rib** (51) is only indistinctly recognizable. The **costal cartilage** (52) begins at the costochondral junction and, slightly distal to this, there is a distinct bend, the **knee of the rib** (53) that in other domestic mammals is in the area of the costochondral junction.

c) The **STERNUM** consists of the **manubrium** (54), the **body of the sternum** (55) with its six **sternbrae** (56), and the **xiphoid process** (57), which is bony cranially, cartilaginous caudally. The first pair of ribs articulates with the manubrium, the second at the synchondrosis that joins the manubrium to the body of the sternum, the third through the seventh at the following sternal synchondroses, and the eighth and ninth jointly at the synchondrosis joining the body to the xiphoid process.

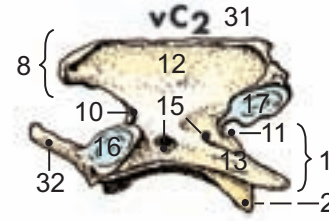
Vertebral column and bones of thorax



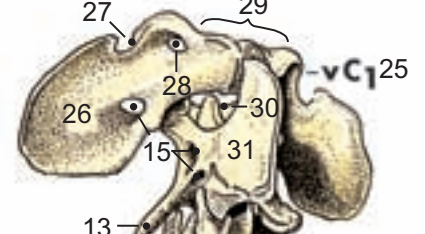
- Cervical vertebrae vC₁₋₇
- Thoracic vertebrae vT₁₋₁₃
- Lumbar vertebrae vL₁₋₇
- Sacral vertebrae vS₁₋₃
- Coccygeal vertebrae vCy_{1-x}
- Body of vertebra (1)
- Ventral crest (2)
- Cranial extremity (3)
- Caudal extremity (4)
- Caudal costal fovea (5)
- Cranial costal fovea (6)
- Vertebral canal (7)
- Vertebral arch (8)
- Intervertebral foramen (9)
- Cranial vertebral notch (10)
- Caudal vertebral notch (11)
- Spinous process (12)
- Transverse process (13)
- Costal fovea (14)
- Transverse foramen (15)
- Cranial articular process (16)
- Caudal articular process (17)
- Costal process (18)
- Accessory process (19)
- Mamillary process (20)
- Hemal process (21)
- Hemal arch (22)
- Intercuate space
- Lumbosacral space (23)
- Sacrococcygeal space (24)



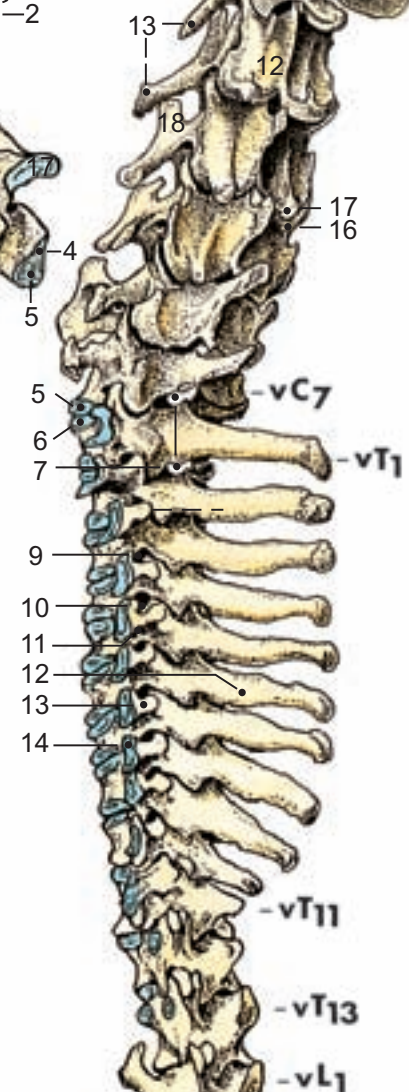
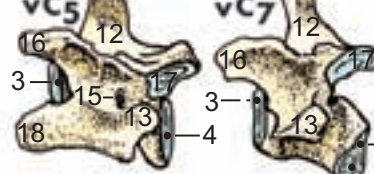
(lateral view)



(dorsolateral view)



(dorsal view)



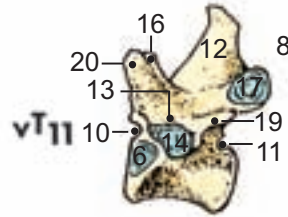
- Atlas vC₁** (25)
- Transverse process [wing] (26)
- Alar notch (27)
- Lateral vertebral foramen (28)
- Dorsal arch (29)
- Ventral arch (30)

- Axis (31)**
- Dens (32)

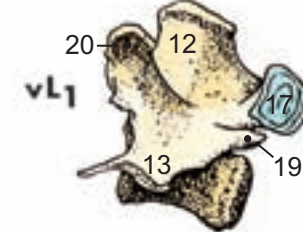
- Os sacrum vS₁₋₃**
- Sacral wing (33)
- Auricular surface (34)
- Median sacral crest (35)
- Lateral sacral crest (36)
- Intermediate sacral crest (37)
- Promontory (38)
- Dorsal sacral foramen (39)
- Ventral sacral foramen (40)

- Ribs**
- Sternal ribs (41)
- Asternal ribs (42)
- Floating rib (43)
- Bony rib (44)
- Head of rib (45)
- Articular facets of head of rib (46)
- Neck of rib (47)
- Body of rib (48)
- Tubercle of rib (49)
- Articular surface of tubercle of rib (50)
- Angle of rib (51)
- Costal cartilage (52)
- Knee of rib (53)

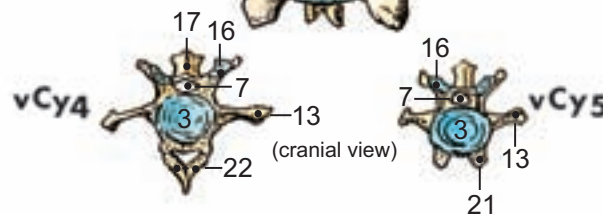
- Sternum**
- Manubrium of sternum (54)
- Body of sternum (55)
- Sternebrae (56)
- Xiphoid process (57)



(lateral view)



(ventral view)



(cranial view)

5. Articulations of the Vertebral Column and of the Thorax; Atlanto-Occipital and Atlanto-Axial Joints

a) JOINTS (ARTICULATIONS)

Name	Participating bones	Form/ Composition	Function	Remarks
I. Atlanto-occipital joint	Occipital condyles and cranial articular foveae of the atlas	Elliptical joint, simple joint	Hinge joint, dorsal and ventral flexion	Right and left joint cavities communicate ventrally.
1 II. Atlanto-axial joint	Fovea of the dens and caudal articular fossa of the atlas, dens and ventral articular surface of the dens	Trochoid joint, simple joint	Axial rotation of the head on the neck, head 'shaking'	The atlanto-axial joint communicates with the atlanto-occipital joint.
III. Joints of the articular processes	Articular processes of adjacent vertebrae	Plane joints	Sliding joints	Considerable mobility in the cervical region, decreasing in the thoracic and lumbar regions.
IV. Joint of the head of the rib (costovertebral joint)	Articular surface of the head of the rib and caudal costal fovea of the more cranial vertebra and cranial costal fovea of the more caudal vertebra with which the rib head articulates	Spheroid joint, composite joint	Hinge joint that, together with the vertebrae, makes possible the variation in thoracic volume in respiration	The convex rib-head joint surface is formed by two articular facets. The articular depression is formed by the costal foveae of the two vertebral bodies and the intervening fibrocartilage of the intervertebral symphysis. The last two to three ribs articulate only with the cranial costal fovea of the same-numbered (the more caudal) vertebra.
V. Joint of the rib tubercle (costotransverse joint)	Articular surface of the costal tubercle and the costal fovea of the transverse process of the same numbered (the more caudal) vertebra	Plane joint, simple joint	Hinge joint	On the last ribs, the costotransverse joint approaches and then fuses with the costovertebral joint.
VI. Sternocostal joint	Cartilaginous ends of the first to the eighth ribs and the sternum	Condylar joint, simple joint	Hinge joint	The first rib articulates with the manubrium of the sternum. The ninth (last sternal) rib is not connected to the sternum by a synovial joint but by fibrous tissue.
VII. Costochondral synchondrosis	Costal bone and costal cartilage	Synchondrosis	Nearly rigid and immoveable	Postnatally a true joint may develop from a synchondrosis.
VIII. Sternal synchondroses	Manubrium of the sternum, sternbrae of the body of the sternum, xiphoid process	Synchondrosis	Increasingly rigid and immoveable	Of the sternal synchondroses, the manubriosternal and xiphosternal synchondroses are specially named.
2 IX. Intervertebral symphysis (joints between the bodies of adjacent vertebrae)	Bodies of adjacent vertebrae, starting with the axis and including the caudal vertebrae	Intervertebral disc without a space	Slight mobility	The discs in the intervertebral region of the sacrum ossify in the second year of life.
X. Sacroiliac joint	See joints of the pelvic limb.			

b) LIGAMENTS OF THE VERTEBRAL COLUMN

Three ligaments extend over longer areas of the vertebral column. Short ligaments bridge over the space between individual vertebrae.

3 The **ventral longitudinal ligament** is attached ventrally to the bodies of the vertebrae and to the intervertebral discs. It extends from the second cervical vertebra to the sacrum.

The **dorsal longitudinal ligament** lies on the floor of the vertebral canal and attaches at the dorsal border of the intervertebral disc. It extends from the axis to the first caudal vertebrae.

The **nuchal ligament** (see p. 29) in the dog consists only of the paired elastic **funiculus nuchae**. It bridges over the cervical vertebral column from the caudal end of the spinous process of the axis and extends to the spinous process of the first thoracic vertebra. Here it is continued by the **supraspinous ligament** with loss of elasticity and attaches to the spinous process of all the vertebrae up to the third sacral vertebra.

The **ligamenta flava** extend as short elastic ligaments from vertebral arch to vertebral arch and thus close the interarcuate spaces dorsally.

Interspinous ligaments are lacking. The **M. interspinalis** lies between the spinous processes of adjacent vertebrae.

c) LIGAMENTS OF THE ATLANTO-OCCIPITAL AND ATLANTO-AXIAL JOINTS, AND OF THE THORAX

At the atlanto-occipital joint, the **dorsal atlanto-occipital membrane** reinforces the joint capsule and bridges over the atlanto-occipital space (access to the cerebellomedullar cistern for withdrawal of cerebrospinal fluid for

diagnostic purposes). The **ventral atlanto-occipital membrane** is a ventral reinforcement of the joint capsule. The **lateral ligament** is a lateral reinforcement of the joint capsule.

On the **atlanto-axial joint** the dens is held to the floor of the vertebral canal and to the occipital bone by the **apical ligament of the dens**, the **transverse atlantal ligament** and the **alar ligaments**. The transverse atlantal ligament is underlain by a synovial bursa and is attached to either side of the atlas. In the case of rupture of these ligaments or fracture of the dens following car accidents or strangulation, damage to the spinal cord may occur with paralysis and death as consequences. The elastic **dorsal atlanto-axial membrane** extends from the cranial projection of the spine of the axis to the dorsal arch of the atlas.

