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Structural and Pigmentary Characteristics of the Skin in Hairless Dog Breeds

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Abstract

The skin of hairless dog breeds exhibits distinct structural and pigmentary adaptations that compensate for the absence of a protective hair coat. Despite lacking hair, their body surface and core temperatures remain comparable to those of coated dogs. The epidermis of hairless breeds is notably thicker, serving as a compensatory barrier that protects against overheating and excessive cooling. Melanin plays a crucial role not only in pigmentation but also in thermoregulation and antioxidant defense. Genetic mechanisms governing pigmentation involve complex interactions between multiple loci (E, A, B, C, and K), which regulate the production and type of melanin. Hairlessness itself is a dominant genetic trait associated with specific mutations—particularly in the FOXI3 gene—which affect the development of hair, teeth, and other ectodermal structures. However, in the American Hairless Terrier, hairlessness is governed by a different, non-lethal genetic mechanism that does not affect dentition. These findings underscore the intricate interplay between structural adaptation, pigment synthesis, and genetic control that enables hairless dog breeds to maintain physiological balance and effective protection despite the absence of coat.

Keywords: Hairless Dog Breeds, Epidermis, Melanin, Genetic Mechanisms

Introduction

Attempts to systematize dogs on the basis of different characteristics date back to antiquity. Given the remarkable variability within the canine species, it is not possible to construct a classification that would fully reflect all groups and breeds. The first list of then-known breeds was compiled by Dr. Leopold Joseph Fitzinger in 1867. At that time, the Imperial and Royal Academy in Vienna, of which he was a full member, published his monumental work “Die Racen des zahmen Hundes.” The significance of this work also lies in the fact that the author, in addition to the nomenclature of breeds adopted at the session of the Academy’s Mathematical-Natural Sciences Section (October 4, 1866), provided all previously known synonyms as well as the names of the authors who had assigned them to particular breeds.

Within this comprehensive review of breeds, Fitzinger classified hairless dogs (*Canes caraibaei*) into Group VII.

1. **Hairless Dog (*Canis caraibaeus*)**. This category included: *Xoloitzcuintli Lupus Mexicanus,* Hernand.; *Nackter Amerikanischer Hund*, Haller; *Nackter Amerikanischer Hund,* Buffon; *Canis mexicanus*, Erxleben; *Canis mexicanus*, Gmelin; *Canis mexicanus, Fisch.; Nackter amerikanischer Hund*, Göz; *Chien caraïbe; Canis fam. caraibaeus*, Lesson; *Canis domesticus s. familiaris, Var. a. Amerikanischer Hund*, Rengger; *Canis fam. orthotus Xoloitzcuintli*, Reichenb.; *Hairless Dog*, Smith; *Canis caraibicus*, Tschudi; *Türkischer Hund*, Youatt, Weiss; *Nackter Hund*, Fitzinger; *Canis fam*

aegypticus, Gieb.; *Nackter Hund; Canis caraibaeus*, Fitzinger.

In his brief description of external characteristics, the author emphasized that these dogs, by their body conformation, differed significantly from other breeds and should therefore be classified into a separate group. Their origin was traced to Central America.

2. **Egyptian Dog (*Canis caraibaeus, aegypticus*).** Synonyms include: *Canis sine pilis,* Aldrov.; *Chien-turc, Buffon; Türkischer Hund*, Haller; *Canis fam. aegyptius*, Linnaeus; *Turksche Hond*, Hout.; *Canis familiaris aegyptius*, Linnaeus; *Can Turco*, Alessandri; *Naked Dog,* Penn.; *Türkischer Hund,* Martini; *Türkischer nackter Hund*, Schreber; *Canis familiaris, Var. bb*, Erxleben; *Canis familiaris aegyptius*, Zimmerman; *Canis familiaris Var. Turcicus,* Boddaert; *Canis familiaris aegyptius*, Gmelin; *Canis familiaris grajus aegyptius*, Bechstein; *Canis familiaris leporarius, aegypticus*, Walther; *Chien turc, Desmarest; Chien turc*, Lesson; *Canis familiaris aegyptius*, Fisch.; *Canis familiaris aegyptius*, Fitzinger; *Canis familiaris laniarius aegyptius*, Reichenbach; *Turkish Naked Dog*, Smith; *Chien turc; Canis fam. caraibaeus,* Laurillard; *Egyptischer, berberischer Hund,* Youatt, *Weiss; Aegyptischer Hund*, Fitzinger; *Canis familiaris aegyptius*, Gieb.

According to Fitzinger, the Egyptian hairless dog was merely a variety of the Hairless Dog (Canis caraibaeus) originating from South America, with hairlessness developing under the influence of climatic conditions.

3. **Hairless Greyhounds (*Canis caraibaeus, aegyptius turcicus*).** Synonyms include: *Levrier chien-turc*, Desmarest; *Levrier chien-turc*, Lesson; *Canis familiaris grajus turcicus*, Fisch.; *Türkischer Blendling*, Götz; *Turkish Naked Dog*, Smith; *Levrier chien-turc*, Laurillard; *Türkischer Windhund*, Youatt; *Nackter Windhund*, Fitzinger.

These dogs were reportedly the result of crossing the Egyptian Dog (Canis caraibaeus, aegyptius) with the Italian Greyhound (Canis leporarius, italicus) (Fitzinger, 1867) [7].

4. **Egyptian Long-Eared Dogs (*Canis caraibaeus, aegyptius lasiotus*).** Synonyms include: *Chien turc et gredin*, Buffon; *Canis familiaris aegyptius*, Zimmerman*; Canis familiaris laniarius aegyptius lasiotus*, Reichenbach; *Langohriger ägyptischer Hund*, Fitzinger.

The long-eared Egyptian dog originated from a cross between the Egyptian Hairless Dog (Canis caraibaeus, aegyptius) and King Charles Spaniels (Canis extrarius, hispanicus brevipilis).

