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

- Fully illustrated with color line diagrams, including unique three-dimensional cross-sectional anatomy, together with radiographs and ultrasound scans
- Includes topographic and surface anatomy
- Tabular appendices of relational and functional anatomy

“A region with which I was very familiar from a surgical standpoint thus became more comprehensible. [...] Showing the clinical relevance of anatomy in such a way is a powerful tool for stimulating students’ interest. [...] In addition to putting anatomical structures into clinical perspective, the text provides a brief but effective guide to dissection.”

The Veterinary Record

“...The present book-atlas offers the students clear illustrative material and at the same time an abbreviated textbook for anatomical study and for clinical coordinated study of applied anatomy. Therefore, it provides students with an excellent working knowledge and understanding of the anatomy of the dog. Beyond this the illustrated text will help in reviewing and in the preparation for examinations. For the practising veterinarians, the book-atlas remains a current quick source of reference for anatomical information on the dog at the preclinical, diagnostic, clinical and surgical levels.”

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

Anatomy of the Dog

with Aaron Horowitz and Rolf Berg

Fifth, revised edition
Anatomy of the Dog

Fifth, revised Edition

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An index of earlier co-workers and of the sources for illustrations, radiographs, and photographs can be obtained from the previous edition.

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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, as far 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 orient-ed 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 mitig-ate 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 pro-cEDURE 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 curricu-lum 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 dis-section as well as for teaching. The subject matter of anatomy was pre pared 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 recipro-cal re-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 ves-sels and nerves considered, laying stress on their nomenclatural agreement. In that way, the concern for the multiplicity, the breadth, and the com-plexity 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 mate-rial and an abbreviated reading supplementing textbook study and class-room 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 accord-ing to the pre-ceding 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 con-tinued. 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 dras-tic shortening and repositioning of the dissection exercises. The successful and exacting method of dissection with the short time avail-able 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 limi-tations 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 depart-ment, Mr. Seifert, Mr. Dressel, and Mr. Schneider.

Berlin, summer 1983
The Authors
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 inestimable 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. Explanatory 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 incisive 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 incisive 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 clinical 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 as of the horse in 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 Arsatotle, Leonardo da Vinci and Goethe show proof in 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 incisive 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

Terms that relate to the 'back' or dorsal (g) parts of the body and can be subdivided into subregions. In the latter case, they appear indented in the following table.

c) Parts of the body and body regions

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.
Body regions and terms of site and direction in relation to parts of the body indicated
2. The Skin (Common Integument)

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 epithelial 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 broader than that of the skin. In areas where soft horn is formed, the epidermis exhibits a stratum granuloso-num between the stratum spinosum and the cornified layers. The stratum granulosum is so-named because of the keratohyalin granules that it contains. Keratohyalin granules 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 horns, 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 inter- and intracellular air bubbles, especially of the medullary cells. The epidermis characterizes the coat. That part of the coat in which the hairs have a uniform direction is called the *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 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, as the same as the medulla, is penetrated by connective tissue 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 thermal isolation.

The hair coat depends on the breed and is characterized by the individual and group-like arrangement of the hairs, the different proportions 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 (Capillii). 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 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 Commodore, 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 openings of the parotid salivary gland (Rama oris). They are provided with tactile stimulators. 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 affected 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 *Flamma 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.

b) The **Hairs** cover nearly the entire body surface, except the *platinum 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 sheaths (Vagina epitelialis 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, as the same as the medulla, is penetrated by connective tissue 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 thermal isolation.

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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

Legend:
- 11 Wool hairs
- 12 Medulla of hair
- 13 Cortex of hair
- 14 Hair cuticle
- 15 Shaft of hair
- 16 Hair terminals
- 17 MEISSNER'S tactile disc
- 18 Sebaceous gland
- 19 Tactile hair
- 20 Blood sinus of follicle
- 21 Root of hair
- 22 VATER-PACINIAN lamellar corpuscles

Legend:
- 23 Stratum corneum
- 24 Stratum lucidum
- 25 Stratum granulosum
- 26 Spinous layer
- 27 Stratum germinativum
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. 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 **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.

