Obecná a srovnávací odontologie

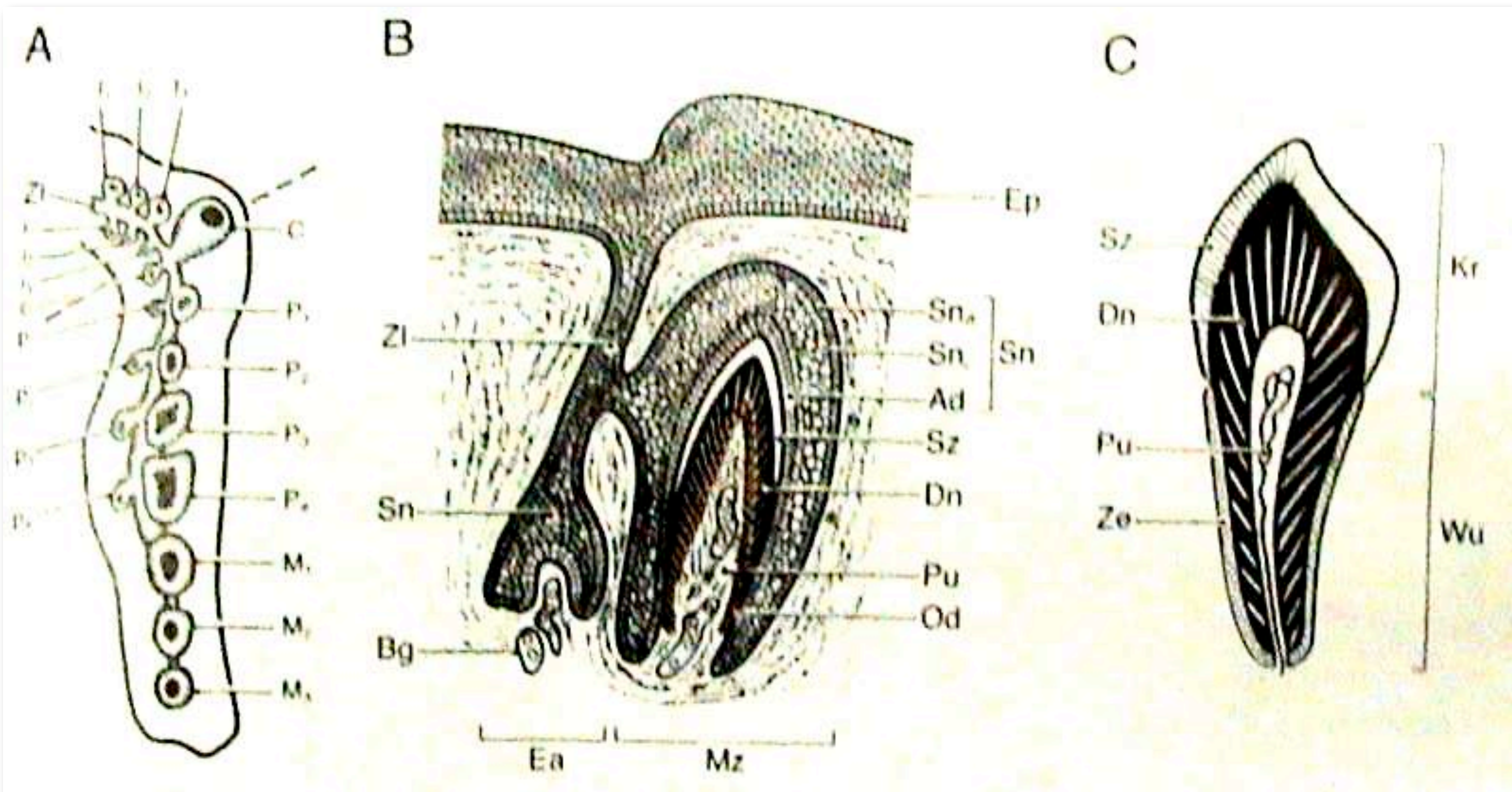
And now something completely different

Vývojové souvislosti 3

dentální lamina a paternování zubů

Zubní lišta - Dentální lamina

- zuby jsou integrovány do dentice
- integračním prvkem, který během ontogeneze uspořádává zuby, je zubní lišta
- tedy: zubotvorný [dentici-tvorny!] embryonální orgán; produkuje zuby; definuje a zakládá jejich pozici a výměnu. EKT (i ENT?) ztluštěnina; přítomnost buněk NL?
- pouze u amniot, resp. savců?