5. **Egyptian Maned Dog (*Canis caraibaeus, aegyptius cristatus*).** Synonyms include: *Chien-turc métis,* Buffon; *Türkischer Hund-Blendling*, Haller; *Can Turco bastardo*, Alessandri; *Türkischer Blendling*, Martini; *Canis familiaris*, Erxleben; *Canis familiaris aegyptius*, Zimmerman*; Chien turc à crinière*, Desmarest; *Chien turc à crinière*, Lesson; *Canis familiaris aegyptius jubatis*, Fisch.; *Canis familiaris aegyptius cristatus*, Fitzinger; *Canis familiaris laniarius aegyptius subjubatus*, Reichenbach; *Chien turc à crinière*, Laurillard; *Egyptischer, berberischer Hund, var. Youatt,* Weiss*; Gemähnter ägyptischer Hund*, Fitzinger.

According to Fitzinger (1867) [7], the Egyptian maned dog was a hybrid resulting from the crossbreeding of the Egyptian Hairless Dog (Canis caraibaeus, aegyptius) with the Small Danish Dog (Canis molossus fricator variegatus).

6. **Mexican Hairless, Humpbacked Dog (*Canis caraibaeus, Hernandesii*).** Synonyms include: *Ytzcuinte Porzotli; Canis mexicana*, Hernand.; *Ytzcuintepotzotli seu Canes gibbi*, Fernand.; *Ytzumbepotzotli; Ein indianischer Hund; Canis mexicana*, Gesner; *Canis mexicanus monstroso corporis habitu*, Klein; *Mexikanischer Hund, Haller; Mexicanischer Hund,* Martini; *Canis familiaris, Erxleben; Canis familiaris americanus*, Gmelin; *Canis gibbosus*, Schinz; *Canis nudus*, Schinz; *Canis familiaris americanus*, Fisch.; *Itzcuinte-potzoli,* Humboldt; *Canis familiaris laniarius gibbosus,* Reichenbach; *Naked Dog of Mexico,* Smith; *Canis familiaris gibbosus*, Gieb.

The existence of hairless dogs as more than an incidental or defective variety of dogs is further supported by the writings of Ludwig Beckmann (1895) [8], a respected authority of his era. He noted that in England hairless dogs were referred to as "Chinese Crested Dogs." However, at dog shows of that time they were often labeled as "African Dogs." Furthermore, he stated that hairless dogs originated from South America and that, in their body conformation, the "Chinese" and "African" dogs bore a strong resemblance to the Italian Greyhound.

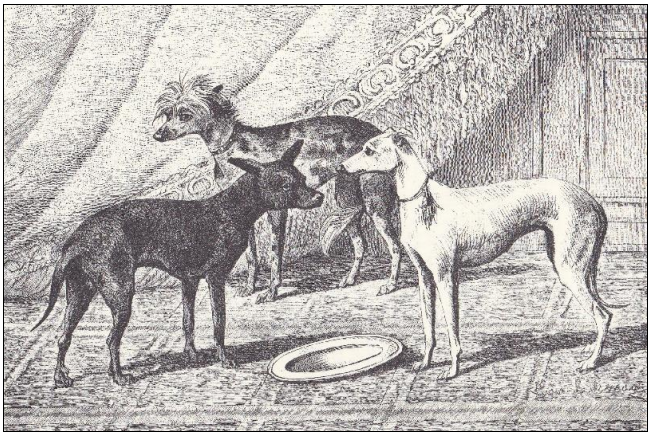

Fig 1: Hairless dogs of South America, the first on the left, a dark-colored dog, and in the background a crested dog, along with an Italian Greyhound (the light-colored dog on the right) (Beckman, 1895) [8]

The preceding illustration provides strong evidence that hairless dogs are genetically stable and have remained unchanged for centuries. From a biological perspective, it is not possible for a form that is non-adaptable to existing environmental conditions, or one that arises as a developmental error, to be maintained in nature. Such forms rapidly disappear - either eliminated by predators or by simple inability to survive. However, hairless dogs have persisted for more than 3,000 years (Räber, 2001) [10].

Contemporary Breeds

The official cynological classification established by the world's largest canine federation (FCI) recognizes three breeds of hairless dogs: the Chinese Crested Dog, the Peruvian Hairless Dog (Inca Orchid Moonflower Dog; Perro sin Pelo del Perú), and the Mexican Hairless Dog (Xoloitzcuintli). The American Hairless Terrier has been recognized as a distinct breed by the American Kennel Club (AKC).

Other hairless breeds acknowledged by local kennel clubs include the Argentine Pila Dog, the Bolivian Hairless Dog (Hairless Khala), the Ecuadorian Hairless Dog, the Hairless Chihuahua, the Indian Hairless Dog (Jonangi), and the Abyssinian Sand Terrier.

There is no unified opinion regarding the origin of hairless dogs; however, it is a fact that certain types—such as the Mexican, Peruvian, and Chinese—have been mentioned for centuries. Hauck (1960) [9] cites that Hernandez (Francisco Hernández, 1514–1578), in his work Historia Animalium et Mineralium Novae Hispaniae, described the existence of Mexican hairless dogs. The book was published posthumously in 1651. This record can be taken as evidence that these dogs existed in Mexico even prior to the arrival of Columbus.

The author further noted that a small amount of hair could occasionally be present at the tip of the tail and on the forehead. The distribution of hairless dogs was reported in Mexico (particularly in Chihuahua), as well as in Peru, Paraguay, and the Antilles.

For the Mexican Hairless Dog, various Latin synonyms have been used: *Lupus mexicanus Recchi*, Lynceus, 1651; *Canis mexicanus* Linne, 1776; *Canis familiaris aegypticus* Gmelin, 1786; *Canis familiaris xoloitzcuintli* Reichenbach, 1835; *Canis nudus* Schinz, 1821; *Canis familiaris* Lesson, 1827; *Canis caraibicus* Tschudi, 1844; *Dysodus gibbus* (=bucklig) Cope, 1887.

