

Resumen por el autor, Edward Phelps Allis, Jr.

Sobre las homologías del hueso escamoso de los peces.

El pterótico (escamoso) y el esfenótico de los peces se desarrollan en posición dorsomesial con referencia a la cresta del canal semicircular lateral, y desde este sitio se extienden mesialmente hacia el frontal y el parietal. Ambos huesos pueden adquirir relaciones primarias con el cartílago subyacente y pueden entonces encerrar, entre las placas externas e internas, un espacio que, cuando es invadido posteriormente por los músculos del tronco, se transforma en la fosa temporal de los peces. En todos los vertebrados superiores este espacio es invadido por el músculo temporal y se transforma en una parte de la fosa temporal de los mamíferos. La porción cerebral de la escama del hombre y el proceso zigomático se derivan solamente del esfenótico de los peces o de este hueso fusionado con el pterótico. La parte auricular de la escama se forma por la placa de la mejilla de los peces. El timpánico de los mamíferos y el cuadrado-yugal de los anfibios y reptiles se derivan del preopérculo de los peces. El yugal se forma por la fusión de algunos de los huesos suborbitarios y postorbitarios de los peces fusionándose con el maxilar de estos para formar el maxilar de los mamíferos. El malar es el postorbitario dorsal de los peces. Las combinaciones de estos diferentes huesos originan cuatro arcos temporales esencialmente diferentes: uno formado por el dermoesfenótico y el postorbitario de los peces (hombre) otro por la placa de la mejilla y el postorbitario o yugal (saurios); otro por el cuadradoyugal y el yugal (arco infratemporal de los reptiles) y finalmente otro arco constituido por el cuadradoyugal y el maxilar de los peces (arco infratemporal de los anfibios).

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## ON THE HOMOLOGIES OF THE SQUAMOSAL BONE OF FISHES

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The squamosal of fishes, frequently called the pterotic by English authors, is primarily a dermal bone which develops along the dorsal surface of the ridge of the lateral semicircular canal and encloses a section of the main infraorbital laterosensory canal that is innervated in part by a prespiracular nerve and in part by a postspiracular one. As the bone develops it extends mesially and, bridging the supraotic depression, articulates either with the parietal alone or with that bone and the frontal. Anteriorly it articulates either with the frontal or the postfrontal, or with both those bones. This is the primitive condition of the bone, and occurs in the recent Holostei and Crossopterygii, the bone in the latter fishes (*Polypterus*) being fused with the parietal to form the squamosoparietal of van Wijhe's ('82) descriptions. In the Teleostei the primarily wholly dermal bone usually acquires primary relations to the chondrocranium, and may then be composed of external and internal plates, both of which project mesially from the lateral portion of the bone, one in the roof and the other in the floor of the piscine temporal fossa, one or both of them reaching and articulating with the parietal. The lateral surface of the bone usually forms part of the dorsal boundary of the articular facet for the hyomandibula, and dorsal to that facet it gives movable articulation to the bones of the cheek.

The postfrontal is difficult to define, and even to identify, and there is, as will later appear, much question as to its homologue in higher vertebrates. In *Amia*, where it occurs in what is considered to be a primitive condition, it is a dermal bone lying along the lateral edge of the hind end of the frontal, with

its own hind end lying on the dorsal surface of the postorbital process of the chondrocranium and there articulating with the anterior end of the dermopterotic. The summit of the postorbital process ossifies as the sphenotic of English authors, and the postfrontal, because of its relations to that bone, is frequently called the dermosphenotic, and, to avoid confusion, I shall hereafter so refer to it. It is traversed by the main infraorbital laterosensory canal and lodges the organ of that line that lies next anterior to the point where the infraorbital and supraorbital canals anastomose with each other, that anastomosis taking place along the mesial edge of the dermosphenotic, between it and the frontal (Allis, '89). The bone of *Amia* does not fuse with the underlying autosphenotic, nor does it, so far as I know, in any of the *Holostei* and *Toleostei*. In *Polypterus* it is completely fused with the autosphenotic even in a 75-mm. specimen, and the conditions indicate that two independent ossifications at no time here existed, a primarily purely dermal bone simply acquiring primary relations to the underlying cartilage.