The **cerebral 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 hepatoïd 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 cloacal (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** to 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 deep in the maxillary recess of the nasal cavity. The evaporation of the fluid lowers the temperature of the nasal breath. The lateral nasal gland, which is located deep in the maxillary recess of the nasal cavity, is composed of sebaceous and apocrine glands with fewer apocrine sweat glands. Their brown, oily secretion is called cerumen.

II. The **pads** of the dog are the **digital pads** (14) at the level of the distal interphalangeal joints, the metacarpal (15) 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 —45) 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.

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 matrix (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 unhaired inner lamella is comparable to the limbus (periole) of the horse. It forms a soft horn (**Eponychium**, —4) over the hard cornified epidermis of the claw. The eponychium corresponds to the periople of the horse and, like the pinna, 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 coronal part of the equine hoof. On the epidermis covering it, the dorsal horn of the wall (dorsal hypo-nychium —8) 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 latere**al, —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:

1. Eponychium
2. Mesonychium
3. Dorsal hyponychium
4. Lateral hyponychium
5. Solear horn
6. Terminal hyponychium

Dermis (Corium):

7. Vallum
8. Dorsum dermale
9. Dermal lamellae
10. Dermal papillae
11. Unguicular process
12. Carpal pad
13. Metacarpal pad
14. Digital pads
15. Tractus of metatarsal pad
16. Retinacula
17. Panniculus adiposus (Fat pad)

Legend:

11. Unguicular process
12. Carpal pad
13. Metacarpal pad
14. Digital pads
15. Tractus of metatarsal 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. Vertebral Column 

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. Thorax 

- **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.

- The body of the vertebrae (1) has a ventral crest (2), distinct in the region of the cervical and cranial (3) and caudal (4) extremes. 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 intervertebral foramen (7) is the space enclosed by the body and the arch. The vertebral canal is formed by the serial intervertebral foramina (9) which are bounded by the lamina dorsally. The arch of the vertebra (8) is made up of a pedicle basally and a flattened lamina dorsally. The interarcuate spaces are dorsal and, in life, closed off by the interarcuate ligaments (21). The vertebral foramen but by the lateral vertebral foramen (28). The vertebral foramen is the space enclosed by the body and its parts, arch and processes, that are modified in different ways according to the functional requirements of the particular region.

- 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.

- The transverse processes of the vertebral column, the **spinosous 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, which is expressed on the cranial articular process (mamillar process) and changes its position at the transition to the thoracic vertebrae. One can see transverse processes as remnants of the thoracic vertebrae. The transverse processes of the lumbar vertebrae are especially long and of significance in forming the transverse canal. On the thoracic vertebrae, the articular facets become indistinct caudally. On the 4th to the 7th or 8th caudal vertebra, the trunk is divided 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 **sternebral ribs** (41), connected to the sternum by synovial articulation. Ribs 10 – 12 are the freely moveable, ‘breathing’ **asternal ribs** (42). The overlapping of the cartilaginous parts of the sternum, a costal arch is formed on both sides of the body. The last rib does not regularly participate in the formation of the arch. The manubrium, the second at the synchondrosis that joins the manubrium with the stem of the sterna, the third through the seventh at the following sterna synchondrosis, and the eighth and ninth jointly at the synchondrosis joining the body to the xiphoid process.

II. The **sacrum** forms 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 **sacral crest** (36). The intermediate **sacral crest** (37) results from the sequential arrangement of the fused mamillar articular 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.

- 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 sternal arch (30) in the place of the body. This is 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 fovea for the first ribs and by the absence of the transverse foramen.