A reliable indication that this is an ancient breed lies in the fact that the Mexican Hairless Dog was regarded as a representative of the god Xolotl and was believed to accompany the souls of the deceased on their journey to the afterlife. For this reason, they were often buried together with their owners (Krämer, 2017). Their precise origin, however, remains unresolved. Whether the Toltecs and Aztecs already kept them as domestic dogs is still uncertain. According to Räber (2001) [10], some authors suggest that seafarers may have introduced hairless dogs from Asia into South America prior to the Aztec period. Hauck (1960) [9], however, considered that there is no substantial evidence to support such claims. Mehus-Roe (2008) [11] argued that this breed is more than 3,000 years old, having developed during the cultures of the Maya and Toltecs, and was later adopted by the Aztecs.

Despite differing opinions, the prevailing view is that the Mexican Hairless Dog represents an autochthonous breed of Mexico. Support for this claim is drawn from the description provided by Hernández, who arrived in Mexico as early as 1500. According to his brief account, these were relatively tall dogs, approximately 90 cm in height. However, the accuracy of his estimation is questionable, as contemporary Mexican Hairless Dogs are considerably shorter.

With regard to the Peruvian Hairless Dog, its existence in antiquity is confirmed by archaeological findings dating back to 300 BC. Hairless dogs were frequently depicted on ceramic artifacts and tiles from the Inca period. It is believed that the breed survived the Spanish conquest and associated brutality due to the fact that members of the Inca people preserved them within isolated enclaves (Canis ingae).

The history of the Chinese Hairless Dog remains even more obscure than that of the South American hairless breeds. Only a very limited number of reliable sources provide insight into the possible origins and historical trajectory of this breed. The most plausible hypothesis is that Chinese seafarers introduced hairless dogs either from Africa or South America. For the outside world, this breed remained virtually unknown until 1885, when a Chinese Hairless Dog was first exhibited at a show in the United States (Westminster). After that, there was a long period of obscurity until 1926, when the breed reappeared at a dog show in Philadelphia.

In contrast to nearly all other hairless dogs, whose histories are rather obscure and extend back many centuries, the case of the American Hairless Terrier is entirely different. In 1972, within a litter of farm dogs ("ratting terriers"), puppies were born with very short, soft coats which, within 8–10 weeks, completely shed, leaving them hairless. This phenomenon continued to recur in subsequent litters, and thus the hairless trait is no longer in question today. Interestingly, this breed is not uniformly colored.

Skin and its Structure

When considering the animal body, the skin represents the largest organ. It serves as both a physical and physiological barrier, functioning as the primary defense mechanism of the organism against the assaults of various external agents. The skin is a specialized type of membrane, composed of epithelial structures, which envelops the surface of the body (Žikić *et al*., 2016) [1]. Depending on the dog's breed and age, the skin may account for 12–24% of the total body mass (Šťastná & Šťastný, 2018) [6].

The main functions of the skin can be classified into several groups:

1. Protective function – The skin protects the body by enclosing it and shielding it from harmful chemical, mechanical, biological, thermal, and other external influences.
2. Metabolic function – The skin plays an important metabolic role through the synthesis of various substances, primarily vitamin D, and is significantly involved in calcium and phosphorus metabolism.
3. Receptive function – In order for a dog to respond adequately to the numerous external environmental factors that surround it, it must be able to receive timely sensory input regarding any external stimuli. Only prompt information about the action of a particular agent allows for an appropriate and timely response. Due to the presence of receptors for pain, pressure, cold, and heat located in the skin, the dog is capable of perceiving and reacting in time to avoid harmful influences.
4. Thermoregulatory function – This function plays a fundamental role in the establishment and maintenance of a constant body temperature.
5. Excretory function – Although listed near the end of the enumeration of skin functions, this role is by no means of marginal physiological importance. On the contrary, excretory processes through the skin are of fundamental significance, as the skin represents the largest excretory organ.
6. Respiratory function (cutaneous respiration) – This refers to the release of carbon dioxide from the body into the external environment and the absorption of oxygen from the surrounding air. In dogs, this process accounts for approximately 0.35–1.7% of the total amount of carbon dioxide eliminated (Troitsky, 1948). The quantity of oxygen absorbed is approximately equal to the amount of carbon dioxide released.

7. Storage function – The skin also serves as a depot for certain substances such as water, mineral elements, fats, and vitamins.

The importance of the skin for the survival of an individual is illustrated by the fact that damage exceeding 25% of the body's total skin surface area leads to death.

Anatomically, the skin (*integumentum commune*) consists of two complex layers: the cutis and the subcutis. The superficial layer, the cutis, is composed of the epidermis and the dermis (*corium*). In general, females have thinner skin compared to males. The thickness of the skin in dogs is not uniform and varies depending on the body region. On the dorsal part of the back, the skin thickness ranges from 2 to 5 mm, while on the flanks it measures approximately 1.5–2 mm. Interestingly, the skin surface exhibits an acidity (pH) level of around 6.0.

The epidermis represents the outer covering layer of the skin and is the portion that directly interacts with the external environment. In many mammalian species, there is an inversely proportional relationship between the thickness of the epidermis and the density of hair coverage (Kligman, 1964, cited in Džuks, 1975). When the epidermal layer has lost a significant portion of its hair covering (as in humans) or when hair has completely disappeared from the body—as in hairless dog breeds—intense and functionally important physiological and anatomical changes occur within the epidermis as part of adaptive modification. These changes aim to compensate for the protective role that the hair once provided. This protection is primarily based on the formation of a markedly altered cornified layer (*stratum corneum*), which becomes thicker, more resistant, flexible, and elastic. Within this layer, several cell types are present, including keratinocytes, melanocytes, Langerhans cells, and Merkel cells. The majority of the epidermis is composed of keratinocytes.

Viewed from the surface toward the deeper layers, the epidermis is composed of several sublayers:

Stratum disjunctum (desquamating layer) – This is the most superficial, outermost layer of the epidermis. It is composed of keratinized, degenerated cells that are shed from the body surface. The cells of this layer contain paraleidin, and they are non-viable (dead) cells.