Dentální lamina u člověka vs. "**zubní řady**, *Zahnreihen*" u ryb

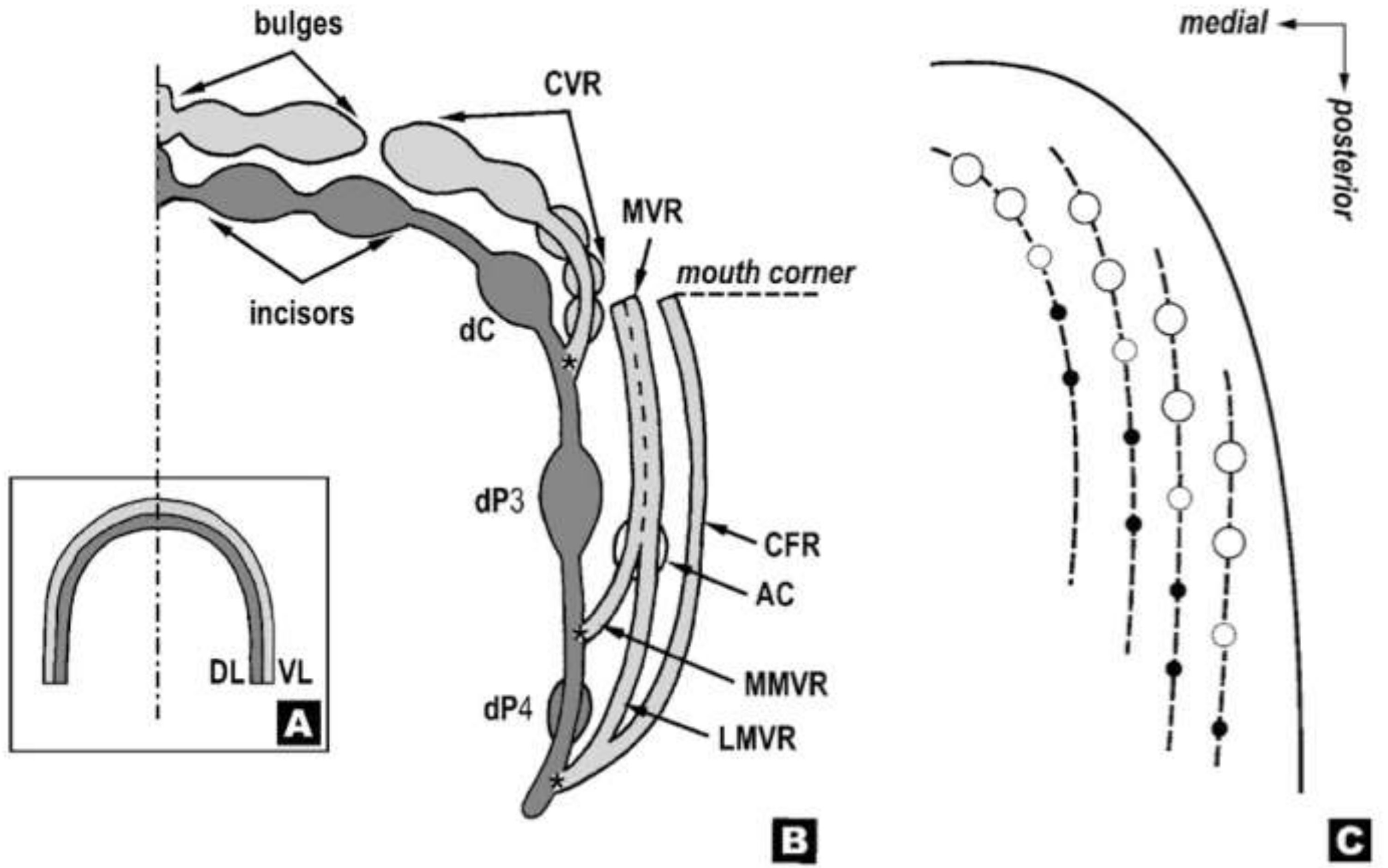


Fig. 7. Schemes of the pattern of the dental and vestibular epithelium in human embryos (A, B) and of developing teeth in fishes (C). (**A**) A textbook concept presenting two parallel U-shaped ridges in human embryos (e.g., Bhaskar, '80): DL—dental lamina (giving rise to the deciduous dentition) and VL—vestibular lamina or labio-gingival band (where oral vestibule will form). (**B**) The 3D reconstructions have documented that no continuous vestibular lamina exists but a set of discontinuous epithelial structures (ridges and bulges) transiently occurs externally to the dental lamina (according to Hovorakova et al., 2005). Dark grey—dental epithelium. Light grey—vestibular epithelium. dC—the deciduous canine; dP3—the first milk molar (corresponding to the deciduous third premolar); dP4—the second milk molar (corresponding to the deciduous fourth premolar). CVR—the canine vestibular ridge; MVR—the molar vestibular ridge splitting in its medial and lateral branch (MMVR and LMVR, respectively); CFR—the cheek furrow ridge. AC—the accessory cap-shaped structure. The star indicates the places of fusion between the dental lamina and vestibular ridges. (**C**) The schematic pattern of tooth rows (Zahnreihen) in fishes (according to data by Edmund, '60). The empty rings and black spots indicate the older and younger teeth, respectively. New teeth are formed at the posterior end of each Zahnreihen.

Eur J Oral Sci 2007; 115: 433–440
Printed in Singapore.

Development of heterodont dentition in house shrew (*Suncus murinus*)

*Yamanaka A, Yasui K, Sonomura T, Uemura M. Development of heterodont dentition in house shrew (*Suncus murinus*). Eur J Oral Sci 2007; 115: 443–440. © 2007 The Authors. Journal compilation* © 2007 Eur J Oral Sci

