

Integuments of amniotes and fishes biology essay

[Science](#), [Biology](#)



Student Name: Fong Siao Wan

Table of Contents

- 1) Scope of Work
- 2) Anatomy, morphology, form
- 3) Synthesis
- 4) Form-function relationship
- 5) Evolutionary Aspects and Adaptations to terrestrial environments
- 5) Comparative approach
- 6) Conclusion
- 7) References

Scope of Work

To describe the integument of amniotes and fishes, describing each different type of integument, its form, function and morphology in different amniotes like class Synapsida, Sauropsida and Aves. Synthesis of the different types of integuments will then be discussed and the form-function relationship of the different integument will be examined. The different types of integuments will then be compared against one another to find out the evolutionary pathways and then a detailed literature review on the integuments of amniotes and their evolution and adaptations from fully aquatic environment to a terrestrial environment will be discussed. Anatomy, morphology and form

Amniotes are categorized into Synapsida, Sauropsida and Aves. Class Synapsida consists of mammals, Class Sauropsida consists of order Testudines, super order Lepidosauria, which consists of Tuatara; and order Squamata which consists of lizards and snakes. The other subclasses consists of crocodilians. The last class, Aves consists of birds. The compact skin of the shell of testudines is made of large scutes, which accumulate beta-keratin (Alibardi 2005ii). Scutes are formed in the living dermis, producing horny scales that are superficially similar to scales. The epidermis is separated into large and flat scutes organised along three columns in the carapace and into various scutes in the plastron. The shell's epidermal area, consisting of the carapace, usually has 38 scutes, and the plastron sixteen. The bone and shield patterns do not precisely overlap each other and the

pattern of the scutes and scales form two minimally overlapping patterns (Scott F. Gilbert et al. 2001). A thin hinge region is between the scutes (Zangerl 1969) and allows tortoises/turtles to pull their carapaces and plastrons tightly together, forming a shield for the animal. The flexible epidermis of the limbs, neck and tail consists of α -keratin and a little β -keratin, the transitional layer also a mix of α and β -keratins, and the shell consists of a thick corneous layer of β -keratin. There are no specialized shedding mechanisms involved in renewing of shell and mostly wear and tear occurs through mechanical insult (Alibardi and Gill 2007). Squamata consists of lizards and snakes. Thus, they have homogeneous epidermis and for both species, thick, dense, inflexible horny scales separated by thin hinge regions cover the whole body. The epidermis of squamata is specially designed for the cyclical sloughing of the whole horny layer (Spearman 1965). Snake scales are constructed by the differentiation of the epidermis. It consists of an outer and inner layer. The epidermis consists of six epidermal layers, termed oberhautchen, beta, mesos, alpha, lacunar, and clear, which are produced during the renewal phase of the epidermis (Alibardi 2005i). The skin overlaps the base of the next scale and this goes on (Greene, W. Harry 2004). Overlapping snake scales are called imbricate scales and are aligned in rows along the different sides of the snake, either in singles or in pairs and snakes have a fixed number of scales when it is born and the number does not change as it grows older. Instead the scales change size and shapes as the snake (Greene, W. Harry 2004). Snake scales come many different shapes and sizes. Snake scales may be coarse-grained, smooth or have a ridge or keel on it. They may have a cycloid shape, long

and pointed shape, broad or leaf-like, or broad and long (Greene, W. Harry 2004). Snake scales are separated into head scales, dorsal scales, ventral scales and tail scales. One of the scales are non-overlapping round shape scales found on the area of the heads of snakes and lizards. The other type of scale is the most commonly occurring scale in snakes is the imbricate scale, having a distinct outer and inner surface. The overlapping scale is asymmetrical, and the outer surface consists of a greatly cornified epidermis and consists of β -keratin, which provide stiffness for the scale (Chen et al 2009). Lizard scales vary in form. They are shaped like imbricate scales, to tubercular or to platelike. On the surface, these scales consists of horny keratinized epidermis, and they probably have osteoderms underneath them, supporting the epidermis (Kardong, K. V. 2002). The horny scales cover all the body parts of lizards and like snakes, large parts of the scales undergo shedding or moulting at regular intervals. In many lizards the scales are regularly shaped and correspond to the regions they overlie (Hyman, L. H. 1979). Crocodilians' epidermal exoskeleton consists of elongated and rounded horny scales, arranged in diagonal rows. The tail scale arrangements are very regular but the scales on the sides of the head and trunk are not so regular and much smaller. Along the mid-dorsal line of the tail, the scales are raised into tall structures that give the tail more traction for swimming (Gadow H. 1909, Reese A. M. 1915). The dermal exoskeleton is made of osteoderms that lay under the epidermal scales of the rear end of the crocodilian. The scales on the top, except in very young animals, are always worn out, and the bony scales are exposed. The inner surface of the scutes is smooth and flat, while the outer surface is rough and uneven. In old