Stratum corneum (cornified layer) – This layer lies beneath the outer desquamating layer. It is composed of keratinized, flattened, non-viable cells arranged in multiple strata. From a phylogenetic perspective, the process of keratinization emerged at the time when vertebrates began adapting to new environmental conditions and transitioning to terrestrial life (Biedermann, 1926; Rothman, 1964, cit. Đuks, 1975). The cells of this layer lack nuclei and cytoplasmic organelles and are completely filled with keratin. In hairless dogs, this layer exhibits specific structural characteristics that differ from the superficial epidermal layer of coated dogs.

Stratum lucidum (clear layer) – This layer consists of keratinized cells arranged in several strata and is present only in regions where the epidermis is thick. A characteristic feature of this layer is the close alignment of its cells, making the boundaries between individual cells often indistinguishable. These cells contain eleidin, an intermediate protein that eventually transforms into keratin. Eleidin is found exclusively in the stratum lucidum. The cells of this layer lose their nuclei and organelles. The clear layer represents a transitional zone between the keratinized and non-keratinized layers of the epidermis. In coated dogs, this layer is thickest on the paw pads, whereas in hairless dogs, it extends over the entire body surface, contributing to the thickness and elasticity of the skin.

Stratum granulosum (granular layer) – This layer is composed of living, non-keratinized cells. Within this zone, the process of keratinization begins, resulting from the accumulation of keratohyalin granules. The stratum granulosum is not uniformly present across all body regions. In animals with a thick epidermis, this layer is well developed, whereas in those with a thin epidermis it is either very thin or completely absent. When present and well defined, it typically consists of four to five layers of cuboidal or rhomboid cells. These cells contain a round nucleus and cytoplasmic keratohyalin granules, the number of which increases toward the upper part of the layer. Desmosomes play an important role in the keratinization process. The keratohyalin granules exhibit a fibrillar structure, contain calcium, and lack sulfhydryl-group proteins—a biochemical characteristic distinguishing keratohyalin from keratin. During the maturation process, cytoplasmic organelles gradually disappear (Snell, 1965; Odland & Reed, 1967, cit. Соколов, 1973 [13]). In addition to keratohyalin granules, the cytoplasm of these cells also contains lipid granules, the contents of which are excreted via exocytosis into the intercellular space. This intercellular substance functions as a binding medium connecting adjacent cells. In contrast to coated dogs, in which the process of keratinization and desquamation is visibly continuous, hairless dogs exhibit a markedly slower and almost imperceptible cycle of cellular keratinization and exfoliation, though the process itself remains active at a much slower physiological rate.

Stratum spinosum (spinous or prickle cell layer) – The structure of this layer is not uniform and varies in the number of cellular strata it contains. The cells located adjacent to the upper portion of the basal layer are typically cuboidal or sometimes prismatic in shape. The cells of this layer contain round nuclei and well-developed cytoplasmic organelles; however, unlike the cells of the basal layer, mitochondria are absent. The cells of the stratum spinosum originate through mitotic activity of the basal layer. Generally, they lack the capacity for further division, although exceptions exist—certain cells within this layer may retain limited mitotic potential (Žikić *et al*., 2016) [1]. A characteristic feature of this layer is the presence of intercellular bridges (desmosomes) and tonofibrils, which provide mechanical strength and cohesion to the epidermis. Compared to the basal layer, the number of ribosomal granules is significantly reduced, while the Golgi apparatus is evenly distributed throughout the cytoplasm. Within this layer are also located Langerhans cells, which play an essential role in the immunoregulatory functions of the skin (Štastna & Štastny, 2018) [6].

Stratum basale (basal layer) or *Stratum germinativum* (germinative layer) – This is the deepest layer of the epidermis, located directly on the basement membrane, which forms the boundary between the epidermis and the dermis. The name derives from its position and its critical role in cellular regeneration. Within this layer, intensive mitotic activity occurs, primarily among keratinocytes, which are gradually pushed toward the surface to replace the continuously desquamating cornified cells. The rate of keratinocyte proliferation is directly related to the rate of desquamation—the slower the exfoliation, the slower the

mitotic activity. The basal and spinous layers contain living cells and are together referred to as the Malpighian layer (*stratum Malpighii*) or rete mucosum (Соколов, 1973) [13]. The basal layer is composed of cuboidal to columnar cells, whose apical surfaces—those adjoining the spinous layer—often exhibit a conical shape. This configuration facilitates close intercellular contact with the overlying stratum spinosum. The shape of the basal cells varies with epidermal thickness: in regions with a thick epidermis, the cells are columnar or prismatic, whereas in areas with a thin epidermis—typical for skin covered with dense hair—they appear flattened. Cells of the basal layer give rise to all layers of the epidermis. They contain mitochondria localized in the perinuclear zone, and surrounding these mitochondria are small protein granules, thought to represent the initial precursors of keratin (Соколов, 1973) [13]. Golgi complexes are concentrated in the distal part of the cytoplasm. Together with the spinous layer, the basal layer forms the proliferative center of the epidermis. The rate of mitotic division varies depending on both the body region and circadian rhythm. In humans, the lowest mitotic activity occurs around 10:00 a.m., while the peak activity is observed near 10:00 p.m. (Соколов, 1973) [13].

Within the epidermis, there are also cells that do not undergo the process of keratinization. These are referred to as non-keratinocytes. For example, Merkel cells, located in the basal layer, are closely associated with nerve endings that extend from the dermis into the epidermis. In coated dogs, these cells are positioned near the hair follicle. Their primary function is mechanoreception—they serve as sensory receptors, particularly within the paw pads, where they detect touch and pressure stimuli. The complex structure formed by a Merkel cell and its associated nerve ending is known as a Merkel corpuscle.

Another type of non-keratinocyte is the Langerhans cell, a branched dendritic cell widely distributed throughout the non-keratinized regions of the epidermis. These cells are of mesenchymal origin, with precursors derived from the bone marrow. Their cytoplasm contains characteristic Birbeck granules, which serve as diagnostic markers for identifying Langerhans cells within the epidermis. Functionally, they act as antigen-presenting cells, playing a key role in the cutaneous immune response.