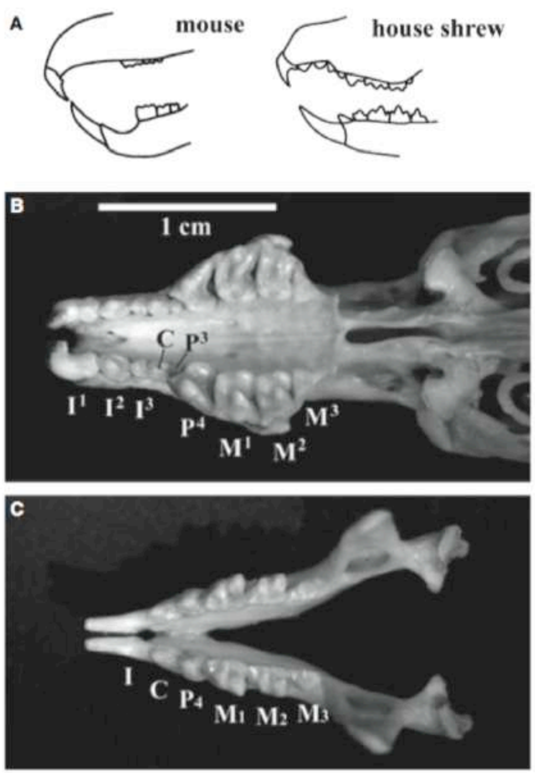
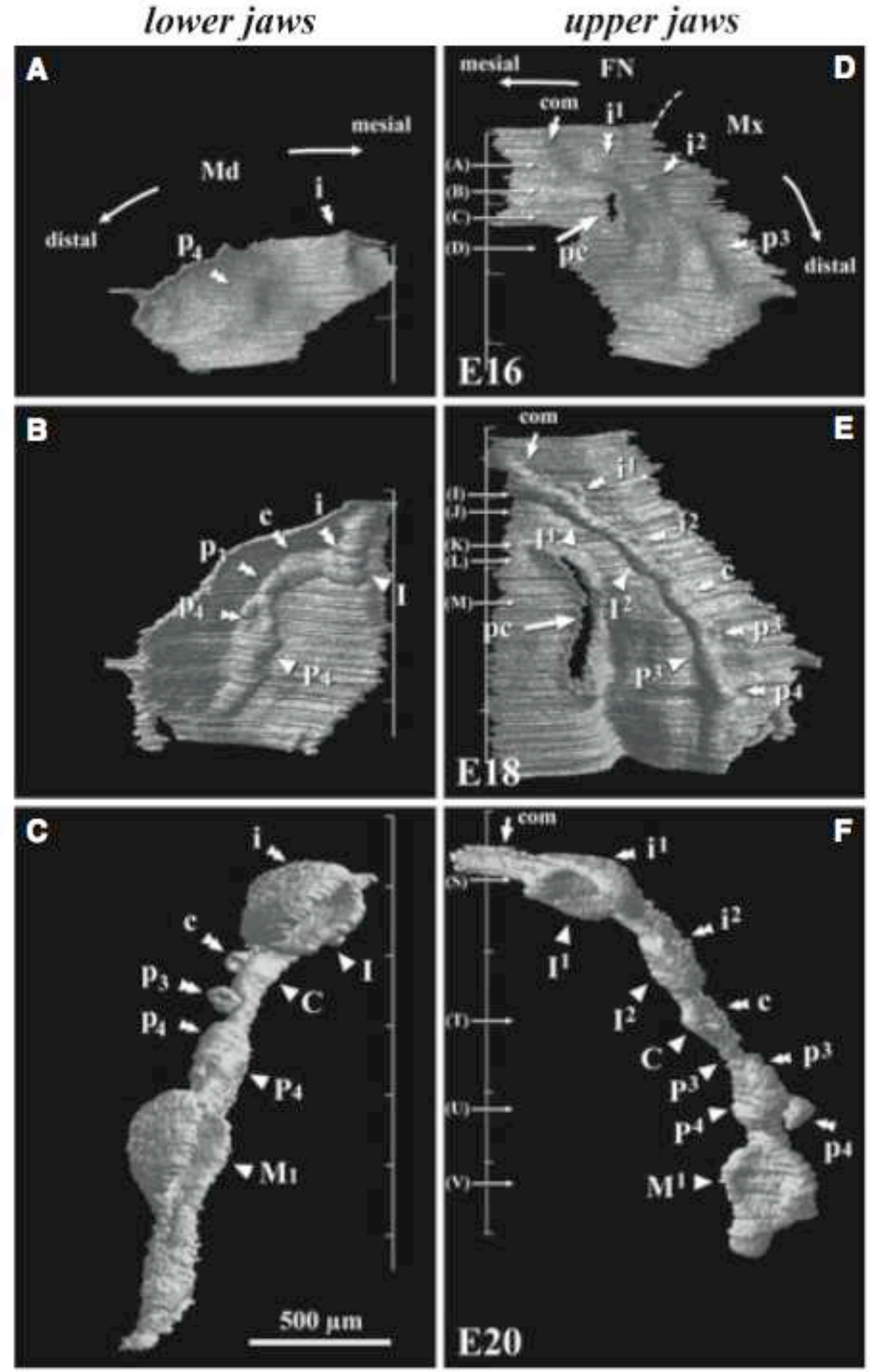


Fig. 1. (A) Permanent dentitions of the mouse (I1/1 C0/0 P0/0 M3/3 = 16) and the house shrew (I3/1 C1/1 P2/1 M3/3 = 30). (B, C) Occlusal views of the upper and lower dentitions in the house shrew. The dentitions comprise all tooth types: incisor (I), canine (C), premolar (P), and molar (M). Superscript and subscript numerals denote upper and lower dentitions, respectively. For example, P^4 represents the upper fourth premolar. Scale bar, 1 cm.