animals the scutes are extremely rough and pitted. The dermal plates are nearly uniform in outline and are adhered together almost in every area (Gadow H. 1909, Reese A. M. 1915). The scutes are grouped into nuchal and the dorsal shields. The former is situated at the back of the head, and in the area of the forelegs, and consists of four larger plates and numerous smaller plates. The dorsal shield, expands to the back in rows along the long axis and rows extending the back. There are six to eight of scutes extending the back at the widest area of the trunk and they gradually reduce towards the tail (Reese, A. M. 1915). The horny layer of the crocodilians is shed continuously, similar to testudines but the thick scutes retain some of the keratin (Gadow, H. 1909, Reese A. M. 1915). These scales are found to contain a mix of α and β keratins, but are different in the arrangement, unlike snakes and lizards (Rudall K. M. 1947). The Tuatara (*Sphenodon punctatus*) are the last living sphenodontids (Alibardi and Gill 2007). The epidermis of the tuatara is similar to that of snakes and lizards. The external layers comprise of beta-keratin which are generally combined into a mass of cytoplasm containing many nuclei in mature epidermis while the inner layers, known as mesos and α -layers, are made of keratinocytes which contain α -keratin. The tuatara does not have a specialized shedding complex, unlike lizards and snakes (Alibardi and Gill 2007). In the tuatara the β -layer is important in that it causes the mechanical resistance of scales. The α -layer is responsible for the elasticity of the scaled epidermis, situated under the β -layer (Alibardi and Gill 2007). However, the mesos region and the α -layer is more important in forming the water loss-barrier that limits water dispersion, by producing lipid-rich lamellar bodies (Lillywhite, H. B, and

Maderson, P. F. A. 1982, Menon et al. 1996). Bird integument shows more diversity of function compared to that of reptiles. Feathers are the most complex vertebrate skin appendage and in most birds, scales are found on the avian foot. Birds have three type of scales on the leg region, the scutella, the scutate, and reticulate scales (Dhouailly, D. 1984 and Sawyer et al. 1986). The foot pad reticulate scales are radially symmetrical. Scutella and scutate scales are similar strutrally, but scutella scales have a reversed orientation and are smaller in size. Both show anterior-posterior polarity (Wu et al. 2004). Avian scutate scales and reptile overlapping scales appear similar morphologically and both have the outer and inner surface and hinged regions (Maderson 1972). However, unlike the reptile overlapping scales, avian scutate scales form placodes. Similar to the reptile scales, the outer surface of avian scutate scales is composed of both α and β keratin (Sawyer 1972). The β keratins are restricted to the stratum intermedium and stratum corneum of the outer scale surface. α -keratins are found in the stratum basale and stratum intermedium of the outer scale surface and throughout the epidermis of the inner scale surface and hinge region (O'Guin and Sawyer 1982). The epidermis in avian reticulate scales only expresses α -keratin in the stratum corneum and stratum intermedium. No β keratin has been detected there (O'Guin and Sawyer 1982). The skin of mammals is made of epidermis, dermis and the hypothermis. Mammals have a unique ability to form α -keratin epidermal products from an infolding epidermal peg into a loose dermis, together with a concentration of dermal cells (Alibardi 2003). Keratinocytes makes up 95% of the epidermis, and can be further differentiated into stratum corneum, stratum lucidum, stratum granulosum,