I formerly considered the most definite characteristic of this bone of fishes to be the laterosensory organ that it lodges (Allis, '04), but as so identified the bone varies greatly in its relations to the other bones of the region, and also to the orbit, this apparently being definitely related to the length of the interval between the orbit (external opening of the orbital fossa) and the postorbital process. In *Polypterus*, where this interval is large, the dermosphenotic lies directly anterior to the dermopterotic and only reaches the hind end of the postorbital, thus forming no part of the boundary of the orbit. In *Amia*, where the interval is less large, the bone also lies directly anterior to the pterotic, but its anterior end here reaches to, and forms part of the boundary of the orbit. In those of the *Teleostei* in which the orbit is large and reaches nearly to the transverse plane of the postorbital process, the bone, as identified by the laterosensory organ it lodges, may be reduced to a small ossicle, may be pushed ventrally and become the dorsal one of the postorbital bones, or, as in *Hydrocyon* and *Alestes*, be pushed dorso-an-

teriorly and become the posterior one of a supra-orbital series (Allis, '04). When the bone lies directly anterior to the dermopterotic it forms the anterior portion of the articular joint for the bones of the cheek, but when it has a postorbital position, it, itself, articulates with the frontal and dermopterotic.

In *Rhizodopsis sauroides* there are two bones which together have the position of the single dermopterotic of *Amia*, and they are called by Traquair ('81) the squamosal and postfrontal. The postfrontal articulates anteriorly with the lateral portion of the hind end of the frontal, that portion of the frontal having the general relations to the orbit and the dorsal postorbital bone that the dermosphenotic (postfrontal) of *Amia* has. The so-called postfrontal of *Rhizodopsis* does not reach the orbit, and its position is such that the main infra-orbital laterosensory canal could not pass from it into the dorsal postorbital without traversing the lateroposterior corner of the frontal. This bone of *Rhizodopsis* is nevertheless said by Traquair to be the homologue of the similarly named bone of *Amia* (my dermosphenotic), which does reach the orbit. The corresponding bone of the *Palaeoniscidae* is said by Traquair to be placed still farther forward, because of the greater proportional length of the squamosal (dermopterotic), and his figure of *Nematopychius* ('77) shows that it may even become a definitely supra-orbital bone. Whether or not this bone of the *Palaeoniscidae* is traversed by the main infraorbital canal is not stated, but as the similarly placed bone of both *Hydrocyon* and *Alestes* is traversed by that canal, it would seem as if the bone of the *Palaeoniscidae* must also be.

In *Osteolepis macrolepidotus* there are two bones which correspond strictly in position to the so-called squamosal and postfrontal of *Rhizodopsis*, but they are called by Goodrich ('19) the supratemporal and intertemporal. They are evidently the homologues of the two bones of *Rhizodopsis*, and they apparently correspond, respectively, to the posterior and anterior portions of the dermopterotic of *Amia*; the one doubtless representing that part of the bone of *Amia* that lodges that part of the laterosensory canal that is innervated by the supratemporal

branch of the glossopharyngeus, and the other the part innervated by the ramus oticus lateralis. Anterior to them there is a bone, called by Goodrich the postfrontal, which has the position of that bone (dermosphenotic) of *Amia*, and the infra-orbital and supra-orbital canals are said to anastomose with each other in it. It articulates anteriorly with a supraorbital bone, resembling in this the dermosphenotics of *Hydrocyon* and *Alestes*, and although it is unusual for the infra-orbital and supra-orbital canals to anastomose with each other in this bone of recent fishes, it is nevertheless probably that bone.

