What is the integument?

What are the functions of dermal bone?

Somatic Ectoderm: epidermis
Neural Crest: chromatophores
Somites (Epimere Mes.): dermis

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What are the major layers in mature skin? How do their functions differ?

How do dense & loose connective tissues in the dermis differ?

Epithelial cells attach to neighbors
Loose connective tiss.
Dense connective tiss.

What is unique about connective tissue in the dermis of fish?

SEM of stratum compactum in Lepisosteus (gar).
Gemballa & Bartsch, 2002
Coronal section through skin

Transverse section through layers of s. compactum

What are the benefits of this design?

Fig. 6.5, Kardong

When did an “exoskeleton” (dermal bone) evolve?

Drepanaspis See Kardong’s phylogeny Fig. 3.4, fossil Ostracoderms

Jawless fossil fish
Ostracoderms (armored fish)
Cyclostomata
Lampreys
Bony fish
Tetrapods

If exoskeleton retained; only bone layer
Reduction of exoskeleton in the trunk
Mineralized endoskeleton
Exoskeleton
= origin of mineralized skeleton
Complex; many types of mineralized layers
Unmineralized endoskeleton

Shimada, Kawanishi, Kaneko, et al. 2013
Describe the design & tissue layers of placoid scales

What layers may form in other fish scales?
“Odontode” unit:
Ectoderm: Ameloblast \(\rightarrow\) enamel, ganoine homolog
Neural Crest: Odontoblast \(\rightarrow\) dentine
Osteogenic unit: Dermatome: Osteoblasts \(\rightarrow\) elasmodine & bone

How are riblets on placoid scales beneficial?

Explain the differences in hardness of these tissues.
What are the advantages of multi-layered scales?

Indent. Hardness \((H)\): max. load, \(P_{\text{max}}\), divided by residual indentation area, \(A_r\), when load added

Young’s modulus \((E)\) = ratio: applied load/cm\(^2\) cross section divided by increase in length per cm.
Teleosts (derived Actinopterygians) have thin, flexible, overlapping scales: elasmoid (thin ganoine & bone)

Skin stretches & bends without wrinkling

Puncture tests on one half of a striped bass.

Fish scales provide protection with composite design

Ganoid Scales: Gar, primitive Actinopterygii

Ganoine

Epidermis

Gar

Spiny Boxfish

(a)

(b)

Mineralized

Collagen

Yang, Naleway, Porter, et al. 2015

Ganoine (gray on surface)

Arapaima (Paiche) in Amazon

Yang, Sherman, Gludovatz et al. 2014

Topics to review & understand:

1. Describe the embryological (germ layer) origin of these: epidermis, dermis & chromatophores. Diagram the location of these mature layers in skin: epidermis, stratum germinativum (= s. basalis), dermis (stratum compactum & stratum spongiosum).

2. Describe the role of the stratum basalis in the growth & maturation of the epidermis. Compare the density of collagen fibers in loose vs dense connective tissues. Describe the collagen fiber arrangement in dense connective tissues of fish & the benefit of the design.

3. What selection pressure may have initiated an exoskeleton for mineral (calcium/phosphate) storage in the skin of jawless fossil vertebrates? What selection pressures led to a rapid enlargement of scales in those early jawless vertebrates?

4. Diagram the tissue layers, size & shape of placoid scales. Diagram water turbulence over a "ribbed" shark scale compared to a flat surface. How are "riblets" & the ability to raise or "bristle" placoid scales hypothesized to improve the swimming drag in sharks?

5. Describe the germ layer origins of enamel (ganoine), dentine, elasmodine & bone in a fossil fish dermal scale. Which tissues contains collagen?

6. Compare the relative hardness of these tissues: enamel (ganoine), dentine, elasmodine & bone. What are the advantages of a composite scale? Summarize the trends in scale size, scale thickness & loss of tissue layers within Actinopterygian dermal scales.

7. What are the mechanical advantages of the thin elasmoid scales in teleosts? Describe their laminate design. How do even thin elasmoid scales resist puncture?

8. Describe & compare the design & function of dermal scales in heavily armored fishes & tetrapods. What design features do their scales/armor share in common with each other? How do they differ?

Compare tetrapods that use dermal armor

Composites: Dermal shells or plates covered with keratinized skin

Rhee, Horstemeyer, & Ramsay, 2011

Alligator presnalis

Armadillos

Ceratophrys cranwelli

Interlocking plates: compact bone outside, softer spongy bone inside
Selected References