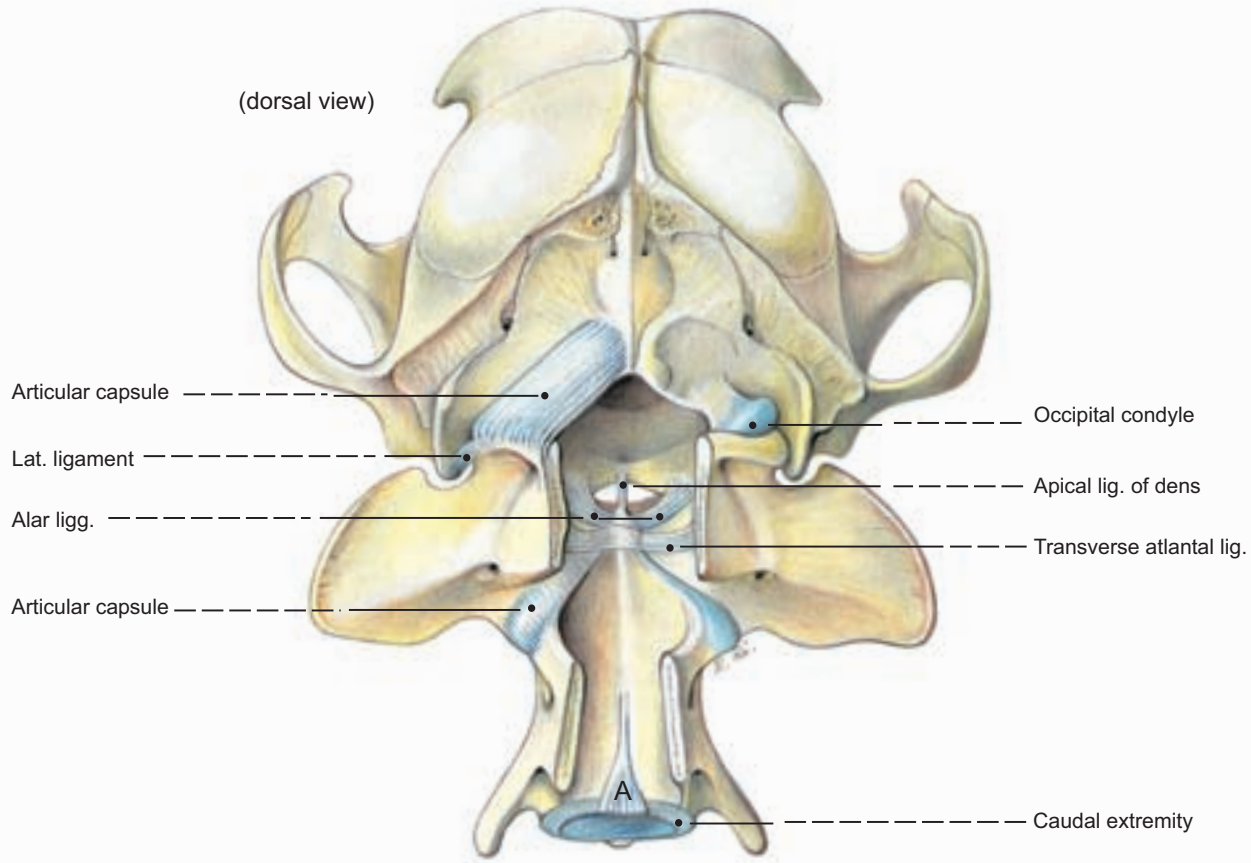
The **joints between the articular processes** of the vertebrae lack ligaments. The joint capsule is either tightly attached or more loose according to the degree of movement and influences the direction of the movement, which depends on the position of the articular surfaces.

At the **joint of the rib-head**, the **intra-articular ligament of the head of the rib** connects the costal heads of both sides and lies over the intervertebral disc. It is also called the **intercapital ligament**. It is lacking at the first and the last two pairs of ribs. The **radiate ligament of the head of the rib** is present as a strengthening of the joint capsule.

At the **costotransverse joints**, the joint capsule is reinforced by a **costotransverse ligament**.

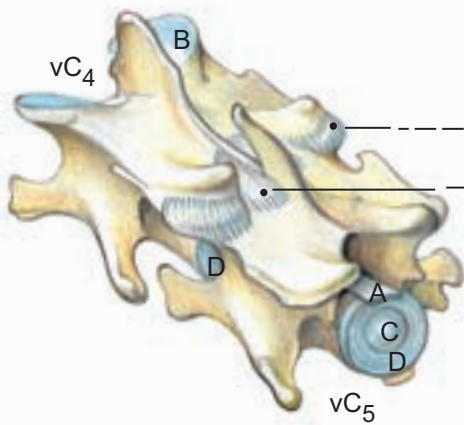
Joints of the vertebral column and the thorax

(dorsal view)



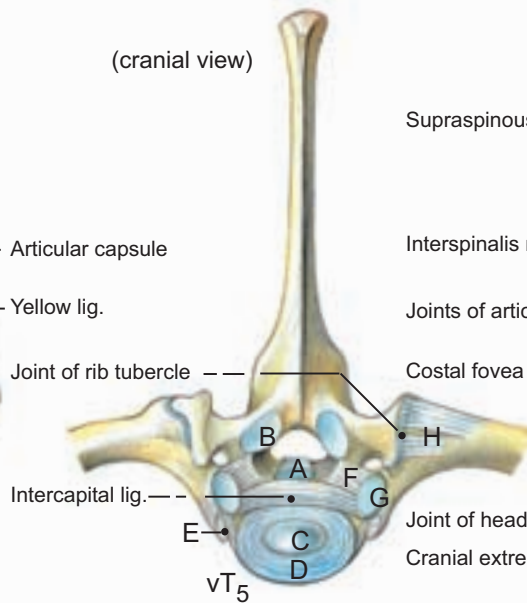
Atlanto-occipital and atlanto-axial joints

(caudolat. view)

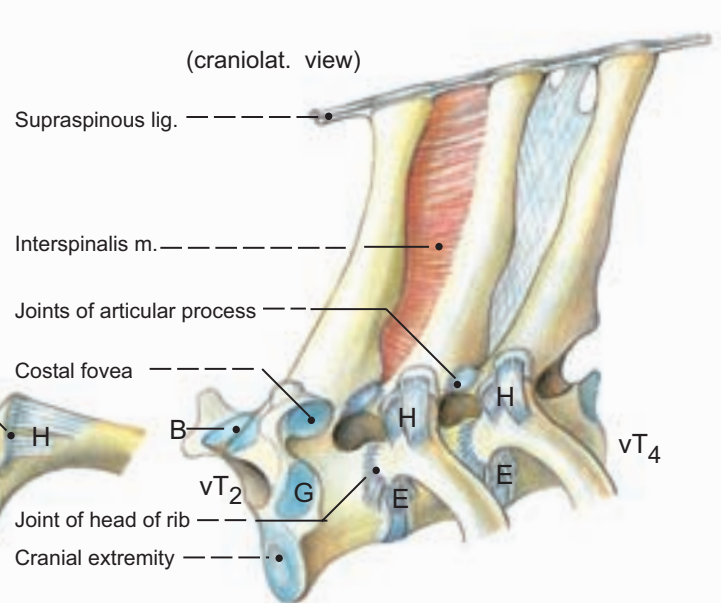


Joint of articular process

(cranial view)

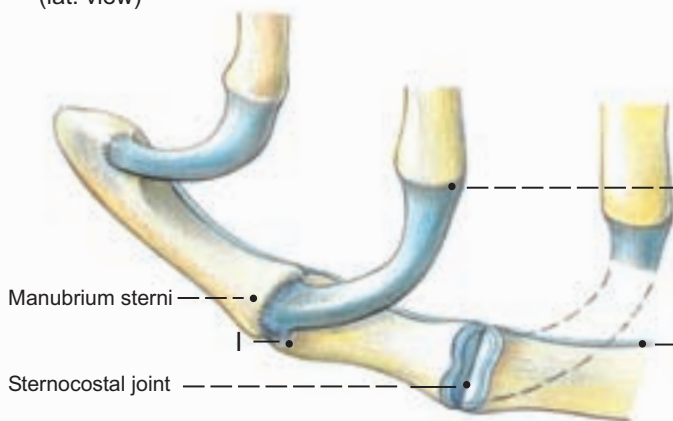


(craniolat. view)



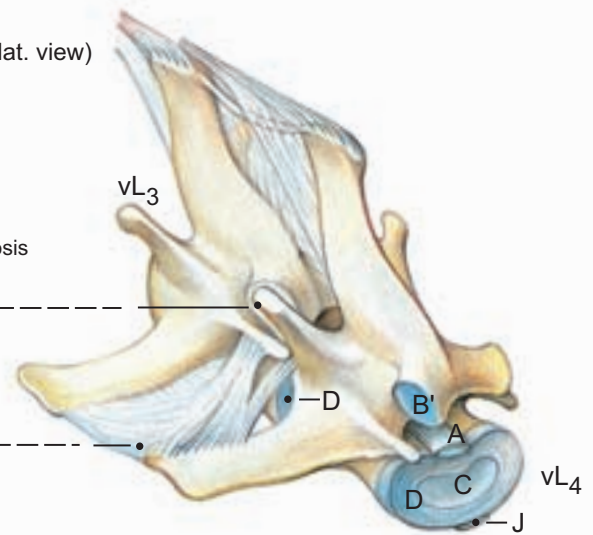
Costovertebral joints

(lat. view)



Sternocostal joints and sternal synchondroses

(caudolat. view)



Intervertebral symphysis

Legend :

- | | | | |
|----------------------------|----------------------|---------------------------------------|-----------------------------|
| A Dorsal longitudinal lig. | Intervertebral disc: | E Radiate lig. of head of rib | H Costotransverse lig. |
| B Cran. articular process | C Nucleus pulposus | F Intra-articular lig. of head of rib | I Radiate sternocostal lig. |
| B' Caud. articular process | D Anulus fibrosus | G Cran. costal fovea | J Ventral longitudinal lig. |

(see pp. 9, 89, 91)