Melanocytes are also classified as non-keratinocytes. They are found within the basal layer and are characterized by numerous dendritic processes, which establish contact with surrounding keratinocytes. A single melanocyte typically interacts with 20–40 keratinocytes, forming what is known as an epidermal–melanin unit. Melanocytes are derived from neural crest cells, and on average, 2–10% of the cells in the basal layer are melanocytes. Their number varies according to breed and coat pigmentation. The main function of melanocytes is the synthesis of melanin, a process regulated by both hormonal and genetic factors (Štastna & Štastny, 2018) [6].

The cell turnover process within the epidermis follows a cyclic pattern, beginning with mitotic division in the basal layer. Newly formed cells proliferate and gradually migrate toward the surface, undergoing a series of qualitative transformations as they progress through the stages of keratinization and cornification. Depending on the breed and specific physiological characteristics, the complete renewal cycle—from cell division to desquamation—takes approximately 20 to 30 days.

It is interesting to note that in newborn Mexican hairless dogs, the epidermis appears thicker, with the presence of epidermal invaginations, which are a clear indicator of rudimentary hair follicles (Fakuta *et al*., 1991). By the time the puppies reach two months of age, these depressions with rudimentary follicles are no longer visible. However, hair follicles and sweat glands remain present on the head and tail. The authors also reported that these dogs exhibit rapid thymic degeneration, emphasizing the need for further studies on the immune system of hairless dogs in future research.

The dermis (*Dermis seu Corium*) is the layer of skin located beneath the epidermis. It is composed of several types of fibers, with collagen fibers being predominant. Fundamentally, it consists of fibroelastic connective tissue, which provides the skin with its strength and elasticity. The epidermis and its associated cutaneous structures are situated above the dermis, relying on it for the nutrients necessary for their maintenance (Đuks, 1975). The dermis is separated from the epidermis by a basal lamina, and it contains sebaceous glands, which are more numerous in hairless dogs than in coated breeds. Consequently, this layer is somewhat thicker in hairless dogs. Within the dermis, striated muscle fibers originating from the subcutaneous musculature can also be found.

The dermis consists of two layers:

*Stratum papillare (*papillary layer*)* – this superficial layer is characterized by the presence of dermal papillae at the junction with the epidermis. It is usually a thin layer rich in capillary networks and connective tissue cells. In addition to capillaries, this layer contains both afferent and efferent nerve fibers. These nerve fibers provide sensory and autonomic innervation to the skin, receiving stimuli from the external environment and contributing to sensory perception and local vascular regulation.

Stratum reticulare (reticular layer) – the deeper and thicker portion of the dermis. It consists of dense irregular connective tissue. The name reticular is somewhat inaccurate, as this layer is primarily composed of thick, coarse collagen fibers rather than reticular fibers. Typically, the reticular layer is thicker than the papillary layer. Within it are located sebaceous glands and nerve endings. This layer lies above the subcutaneous connective tissue, with which it is not always clearly demarcated; the boundary is generally found at the level of the hair follicles or the roots of hair shafts. The dermis is composed of connective tissue dominated by fibroblasts, which synthesize both the extracellular ground substance and collagen fibers. The thickness of the dermal layer varies across different regions of the body.

Subcutaneous connective tissue (*subcutis or hypodermis*) – is composed of connective tissue rich in collagen fibers, adipocytes, and larger blood vessels. The subcutis serves to anchor the skin to the underlying fascia and musculature, acts as an insulator and shock absorber, participates in thermoregulation, and represents an energy reserve derived from the breakdown of lipids stored within this layer.

Skin glands

The skin functions as both a communicative and informational organ. In dogs, two types of sweat glands are present: merocrine and apocrine glands. Although apocrine glands are technically classified as sweat glands, they do not

produce sweat; instead, they secrete pheromones, which play a role in individual recognition among animals.

Apocrine glands are distributed across the entire surface of the skin. In the anal and genital regions, these glands merge with sebaceous glands (Polishchuk & Trofimenko, 2007). According to the authors, the density of the hair coat, that is, the number of hair shafts per unit area, is highly variable, generally ranging from 1,000 to 9,000 hairs/cm². Apocrine glands are located adjacent to hair follicles. Structurally, they are tubular glands that lack their own excretory ducts to the skin surface; instead, their secretions are discharged into the hair follicle. The secretion produced by these glands has a distinct odor that is species-specific.

However, in his monograph on the skin, Sokolov (1973) states that the excretory duct of the apocrine gland is located very close to the hair follicle, running parallel to it toward the surface, and opens into the lumen of the hair canal. It may occur that two apocrine glands discharge into a single hair follicle. Occasionally, though rarely, an excretory duct of this type of gland may reach the skin surface directly and release its secretion there. The cytoplasm of each apocrine gland cell contains fine, delicate basophilic granules. In the basal portion of the glandular cell, there is typically one large spherical nucleus, although occasionally two nuclei may be present. Each nucleus contains one or two prominent nucleoli rich in ribonucleic acid (RNA). The nucleus of the secretory cell is enveloped by two membranes — the inner membrane, which is thicker, and the outer membrane, which is thinner.

Sweat glands may be merocrine (or eccrine) — where the secretion is released from secretory granules by exocytosis, or apocrine — where the apical portion of the cell is released along with the secretory granules. Sebaceous glands, on the other hand, are holocrine, meaning that the entire cell becomes part of the secretory product. In apocrine secretory glands, in addition to numerous lipid components, iron is also present. The iron content varies considerably — some cells contain a significant amount, while others have very little. The pigmentation of the glands is an individual characteristic, depending on the quantity, number, and color of pigment granules. The diameter of these pigment granules is highly variable, ranging from barely visible particles to those nearly the size of a nucleus. Merocrine (eccrine) glands play a more significant role in thermoregulation. When a dog's body temperature rises excessively, these glands produce sweat. They are located exclusively on the paw pads and absent elsewhere on the body. Structurally, they are simple, coiled tubular glands. Unlike apocrine glands, merocrine glands possess their own excretory ducts, through which they release secretion independently of the hair follicle (Žikić *et al*., 2016) [1].