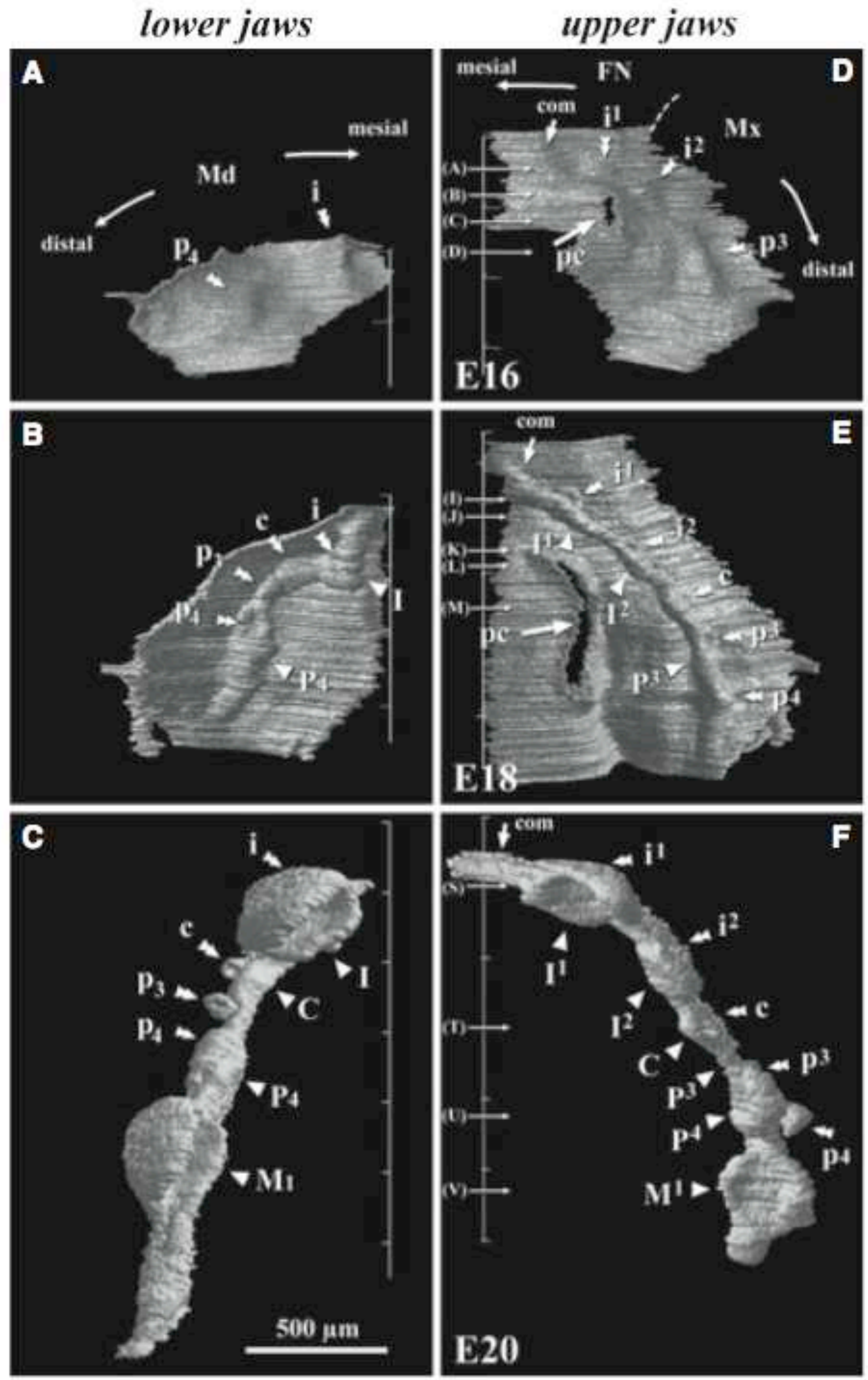


Eur J Oral Sci 2007; 115: 433–440

Development of heterodont dentition in house shrew (*Suncus murinus*)

*Yamanaka A, Yasui K, Sonomura T, Uemura M. Development of heterodont dentition in house shrew (*Suncus murinus*). Eur J Oral Sci 2007; 115: 443–440. © 2007 The Authors. Journal compilation* © 2007 Eur J Oral Sci