*Osteolepis* thus, in so far as the bones here under consideration are concerned, strikingly resembles *Amia*, but *Glyptopomus kinnairdi*, which is also one of the *Osteolepidae*, just as strikingly resembles *Polypterus*. Like the latter fish, *Glyptopomus* is greatly elongated and has a small orbit placed far forward. Lateral to the parietal there are two bones which are called by Watson and Day ('16) the supratemporal and intertemporal, and they have exactly the positions of the similarly named bones of *Osteolepis* and also of the pterotic portion of the squamosoparietal of *Polypterus*. Anterior to them, along the lateral edge of the hind end of the frontal, there is a narrow so-called postfrontal which has exactly the position of the dermosphenotic of *Polypterus*, and seems unquestionably to be the homologue of that bone. Comparison with *Rhizodopsis* would then confirm my conclusion that the dermosphenotic of that fish has fused with the frontal, if it be not that the bone, which is inconspicuous in *Polypterus*, has simply been overlooked. Ventrolateral to it and the frontal there is, in *Glyptopomus*, a long postorbital, which, with the jugal, forms the posterior boundary of the orbit.

There are two cheek-plates in *Rhizodopsis*, one dorsal to the other. The dorsal one and the preoperculum, together, are said by Traquair to correspond to the large cheek-plate of his descriptions ('70) of *Polypterus*. The ventral one lies immediately above the articular extremity of the mandible and external to the ventral end of the preoperculum, and Traquair considers it to be the homologue of the bone *y''* of his descriptions of *Polyp-*

terus. In both *Osteolepis* and *Glyptopomus* these two cheek-plates of *Rhizodopsis* have fused to form a single bone, and it is called by both Goodrich and Watson and Day the squamosal. In *Polypterus* the two bones have fused with each other and also with the preoperculum, while in *Amia* they remain separate and are represented in the posterior portions of the two postorbitals. The cheek-plate lies external to the adductor mandibulae and dilatator operculi muscles, and external also to the trigeminofacialis chamber, the lateral wall of that chamber being formed by the posterior branchial-ray bar of the mandibular arch (Allis, '18).

The names given by Goodrich and Watson and Day to the bones above referred to in *Osteolepis* and *Glyptopomus* are those recently adopted by a Committee of the American Paleontological Society (Gregory, '17) for certain of the cranial bones of the Tetrapoda, and their use by these authors indicates that they consider the bones of these fishes to be the homologues of the similarly named ones of the Tetrapoda. The cheek-plate of fishes thus becomes the homologue of the squamosal of mammals. That this bone of fishes might become the zygomatic process of the squamosal of mammals is possible, but that it could become the squamous portion of the temporal bone of man, which lies internal to the temporalis muscle, seems to me wholly impossible. My views regarding it can be best presented by considering the conditions in *Polypterus*.

In *Polypterus* the *musculus adductor mandibulae* has been differentiated into *masseter*, *temporalis*, and *pterygoideus* portions (Pollard, '92). The *masseter* portion arises mainly from the external surface of the suspensorial apparatus, but partly also from the internal surface of the dorsal margin of the large cheek-plate. Its surface of origin lies wholly posterior to the postorbital process of the chondrocranium, and the muscle is covered externally by the cheek-plate. The *temporalis* runs upward anterior to the postorbital process, and having worn through the cartilaginous roof of the posterior portion of the orbital fossa, has its origin on the ventral surface of the frontal. The muscle occupies the posterior two-thirds of the greatly

elongated orbital fossa, this portion of the fossa thus corresponding, in this respect, to the ventral portion of the temporal fossa of man. The sphenotic, formed by the fusion of the dermosphenotic and autosphenotic, has a long anterior process which projects forward along the external surface of the temporalis, and, articulating with the postorbital bone, forms a supratemporal arch.