Eccrine sweat glands are simple coiled tubular structures that extend from the epidermis into the middle layers of the dermis, and in some cases, even reach the subcutaneous adipose tissue.

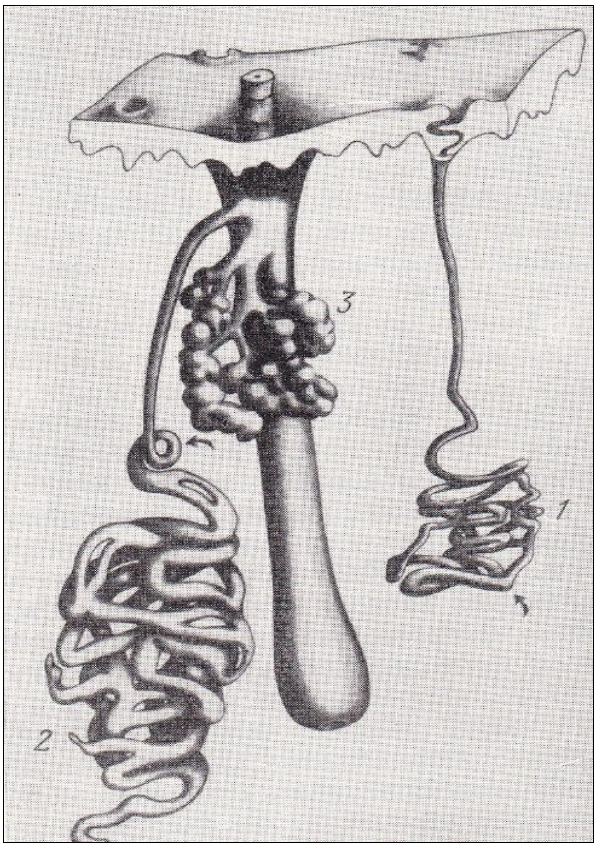

Fig 2: Schematic representation of the structure of eccrine (1), apocrine (2), sweat, and sebaceous glands (3) (Sokolov, 1973).

Depending on their depth of penetration, eccrine glands are divided into two groups: a) deep glands and b) superficial glands. Each gland consists of an irregularly coiled basal portion and a straight duct that extends toward the proximal part of the epidermis. The diameter of the excretory duct is typically about one-third of that of the secretory segment.

Two types of cells are distinguished in eccrine glands. The first group includes small, superficial cells, which exhibit variable translucency. Their cytoplasm contains granules that impart a dark coloration, hence the term dark cells (Montagna *et al*., 1953, cit. Sokolov, 1973). These cells contain ribonucleic acid (RNA), basophilic components, and mucopolysaccharides (Ito *et al*., 1951; Montagna *et al*., 1953; Formisano & Lobitz, 1957; Dobson & Lobitz, 1958; Dobson *et al*., 1958; cit. Sokolov, 1973). Their nuclei are oval and compact, with a rarely visible chromatin network. The second group consists of larger basal cells containing acidophilic cytoplasmic granules; hence they are referred to as light cells. The nuclei of these cells are round and filled with granular material.

The thermoregulatory system in hairless dogs operates differently. Their bodies lack the insulating hair coat, and due to this anatomical and physiological specificity, the superficial dermal capillary network functions as an active

component of heat dissipation through vasodilation. In general, hairless dogs are thermally more labile, meaning they cool more rapidly at low temperatures and overheat more quickly in warm environments. Both apocrine and eccrine glands are present in hairless dogs, but their number is significantly lower than in coated breeds.

Skin Pigmentation

When it comes to skin pigmentation, two main types can be distinguished:

a) Endogenous pigmentation – this type is further divided into hemoglobin pigmentation and autogenous pigmentation;

b) Exogenous pigmentation.

Hemoglobin pigmentation arises as a causal consequence of erythrocyte breakdown, during which pigments such as hemosiderin and bilirubin are released. The process of erythrocyte degradation depends on numerous factors, both physiological and pathological.

Autogenous pigmentation is determined by the deposition and quantity of melanin.

Exogenous pigmentation depends on the deposition within the skin of substances foreign to the organism (for example, as a result of the therapeutic application of certain ointments).

Unlike in humans, where skin pigmentation becomes established after birth, in dogs, the formation of skin pigment occurs during the development of hair follicles. In general, skin pigmentation depends on the presence of two types of pigments. The first pigment is a blood hemoglobin derivative containing hemosiderin, while the second is the typical skin pigment that contains no iron and is known as melanin. Melanin is a complex polymer (Troitsky, 1948), and its synthesis is based on the amino acid tyrosine.

There is no unified view regarding the exact process of melanin formation, but it is certain that it occurs within the melanocytes located in the basal layer of the epidermis. There is approximately one melanocyte for every 10–20 keratinocytes. Melanocytes originate from neural crest cells and migrate into the epidermis early in fetal life. Special staining techniques reveal that melanocytes possess long cytoplasmic extensions which interdigitate between keratinocytes, thus establishing an intimate functional relationship between these two cell types. Within melanocytes, melanosomes and premelanosomes can be observed in the cytoplasm, where the greatest amount of melanin pigment is concentrated.