Index

3D-models 177

A

Abdomen 50
Abdominal aorta 60
Abdominal cavity 50
Abdominal muscles 34, 185
Abdominal organs 50
Abdominal ostium of the uterine tube 66
Abdominal tendon 34
Abdominal wall 28
Absorption 166
Accessory carpal bone 16
Accessory glands 158
Accessory pancreatic duct 54
Accessory lobar bronchus 38
Acetabulum 74
Acinar glands 158
Acoustic impedance 166
Acromion 16, 183
Adenohypophysis 152, 203
Adipose capsule 62
Adrenal cortex 152
Adrenal glands 70, 152, 194, 210
Adrenal medulla 152
Adrenal plexus 60
Adventitia 154
Afferent fibers 150
Afferent lymphatic vessels 156
Afferent neurons 108, 150
Ala nasi 98
Alar canal 88
Alar fold 100
Alar ligament 10
Alar notch 8
Alar spine 74
Alveolar canals 88
Alveolar glands 158
Alveolar juga 88
Alveolar margin 90
Alveolar process 90
Ammon's horn 114
Ammonic horn 203
Amphiarthrosis 144
Ampulla
 of the ductus deferens 68
 of the uterine tube 66
Ampullary crests 120
Amygdaloid body 112
Anal sacs 190
Anatomic diameter 146
Anconeal process 16, 183
Anesthesia of the eye 198
Angle of the mandible 90
Angular process 90
Angulation of the joint 122
Antebrachial fascia 184
Antebrachial muscles 22
Antebrachium 16
Anterior chamber of the eye 118
Annular cartilage 102, 120
Anuli fibrosi 46
Anulus osseus perichondralis 140
Aorta 185
Aortic arch 40
Aortic plexus 60
Aortic valve 44, 188
Apex of the nose 98
Apex pulmonis 38
Apical foramen 104
Apical ligament of the dens 10
Apocrine glands 158
Aponeuroses 148
Apophyses 140
Arachnoidea 108, 110
Arbor vitae 110
Archipallium 112
Arcuate line 74
Arcus veli palatini 100
Artery (ies), Arteria (ae), Vessels
 arcuate 62
 axillary 24
 basilar 114
 bicipital 24
 brachial 24
 broncho-esophageal 40
 caudal auricular 102
 caudal circumflex humeral 24

 caudal deep temporal 102
 caudal epigastric 70
 caudal gluteal 70, 84
 caudal mesenteric 56, 60
 caudal pancreaticoduodenal 56
 caudal rectal 72
 caudal superficial epigastric 32, 36
 caudal vesical 70
 cecal 56
 celiac 56, 60
 collateral ulnar 24
 common carotid 14, 102
 common interosseous 24
 coronariae 46
 cranial abdominal 60
 cranial circumflex humeral 24
 cranial epigastric 40
 cranial gluteal 70, 84
 cranial laryngeal 102
 cranial mesenteric 56, 60
 cranial pancreaticoduodenal 56
 cranial rectal 56
 cranial superficial epigastric 40
 cranial tibial 84
 deep brachial 24
 deep circumflex iliac 60
 deep femoral 70, 84
 descending genual 84
 distal caudal femoral 84
 dorsal pedal 84
 dorsal perineal 70, 72
 ductus deferens 68
 external carotid 102
 external iliac 60, 70, 84
 external ophthalmic 102
 external pudendal 32, 36, 70
 external thoracic 24
 facial 92, 102
 femoral 84
 gastricae breves 56
 gastroduodenal 56
 greater palatine 102
 hepatic 56, 58
 ileal 56
 ileocolic 56
 iliolumbar 70
 inferior alveolar 102
 infraorbital 102
 intercostal 40
 interlobar 62
 internal carotid 102, 114
 internal iliac 60, 70
 internal pudendal 70, 72
 internal thoracic 32, 40
 jejunal 56
 lateral circumflex femoral 84
 lateral coccygeal 70
 lateral plantar 84
 lateral thoracic 24, 32
 left colic 56
 left common carotid 40
 left gastric 56
 left gastroepiploic 56
 left subclavian 40
 lesser palatine 102
 lienal 56
 lingual 102
 maxillary 102
 medial plantar 84
 median 24
 median sacral 70
 middle caudal femoral 84
 middle colic 56
 middle rectal 70
 occipital 102
 of the brain 203
 of the clitoris 72
 of the penis 72
 ovarian 60, 66, 70
 popliteal 84
 prostatic 70
 proximal caudal femoral 84
 radial 24
 renal 60, 62
 right colic 56
 right common carotid 40
 right gastric 56
 right gastroepiploic 56
 right subclavian 40

 rostral auricular 102
 rostral deep temporal 102
 rostral hypophysial 152
 saphenous 80, 84
 short gastric 56
 sphenopalatine 102
 splenic 56
 sublingual 102
 subscapular 24
 superficial bacial 24
 superficial cervical 40
 superficial circumflex iliac 84
 superficial epigastric 32
 superficial temporal 102
 testicular 68
 thoracodorsal 24
 transverse cubital 24
 ulnar 24
 uterine 66, 70
 vaginal 70
 ventral spinal 108
 ventral labial 32
 ventral perineal 72
 ventral scrotal 32
 vertebral 40, 114
Arterial rete mirabile 154
Arterioles 154
Arteriovenous anastomoses 4, 154
Arthrology 144
Articular surface 8, 16, 76, 88
Articular capsule 144
Articular cartilage 142, 144, 208
Articular cavity 144
Articular circumference 16
Articular disc 144
Articular facets 8
Articular menisci 144
Articular processes, joints of the 10
Articulations 10
Atresia of the anus, rectum and both 190
Arytenoid cartilage 100
Atlanto-axial joint 10
Atlantoaxial membrane 10
Atlanto-occipital joint 10
Atlanto-occipital membrane 10
Atlas 8
Atrioventricular bundle 46
Atrioventricular node 46
Atrioventricular ostium 44
Atrioventricular valves 46
Auditory ossicles 120
 pathway 114
 tube 100, 120, 200
Auricle 120
Auricular cartilage 102
Auricular concha 205
Auricular muscles 94, 120, 131
Auricular surface 8, 74
Auris 120
Autonomic ganglia 150
Autonomic nervous system 48, 60, 102, 150, 188
Auxillary structures of muscles 148
Axis 8
Axon 150

B

Ball-and-socket joint 144
Bands, connective tissue 6
Basal cells 122
Basal fold 100
Basal layer 4
Basal nuclei 112, 203
Basihyoid 88
Basilar sinus 116
Basis pulmonalis 38
Basis stapedis 120
Basisphenoid bone 88
Biaxial joint 144
Bicipitoradial bursa 26
Bicuspid valve 44, 46, 187
Bifurcation of the trachea 38
Bipennate muscle 146
Bladder, round ligament 70
Blind part of the retina 118
Blind spot 118
Blocking arteries 154
Blood capillaries 158

Blood sinus 4
Blood supply 4
Blood vessels 32, 40, 148, 154, 207
Body
 of the femur 76
 of the humerus 16
 of the mandible 90
 of the radius 16
 of the tibia 76
 of the ulna 16
Body regions 2
Body wall 32
Bone forming cells 140
Bone marrow 142
Bone shape 208
Bone tissue 142
Bones of the crus 76
Bones of the digit 16
Bony pelvis girdle 74
Brachial plexus 183
Brachiocephalic trunk 40
Brain 110
Brain stem 112, 203
Bronchi 38, 185
Bulb of the eye 118
Bulb of the glans 68
Bulb of the penis 68
Bulbus oculi 118
Bulla tympanica 88
Bursae 208

C

Calcaneal cap 82, 196
Calcaneus 76
Cambium 142
Canal of the n. trigeminal 90
Canal of the transverse sinus 90
Canales perforantes 142
Canaliculus of the chorda tympani 88, 90
Canine tooth 104, 201
Capillaries 154
Capillary rete 152
Cardiac conduction system 46
Cardiac heart musculature 146
Cardiac nerves 46, 48
Cardiac skeleton 46
Cardiac veins 46
Cardiovascular system 154
Carnassial teeth 202
Carotid crest 88
Carotid sinus 102
Carpal bones 16
Carpal joint 26, 184
Cartilage 208
Cartilage of the acoustic meatus 120
Cartilage tissue 142
Cartilaginous joints 144
Cartilaginous matrix 140
Cartilaginous part 120
Caruncula sublingualis 104
Cataract of the lens 205
Categorizing structures on the sonograph 167
Cauda equina 108
Caudal abdominal region 50
Caudal alar foramen 88
Caudal carotid foramen 88
Caudal cerebellar peduncle 114
Caudal colliculus 110, 114
Caudal constrictors of the pharynx 102
Caudal leg (crural) muscles 82
Caudal crus 120
Caudal dorsal iliac spine 74
Caudal fossa of the cranium 90
Caudal gluteal line 74
Caudal gubernaculum 64
Caudal leg (crural) muscles 130
Caudal lobar bronchus 38
Caudal omental recess 52
Caudal palatine foramen 88
Caudal pharyngeal constrictors 133
Caudal thigh "hamstring" muscles 129
Caudal vena cava 60
Caudal ventral iliac spine 74
Caudal vertebral column 181
Caudate nucleus 112, 114
Caudomedial muscles of the forearm 22, 125