Fig. 2. Three-dimensional images of lower (A–C) and upper (D–F) tooth germs reconstructed from serial histological sections of house shrew embryos on embryonic day (E)16 (A, D), E18 (B, E), and E20 (C, F). Tissues other than oral or dental epithelium have been removed to show the basal surfaces from the mesenchymal side. Dental epithelial thickenings and buddings are visible as swellings on the images. Deciduous (primary) tooth germs are indicated by lower-case letters (i, incisor; c, canine; p, premolar) with double arrow heads, and successional (secondary) tooth germs are indicated by capital letters (I, incisor; C, canine; P, premolar; M, molar) with single arrow heads. Superscript and subscript numerals denote upper and lower dentitions, respectively. For example, p^4 represents the deciduous upper fourth premolar germ, whereas P^4 represents the successional upper fourth premolar germ. Deciduous tooth germs of i and p_4 in the lower jaw, and of i^1 and p^3 in the upper jaw, on E20 cannot be observed behind the corresponding successional germs in (C). They are located on the labial/buccal surfaces of the successional enamel organs and present concaved morphology. Development of the lower successional third premolar germ does not proceed. Consequently, the lower third premolar does not exist in the permanent dentition (Fig. 1C). The broken line in (D) represents the boundary between the frontonasal and maxillary processes. FN, frontonasal process; Mx, maxillary process; Md, mandibular process; pc, primitive choana; com, commissure between the right and left dental laminae. Graduations on the midline: 250 μm. Scale bar, 500 μm. Letters in parentheses in the upper jaws indicate the levels of frontal sections in Fig. 3.



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Development of heterodont dentition in house shrew (*Suncus murinus*)