stratum spinosum and stratum germinativum (Tortora, G. J and Derrickson, B. 2009). Due to the corneous cell envelope, mammalian corneocytes are mechanically and chemically resistant, but pliable in their fibrous core and lipid-heavy extracellular material (Matoltsy A. G. 1987, Elias et al. 1987). A pliable skin is important for fine receptiveness and to produce a plastic distortion of the skin, which is a mammalian characteristic (Alibardi 2003). In areas where hairs are emerging from the epidermis, keratohyalin might become concentrated; this causes a special type of cornification in the inner root sheath of hairs (Alibardi 2003). The skin of most living fishes is covered with mucus and not keratinized. The fish dermis creates dermal bone, which then creates dermal scales (Kardong, K. V. 2002). In primitive fishes, the form of the fish is enclosed in noticeable, protruding bony plates of dermal armor. In the anterior region, these dermal armor are large in size, but in the posterior region, they have been divided into smaller dermal scales.

Hagfishes and lampreys' skin is different, and the dermal bone is degenerated. Instead of dermal bones, the dermis is comprised of layers of living epidermal cells (Kardong, K. V. 2002). In cartilaginous fish, dermal bone is also not present. They instead have placoid scales. These types of scales are in structure similar to vertebrate teeth. Enamel covers the tip, dentin lies beneath and underneath the dentin is a pulp cavity (Kardong, K. V. 2002). In bony fishes, leptoid, cosmoid and ganoid scales are found. Leptoid scale only contains lamellar bone and lacks enamel, dentin and a vascular bone layer. As bony fishes grow older, these scales add concentric layers, overlap and allow less drag. There are two types, cycloid and ctenoid. Cycloid scales are made of concentric rings while ctenoid scales have a

fringe of projections along the posterior margin. Cosmoid scales reside on a double layer of bone. Enamel and dentin is coated on the upper layer of the bone. Ganoid scales have a thick layer of enamel without an underlying layer of dentin. Most are diamond-shaped and connected by peg-and-socket joints (Kardong, K. V. 2002). Synthesis The development in squamate scales begins with the epidermal papillae. The epidermal papillae are furrows of the epidermal surface, producing symmetric dermo-epidermal crests (Maderson 1965, Dhouailly 1975). The epidermis becomes contorted to form primordia of scale. This is due to differences in scale growth rate or mechanical forces between the two layers of dermis and epidermis (Dhouailly and Maderson 1984). Alibardi (1996) identified four developing stages, they include the flat bilayered epidermis, the symmetric scale anlagen, the asymmetric scale anlagen and the β -keratinising asymmetric scale. Crocodile scale development is similar to that of other reptiles. This indicates that scales represent repetitive folding of the initially linear epidermal sheets in which the outer side of a scale represents a specialized epidermal area (Alibardi, L. and Thompson, M. B. 2000). The basal and the first few layers of suprabasal cells produce cytokeratins initially, but cytokeratins are mostly replaced by solid, compact bundles of β -keratins in corneous cells, which then are condensed in the thick corneous layer corneocytes. Although epidermis of lepidosaurians have this property in common, there is a clear vertical alternation of epidermal layers (alpha- to beta-layers and beta- to alpha layers) in crocodylians (Parakkal, P. F and Alexander, N. J. 1972; Maderson 1985). Hinge regions' cornified cell envelope are probably made up of other proteins, present in thinner corneocytes of but also in typical beta-cells of