- Caudovernal (basal) border 38
Cavernous body of the glans 68
Cavernous sinuses 116
Cavity of the larynx 100
Cavum oris 158
Cavum thoracis 42
Cecocolic ostium 56
Cecum 56
Celiac ganglion 108
Celiacomesenteric plexus 150
Cementum 104
Central canal 108, 116, 142
Central nervous system 108, 150
Central tarsal bone 76
Central tendon 148
Cephalic and spinal meninges 203
Ceratohyoid 88
Cerebellar cortex 110
Cerebellar fossa 90
Cerebellomedullary cistern 108, 110, 203
Cerebellum 110, 203
Cerebral arterial circle 114
Cerebral cortex 112
Cerebral gyri 112
Cerebral hemispheres 110, 112
Cerebral meninges 110
Cerebral peduncle 110
Cerebral sinuses 204
Cerebral sulci 112
Cerebral veins 116
Cerebral ventricles 116
Cerebrospinal fluid 116, 204
Cerebrum 112, 203
Ceruminous glands of the ear 180
Cervical canal 66
Cervical enlargement 108
Cervical region 12
Cervical visceral structures 14
Cervicothoracic (stellate) ganglion 48, 188
Cervix of the uterus 66, 193
Cervix vesicae 64
Cheek tooth 201
Chest region 12
Chiasmatic sulcus 90
Choanae 88
Chondral ossification 140
Chondroclastic activity 206
Chondroclasts 140
Chorda tympani 88
Chordae tendineae 44, 46
Choroid 118
Choroid plexuses 114, 116
Ciliary body 118
Ciliary ganglion 98
Ciliary processes 118
Cingulum membri pelvini 74
Circular folds 158
Circumanal glands 180, 190
Cisterna chyli 52
Clastrum 112
Clavicular intersection 14
Claw 6, 180
Clitoris 66, 193
Club-shaped corpuscles 122
Coccygeus and levator ani muscles 128
Cochlea 120
Cochlear joint 144
Coils of the small intestine 50
Collagen fibrils 146
Collagenous fibers 142
Collateral arteries 154
Colliculus seminalis 194
Colon 56, 190
Columnae uretericae 64
Columnar epithelium 158
Columnar pseudostratified epithelium 158
Commissural fibers of the fornix 112
Common bile duct 54
Common calcanean tendon 82, 196
Common dorsal mesentery 52
Common integument 4
Common nasal meatus 100
Common papillary duct 62
Compact bone substance 142
Complex joint 144
Composite joint 144
Composition 144, 158
Computed Tomography 176
Concha auriculae 120
Conduction pathways 114
Condylar canal 88
Condylar joint 144
Condylar process 90
Conical papillae 104
Conjugate diameter 74
Conjunctival valves 156
Connections of the bones 144
Connective tissue capsule 156
Connective tissue septa 68
Constriction of the trachea 182
Contraction of smooth muscles 209
Contrast media series 177
Conus arteriosus 44
Conus medullaris 108
Convolutated arteries 154
Coracoid process 16
Corium 4, 180
Cornea 118, 205
Corona ciliaris 118
Coronary arteries 46, 188
Coronary groove 44
Coronary vessels 46
Coronoid process 90
Corpora quadrigemina 110
Corpus callosum 110, 112
Corpus cavernosum penis 68
Corpus luteum 152
Corpus medullare 110
Corpus rigidum penis 68
Corpus spongiosum glandis 68
Corpus spongiosus penis 68
Corpus striatum 112
Corpus vesicae 64
Cortex of the ovary 66
Cortical areas 112
Cortical bone substance 142
Costae 8
Costal pleura 42, 186
Costal surface 16
Costocervical trunk 40
Costochondral synchondrosis 10
Costodiaphragmatic recess 42, 186
Costomediastinal recess 42
Costotransverse joints 10
Costotransverse ligaments 10
Cranial 2
Cranial abdominal region 50
Cranial border of the triangle 38
Cranial cavity 88, 90
Cranial dorsal iliac spine 74
Cranial gubernaculum 64
Cranial lobar bronchus 38
Cranial margin of the tibia 76
Cranial mesenteric ganglion 150
Cranial nerves 136, 150
Cranial nerves of the vagus group 102
Craniofacial and caudal tibial muscles 196
Craniofacial crural (leg) muscles 82
Craniofacial forearm muscles 22
Craniofacial leg (crural) muscles 130
Craniofacial muscles of the forearm 126
Cranium 88, 197
Crest of the greater tubercle 16
Crest of the lesser tubercle 16
Cricoaerthyenoid joint 106
Cricoid cartilage 100
Cricothyroid joint 106
Cricothyroid ligament 106
Cricotracheal ligament 106
Cross-section of the spinal cord 108
Cross-stration 146
Cross-striated skeletal musculature 146
Croup 84
Croup muscles 78, 129
Crown of the tooth 104
Crural interosseous space 76
Crus cerebri 110
Crus penis 68
Cubital joint 26
Cutaneous muscles 12, 148
Cutaneous nerves 12
Cutaneous pouch 120
Cystic duct 58
- D**
Deep antebrachial vessels 24
Deep digital flexor tendon 82
Deep inguinal ring 36
Deep muscles of the hip joint 78, 129
Deep pectoral muscle 14
Deep sensibility 122
Deep trunk fascia 32
Deferent duct 68, 158, 194
Deltoid tuberosity 16
Dendrites 150
Dens lupinus 104
Dental alveoli 88
Dental enamel 202
Denticulate ligaments 108
Dentin 104
Dentition 104
Dermal lamellae 6
Dermis 4
Descending aorta 40, 42
Descending duodenum 50, 190
Descent of the testes 192
Dewclaws 195
Diaphragm 30, 127
Diaphragma sellae 110
Diaphragmatic herniae 184
Diaphragmatic pleura 42
Diaphysal ossification center 140
Diaphysis 140
Diastema 104
Diencephalon 110
Digestive apparatus 158
Digital bones 76
Digital endorgans 6
Digital extensors 22
Dilator of the pharynx 102
Diploe 90
Discontinuous endothelium 154
Disc-shaped nerve endings 122
Distal infrapatellar bursa 86
Distal infrapatellar subtendinous bursa 144
Distal interphalangeal joints of the manus 26
Distal mesorchium 64
Distal phalanx 16, 76
Distal radioulnar joint 26
Distal sesamoid bones 16, 76
Distal tibiofibular joint 86
Dorsal arch 8
Dorsal border of the triangle 38
Dorsal buccal branch 92
Dorsal caudal (Tail) organ 6, 180
Dorsal extrinsic muscles of the limbs 12
Dorsal funiculus 108
Dorsal horn 108
Dorsal intermediate sulcus 108
Dorsal lateral sulcus 108
Dorsal longitudinal ligament 10
Dorsal margin 16
Dorsal mesogastrium 50, 52
Dorsal muscles connecting the trunk 124
Dorsal nasal concha 90
Dorsal nasal meatus 100
Dorsal nerve of the penis 72
Dorsal root 108, 150
Dorsal sacral foramina 8
Dorsal sagittal sinus 116
Dorsal sesamoid 16
Dorsal transverse diameter 74
Dorsal vaginal trunk 42, 48, 108
Dorsal vertebral muscles 126
- Dorsum**
dermale 6
linguae 104
nasi 98
of the manus 24
of the pes 84
of the tongue 104
- Ductus choledochus 54, 58
Ductus deferens 68
Duodenum 50, 54
Dura mater 108, 110, 202
- E**
Ear 120
Eccrine glands 158
Echography 166
Ectomeninx 108, 110
Ectoturbinate 90
Efferent lymphatic vessels 156
Efferent nerve fibers 150
Efferent neurons 108, 150
Elastic arteries 154
Elastic auricular cartilage 120
Elastic cartilage 142
Elbow joint 26, 184
Ellipsoid joint 144
Enamel 104
Enarthrosis 144
Encephalitis 203
Encephalography 204
Encephalon 110
End arteries 154
Endocardium 44, 187
Endochondral ossification 206
Endocrine (modified) myocardial cells 46
Endocrine glands 158
Endocrine system 152
Endolymph 120
Endolymphatic duct 120
Endomeninx 108
Endomysium 146
Endoneurium 150, 209
Endosteum 142, 207
Endothelial cells 156
Endothoracic fascia 32, 42
Endoturbinates 90
Epicardium 42, 44, 187
Epidermis 4, 180
Epididymal sinus 64
Epididymis 68, 194
Epidural anesthesia 202
Epiglottic cartilage 100
Epihyoid 88
Epimysium 146
Epineurium 150, 209
Epiphyseal growth plate 206
Epiphysal ossification center 140
Epiphysis 110, 114, 140, 203
Epiphysis cerebri 152
Epiploic foramen 52
Epiplöon 52
Epithalamus 110
Epitympanicum 120
Eponychium 6
Erectile body 68
Erection 194
Eruption 104
Esophageal impression 58
Esophagus 14, 42, 54, 182
Ethmoid bone 88, 90
Ethmoidal foramina 88
Ethmoidal fossae 90
Exocrine glands 158
Expiratory muscles 30, 127, 184
Extensor groove 76
Extensor process 16, 76
Extensors of the carpal joint 22
External acoustic meatus 102, 120
External acoustic pore 88
External auditory canal 205
External auditory meatus 200
External carotid foramen 88
External circumferential lamellae 142
External ear 120
External fascia of the trunk 32, 36
External front crest 88
External genital organs 66, 68
External iliac fascia 36
External inguinal ring 34, 36
External jugular vein 182
External lamina 90
External muscles of mastication 94, 132
External nasal region 98
External nose 98
External occipital protuberance 88
External perimysium 146
External sagittal crest 88
External spermatic fascia 32, 36
External tunic 154
External urethral ostium 66, 68
External uterine ostium 66
Extrapyramidal system 114
Extrinsic muscles of the tongue 133
Eye 118
Eye muscles 98
- F**
Face 88
Facial bones 90
Facial canal 90
Facial muscles 94
Facial paralysis 198
Facies aspera 76
Facies auricularis 74
Facies serrata 16