Assume that, in a vertebrate in which the conditions were as above set forth in *Polypterus*, the postorbital process of the chondrocranium were to be retarded in development, or to actually diminish in relative importance, as is actually the case in the *Amphibia* and *Reptilia* (Allis, in press). The *musculus temporalis* would then naturally push posteriorly beneath the frontal and the dermopterotic, but external to the primary (substituent) portions of the sphenotic and pterotic, if present, and would necessarily enter the supra-otic depression on the dorsal surface of the otic capsule; and this is exactly the position that the posterior portion of this muscle has in embryos of both *Hatteria* and *Chelone* (Fuchs, '11; figs. 31 to 38). This invasion of the supra-otic depression by a muscle is not exceptional, for it is so invaded in *Amia* and many of the *Teleostei*, the invasion there, however, being, either from the side by the *masseter* or from behind by the trunk muscles. The latter invasion gives origin to the piscine temporal fossa, and when the pterotic has primary relations to the chondrocranium, as in the *Teleostei*, the dermopterotic tends to become less strongly developed, and may almost entirely disappear, the primarily closed temporal fossa then becoming a more or less open groove on the dorsal surface of the cranium. If similar reduction, first of the pterotic and then of the sphenotic and frontal, were to take place in a vertebrate in which the supra-otic depression had been invaded by the *musculus temporalis*, it would first give rise to the small supratemporal fenestra of the *Crocodilia* and then to the larger one of man. If the supra-otic depression were to open posteriorly on to the posterior surface of the cranium by passing internal to the dermopterotic, and internal also to the *extrascapula* (supratemporal) if it persisted, as the piscine temporal fossa

does in *Amia*, a posttemporal arch would be formed similar to that in *Hatteria*. If this arch were to disappear, it would give rise to the conditions in *Testudo tabulata* (Gaupp, '94, fig. 3); and if, in addition, the supratemporal arch were to disappear, the conditions in *Cistudo* would arise. Williston's ('04) conclusion that the large fossa of the Testudinata is not a supratemporal fossa would thus seem incorrect, for the fossa of these reptiles has the same relations to the otic capsule that it has in *Crocodylus* and *Hatteria*, lodges the same muscle, and is bounded by the same bones. The roof of the fossa may have here disappeared as the result of emargination from behind, as Williston suggests, but this would not affect the homologies of the fossa.

That the temporal fossa must have been thus developed from conditions similar to those in *Polypterus* seems almost self-evident, and if so the bounding and related bones should be homologous. Comparison is most easily first made with man. In man the fossa lodges the *musculus temporalis* in its dorsal portion, and that muscle and the *pterygoideus* in its ventral portion, as it does in *Polypterus*. The inner aspect of the squama of man has (Bryce, '15) cerebral and aural parts separated by a projecting ridge (*crista petrosa*) which articulates with the outer edge of the *tegmen tympani*. The so-called *tegmen tympani* of mammalian embryos is a cartilaginous ridge which corresponds to the sphenotic portion of the sphenopterotic ridge of fishes (Allis, in press), and as the *crista petrosa* articulates with it, that *crista* is a ridge along the internal surface of the lateral edge of the *dermosphenotic* of fishes. The aural part of the squama lies morphologically ventral to the *crista petrosa*, forms the outer wall of the *recessus epitympanicus* and the *antrum mastoideum*, and lies external to the *incus* and the *tensor tympani*. The *incus* is derived, if I am correct in my recent conclusions (Allis, in press), from the posterior branchial-ray bar of the mandibular arch, and is the homologue of the lateral wall of the *trigeminofacialis* chamber of fishes; and the *tensor tympani* would seem to have certainly been derived from the *dilatator operculi* of fishes, for the two muscles have similar relations to the cheek-plate and are both innervated by the *nervus*