the outer scale surface. The tuatara scale morphogenesis is similar to that of squamates, with four developing stages. The embryonic epidermis of the tuatara is made of an outer and an inner periderm, and the layering of embryonic layers resemble that of the alligator, with an outer and inner periderm before the β -cells are formed (Alibardi and Gill 2007). The formation of scales starts in the hind end of the body and near the tail, similar to that of lizards and snakes (Maderson, 1965; Alibardi, 2002, 2003) and crocodylians (Alibardi & Thompson, 2001). A folding out of the epidermis and dermis towards the surface causes the epidermis/ dermis to form symmetric/ asymmetric bumps. This causes the outer scale surface to rapidly expands while the inner surface remains the same (Alibardi and Gill 2007). The structural layering in the embryonic epidermis of tuatara mirror that of the alligator, with an outer and an inner periderm before β -cells are formed. In embryonic scales, there is no distinct clear layer is formed underneath the embryonic epidermis, and the first oberhautchen/beta-cells join with each other to form a dense β -layer. This dense β -layer produces large, spiny protrusions that form a segmented macro-ornamentation in the tuatara. After the β -layer and the mesos region are constructed, the α -layer persisted in thickening because of the addition of more α -cells (Alibardi and Gill 2007). The composition of the α -keratogenic generation of epidermis in tuatara is thought to represent a gradual gradation between a mesos region and an α -layer (Alibardi & Maderson, 2003i, ii). Lamellar bodies exist in most α -keratogenic cells and form an intermediate region, and they do not just occur in mesos cells, Instead of a shedding complex, an intermediate region with spiny cells is present. The spiny protusions situated at boundaries and

the keratin-pattern proves that the epidermal cells have mixed characteristics of α and β -cells. The incorporation of dark granules among the β -keratin mass make up the more electron-dense parts of horny cytoplasm (Alibardi and Gill 2007). Tortoises and turtles adopt a growth pattern of scales and scutes that is seasonal. During the resting season, little α -keratin cells are produced in the epidermis of pliable skin and hinge areas of the scutes, with sporadic β -keratin cells in the scute outer surface. As a result of this sporadic growth, these cells have a mix of α and β -keratin and form a thin corneous layer in the hinge region. When growth continues in spring, there is intense cell proliferation, mainly around hinge regions and tips of border scutes. β -keratin cells are produced around the hinge regions and there is not scute shedding, while α -keratin cells disappear. β -cells make up a new thick corneous layer around the hinge regions. This thick corneous layer moves towards the old stratum corneum, and is gradually moving away from the hinge region. As a result of this activity, the old corneous layer becomes dislodged from the newly made corneous layer and caused a mark, which forms the border of the growing rings. β -keratin cells produced in the middle parts of scutes conserve a homogeneous thickness of the corneous layer along the whole scute surface. Shedding of scutes is not present in testudines and the horny layer is slowly lost by wear (Alibardi 2005ii). Avians have smooth skin when they begin development. The stratum corneum on the feet start to keratinize and form scales. They are reticulate and scutellate scales. Avian scales have three developing stages. They are the prereticulum, reticulum primordia and symmetrical prominent elevation stage (Sawyer, R. H. and Craig, K. F. 1977). For the reticulate scales, at the

beginning, the epidermis on the plantar surface of the foot consists of a basal row of cuboidal cells and a surface layer of flattened peridermal cells. Except for a few presumptive dermal cells directly below the epidermis, the mesoderm is loosely organized with attenuated cells. After several days, two layers can now be distinguished in the dermis; an upper layer containing many nuclei with round profiles in longitudinal section, and a deeper region of randomly organized mesenchymal cells. When the reticulate scale anlagen forms, they produce symmetrical elevations in the epidermis and as they develop further, they become heavily cornified and the α -keratinized cells are loosely arranged and have a vacuous appearance (Sawyer, R. H. and Craig, K. F. 1977). For scutellate scales, the epidermis on the anterior surface of the shank and foot consists of a basal row of cuboidal cells and a surface layer of flattened epidermal cells. The epidermal placodes form along the anterior surface of the shank and foot late on the ninth or early on the tenth day of incubation and then it becomes asymmetrical and small humps can be seen along the anterior surface of the shank. The superficial dermis continues to give a scalloped appearance. The scutellate scales continue to grow distally and overlap each other and the outer and inner epidermal surfaces become more distinct during this time. Transition from the stratum intermedium to the stratum corneum is very gradual for the outer epidermal surface of scutellate scales. Also the stratum corneum does not have a vacuolated appearance (Sawyer, R. H. and Craig, K. F. 1977). Fish epidermal covering includes a basal layer of cells and above this layer of cells are stratified epidermal cells. As they move towards the surface, these cells undergo cytoplasmic transformation, but do not become keratinized.