- Falciform ligament 50, 52, 58
False joint 208
Falx cerebri 110
Fascia 146, 148
Fascia lata 32
Fascial and muscular suspensory apparatus 32
Fasciculus cuneatus 108, 114
Fasciculus gracilis 108, 114
Female genital organs 66
Femine urethra 66
Femoral bone 76
Femoral canal 36, 80
Femoral muscles 130
Femoral ring 36, 185
Femoral space 36, 80
Femoral trigone 36
Femoral trochlea 76
Fenestrated endothelial cells 154
Fiber-tracts 114
Fibrae reflexae 34
Fibrocartilaginous discs 144
Fibrous capsule 62
Fibrous joints 144
Fibrous layer 144, 148, 150
Fibrous pericardium 42
Fibrous rings 46
Fibrous tunic 118
Fibular articular surface 76
Field of the lung 185
Fila olfactoria 114
Filiform papillae 104
Filum terminale 108
Fixation fibers 156
Flat bones 142
Flexor retinaculum 82
Flexor tubercle 16, 76
Flexor tuberosity 16, 76
Fold of the deferent duct 64
Foliate papillae 104, 122
Foot 84
Foot plate 120
Foramen magnum 88
Foramen ovale 88
Foramen rotundum 88
Foramen venae cavae 30
Forearm muscles 22
Form of muscles 146, 148
Form of the joint 144
Form of the lungs 38
Form of the secretory end-pieces 158
Fornix 112
Fossa of the lacrimal sac 90
Fossa ovalis 44, 187
Fourth ventricle 116
Fovea capitis 76
Fractures of the olecranon 183
Frenulum 104
Frontal bone 88
Frontal lobe 112
Frontal process 90
Frontal sinuses 88
Fundus nasi 100
Fungiform papillae 104, 122
Funiculus nuchae 10
Funiculus spermaticus 64
- G**
Galea calcanea 82
Gall bladder 50, 58, 191
Ganglia 48
Ganglia of the sympathetic nerve trunk 150
Ganglion
caudal mesenteric 60
celiac 60
cranial cervical 102
cranial mesenteric 60
Gaster 54
Gastric mucous membrane 54, 189
Gastrointestinal endocrine cells 152
Gastrolial ligament 52
Gastrosplenic ligament 52
Gastrotomy 190
Genital organs 62, 64, 68
Genu costae 30
Genu joint 86
Gingiva 104, 202
Ginglymus 144
Gland, Glands
accessory genital 66
adrenal 62, 152
apocrine sweat 6
ceruminal 6
circumanal 6
cutaneous 6
lacrimal 98
mammary 6, 32
mandibular 104
merocrine sweat 6
monostomatic sublingual 104
odor 6
of the eyelids 6
of the wall of the paranasal sinus 6
parathyroid 152, 182
parotid 104
pineal 152
polystomatic sublingual 104
salivary 104
sebaceous 6
sudoriferous 6
superficial of the third eyelid 98, 198
sweat 6
thyroid 152, 182
zygomatic 104
Glans penis 68
Glenoid cavity 16
Gliding joint 144
Globe of the eye 118
Globus pallidus 112
Glomerular arteriovenous anastomoses 154
Glossopharyngeal and vagal nerves 200
Glottis 100, 199
Gluteal fascia 78
Gluteal surface 74
Gluteal tuberosity 76
Goblet cells 158
Gomphoses 144
Gonadal ligaments 64
Gonads 152
Great auricular nerve 12
Greater ischiadic notch 74
Greater omentum 50, 52, 189
Greater palatine foramen 88
Greater trochanter 76
Greater tubercle 16
Grey communicating rami 48, 108, 150
Grey substance 108, 122, 150
Groove of the brachialis muscle 16
Growth plate 206
Gustatory
bud 122
cells 122
organ 122
papillae 104, 122
pore 122
sense 122
- H**
Hair 4
Hamate process 16
Hammer 120
Hamstring muscles 78
Hamulus 90
Hard palate 199
Head
of the femur 76, 195
of the humerus 16
of the malleus 120
of the radius 16
of the ulna 16
Heart 44
valves 46
vessels 46
Helicotrema 120
Hemal arch 8
Hemilaminectomy 181
Hemivertebrae 180
Hepatic ducts 58
Hepatic portal circulation 154
Hepatoduodenal ligament 52
Hepatogastric ligament 52
Hepatorenal ligament 58
Hilus lienis 52
Hip joint 78, 86, 196
Hippocampus 112, 114
Hock joint 86
Holocrine glands 158
Horizontal lamina 90
Hormonal glands 158
Horn of the claws 4
Horn, solear 6
Horn, terminal 6
Hounsfield Unit 177
Humeral condyle 16
Humeral crest 16
Humeral joint 26
Humerus 16, 183
Hyaline cartilage 142
Hyoepiglottic ligament 106
Hyperdense 176
Hyoid apparatus 88, 106, 197
Hyoid bone 88, 106
Hyoid muscles 104
Hypodense 176
Hypoglossal canal 88
Hyponychium laterale 6
Hyponychium terminale 6
Hypophyseal fossa 90
Hypophysis 100, 152
Hypothalamic-hypophysial system 152
Hypothalamus 110, 152, 203
Hypotympanicum 120
- I**
Ileal ostium 56
Ileocecal fold 54
Iliac bone 74
Iliac crest 74
Iliac fascia 36
Iliac lamina 36
Iliac surface 74
Iliopubic cartilage 34
Iliopubic eminence 34, 74
Ilium 74
Image formation and recording 160
Incisive bone 90
Incisive duct 122
Incisive papilla 100, 122
Incisor teeth 104
Incisors 201
Incus 120
Inferior palpebrae 118
Infraglenoid tubercle 16
Infraorbital foramen 90
Infraspinous fossa 16
Infundibulum 66
Inguinal canal 36
Inguinal hernia 185
Inguinal ligament 34, 36
Inguinal region 36
Inguinal space 36
Innervation of skeletal muscle 209
Insertion of the tendon on bone 146
Inspiratory muscles 30, 127, 184
Insulin 210
Inner urethral ostium 64
Interalveolar septa 88
Interatrial septum 44
Intercapital ligament 10
Intercavernous sinus 116
Intercellular apertures 154
Intercondylar eminence 76
Intercondylar fossa 76
Intercostal nerves 32
Intercrural cistern 110
Intercrural fossa 110
Interganglionic branches 48
Interior of the eye 118
Interlobar fissures 38
Intermandibular articulation 106
Intermandibular suture 106
Intermandibular symphysis 106, 202
Intermandibular synchondrosis 106
Intermediate olfactory tract 114
Intermediate sacral crest 8
Intermediate sinuses 156
Intermediate zone 142
Internal acoustic pore 90
Internal carotid foramen 88
Internal circumferential lamellae 142
Internal ear 120
Internal fascia of the trunk 32, 36
Internal iliac fascia 36
Internal inguinal ring 36
Internal meninges 110
Internal muscles of mastication 96, 132
Internal perimysium 146
Internal smooth muscle of the eyeball 132
Internal spermatic fascia 32, 36
Internal structure of a muscle 209
Internal urethral ostium 68
Internal uterine ostium 66
Interparietal bone 88
Interspinous ligament 10
Interstitial lamellae 142
Interthalamic adhesion 110
Intertubercular groove 16
Interventricular foramen 116
Interventricular septum 44, 187
Intervertebral discs 144, 181, 208
Intervertebral foramen 8, 108
Intervertebral symphysis 10
Intestinal crypts 158
Intestinal lymph 189
Intestinal villi 158
Intraluminal macrophages 156
Intramural nervous system 150
Intranasal reticular fibers 156
Intrinsic muscles of the larynx 133
Intrinsic tongue muscles 201
Iridocorneal angle 118
Iris 118
Irregular bones 142
Ischiadic arch 74
Ischiadic bone 74
Ischiadic spine 74
Ischiadic table 74
Ischiadic tuber 74
Ischial musculature 195
Ischioanal fossa 72
Ischium 74
Isthmus of the uterine tube 66
- J**
Jejunum 50, 54
Joint, Joints
capsule 208
fluid 144
ligaments 144
receptors 122
of the digits 86
of the head 106
of the manus 26
of the thoracic limb 26
Jugular foramen 88
Jugular process 88
Juxtglomerular complex 152
- K**
Kidneys 62, 152, 191
Knee joint 86, 197
- L**
Labeling radiographs 166
Labia pudendi 66
Labyrinthitis 206
Lacrimal apparatus 98
Lacrimal bone 90
Lacrimal canal 90
Lacrimal gland 198
Lacrimal groove 90
Lactation period 32
Lactiferous ducts 32
Lactiferous sinus 32
Lamellar corpuscles 122
Lamina cribrosa 90
Lamina interna 90
Lamina muscularis mucosae 158
Lamina propria mucosae 158
Lamina tecti quadrigemina 110
Laminectomy 181
LANGERHANS islets 54
Laryngeal cartilages 100, 199
Laryngeal fibroelastic membrane 106
Laryngeal mucosa 100, 199
Laryngeal muscles 100, 133, 199
Laryngeal ventricle 100
Laryngopharynx 100
Larynx 100
Lateral coronoid process 18
Lateral epicondyle 16, 76
Lateral femoral condyle 76
Lateral frontal sinus 90
Lateral funiculus 108
Lateral geniculate body 110, 114
Lateral horn 108
Lateral ligament 10, 106
Lateral olfactory tract 114
Lateral recess 116
Lateral sacral crest 8
Lateral shoulder and arm muscles 20, 125
Lateral styloid process 16
Lateral supracondylar tuberosity 76
Lateral ventricles 114, 116, 199

- Lateral vertebral foramen 8
 Layer thickness 176
 Left atrium 44
 Left cardiac notch 38
 Left lung 38
 Left ventricle 44
 Leg 76
 Lens 118
 Lenticular bone 120
 Lentiform nucleus 112
 Leptomeninx 108, 110
 Lesser ischiadic notch 74
 Lesser omentum 50, 52
 Lesser palatine foramina 88
 Lesser trochanter 76
 Lesser tubercle 16
 Lien 52
 Ligament, Ligamentum, Ligaments 10, 102
 arteriosum 44, 186
 inguinale ovarii 64
 inguinale testis 64
 latum uteri 64
 of the gonads 64
 of the larynx 106
 of the tail of the epididymis 64
 of the vertebral column 10
 teres uteri 64
 Limbic system 112
 Limbus of the cornea 118
 Limen pharyngoesophageum 100
 Line of the triceps muscle 16
 Linea alba 34, 185
 Lines of pressure and tension 142
 Lingual branch 102
 Lingual muscles 104
 Liver 50, 58, 191
 Lobar bronchi 38
 Long bones 142
 Long crus 120
 Long hyoid muscles 124
 Long thoracic nerve 14
 Lumbar aortic lymph nodes 68
 Lumbar enlargement 108
 Lumbar plexus 60, 191
 Lumbar splanchnic nerves 60
 Lumbar sympathetic trunk 60
 Lumbosacral articulation 181
 Lumbosacral space 8
 Lumbosacral trunk 70, 194
 Lunate surface 74
 Lung 38, 185
 Lymph capillaries 156, 158
 Lymph drainage 24, 54
 Lymph nodes 52, 134, 156, 210
 Lymph vascular system 156
 Lymph vessels 32
 Lymphangion 156
 Lymphatic organs 156
 Lymphatic system 4, 14, 156
 Lymphnode, Lymphnodes, Lymphnode (i)
 accessory axillary 18, 24
 axillary 18, 24
 caudal mesenteric 52
 colic 52
 cranial mediastinal 40
 cranial sternal 40
 gastric 52
 hepatic 52
 intercostal 40
 jejunal 52
 lienal 52
 lumbar aortic 62, 68
 mandibular 92, 134
 medial iliac 62, 68, 194
 medial retropharyngeal 14, 92
 parotid 92, 134
 portal 52
 pulmonary 40
 sacral 62
 sacral iliac 68
 splenic 52
 sternal 186
 superficial cervical 14, 24, 182
 superficial inguinal 32, 68
 superficial popliteal 84
 superficial scrotal 68
 tracheobronchial 40
 Lymphocenter, Lymphocentrum 134
 axillary 135
 bronchial 134
 caudal mesenteric 135
 celiac 135
 cranial mesenteric 135
 deep cervical 134
 dorsal thoracic 134
 iliosacral 135
 lumbar 135
 mediastinal 134
 popliteal 135
 retropharyngeal 134
 superficial cervical 134
 superficial inguinal 135
 ventral thoracic 134
 Lymphocytes 156, 210
 Lymphoreticular tissue 156
 Lyssa 104
- M**
 Macula sacculi 120
 Macula utriculi 120
 Major duodenal papilla 54
 Male genital organs 68
 Malleus 120
 Mammae 32
 Mammary branches 40
 Mammary gland 184
 Mammary body 110, 114
 Mandibula 90, 198
 Mandibular foramen 90
 Mandibular fossa 88
 Mandibular muscles 94, 132
 Manica flexoria 22
 Manubrium 8, 120
 Manus 24
 Marginal papillae 104
 Masculine urethra 68
 Masseteric fossa 90
 Mastoid process 88, 90
 Maxilla 90, 198
 Maxillary foramen 90
 Maxillary recess 90
 Mechanical papillae 104
 Medial coronoid process 16
 Medial epicondyle 16, 76
 Medial femoral condyle 76
 Medial frontal sinus 90
 Medial geniculate body 110, 114
 Medial iliac lymph nodes 68
 Medial malleolus 76
 Medial shoulder and arm muscles 18, 125
 Medial styloid process 16
 Medial supracondylar tuberosity 76
 Medial thigh muscles 130
 Medial tibial condyle 76
 Medial trochlea 16
 Medial veins of the thoracic limb 18
 Median crista galli 90
 Median ligament of the urinary bladder 52
 Median sacral crest 8
 Mediastinum 42, 186
 Mediastinum testis 68
 Medulla 112
 Medulla oblongata 110
 Medullary body 110
 Medullary cavity 142
 Medullary chords 156
 Medullary impression 90
 Medullary roots 114
 Medullary sinuses 156
 Medullary spaces 142
 MEISSNER'S tactile discs 4
 Membranous labyrinth 120
 Membranous ossification 140
 Meningeal coverings 110
 Meninges 108
 Mental foramina 90
 Mental nerves 198
 Mesencephalic aqueduct 110, 116
 Mesencephalon 110
 Mesenchymal cells 140
 Mesentery 158
 Mesepididymis 64
 Mesocolon 52
 Mesoductus deferens 64
 Mesofuniculus 64
 Mesogastrium 50
 Mesometrium 64
 Mesonychium 6
 Mesorectum 52
 Mesosalpinx 64
 Mesotendineum 148
 Mesothelium 158
 Mesotympanicum 120
 Mesovarium 64
 Metacarpal bones 16
 Metacarpophalangeal joint 26
 Metaphysis 140
 Metatarsal bones 76
 Metra 66
 Microvilli 158
 Midbrain 203
 Middle ear 120, 206
 Middle pharyngeal constrictor 133
 Middle transverse diameter 74
 Minor duodenal papilla 54
 Minor trochanter 76
 Mitral valve 187
 Mixed glands 158
 Modified cells of the tunica media 152
 Modiolus 120
 Molar teeth 104
 Motor end plates 150, 209
 Motor neurons 108
 Motor pathways 114
 Mucous glands 158
 Mucous membrane
 of the intestine 158
 of the genital tract 158
 of the urinary bladder 192
 of the urinary tract 158
 Multiaxial joint 144
 Multicellular glands 158
 Multipennate muscle 146
 Muscle and tendon spindles 206
 Muscle tears 209
 Muscle, Muscles, Musculus (i)
 abductor cruris caudalis 129
 abductor pollicis longus 126
 adductor brevis 130
 adductor magnus 80, 130
 anconeus 20, 125
 arrector pili 4
 arytenoideus transversus 133
 biceps brachii 18, 125, 183
 biceps femoris 78, 129
 biventer cervicis 28
 brachialis 18
 brachiocephalicus 14, 124
 brachioradialis 22, 126
 buccinator 94, 131
 bulbospongiosus 72, 128
 caninus 94, 131
 cardiac sphincter 54
 caudal crural abductor 78
 caudal tibial 82
 cervicoauricularis 131
 cervicoauricularis superficialis 94
 cervicoscutularis 94, 131
 ciliaris 118, 132
 cleidobrachial 14, 20
 cleidocervicalis 12, 14, 124
 cleidomastoid 14
 coccygeus 72, 128
 common digital extensor 22
 complexus 28
 constrictor vestibuli 66, 72, 128
 constrictor vulvae 72, 128
 coracobrachialis 18, 125
 cranial preputial 32
 cranial supramammary 32
 cranial tibial 82
 cremaster (externus) 36
 cricoarytenoideus dorsalis 133
 cricoarytenoideus lateralis 133
 cricopharyngeus 102, 133
 cricothyroideus 133
 cutaneus faciei 94
 cutaneus trunci 12
 deep digital flexor 22, 82
 deep gluteal 78
 deltoid 14, 20, 124, 125
 digastricus 94, 132, 148
 dilator pupillae 118, 132
 extensor carpi radialis 22
 extensor carpi ulnaris 22, 126
 extensor digitalis brevis 82, 130
 extensor digitalis communis 126
 extensor digitalis lateralis 22, 82, 126, 130
 extensor digitalis longus 82, 130, 196
 extensor digiti I 22, 82, 126, 130
 extensor ulnaris lateralis 22
 external anal sphincter 56, 72
 external obturator 78, 80
 flexor carpi radialis 22, 125
 flexor carpi ulnaris 22, 125, 184
 flexor digitalis profundus 125, 130
 flexor digitalis superficialis 22, 82, 125, 130
 frontoscutularis 94, 131
 gastrocnemic 82, 130
 gemelli 78, 129
 genioglossus 104, 133
 geniohyoideus 104
 gluteus medius 129
 gluteus profundus 129
 gluteus superficialis 78, 129
 gracilis 80, 130, 196
 great papillary 44
 hyoglossus 104, 133
 hyopharyngeus 102, 133
 iliacus 60, 128
 iliocostalis 28, 126
 iliopsoas 36
 infraspinatus 20, 125, 183
 intercostales externi 30, 127
 intercostales interni 30, 127
 internal anal sphincter 56
 internal obturator 78
 interscutularis 94, 131
 interspinales 10, 28, 126
 intertransversarii 28, 126
 ischiocavernosus 72, 128
 lateral digital flexor 82
 latissimus dorsi 12, 124
 levator anguli oculi medialis 94, 131
 levator ani 72, 128
 levator labii superioris 94, 131
 levator nasolabialis 94, 131
 levator palpebrae superioris 98, 132
 levator veli palatini 102, 133
 levatores costarum 30, 127
 lingualis proprius 104, 133
 long abductor of digit I 22
 longissimus 28, 126
 longus capitis 28, 127
 longus colli 28, 127, 184
 malaris 94, 131
 mandibuloauricularis 131
 masseter 94, 132
 medial digital flexor 82
 middle gluteal 78
 multifidi 28, 126
 mylohyoideus 94, 132
 obliquus capitis caudalis 28, 127
 obliquus capitis cranialis 28, 127
 obliquus dorsalis 98, 132
 obliquus externus abdominis 34, 36, 128
 obliquus internus abdominis 34, 36, 128
 obliquus ventralis 98, 132
 obturator externus 129
 obturator internus 129
 occipitalis 94, 131
 of facial expression 131
 of mastication 96, 198
 of the cheek 94, 131
 of the eye 98, 132
 of the eyelids 94, 131
 of the hip joint 129
 of the lips 94, 131
 of the nose 94, 131
 of the soft palate 133
 of the tongue and hyoid apparatus 133
 of the vertebral column 28, 126, 127
 omotransversarius 12, 124
 orbicularis 148
 orbicularis oculi 94
 orbicularis oris 94, 131
 palatopharyngeus 102, 133
 papillares parvi 44
 papillaris magnus 44
 papillary 46
 parotidoauricularis 94, 131
 pectinati 44
 pectineus (and adductor longus) 34, 80, 130, 196
 pectorales superficiales 14, 124
 pectoralis descendens 14
 pectoralis profundus 124
 pectoralis transversus 14
 perineal 72, 128