trigeminus. The masseter, which in *Polypterus* arises from the outer surface of the suspensorial apparatus and the inner surface of the dorsal margin of the cheek-plate, arises, in man, from the zygomatic process, an origin which would be naturally acquired as the hyomandibula and quadrate became functionally related to the ear. The aural part of the squama thus has exactly the topographical position and relations of the cheek-plate of fishes, and as this bone of fishes frequently fuses with adjacent bones, it seems certain that it has here fused with the sphenotic. The cerebral part of the squama and the zygomatic process are then both parts of the sphenotic of fishes, the zygomatic process apparently representing the dermal component of that bone as found in *Polypterus*, and the cerebral part of the squama being either the autosphenotic, ossified in membrane that represents an unchondrified portion of the postorbital process, or being an internal plate of the dermosphenotic, not found in fishes, which has developed, as shown in Fuchs's figure ('11, fig. 38) of *Chelone*, internal to the temporalis, along the outer surface of the chondrocranium, and there replaced the mesial limb of the autosphenotic. In favor of the latter supposition is Bryce's (l.c., p. 72) statement that: "According to Sutton the tegmen tympani is the seat of a separate centre (pterotic), which extends from the superior and over the lateral semicircular canal, and encloses the tympanic part of the facial canal." The cerebral part of the squama thus has to this so-called pterotic center of ossification the relations that the dermosphenotic of fishes has to the autosphenotic, and it is exceedingly probable that these two ossifications of the skull of man are the homologues of the two bones of fishes. If this be so, the autopterotic of fishes is either absent in man, as it is in *Polypterus*, or has fused with the autosphenotic; and the dermopterotic must also either be absent or be fused with either the dermosphenotic or the parietal.

In the Reptilia and Amphibia the conditions differ somewhat from those above described.

In early embryos of Hatteria (Schauinsland, '03; Fuchs, '11) the lateral edge of the so-called squamosal lies along the outer

surface of the ridge of the lateral semicircular canal, slightly overlapping the dorsal edge of the quadrate. From there the squamosal projects dorsomesially across the supraotic depression, and its posterior portion acquires articulation with the parietal. The supraotic depression lodges the musculus temporalis. In later stages of development the squamosal sends a process anteriorly, approximately in the line prolonged of the ridge of the lateral semicircular canal, and, acquiring contact with the hind end of the postorbital, forms the supratemporal arch. A second process is sent ventrally along the external surface of the quadrate, and, passing external to the anterior edge of the quadratojugal, acquires contact with the hind end of the jugal, thus forming, with the two latter bones, the infratemporal arch. The internal plate of the bone, said by Fuchs to develop later than the external one and to form the floor of the temporal fossa, replaces the mesial limbs of the autosphenotic and autopterotic, one or both, of fishes. The jugal is formed by the fusion of certain of the suborbital and postorbital bones of fishes.

The squamosal of *Hatteria* thus markedly resembles the sphenotic and pterotic, combined, of *Polypterus*, fused with the cheek-plate of that fish. There is no indication, in the ontogenetic development of this reptile, that the squamosal has been formed by the fusion of two primarily independent bones, but this does not definitely establish that it was not so represented phylogenetically. Baur is said to have considered it to be formed by the fusion of the squamosal and prosquamosal of certain other reptiles, which bones are the pterotic and cheek-plate of fishes. Whether or not the prosquamosal of these reptiles contained some part of the preoperculum of fishes, as the cheek-plate of *Polypterus* does, is not indicated.

The preoperculum of fishes is quite certainly formed, phylogenetically, by the fusion of several primarily independent laterosensory ossicles, and as it is extensively present in fishes, it seems improbable that it has wholly disappeared in higher vertebrates. Its dorsal end is attached to the hyomandibula, but its ventral end may be attached to the quadrate, the bone

then extending from the hyal to the mandibular arch, across the ventral end of the spiracular cleft. In both the Reptilia and Amphibia the hyomandibula becomes functionally related to the ear. The dorsal end of the preoperculum would consequently lose its underlying support, and hence be obliged either to acquire other support, to undergo functional modification, or to disappear. When, in mammals, the quadrate also became functionally related to the ear, the preoperculum apparently became the tympanic, that bone hence naturally forming the ventral boundary of the persisting remnant of the spiracular cleft. In reptiles, where the quadrate persists, the ventral portion of the preoperculum has shifted forward on to the external surface of that element and become the quadratojugal. The dorsal portion of the bone has probably here wholly disappeared, but the cheek-plate, which is related to it, and in *Polypterus* fused with it, seems certainly to have persisted, as it has in man, and, acquiring attachment to the quadrate, become the ventral process of the squamosal.