Within these layered epidermal cells contain singular unicellular glands, secretory and club cells. These are the source of the mucous cuticle, or "slime" (Kardong, K. V. 2002). There are five stages of differentiation. Early morphogenesis is where fibroblasts accumulate along the epidermal-dermal boundary and late morphogenesis is characterized by the differentiation of scale papillae immediately below the epidermis and at precise loci among the population of accumulated cells. Early differentiation is where the two upper cell layers of the scale papillae differentiate into scale-forming cells and deposit the first-scale matrix of the external layer in between. Late differentiation is when the scale-forming cells located at the deep surface of the scale matrix differentiate into particular cells, the elasmoblasts which are responsible for the deposition of elasmordin, the plywood-like tissue. The next stage, folding, is when when the epidermis starts to fold around the posterior margin of the scale, a step which also corresponds to the overlap with the neighbouring scales. During these five steps the anterior region of the scales progressively withdraws from the epidermis surface and sinks in the dermal stroma. The scales become obliquely oriented in the dermis whereby only the posterior region remains in contact with the epidermis (Sire, J. Y. and Akimenko, M. A. 2004). Mammalian amniotes have evolved a quite different type of epidermis from that of lower vertebrates.

Keratinocytes in the stratum basale proliferate through mitosis and the daughter cells move up the strata changing shape and composition as they undergo multiple stages of cell differentiation to eventually become anucleated. During that process keratinocytes will become highly organized, forming cellular junctions (desmosomes) between each other and

secreting keratin proteins and lipids which contribute to the formation of an extracellular matrix and provide mechanical strength to the skin.

Keratinocytes from the stratum corneum are eventually shed from the surface (desquamation) (Breitkreutz, D., Mirancea, N. and Nischt, R. 2009).

Form-function relationshipsThe integument of fishes is the outer protective barrier that separates the animal from its aquatic environment. The skin encases the body tightly and fulfils several important functions, among which maintaining the body shape, protecting the fish from shocks and various foreign attacks, improving hydrodynamics, and housing sensory functions that are essential for its survival (Le Guellec, D., Morvan-Dubois, G. and Sire, J. Y. 2004). The integument of avians shields the underlying musculature but does not help to hold the internal organs in place. A protective envelope for the body, the skin keeps out injurious substances and gasses while retaining vital ones (Stettenheim, P. R. 2000). The corneous layer impedes, but does not block the flow of water vapor in and out of the body (Spearman and Hardy, 1985; Menon et al., 1996). As the feathers provide mechanical protection, the epidermis is simpler than reptilian epidermal generation (Stettenheim, P. R. 2000). The continual renewal of this layer acts to repel parasitic microorganisms. Sensory receptors for various modalities in the skin detect ambient conditions. Importantly, the skin produces and supports feathers, which themselves have many functions. Together with the feathers, the skin is more active in thermoregulation in birds than in reptiles (Stettenheim, P. R. 2000). Its surface radiates excess body heat, absorbs solar radiation, and cools the body by cutaneous water loss (Bernstein, M. H. 1971; Bartholomew, G. A.

1972). The feathering (feather covering) is a much lighter and more efficient thermal insulation than reptilian scales, owing to the air trapped within it (Stettenheim, P. R. 2000). Non-avian epidermis act as a barrier against the terrestrial environment. It is an effective barrier against water loss and mechanical wear and tear. They evolved a tough, protective scaly integument and gradually adapted to land. This was a major evolutionary innovation (Wu et al 2004). The scales protect non-avians against desiccation and also solve the problem of flexibility of the exoskeleton. For crocodiles, scales form an armour against the outer environment and prevent predation. For snakes, scales serve to reduce friction as it moves and the ventral scales of snakes are used sometimes to grip branches, aiding them in climbing. Scales also help to prevent moisture loss. Tortoises and turtle scales help form the carapace and plastron of the shell, which greatly help the tortoise/turtles in protection. Once the tortoise/turtle withdraws into its shell, it's hard to harm them. Mammalian epidermis forms a protective barrier over the body's surface, responsible for keeping water in the body also prevent water loss and preventing pathogens from entering (Proksch, E., Brandner, J. M., Jensen, J. M. 2008) The epidermis also helps the skin regulate body temperature and contains a variety of nerve endings that react to changes in sensation (Romer, A. S. and Parsons, T. S.