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**Note:** The diagram represents the lumbar vertebra (27), with labels for cranial (20) and caudal (19) vertebral notches, pedicle (21), lamina (22), articular processes (23), interarcuate spaces (24), transverse processes (25), spinous process (26), costal fovea (27), alar notch (28), lateral mass (29), ala (30), sacral wing (31), articular facets (32), dens (33), sacral wing (34), sacrococcygeal (35), sacroccygeal (36), lateral mass (37), ala (38), lumbosacral (39), iliac (40), sacral (41), costal arch (42), costal process (43), costal (44), costal (45), articular processes (46), articular facets (47), head (48), pedicle (49), vertebral arch (50), vertebral (51), thoracic (52), vertebrale (53), lumbar (54), manubrium (55), sternal (56), xiphoid (57).
Vertebral column and bones of thorax

Cervical vertebrae vC
Thoracic vertebrae vT
Lumbar vertebrae vL
Sacral vertebrae vS
Coccygeal vertebrae vCy
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)
Intervertebral space
Lumbosacral space (23)
Sacrococcygeal space (24)

Atlas vC (25)
Transverse process [wing] (26)
Alar notch (27)
Lateral vertebral foramen (28)
Ventral arch (29)

Axis (31)
Dens (32)

Os sacrum vS
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)
Asterial 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)
5. Articulations of the Vertebral Column and of the Thorax; Atlanto-Occipital and Atlanto-Axial Joints

a) JOINTS (ARTICULATIONS)

<table>
<thead>
<tr>
<th>Name</th>
<th>Participating bones</th>
<th>Form/Composition</th>
<th>Function</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Atlanto-occipital joint</td>
<td>Occipital condyles and cranial articular foveae of the atlas</td>
<td>Elliptical joint, simple joint</td>
<td>Hinge joint, dorsal and ventral flexion</td>
<td>Right and left joint cavities communicate ventrally.</td>
</tr>
<tr>
<td>II. Atlanto-axial joint</td>
<td>Fovea of the dens and caudal articular fossa of the atlas, dens and ventral articular surface of the dens</td>
<td>Trochoid joint, simple joint</td>
<td>Axial rotation of the head on the neck, head ‘shaking’</td>
<td>The atlanto-axial joint communicates with the atlanto-occipital joint.</td>
</tr>
<tr>
<td>III. Joints of the articular processes</td>
<td>Articular processes of adjacent vertebrae</td>
<td>Plane joints</td>
<td>Sliding joints</td>
<td>Considerable mobility in the cervical region, decreasing in the thoracic and lumbar regions.</td>
</tr>
<tr>
<td>IV. Joint of the head of the rib (costovertebral joint)</td>
<td>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 vertebrae with which the rib head articulates</td>
<td>Spheroid joint, composite joint</td>
<td>Hinge joint that, together with the vertebrae, makes possible the variation in thoracic volume in respiration</td>
<td>The convex rib-head joint surface is formed by two articular facets. The articular depression is formed by the costal fovea 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.</td>
</tr>
<tr>
<td>V. Joint of the rib tubercle (costotransverse joint)</td>
<td>Articular surface of the costal tubercle and the costal fovea of the transverse process of the same numbered (the more caudal) vertebra</td>
<td>Plane joint, simple joint</td>
<td>Hinge joint</td>
<td>On the last ribs, the costotransverse joint approaches and then fuses with the costovertebral joint.</td>
</tr>
<tr>
<td>VI. Sternocostal joint</td>
<td>Cartilaginous ends of the first to the eighth ribs and the sternum</td>
<td>Condylar joint, simple joint</td>
<td>Hinge joint</td>
<td>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.</td>
</tr>
<tr>
<td>VII. Costochondral synchondrosis</td>
<td>Costal bone and costal cartilage</td>
<td>Synchondrosis</td>
<td>Nearly rigid and immovable</td>
<td>Postnataally a true joint may develop from a synchondrosis.</td>
</tr>
<tr>
<td>VIII. Sternal synchondroses</td>
<td>Manubrium of the sternum, sternum of the body of the sternum, xiphoid process</td>
<td>Synchondrosis</td>
<td>Increasingly rigid and immovable</td>
<td>Of the sternal synchondroses, the manubriosternal and xiphoid sternal synchondroses are specially named.</td>
</tr>
</tbody>
</table>

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. 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 vertebra.

The muscolar 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 spinal 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.

Intertransverse 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 rein-forcing 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 radiation 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

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