Currently, five main theories explain the pathways and mechanisms of melanin formation:

1. Biochemical (Enzymatic) Theory – This is the most widely accepted explanation of melanin synthesis, also known as the Raper–Mason pathway. The core of this process involves the conversion of tyrosine into DOPA (dihydroxyphenylalanine), which is then oxidized into dopaquinone (DQ). The reaction begins in the presence of the enzyme tyrosinase. The subsequent steps of melanin formation proceed through spontaneous cyclization and polymerization, resulting in eumelanin, or, in the presence of cysteine, in pheomelanin (Raper, H.S., 1928) [16].
2. Free Radical Theory – This theory is based on the concept that melanin has an adaptive function, serving as a neutralizer of free radicals and reactive oxygen species (ROS). The oxidation of tyrosine and other aromatic compounds helps remove potentially toxic radicals, with the final product being a stable pigment (Mason, H.S., 1948) [17].
3. Photoprotective Theory – According to this hypothesis, melanin evolved as a protective mechanism against UV radiation. Melanin acts as a biological filter that prevents the harmful effects of ultraviolet rays, thereby protecting DNA strands from damage and mutagenic changes. Over time, the functional roles of melanin expanded to include thermoregulation and visual characterization (such as skin and coat coloration) (Solano, 2014) [18].
4. Innate Defense Theory – This theory suggests that melanogenesis is part of the organism's innate immune defense system. Melanin is often produced at sites of injury or infection, where it serves as both a physical and chemical barrier. In mammals, melanocytes and melanin participate in immunomodulation of the skin and in the neutralization of various toxins (d'Ischia *et al*., 2015) [19].
5. Neurobiological Theory – This theory focuses on neuromelanin, a specific form of melanin that accumulates in neuronal cells of the brain. Neuromelanin is formed through the spontaneous oxidation of catecholamines (dopamine, noradrenaline), which suggests its potential role in neuronal protection (Zecca *et al*., 2003) [2]. U intermedijalnom sloju kože lociraju se melanociti koji potom prolaze u epiderm, a posle prelaze u dlačni mešak. Ovde se melanociti raspadaju a pigment, koji je bio u njima, prelazi u epidermalne ćelije i nakuplja oko ćelijskog jedra.

The onset of hair formation occurs during embryonic development.

The process begins with accelerated cell division in specific regions of the epidermis. In certain hairless dog breeds (such as the Mexican and Peruvian Hairless Dogs), this process—responsible for the formation of the hair follicle and subsequent development of the hair coat—remains active only in particular areas of the body: the upper parts of the limbs, the neck, and almost the entire length of the tail. In all other regions, embryonic formation of hair follicles does not occur, and consequently, hair is absent later in life.

In contrast, in the Chinese Crested Dog, the process of follicle formation is not as drastically interrupted. As a result, the body surface shows numerous fine hair filaments, while denser hair growth appears on the lower parts of the legs, head, neck, and tail tip. Occasionally, individuals may even exhibit a fully developed hair coat.

There are three types of melanin:

a) Neuromelanin – located in the brain tissue;

b) Eumelanin – dark in color, responsible for the dark skin pigmentation of the Mexican and Peruvian Hairless Dogs;

c) Pheomelanin – derived from cysteine, it contains red-brown benzothiazine polymers. This type of melanin causes lighter, reddish mottling of the skin, as seen in the Chinese Crested Dog and the American Hairless Terrier.

The synthesis of melanin from dihydroxyphenylalanine (DOPA) occurs in pigment cells (melanocytes) of various organs and is particularly pronounced and intense in the epidermis. Melanin synthesis begins with the oxidation of dihydroxyphenylalanine under the influence of the enzyme tyrosinase, producing dopachinone. Through further oxidation and indole ring closure, dopachinone is converted into 2-carboxy-2,3-dihydro-5,6-dioxyindole

(leucodopachrome), which subsequently undergoes decarboxylation and oxidation to form 5,6-dioxyquinone. This compound is then oxidized to indole-5,6-quinone, and polymerization of multiple indole-5,6-quinone molecules results in the formation of melanin.

In simpler terms, melanin is synthesized within specialized organelles called melanosomes, located in the central region of melanocytes. Within these organelles, tyrosine is oxidized to DOPA, and continued oxidation ultimately produces melanin as the final product.

Under the influence of ultraviolet (UV) radiation, melanosomes reorganize and move toward the cell periphery via microtubules, after which they are transferred through melanocyte dendrites into keratinocytes. This process mainly occurs in the upper layers of the epidermis, where melanin provides maximum protection against UV radiation.

Melanin is found intracellularly as microscopically visible granules or clumps, or diffusely distributed as submicroscopic dust-like particles. Cells that synthesize melanin themselves are called melanophores, while those that receive pigment from other cells are referred to as melanophages.

From a chemical standpoint, melanin consists primarily of carbon (C), nitrogen (N), oxygen (O), and hydrogen (H). It is soluble in alkaline media, but insoluble in water and organic solvents, and exhibits high chemical resistance.

The synthesis of melanin is induced by exposure to light, specifically ultraviolet (UV) radiation. The production of melanin, or melanogenesis, functions as a protective mechanism. Although hairless dogs lack a coat, their epithelium is rich in melanocytes, which actively produce melanin. It should be emphasized that melanin is an exceptionally effective light absorber—approximately 99.9% of incident light is absorbed and then scattered, preventing light from penetrating into the deeper layers of the skin. Consequently, light energy does not accumulate, and overheating of the dog's body does not occur. The small portion of energy not absorbed or reflected is still taken up by melanin, thus contributing to the maintenance of a constant body temperature.

In addition to its role in regulating the energy balance, melanin also acts as a powerful antioxidant. It reduces oxidative stress within cells by neutralizing free radicals.

A significant problem arises when irresponsible owners improperly clip their dogs, removing the natural protective hair coat and exposing the skin directly to sunlight. Inadequately pigmented skin, which lacks sufficient melanin, has no natural photoprotection, making it highly susceptible to damage from ultraviolet radiation.

The Functional System of Melanocytes

Melanocytes are specialized cells located within the hair follicle and represent the primary site of melanin production. For melanin to be synthesized, a synchronized interaction of numerous processes and biochemical mechanisms is required.

Melanin synthesis is governed by the activity of multiple genes distributed across several loci, commonly designated as E, C, B, A, and K. Each of these loci carries different alleles that influence pigment expression.