1977)Evolutionary Aspects and Adaptations to terrestrial

environmentsAmniotes evolved from amphibians when they adapted to a terrestrial environment. From the amphibian epidermis to the amniote epidermis, soft and hard cornification evolved (Alibardi, L. 2003). In amphibians more adapted to terrestrial life, mucus or complex lipids might

have been present among keratin to limit water loss (Fox, H. 1996). The soft cell membrane of superficial keratinocytes accumulated proteins and ceramides that cross-linked with transglutaminases and produced the initial hardening of the corneous layer of early epidermises. As amphibians evolved, terminal differentiation occurred in the epidermis where superficial corneocytes were lost by a slow desquamation or periodic shedding. This allowed layers of dead cells to accumulate on the surface of the epidermis and produced parakeratotic horny layer (Alibardi, L. 2003). As the primitive amniote epidermis was formed, a new form of corneous protein called β -keratin was produced. This β -keratin contributed to the formation of a hard, mechanically resistant corneous layer and increased the strength of the epidermis. The evolution of modern amniote non-avian scales from primitive reptiles happened by a specialization for the cornification process (Alibardi, L., Valle, L. D., Nardi, A. and Toni, M. 2009). Depending on the amniote non-avian species, the accumulation of β -keratins determined sloughing at hatching. After development of epidermis ended, it would have been completely differentiated into anapsid, archosauria, and lepidosaurian reptiles, as well as avians. Further evolution of epidermis involved the differentiation of reptile epidermis to avian epidermis and also into mammalian epidermis (Cheng et al. 2009). Reptilian scales and avian feathers are considered to be homologous structures (Maderson, P. F. A. 1972). The epidermal cells which make both types of integument arise from the same progenitors, and that suggests that feathers evolved through some sort of modification of the embryonic epidermis (Sawyer, R. H. and Knapp, L. W. 2003, Sawyer, R. H., Rogers, L., Washington, L. et al. 2005). During the

evolution of the avian skin, the rigid layer of corneous cells of archosaurian scales became restricted to smaller areas. Most of the skin became softer and non-specialized and the flat scale became more and more narrow and tuberculate. The epidermis was nourished by a vascularised mesenchyme and also exchanged morphoregulative or inductive signals with the epidermis. This led to the formation of specialized cells in both scales and feathers (Alibardi et al. 2009). The evolution of reptile epidermis to mammalian epidermis was not very clear as mammalian hair did not fossilize well, thus there was not much information in the fossil record. It was thus hypothesized that the evolution of hairs from reptiles resulted from a reduction of a primordial, scaled skin to a hairy, softer skin. Several hypotheses have been made on this particular evolution. Maderson (1970, 1972, 2003) proposed that hairs came about from reptilian sensory appendages of the mechanoreceptor. It was located in the hinge region of ancient reptiles and form follicle-like structures. The mechano-sensory role of the hairs might had been replaced by thermal insulatory funtion, and a mutation might have led to an increase in hair density and expansion of sensory bristles (Chang et al. 2009). Dhouailly and Sun (1989) proposed that by comparing the topology and keratin types of scales and hairs with those of filiform papillar taste buds, gradual changes in the keratin expression in the inner surface of scale epidermis might have triggerd a transformation for scale structure from a hemi-cylindrical form to a more cylindrical structure that is found in hair (Chang et al. 2009). Lorenzo Alibardi provided yet another hypothesis on hair formation (Alibardi, L. 2004i-iii). He proposed a variation in areas of dermal-epidermal interactions in the epidermis during