- peroneus (fibularis) brevis 82, 130
peroneus (fibularis) longus 130
piriformis 78, 129
popliteus 82, 130, 196
pronator quadratus 22, 125
pronator teres 22, 125
psoas major 60, 128
psoas minor 60, 128
pterygoideus 96, 132
pterygopharyngeus 102, 133
pyloric sphincter 54
quadratus femoris 78, 129
quadratus lumborum 60, 128
quadriceps femoris 80, 130
rectococcygeus 74, 128
rectus abdominis 34, 36, 128
rectus capitis dorsalis major 28, 127
rectus capitis dorsalis minor 28, 127
rectus dorsalis 98, 132
rectus lateralis 98, 132
rectus medialis 98, 132
rectus thoracis 30, 127
rectus ventralis 132
retractor anguli oculi lateralis 94, 131
retractor bulbi 132
retractor clitoridis 74, 128
retractor costae 30, 127
retractor penis 74, 128
rhomboideus 12, 124
sacrocaudalis (-coccygeus) dors. lat. 28, 126
sacrocaudalis (-coccygeus) dors. med. 126
sartorius 80, 130
scaleni 28, 127
scutuloauricularis superficialis 94, 131, 198
semimembranosus 78, 129
semispinalis capitis 28, 126
semitendinosus 78, 129
serratus dorsalis caudalis 30, 127
serratus dorsalis cranialis 30, 127
serratus ventralis 14, 124
small papillary 44
sphincter ani externus 128
sphincter ani internus 128
sphincter colli profundus 131
sphincter colli superficialis 94, 131
sphincter pupillae 118, 132
spinalis cervicis 28
spinalis et semispinalis cervicis et thoracis 28, 126
spinalis thoracis 28
splenius 28, 126
stapedius 120
sternocleidomastoid 14, 124
sternohyoid 14, 124
sternomastoid 14
sterno-occipital 14
sternothyroid 14, 124
styloglossus 104, 133
stylopharyngeus caudalis 102, 133
subarterial papillary 44
subauricular papillary 44
subcostales 30, 127
subscapular 18, 125
superficial digital flexor 22, 82
superficial gluteal 78
supinator 22, 126
supraspinatus 20, 125
temporalis 94, 132
tensor fasciae antebrachii 18, 125
tensor fasciae latae 78, 129
tensor tympani 120
tensor veli palatini 102, 133
teres major 125
teres minor 125
thyreochoideus 104
thyroarytenoideus 133
thyrohyoideus 133
thyropharyngeus 102, 133
tibialis caudalis 130
tibialis cranialis 130
transversus abdominis 30, 34, 36, 128
transversus thoracis 30, 127
trapezius 12, 124
triceps brachii 20, 125, 184
ulnaris lateralis 126
urethralis 68
zygomatikus 94, 131
Muscular arteries 154
- Muscular tunic 54
Musculature 146
Musculature of the urinary bladder 192
Myelin formation 209
Myelinated nerve fiber 150
Myelencephalon 110
Myenteric plexus 108
Mylohyoid line 90
Myocardium 44, 187
Myogenesis 208
Myoid intimal cushions 154
Myology 124, 146, 148
Myotendinous junction 146
- N**
Nasal bone 90
Nasal cavity 100, 198
Nasal meatuses 100
Nasal plane 6
Nasal process 90
Nasal vestibule 100
Nasolacrimal duct 198
Nasolacrimal ostium 98
Nasopharynx 100
Nearthrosis 208
- Neck**
of the femur 76, 195
of the humerus 16
of the malleus 120
of the mandible 90
of the radius 16
- Neck region 12
Neopallium 112
Nerve cells 150
Nerve fiber 150
Nerve regeneration 209
Nerve supply 4
Nerve supply of the cervical platysma 12
Nerve terminals 4
- Nerve, Nerves, Nervus (i)**
abducens 98, 114, 136
accessory 14, 102, 108, 114, 138
accessory axillary 14, 18
auriculopalpebral 92
auriculotemporal 96
axillary 14, 18, 20
brachiocephalic 14, 18
buccal 96
caudal auricular 92
caudal cutaneous antebrachial 18
caudal cutaneous femoral 70, 72
caudal cutaneous sural 82
caudal gluteal 70, 78
caudal iliohypogastric 28, 32, 34, 60
caudal laryngeal 102
caudal nasal 96
caudal rectal 72
cochlear 120, 138
common peroneal (fibular) 78, 82, 196
cranial cutaneous antebrachial 20
cranial gluteal 70, 78, 84
cranial iliohypogastric 28, 32, 34, 60
cranial laryngeal 102, 138
cranial lateral cutaneous brachial 20
deep perineal 72
deep temporal 96, 136
dorsal clitoridis 72
dorsal common digital 22
dorsal lumbar cutaneous 28
ethmoidal 98, 136
facial 92, 114
femoral 36, 60, 80
frontal 98, 136
genitofemoral 32, 36, 60, 150
glossopharyngeal 102, 114, 138
greater palatine 96, 136
hypogastric 60
hypoglossal 104, 114, 201
ilioinguinal 28, 34, 60
inferior alveolar 96, 136
infraorbital 96, 198
infratrochlear 98, 136
intermediocervical 92, 138
ischial 70, 78
lacrimal 98
lateral cutaneous femoral 28, 60
lateral cutaneous sural 82
lateral lumbar cutaneous 28
lateral plantar 82
lateral thoracic 18
- left recurrent laryngeal 48
lesser palatine 96, 136
lingual 96, 136
long ciliary 98, 136
long thoracic 18
major splanchnic 48, 108
mandibular 96, 136
masticatorius 96, 136
maxillary 96, 136
medial cutaneous antebrachial 18
medial plantar 82
median 18, 22
minor splanchnic 108
musculocutaneous 18
mylohyoid 96, 136
nasociliary 98, 136
obturator 60, 80
oculomotor 98, 114, 136
of the eye 98, 136
of the vessels 154
olfactory 100, 114, 136
ophthalmic 98, 136
optic 88, 98, 110, 118, 136
phrenic 30
pterygopalatine 96, 136
pudendal 70, 72
radial 18, 20, 22, 183
recurrent laryngeal 14, 182, 188
saphenous 36, 80
sciatic 195
splenic 52
sublingual 96
subscapular 18
suprascapular 18, 20, 183
thoracodorsal 18
tibial 78, 82
trigeminal 96, 114
trochlear 98, 114, 136
ulnar 18, 22, 183
vagus 48, 102, 114
ventral lumbar cutaneous 28
vertebral 48
vestibulocochlear 114, 120, 206
vomeronasal 122
zygomatic 96
- Nervi vasorum** 156
Nervous system 150
Neurite 150
Neuroglia 209
Neurohypophysis 152
Neurolemmal cell 150
Neuromuscular spindles 122
Neuromuscular lacuna 36
Neurons 150
Neurotendinous spindles 122
Neurothelium 150
Nerve plexuses 150
Nodes of Ranvier 209
Nose 100
Nostrils 198
Nuchal crest 88
Nuchal ligament 10, 28
- O**
Obturator foramen 74
Occipital bone 88
Occipital condyle 88
Occipital lobe 112
Occluding veins 154
Olecranon 16
Olfactory bulb 114
Olfactory organ 100, 122
Olfactory peduncle 114
Olfactory trigone 114
Olive 114
Omentum majus 52
Open junctions 156, 210
Ophthalmic nerve 98
Ophthalmic plexus 116
Optic canal 88, 90
Optic chiasm 114
Optic disc 118
Optic nerve 98
Optic part of the retina 118
Optic tract 114
Ora serrata 118
Oral cavity 100
Oral vestibule 199
Orbicular ciliaris 118
Orbit 88
Orbital fissure 88
Orchis 68
- Organ of Corti 120
Oropharynx 100
Os costae 8
Os femoris 76
Os penis 68, 194
Osseous external acoustic meatus 120
Osseous labyrinth 120
Osseous matrix 140
Osseous semicircular canals 120
Osseous spiral lamina 120
Osseous tentorium cerebelli 90
Osseous tissue 142
Osseus pelvic girdle 195
Ossification 140
Osteoblastic function 206
Osteofibrotic sites 209
Osteogenic layer 142
Osteology 140, 142
Ostium of the ovarian bursa 66
Ostium ureteris 64
Ovarian bursa 64, 66
Ovarian interstitial cells 152
Ovarian medulla 66
Ovary 50, 66, 152, 192
Ovary, proper ligament 64
- P**
Pads 6, 180
Palatine bone 90
Palatine fissures 88
Palatine process 90
Palatine raphe 100
Palatine rugae 100
Palatine tonsil 100
Palatopharyngeal arch 100
Paleopallium 112
Pallidum 112
Palpebrae 118
PALS 52
Pampiniform plexus 68
Pancreas 50, 54, 190
Pancreatic islets 54, 152
Papilla mammae 32
Papillae 6
Papillary duct 32
Papillary layer 4
Papillary ostium 32
Paracanal interventricular groove 44
Paracortex 156
Parodontium 202
Paralysis of the mandibular nerve 198
Parametrium 64
Paranasal sinuses 56, 180
Paranasal sinuses 90, 197
Parasympathetic fibers 46, 102
Parasympathetic nerve supply 104
Parasympathetic nervous system 48
Parasympathetic neurons 108
Parasympathetic system of the sacral spinal cord 60
Parathyroid gland 14, 152, 182
Paraunguicula 76
Parietal bone 88
Parietal cusp 44
Parietal lobe 112
Parietal peritoneum 50, 52, 158
Parietal pleura 42
Parietal vaginal tunic 64
Parotid duct 104
Parotid gland 201
Pars laryngea pharyngis 100
Pars nasalis pharyngis 100
Patella 76, 197
Patellar ligament 80
Pecten ossis pubis 74
Pectoral girdle 16
Pelvic cavity 70
Pelvic diameters 74
Pelvic diaphragm 72, 128
Pelvic fascia 32
Pelvic limb 76, 84
Pelvic outlet 72
Pelvic resesses 62
Pelvic symphysis 74, 195
Pelvic tendon 34
Pelvis 62
Pelvis nerves 70
Penis 68
Penis, suspensory ligament of the 32
Perianal glands 180
Pericardiac pleura 42
Pericardial cavity 42, 186