The postfrontal of *Hatteria* lies dorsal to the postorbital, between it and the frontal and parietal, and widely separated from both the squamosal and the otic capsule, and it is apparently the homologue of the postfrontal of the *Stegocephali*. The bone in the latter vertebrates has somewhat the position of the postfrontal of *Hydrocyon* and *Alestes*, but it is, in all of the several species figured by Moodie ('08), definitely related to the groove of the supra-orbital laterosensory line and not to that of the infra-orbital one. The infra-orbital groove varies somewhat in general position and in its relations to the cranial bones. In a diagram given by Moodie and said to represent all of the grooves that occur on the crania of the *Stegocephali*, the infra-orbital groove passes from the postorbital on to the frontal and then on to the so-called squamosal of his descriptions, but in the figures given of *Anachisma*, *Metoposaurus*, and *Trematosaurus*, it passes from the postorbital directly on to the so-called squamosal. In both *Anachisma* and *Metoposaurus* it is interrupted as it crosses the latter bone, this interruption evidently indicating that that part of the laterosensory line that is related to this

bone was innervated, as it is in fishes, in part by a prespiracular nerve and in part by a postspiracular one. The parts so innervated apparently correspond to the intertemporal and supratemporal of Fuchs's ('10) figure of what he calls the skull of a primitive species of these vertebrates, and the intertemporal part of the bone articulates anteriorly with both the postfrontal and the postorbital. The infraorbital groove runs forward, as above stated, on to the postorbital without coming into any relation whatever to the postfrontal.

There accordingly is question as to which bone of the Stegocephali corresponds to the dermosphenotic (postfrontal) of fishes. If the laterosensory lines are here of any value in establishing the homologies of the related bones, the dermosphenotic of fishes cannot either be, or be included in, the postfrontal of the Stegocephali, and it must accordingly be either the intertemporal or the postorbital, or be included in one of those two bones, and the fact that the infra-orbital and supra-orbital grooves anastomose with each other in the postorbital in both *Anachisma* and *Mastodonsaurus* favors the view that that bone is the homologue of the postfrontal of *Osteolepis*, and hence probably a dermosphenotic. It must, however, be borne in mind that the laterosensory lines of the Stegocephali were probably lines of pit organs, and hence presumably less fixed in their relations to the underlying bones than the canal lines of fishes are. The postfrontal of these vertebrates may accordingly be a dermosphenotic, notwithstanding its different relations to the laterosensory lines. The postfrontal of the Reptilia, however, lies so far in front of the otic capsule that it would seem as if it could not be a dermosphenotic, and if this be so, the latter bone must be either included in the intertemporal or the postorbital, or be represented by one of those two bones, and comparison with *Polypterus* and *Glyptopomus* would seem to indicate that it is included in the intertemporal, and hence in the squamosal of Hatteria.

In the Reptilia the maxillary is apparently of the mammalian type, and, as already stated, certain of the suborbital and postorbital bones have fused to form the jugal. The inferior tem-

poral arch of *Hatteria* has accordingly been formed by the cheek-plate and preoperculum of fishes, posteriorly, and the suborbital and postorbital bones anteriorly; and the superior arch by the sphenotic and pterotic, one or both, and the dorsal postorbital. In the *Amphibia* and *Stegocephali* the maxillary is certainly frequently of the piscine type, and the quadratojugal (preoperculum) has accordingly here acquired contact with the hind end of the maxillary, possibly with the intermediation of the bone *y''* of *Polypterus*, and so formed the inferior arch of these vertebrates, which thus, as is generally accepted, is not the homologue of the inferior arch of the *Reptilia*.