the process of evolution led to the origins of feathers. By comparing scales, feathers and hairs, it was hypothesized that progressive reduction of the outer surface of reptilian scales had restricted the active dermis into smaller areas, forming cell condensations indicating for dermal papillae (Chang et al. 2009). Early therapsid amniotes never possessed/ later lost β -keratogenic tissue. Their α -keratogenic tissue was toughened by the evolution of mammalian-type histidine rich protein (Chang et al. 2009). For amniotes to adapt to a terrestrial environment, the integument must change drastically. This step towards terrestrial adaptation happened about 340 million years ago, in the mid Carboniferous (Alibardi, L. 2003). The major challenge is to produce a barrier in the skin to limit water loss caused by transpiration or evaporation. The integument must be able to protect the organism against desiccation, mechanical wear and UV damage (Chang et al. 2009). The epidermis of amniotes evolved by developing a barrier to prevent water loss to the external environment. It accumulates keratin bundles, inter-keratin histidine-rich matrix preteins (HRPs), corneous cell envelope proteins and complex lipids. The mature tissue is covered by a dead stratum corneum that is almost impenetrable to gases (Alibardi, L. 2003). The epidermis also developed a radiation resistant mechanism to prevent the skin from being damaged by UV irradiation. This process is attained by biochemical, morphological and physical mechanisms (Chang et al. 2009). A tough, stiff and strong shield of the skin, both in the dermis and epidermis, is developed. This is done by producing hard proteins like β -keratins or keratin-associated proteins (Chang et al. 2009). Another adaptation is to develop different adaptive structures related to various different environments. The epidermis

does this by developing various sensory functions on the skin with pit-like morphology (Von Düring, M. and Miller, M. L. 1979). Comparative Approach Despite the diversity, the epidermises of the various amniotes show many common areas during their early development. They are made of epithelial and mesenchymal cells and result from interactions between the two tissues. The various epidermises and dermises go through a series of developmental stages: induction, morphogenesis, differentiation and molting/regeneration (Widelitz, R. B., Jiang, T. X., Yu, M. 2003). Epithelial cells within the primordia of epidermis is triggered to respond to the development by either protruding above the skin surface, or form local thickenings by invaginating or branching. Once the anlage of an epithelial organ is formed, it starts to differentiate structurally or chemically. Not all epidermis/dermis of amniotes undergo molting cycles, but many have the ability to regenerate following trauma or injury (Chuong, C. M and Homberger, D. G. 2003). In chelonians, the basal layer and the suprabasal layer one to two layers thick consists of α -keratin, the transitional layer consists of alternating layers of α and β -layers, the mesos region is a very thick corneous layer and the soft epidermis of the limbs, neck and tail consists of α -keratin and a little β -keratin. The chelonians have no specialized shedding complex and the epidermis is shed by mechanical wear (Alibardi, L. and Gill, B. J. 2007). In crocodylians, the basal layer consists of α -keratin, the suprabasal layers consists of two layers, upper with β -keratin and lower with α -keratin, the transitional layer consists of β -keratin, the mesos layer a thick corneous layer with many cell boundaries made of β -keratin and the hinge regions consists of a mix of α and β -cells. Crocodylians

do not have a shedding complex (Alibardi, L. and Gill, B. J. 2007). In lizards, snakes and tuatara, the basal, suprabasal, α -layer, mesos region and β -layer of the epidermis consists of α -keratin in the resting stage (Alibardi, L. and Gill, B. J. 2007). In embryos of snakes and lizards studied thus far a shedding complex, consisting of embryonic clear and oberhautchen layers, is formed beneath the inner periderm of the embryonic epidermis and underlying layers. Therefore, in lepidosaurians a functional similarity can be observed between the inner periderm of the embryonic epidermis and the clear-layer of adult epidermis. The tuatara has a multi-layered shedding complex and there is a transitional region in the renewal phase of the epidermis. In the tuatara, one layer of partially overlapped oberhautchen cells merges with the β -layer to form a serrated line. This less specialized area of scission, as in crocodilians and chelonians, is another primitive characteristic of tuatara epidermis compared with the epidermis of lizards and snakes. This characteristic remains also in the adult epidermis, which shows a more primitive stage of evolution of an intra-epidermal shedding region (Alibardi, L. and Maderson, P. F. A. 2003ii, Alibardi, L. 2004iv).