The production of melanin begins with the activity of the MC1R (melanocortin 1 receptor) protein, encoded by the E locus. This membrane-bound protein of melanocytes plays a key role in receiving and interpreting external cellular signals. When there are no activating signals from other cells, MC1R remains active and promotes the synthesis of eumelanin, the dark pigment. Conversely, when specific signaling molecules (such as agouti signaling protein) interact with MC1R, it shifts its activity toward the production of pheomelanin, the yellow-to-red pigment. Thus, the functional state of MC1R determines which type of melanin is produced within the melanocyte, making it a crucial molecular switch in the regulation of coat and skin pigmentation.

The question arises: where does the informational signal that activates the MC1R protein originate? This signal is mediated by the ASIP (Agouti Signaling Protein), encoded at the A locus. This protein is synthesized by other skin cells, and when present in sufficient concentration, it binds to the MC1R receptor on melanocytes. Upon binding, MC1R activity is redirected toward the production of pheomelanin, the yellow-to-red pigment. The synthesis of pheomelanin continues as long as ASIP remains bound to MC1R. During this period, the developing hair shafts exhibit a lighter, yellowish-red coloration. When the ASIP protein detaches from MC1R, the receptor reactivates the pathway leading to eumelanin production, resulting in the synthesis of the dark pigment.

A similar interaction occurs with another protein encoded at the K locus, known as CBD103 (β-defensin 103). When CBD103 binds to MC1R, it inhibits the activity of ASIP, thereby allowing melanocytes to produce eumelanin. Although CBD103 itself does not directly stimulate eumelanin synthesis, it acts as an inhibitor of ASIP, preventing its attachment to MC1R. Consequently, the type of pigment produced—either pheomelanin or eumelanin—depends on which of these two proteins (ASIP or CBD103) successfully binds to the MC1R receptor and dominates the signaling pathway.

Melanin synthesis takes place within melanosomes, which are located inside melanocytes. For this process to proceed smoothly, the SLC45A protein, located at the C locus, is responsible.

Genetic Regulation of Hair Growth

Hair primarily serves a protective function, shielding the body from extreme climatic conditions. Depending on the environmental region, the structural characteristics of hair vary considerably. Among the wide range of domesticated dog breeds, there are individuals completely hairless, as well as those with short, harsh, or long coats. Hair can be straight, slightly wavy, or even curly.

From a genetic standpoint, it is known that short-haired phenotypes are dominant over long-haired ones, and that wire-haired coats are dominant over short-haired coats (Stur, 2016) [3]. From a molecular genetic perspective, it has been established that three genes determine coat variability within breeds: FGF5, RSPO2, and KRT71.

The FGF5 gene is responsible for controlling hair growth and development. If no mutations occur in this gene, it will appropriately signal the cessation of hair growth at the proper stage, resulting in a short-haired dog. In cases where mutations are present in this gene, hair growth continues, producing a long-haired dog. The gene for short hair is dominant over the altered gene that causes long hair.

The RSPO2 gene is part of a gene group responsible for hair fiber growth from the follicle. A mutation in this gene ("gain

of function") is associated with wiry hair texture and the development of beards and eyebrows in dogs.

The KRT71 gene belongs to the keratin gene family. It influences the level of keratin within the hair follicle, thereby determining the stability and structure of the hair shaft.

Another gene responsible for hairlessness is FOX13 (Drögenmüller *et al*., 2008; cited in Stur, 2016 [3]). It plays a crucial role in the development of the skin, hair, sensory organs, teeth, and the nervous system. A mutation in this gene leads to alterations such as hair absence and tooth deficiency, which is why hairless dogs often lack teeth. Hairlessness also has a specific characteristic — in cases of homozygosity, the puppies die either during embryonic development or shortly after birth.

In the case of the American Hairless Terrier, the situation is completely different. Puppies are born with a slight coat, having dense, fine, short hair that sheds by the age of 8–10 weeks. Another significant difference is that this hairless breed does not exhibit tooth deficiency. Therefore, in this instance, the gene responsible for hairlessness does not affect the number of teeth in the jaw.

Genetic formula of hairless dogs

As already mentioned, in the breeding of hairless dogs (those lacking coat on the body), fully coated variants also occur. Hairlessness is a genetically dominant trait. The gene for hair is represented as dominant (H) and recessive (h). A hairless dog carries the (Hr) combination, which is dominant over the recessive form (hr). It should be emphasized that the gene responsible for hairlessness is an incompletely lethal dominant gene. This means that if a puppy carries the combination (Hr Hr), it will die in utero or shortly after birth. In contrast, when a puppy inherits the double recessive combination (hr hr), it represents a homozygous powder puff—thus, the body is fully coated. This genetic combination is not lethal.

It should be emphasized that hairlessness is dominant over the presence of hair. All hairless dogs carry the gene for coat. All hairless dogs are heterozygous (Hh).

The amount of tyrosinase in melanocytes is regulated by the melanocyte-stimulating hormone receptor (MSHR). The production of pheomelanin and eumelanin is controlled by genes located at the (A) (agouti) and (E) (extension) loci, where the allele at the (E) locus is encoded by MSHR, while the alleles at the (A) locus encode a peptide that acts as an antagonist to MSHR.

The shape and intensity of the granular eumelanin pigment are determined by the gene located at the (B) (brown) locus, where the dominant form is responsible for eumelanin production, while the recessive allele (b) is responsible for pheomelanin production. The control of tyrosinase production, and consequently the intensity of pigmentation, is regulated by the (C) (albino) locus.

Such genetic regulation is responsible for the Chinese Crested Dog, the Mexican Hairless Dog, and the Peruvian Hairless Dog. In the American Hairless Terrier, however, the process follows a different course. In the available literature, there are no data regarding the occurrence of similar mechanisms in other hairless breeds.

Conclusion

The body surface temperature, as well as the overall body temperature, are the same as in other dogs. Dogs with a coat have a thinner epidermal layer compared to hairless dogs. The increased thickness of the epidermis compensates for the absence of hair and assumes its protective role in preventing overheating or excessive cooling.

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