- Perichondral ossification 206
 Perilymph 120
 Perimetrium 64
 Perineum 195
 Perineurium 150, 209
 Periosteum 108, 110, 140, 142, 207
 Peripheral nervous system 150
 Peritoneal cavity 50, 52
 Peritoneal folds 64
 Peritoneum 36, 50, 52, 158
 Perpendicular lamina 90
 Petro-occipital fissure 90
 Petrotympanic fissure 88, 90
 Petrous part of the temporal bone 90
 Pharyngeal muscles 102, 133, 200
 Pharyngeal ostia of the auditory tubes 100
 Pharyngeal tubercle 88
 Pharynx 100
 Philtrum 98
 Phrenicopericardiac ligament 42
 Physical cartilage 140
 Physiological diameter 146
 Pia mater 108, 110
 Pineal body 110
 Pineal gland 152
 Piriform fossae 90
 Piriform lobe 112, 114
 Placenta 152
 Plane joint 144
 Planum nasale 98
 Platysma 12, 131
 Pleura 42, 186
 Plexus nerves 150
 Plica
 ductus deferentis 64
 vasculosa 64
 venae cavae 42
 Pollex muscles 22
 Polydontia 201
 Pons 110, 114
 Pontine impression 90
 Porta hepatis 58
 Portal vein 56
 Portal venous system 190
 Postcapillary lymph vessels 156
 Postcapillary venules 154
 Posterior chamber of the eye 118
 Postganglionic unmyelinated fibers 150
 Preganglionic myelinated fibers 150
 Pregnancy 32
 Premolar tooth 104
 Prepubic tendon 34
 Prepuce, Preputium 32
 Preputial ostium (orifice) 32, 184
 Presphenoid bone 88
 Primal ossification center 140
 Primary medullary cavity 140
 Primary muscle fiber bundle 146
 Primary osseous trabeculae 140
 Primary trabeculae of woven bone 140
 Primordial cranium 197
 Process
 accessory 8
 caudal articular 8
 costal 8
 cranial articular 8
 hemal 8
 lateral 8
 mammillary 8
 spinous 8
 transverse 8
 Projection fibers 112
 Promontory 8
 Pronator muscles 22
 Proper ligament of the testis 64
 Prostate 68, 194
 Prostatic utricle 193
 Proximal mesorchium 64
 Proximal phalanx 16, 76
 Proximal sesamoid bones 16, 76
 Proximal tibiofibular joint 86
 Pseudoarthrosis 208
 Pseudostratified ciliated columnar epithelium 158
 Psoas minor tubercle 74
 Pterygoid crest 88
 Pterygoid fossa 90
 Pterygopalatine fossa 88
 Pubic bone 74
 Pubovesical pouch 52
 Pudendoepigastric trunk 70
 Pulmo 38
 Pulmonary
 circulation 154
 ligament 42
 pleura 42
 trunk 40
 Pulp cavity 104
 Pupil 118
 Putamen 112
 Pylorus 54, 189
 Pyramid 114
 Pyramidal decussation 114
 Pyramidal system 114
 R
 Radiography 160
 Absorption 160
 Laws of projection 161
 Protection 166
 Quality of radiographs 163
 Superpositioning 161
 Radial carpal bone 16
 Radial fossa 16
 Radial notch 16
 Radial tuberosity 16
 Radius 16
 Radix linguae 104
 Ramus colli 92
 Ramus of the mandible 90
 Ranvier's nodes 150
 Rapidity of movement 122
 Reconstruction algorithms 177
 Rectal ampulla 56
 Rectogenital pouch 52
 Rectum 56
 Rectus sheath 34
 Red splenic pulp 52
 Relationship of the fasciae 32
 Ren 62
 Renin 210
 Reserve zone 140
 Resorption 158
 Respiratory muscles 30, 127
 Respiratory tract 158
 Rete capillare I + II 152
 Rete lymphocapillare 156
 Reticular cells 156
 Reticular fibers 146, 156
 Reticular formation 108, 203
 Reticular layer 4
 Retina 118, 205
 Retinacula 148
 Retinal blood vessels 118
 Retroarticular foramen 90
 Retroarticular process 88
 Retroperitoneal space 50, 62
 Rhinencephalon 110, 114
 Rhombencephalon 110
 Rib 8, 10
 Right atrium 44
 Right cardiac notch 38
 Right lung 38
 Right ventricle 44
 Ring of fibrocartilage 120
 Root canal 104
 Root
 of the nose 98
 of the penis 68
 of the tongue 200
 of the tooth 104
 of the spinal nerves 108
 Rostral alar foramen 88
 Rostral auricular branches 92
 Rostral cerebellar peduncle 114
 Rostral colliculus 110
 Rostral commissure 110, 112
 Rostral frontal sinus 90
 Rostral pharyngeal constrictors 133
 S
 Sacculus 120
 Sacral
 lymph nodes 68
 plexus 70
 spinal chords 70
 tuber 74
 wing 8
 Sacrocaudal space 8
 Sacrococcygeal space 8
 Sacroiliac joint 10, 86
 Sacropelvic surface 74
 Sacrum 8
 Saddle joint 144
 Sagittal 2
 Salivary glands 201
 Salpinx 66
 Scala tympani 120
 Scala vestibuli 120
 Scan images 178
 Scapula 16
 Scattering 166
 Schwann cell 150
 Sclera 118, 205
 Scrotal ligament 64
 Scutiform cartilage 94
 Sebaceous gland 4, 180
 Secondary ossification center 140
 Secondary sensory cells 122
 Secretion 158
 Sectorial tooth 104
 Sella turcica 88, 90, 197
 Sellar joint 144
 Semicircular ducts 120
 Semilunar trochlear notch 16
 Semilunar valves 44, 46
 Seminal colliculus 64, 68
 Sense of taste 122
 Sense organs 118
 Sensibility 122
 Sensory fibers 150
 Sensory innervation 32, 158
 Sensory neurons 108, 150
 Septal cartilage 46
 Septal cusp 44
 Septal groove 90
 Septal part of the rhinencephalon 114
 Septomarginal trabeculae 44
 Septum pellucidum 112
 Serous cavities 42, 158
 Serous tunic 54
 Sesamoid bones 16, 76, 142, 208
 Sexual maturity 32
 Shape of bones 142
 Sharpness or blurring 163
 Short bones 142
 Shoulder girdle 16
 Shoulder joint 26, 184
 Sigmoid sinus 116
 Simple columnar epithelium 158
 Simple joint 144
 Sinoatrial node 46
 Sinus hair 4
 Sinus venarum cavarium 44
 Sinus venosus 44
 Sinuses of the dura mater 110, 116
 Skeletal musculature 146, 148
 Skin 4, 36
 Skin, modifications of the 6
 Skull 88, 90
 Sleeve of trabecular bone 140
 Small intestine 54
 Small pelvic association 129
 Smooth muscle cells 146
 Soft meninges 110
 Soft tissues of bone 142
 Solar plexus 150
 Solitary lymph nodules 189
 Somatic nervous system 150
 Somatotopic division 112
 Spermatic cord 64, 68
 Sphenoid bone 88
 Spheroid joint 144
 Sphincter muscle of the cardia 189
 Spinal cord 108, 203
 Spinal ganglion 108, 150
 Spinal nerves 18, 150
 Spinal roots 114
 Spine of the scapula 16
 Spinous layer 4
 Spiral ganglion 120
 Spiral joint 144
 Spiral ligament of the cochlea 120
 Spiral membrane 120
 Spiral organ 120
 Spleen 50, 52
 Splenic function 189
 Spongiosa 90
 Spongy substance 142
 Stapes 120
 Sternal synchondroses 10
 Sternebrae 8
 Sternocostal joint 10
 Sternum 8
 Stifle joint 86
 Stimulus-generating system 46
 Stomach 50, 54
 Stomach functions 189
 Straight fold 100
 Straight sinus 116
 Stratified squamous epithelium 158
 Stratum corneum 4, 180
 Stratum germinativum 4
 Stratum granulosum 4
 Stratum lucidum 4
 Striate body 112
 Striated skeletal musculature 146
 Stylohyoid 88
 Stylo mastoid foramen 88, 90
 Stylo mastoid process 88
 Subarachnoid space 108, 110, 202
 Subcapsular sinus 156
 Subcutaneous olecranon bursa 26, 184
 Subcutaneous synovial bursa 148
 Subcutis 4, 180
 Sublingual glands 201
 Sublumbal muscles 60, 128
 Submucosal plexus 108
 Subpapillary network 4
 Subscapular fossa 16
 Subserosal layer 158
 Subserosal plexus 108
 Subsinual interventricular groove 44
 Subtendinous bursae 26
 Subtendinous calcanean bursa 82, 86
 Subtendinous synovial bursa 148
 Sulcus of the transverse sinus 90
 Superficial digital flexor tendon 82
 Superficial fascia 78
 Superficial hair cuticle 4
 Superficial inguinal ring 36
 Superficial sensibility 122
 Superficial trunk fascia 32
 Superior conjunctival fornix 98
 Superior palpebrae 118
 Supracondylar crest 16
 Supraglenoid tubercle 16
 Supraspinous fossa 16
 Supraspinous ligament 10
 Supratrochlear foramen 16
 Surgical approach to the peritoneal cavity 188
 Suspensory ligament
 of the testis 64
 of the ovary 192
 Sustentacular cells 122
 Sustentaculum tali 76
 Sutures 144
 Sutures of the upper jaw 106
 Sympathetic fibers 46
 Sympathetic nervous system 48
 Sympathetic neurons 108
 Sympathetic part 200
 Sympathetic trunk 102, 108
 Symphyseal branch of the ischium 74
 Symphyseal tendon 80
 Symphysis 144
 Synchondrosis 144
 Syndesmoses 144
 Synostosis 144
 Synovial bursae 26, 144, 148
 Synovial membrane 148
 Synovial sheaths 26, 86, 144, 148
 Systemic circulation 154
 T
 Tactile hair 4
 Tactile menisci 122
 Tall columnar epithelium 158
 Talus 76
 Tapetum cellulosum 118
 Tapetum lucidum 118
 Tarsal bones 76
 Tarsal joint 86, 197
 Taste bud 122
 Taste receptors 201
 Teat 32
 Tectum 110
 Tegmentum of the mesencephalon 110, 114
 Tela submucosa 158
 Telencephalic septum 112
 Telencephalon 110, 112
 Temporal bone 88
 Temporal lobe 112
 Temporal process 90
 Temporal sinus 116