In *Crocodylus* (Shiino, '14) the squamosal (sphenopterotic) is similar to that in *Hatteria*, but its ventral process is less long. In *Chelone* the quadrate has either grown or shifted upward, and in embryos its dorsal edge lies dorsal to the ridge of the lateral semicircular canal (Fuchs, '11, and Kunkel, '11). The squamosal of this reptile has accordingly been forced away from the otic capsule and has, in embryos, no direct relations to it. Whether the cheek-plate has fused with this bone or with the quadratojugal is uncertain. Williston ('04) concluded that, if present, it had fused with the quadratojugal.

In the *Sauria* the conditions are somewhat different from those above considered. Here, in both *lacerta* (Gaupp, '94) and *Scleroporus* (Thyng, '06), a bone develops in exactly the general position of the squamosal of *Hatteria* and *Crocodylus*, but neither anterior nor ventral processes are later developed. This bone was first called by Gaupp the squamosal, but later ('10; p. 416) the supratemporal; but whether he intended, by this choice of name, to homologize this bone with the supratemporal of the *Stegocephali* or with that of fishes, is not apparent. Thyng calls it the supratemporal, and hence definitely homologizes it with the similarly named bone of his descriptions of the *Stegocephali*, which has the position of the pterotic of fishes. Williston ('04) proposes for it the name 'paroccipital plate,' and definitely homologizes it with the epiotic (tabulare) of the *Stegocephali*. It, however, seems to me to certainly be the dermopterotic of fishes, and it certainly does not include the dermo-

sphenotic. Ventral to it there is another bone, which Gaupp first called the paraquadratum but later the squamosal. Thyng calls it the squamosal, and hence homologizes it with that bone of his descriptions of the Stegocephali, which is the cheek-plate of fishes. Williston calls it the squamosal, but the so-named bone of the terminology at that time employed by him lies dorsal to the cheek-plate and hence in the position of the pterotic of fishes. The hind end of this bone lies, in early embryos, ventral to the bone above referred to as the dermopterotic, and external to the dorsal end of the quadrate, but in the adult it has shifted upward on to the external surface of the dermopterotic. From there the bone extends anteriorly, or anteroventrally, and is applied along the ventral edge of the postorbital, there approaching but not quite reaching the hind end of the jugal. In *Lacerta* there are two postorbital bones, the dorsal one called by Gaupp the postfrontal. In *Scleroporos* these two bones have fused to form a single postorbital.

Comparing the conditions in these two saurians with those in *Hatteria* and fishes, it seems certain, as above stated, that the dorsoposterior one of the two bones here under consideration is the dermopterotic. A dermosphenotic is then wanting, unless it be represented in the so-called squamosal of the authors quoted. The position of the latter bone in early embryos, and its later position along the ventral edge of the postorbital, are, however, opposed to this view, and it seems probable that the dermosphenotic does not develop, possibly being represented in the cord of tissue said by Gaupp ('00; p. 463) to extend, in *Lacerta*, from the tip of the processus paroticus to a sharp ridge which runs forward dorsal to the columella auris. The dermosphenotic not being present, the temporal arch of these reptiles is formed by the cheek-plate and postorbital of fishes, and corresponds to that part of the inferior temporal arch of *Hatteria* that is formed by the ventral process of the squamosal of that reptile. The small fenestra said by Williston ('04; p. 183) to have been figured in one species of *Cyngonathus*, but disputed by Broom, might then be a fenestra between this arch of the Sauria and the infratemporal arch of *Crocodylus*.

There thus apparently are four distinctly different temporal arches in the vertebrates above considered: one formed by the dermosphenotic and the postorbital (man, upper arch in Hatteria and Crocodilus); one formed by the cheek-plate of fishes and the postorbital or jugal (Lacerta, Scleroporus, part of lower arch of Hatteria); one formed by the quadratojugal and jugal (lower arch of Crocodilus, part of lower arch of Hatteria), and one formed by the quadratojugal and maxillary (Amphibia).

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