- Temporohyoid articulation 106
Temporomandibular joint 106, 202
Tendinous intersections 34, 148
Tendons 146, 209
Tentorial processes 90
Tentorium cerebelli membranaceum 110
Tentorium cerebelli osseum 110
Terminal arteries 154
Terminal division of the aorta 70
Terminal division of the caudal vena cava 70
Terminal line 74
Testicle 68
Testicular bursa 64
Testicular interstitial cells 152
Testicular tunics 192
Testis 68, 152, 193
Thalamus 110, 203
Third eyelid 118, 205
Third ventricle 110, 116
Thoracic region 12
Thoracic cavity 38, 42
Thoracic duct 14, 42
Thoracic wall 28
Thoracodorsal nerve 12
Thoracolumbar fascia 12, 32, 34
Thorax 8, 10
Thymus 40, 186
Thyroepiglottic ligament 106
Thyrohyoid 88
Thyrohyoid membrane 106
Thyroid cartilage 100
Thyroid gland 14, 152, 182, 210
Tibial cochlea 76
Tibial tuberosity 76, 195
Tip of the tongue 201
Tomograms 176
Tomography 176
Tongue 104
Tonsils 100, 200
Tooth structure 104
Torsion of the stomach 189
Trabeculae carnae 44
Trachea 14, 42, 158
Tracheal bifurcation 38
Tracheal stenosis 182
Tractus tori 6
Transitional epithelium 158
Transudation 158
Transversalis fascia 32, 36
Transverse arytenoid ligament 106
Transverse atlantal ligament 10
Transverse cervical nerve 12
Transverse folds 158
Transverse foramina 8
Transverse sinus 116
Trapezoid body 114
Tricuspid insufficiency 187
Tricuspid valve 46
Trochanteric fossa 76
Trochlea 76, 98
Trochlea of the radius 16
Trochoid joint 144
True joint 144
Trunk-limb muscles 12, 14
Tubal fimbriae 66
Tuber calcanei 76
Tuber coxae 74
Tuber ischiadicum 74
Tuber olecrani 16
Tubular glands 158
Tunica
 adventitia 156, 158
 externa 154, 156
 interna 156
 intima 154, 156
 media 154, 156
 mucosa 158
 muscularis 158
 serosa 158
 vaginalis parietalis 64
 vaginalis visceralis 64
Tympanic bulla 120
Tympanic cavity 120
Tympanic membrane 120
Tympanohyoid 88
- U
Ulna 16
Ulnar epiphyseal suture 183
Ultrasound 166
- Doppler echography 168
Heart 169
Kidney 173
Liver 172
Membrum pelvinum 175
Orientation 168
Ovary 173
Pelvic limb 175
Pregnancy 175
Prostate 174
Reflection 166
Refraction 166
Resolution 167
Stomach 172
Testis 174
Transducer-dependent form 167
Urinary bladder 174
Uterine horns 174
Wave propagation velocity 166
- Umbilical hernia 185
Umbilical region 50
Umbilical ring 34
Unfenestrated endothelial cells 154
Unguicula 6, 16, 76
Uniaxial joint 144
Unicellular glands 158
Unipennate muscle 146
Unmyelinated nerve fiber 150
Upper and lower eyelids 204
Ureter 62, 158, 192
Urethra 64, 192
Urethral orifice 193
Urinary bladder 50, 62, 64
Uterine papilla 66
Uterine tube 66, 158, 193
Uterus 50, 64, 66, 193
Uterus masculinus 193
Utriculus 120
Uvea 205
- V
Vagina 64, 66
Vagina synovialis intertubercularis 26
Vagina synovialis m. coracobrachialis 26
Vaginal process of the peritoneum 36, 64
Vaginal ring 36, 52, 64, 68
Vaginal tunic 68
Vaginal tunic in the male 36
Vagosymphathetic trunk 14
Vagus group 102
Vallate papillae 104, 122
Vallum 6
Valva aortae 46
Valva trunci pulmonalis 46
Valve of the pulmonary trunk 187
Valves of the lymph vessels 156
Valvular apparatus 46
Vasa lymphatica myotypica 156
Vasa lymphatica fibrotypica 156
Vasa vasorum 154, 156
Vascular fold 64
Vascular lacuna 36
Vascular tunic 118
VATER-PACINIAN lamellar corpuscles 4
Vegetative nervous system 48, 150
Vein, Veins, Vena (ae) 18, 210
 accessory cephalic 20
 angular of the eye 92
 angular of the mouth 92
 axillary 18, 24
 axillobrachial 14, 20
 bicipital 24
 brachial 18, 24
 brachiocephalic 42
 caudal auricular 92
 caudal circumflex humeral 18, 24
 caudal gluteal 70
 caudal mesenteric 56
 caudal superficial epigastric 32, 36
 cava caudal 42, 58, 60, 70
 cava cranial 42
 cephalic 14, 20, 183
 collateral ulnar 24
 common iliac 70
 common interosseus 18, 24
 common mesenteric 56
 cordis dextrae 44, 46
 cordis magna 46
 cordis media 46
 cordis minima 46
 costocervical 42
 cranial circumflex humeral 18, 24
 cranial gluteal 70
 cranial mesenteric 56
 deep brachial 24
 deep facial 92
 diploic 116
 dorsal cerebral 116
 dorsal nasal 92
 dorsal perineal 70
 external jugular 14, 42, 92
 external pudendal 32, 36
 external thoracic 18, 24
 facial 92
 gastric 54
 gastroduodenal 56
 great cardiac 46
 great cerebral 116
 hepatic 58
 hypophysial portal vein 152
 iliolumbar 70
 inferior labial 92
 internal iliac 70
 internal jugular 14, 42, 116
 internal pudendal 70, 72
 internal thoracic 32, 42
 last parietal 70
 lateral coccygeal 70
 lateral nasal 92
 lateral saphenous 82, 196
 lateral superficial cutaneous 20
 lateral thoracic 18, 24, 32
 left brachiocephalic 42
 lingual 92
 linguofacial 14, 92
 maxillary 14, 92, 116
 medial saphenous 80
 median 18, 24
 median cubiti 18, 20
 median sacral 70
 middle cardiac 46
 minimal cardiac 46
 of the wall of the cranium 116
 omobrachial 14, 20
 ovarian 66
 periosteal 142
 portal 58, 191
 pulmonary 40, 44
 radial 24
 right azygos 42
 right brachiocephalic 42
 rostral auricular 92
 splenic 56
 subclavian 42
 sublingual 92, 198
 submental 92
 subscapular 18, 24
 superficial brachial 18, 24
 superficial cervical 14
 superficial epigastric 32
 superficial temporal 92
 superior labial 92
 testicular 68
 thoracodorsal 18, 24
 transverse cubital 24
 ulnar 24
 uterine 66
 ventral labial 32
 ventral scrotal 32
 velar part of the greater omentum 52
 Velum omentale 50, 52
 Venous plexuses 154
 Venous portal system 152
 Ventral abdominal muscles 128
 Ventral horn 108
 Ventral internal vertebral plexus 108, 116
 Ventral longitudinal ligament 10
 Ventral mesogastrium 50, 52
 Ventral nasal concha 90
 Ventral nasal conchal bone 90
 Ventral nasal meatus 100, 199
 Ventral petrosal sinus 116
 Ventral pubic tubercle 74
 Ventral root 108, 150
 Ventral sacral foramina 8
 Ventral system of dural venous sinuses 116
 Ventral transverse diameter 74
 Ventral vagal trunk 42, 48, 108
 Ventral vertebral muscles 127
- Ventricles of the brain 116
Ventriculus 54
Venules 154
Vertebra, Vertebrae 8, 180, 181
Vertex 64
Vertical diameter 74
Vesicogenital pouch 52
Vessels of bone 142
Vestibular
 apparatus 120
 bulb 66
 folds 100
 ganglia 120
 ligament 106
 membrane 120
 window 120
Vestibule
 of the larynx 100
 of the omental bursa 52
Visceral bones 142
Visceral peritoneum 50, 52, 158
Visceral pleura 42
Visceral sensibility 122
Visceral sensory neurons 150
Visceral vaginal tunic 64
Viscerosensory innervation 185
Visual centers 118
Visual pathways 118
Vitreous body 118
Vitreous chamber of the eye 118
Vocal apparatus 100
Vocal ligament 106, 199
Volkmann's canals 142
Vomer 90
Vomeronasal organ 100, 122
Vulva 66
- W
Wall of the cranium 197
Wall of the skull 90
Weakened profile 176
White communicating rami 108, 150
White splenic pulp 52
White substance 108, 112, 150
Window technique 177
Wing of the ilium 74
Wing of the nostril 98
Wolf's tooth 104
Wolf's claw 76
Wool hair 180
- X
Xiphoid region 50
x-rays 160
- Z
Zona resorbens 140
Zonular fibers 118
Zygomatic bone 88
Zygomatic process 88, 90
Zygomaticofacial ramus 96
Zygomaticotemporal ramus 96