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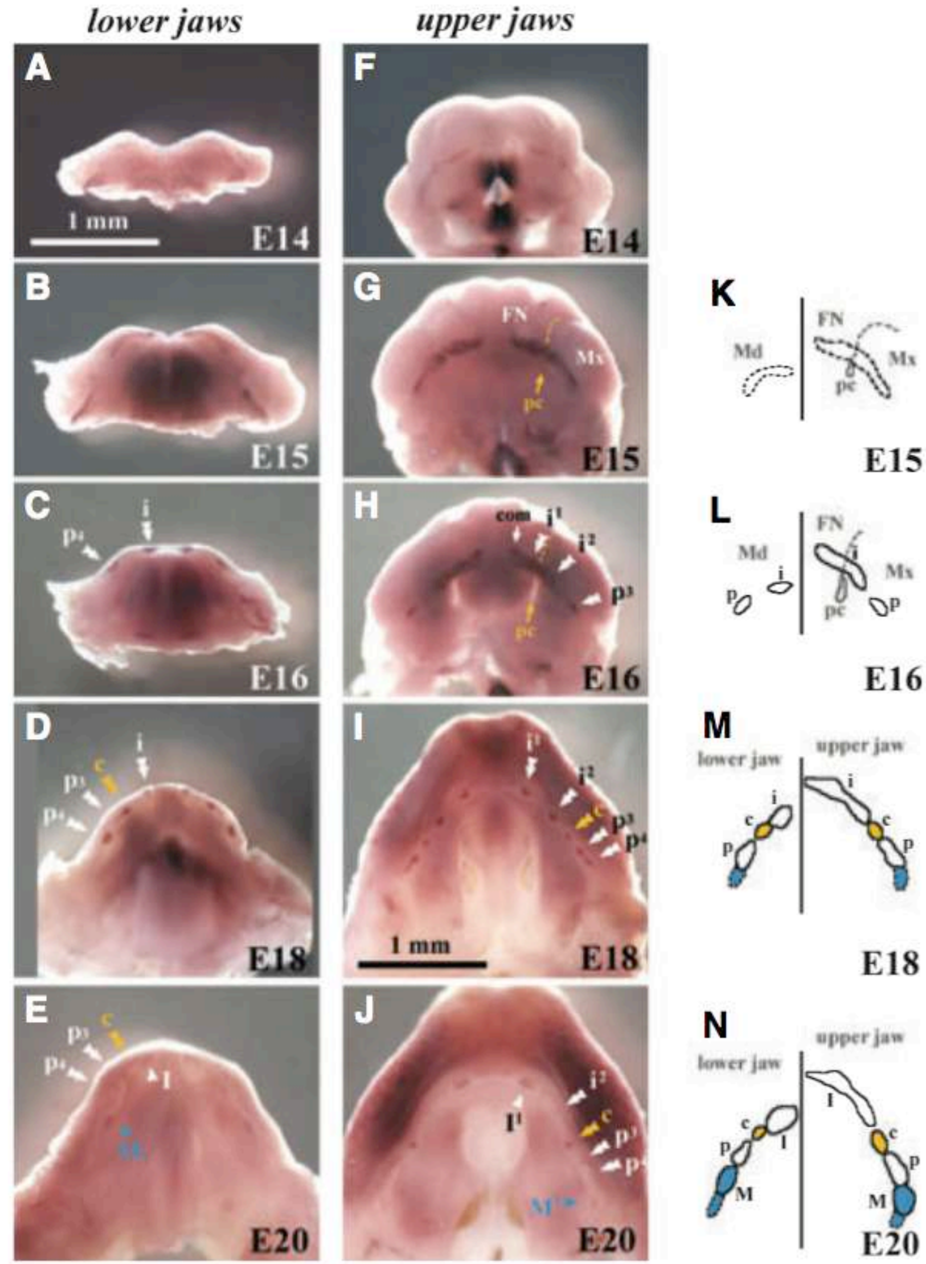
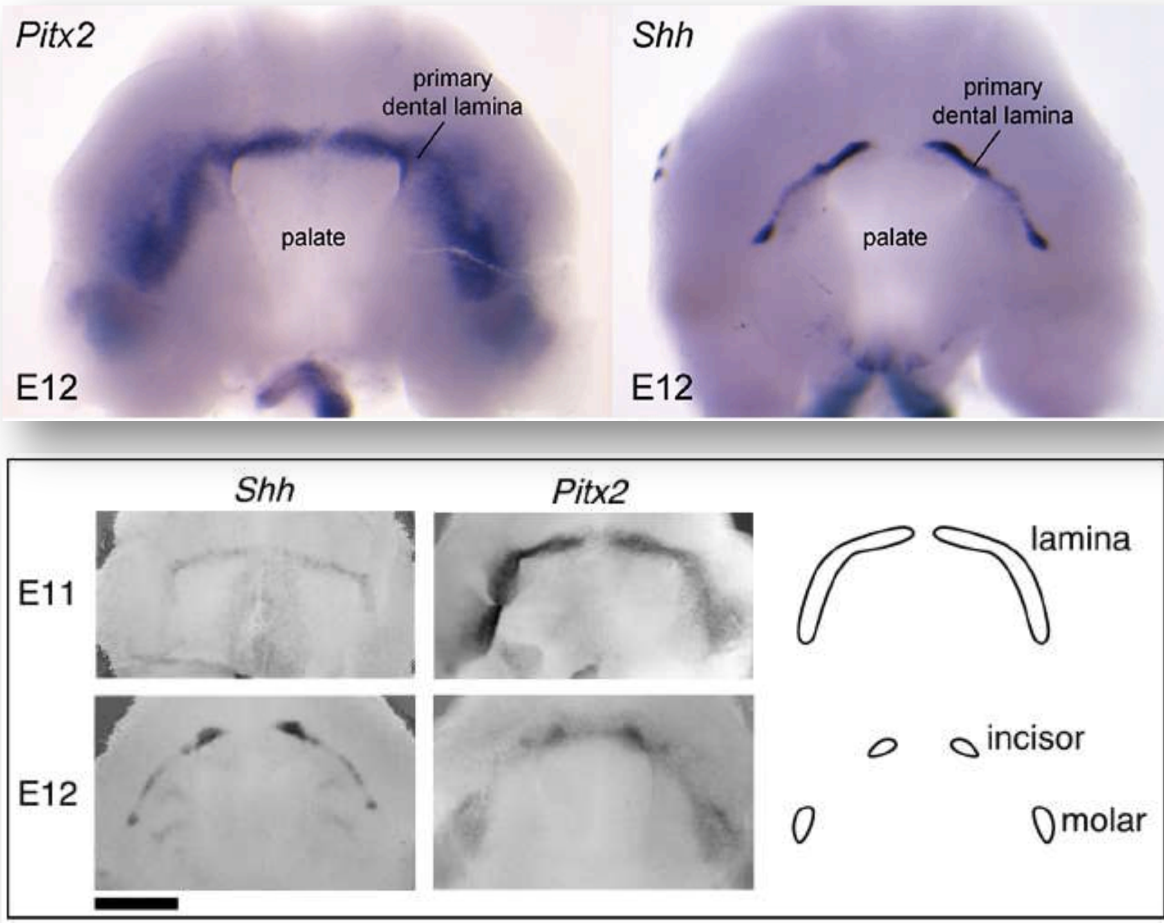
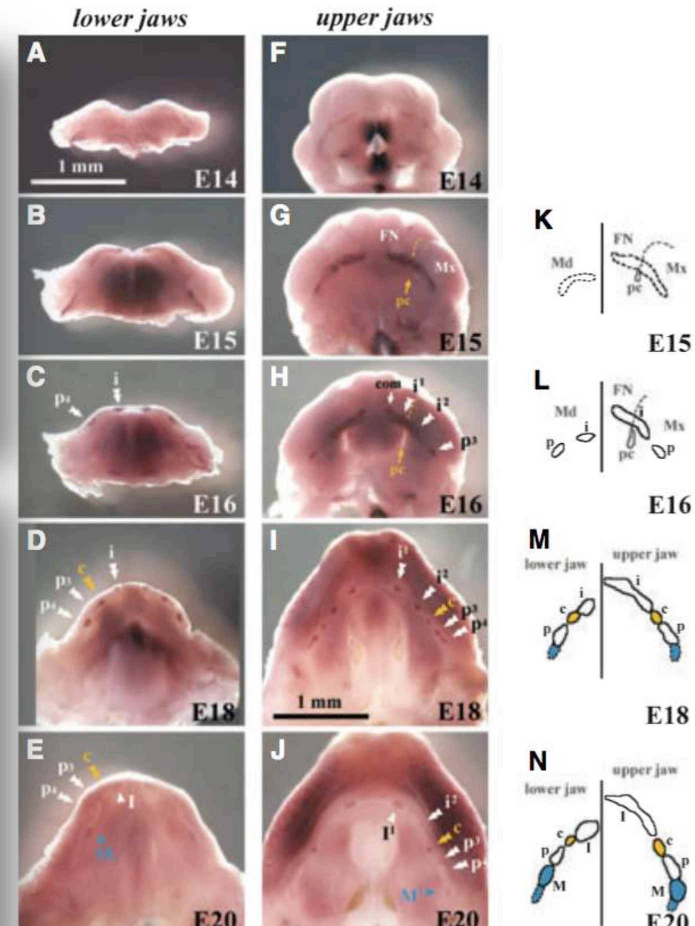


Fig. 4. Whole-mount expression patterns of *Sonic hedgehog* (*Shh*) in the lower jaws (A–E) and in the upper jaws (F–J) during dentition development of the house shrew, with schematic diagrams illustrating the tooth-forming regions (K–N) at embryonic day (E)14 (A, F), E15 (B, G, K), E16 (C, H, L), E18 (D, I, M), and E20 (E, J, N). Single and double arrowheads pointing to *Shh* expression correspond directly to the same arrowheads pointing to tooth germs on the three-dimensional reconstructions in Fig. 2. Yellow and gray broken lines in (G), (K), (H), and (L) represent the boundary between the frontonasal (FN) and maxillary (Mx) processes. Areas enclosed by black broken lines in (K)–(N) denote the presumptive tooth-forming regions, whereas areas enclosed by black solid lines denote the tooth-forming regions. FN, frontonasal process; Mx, maxillary process; Md, mandibular process; pc, primitive choana; com, future commissure between right and left dental laminae; i/I, incisor-forming region; c/C, canine-forming region; p/P, premolar-forming region; M, molar-forming region. Scale bar, 1 mm.

Myš, člověk, etc, tedy ssavci:
Dentální lamina, z ní (v ní!) pak jednotlivé dentální plakody

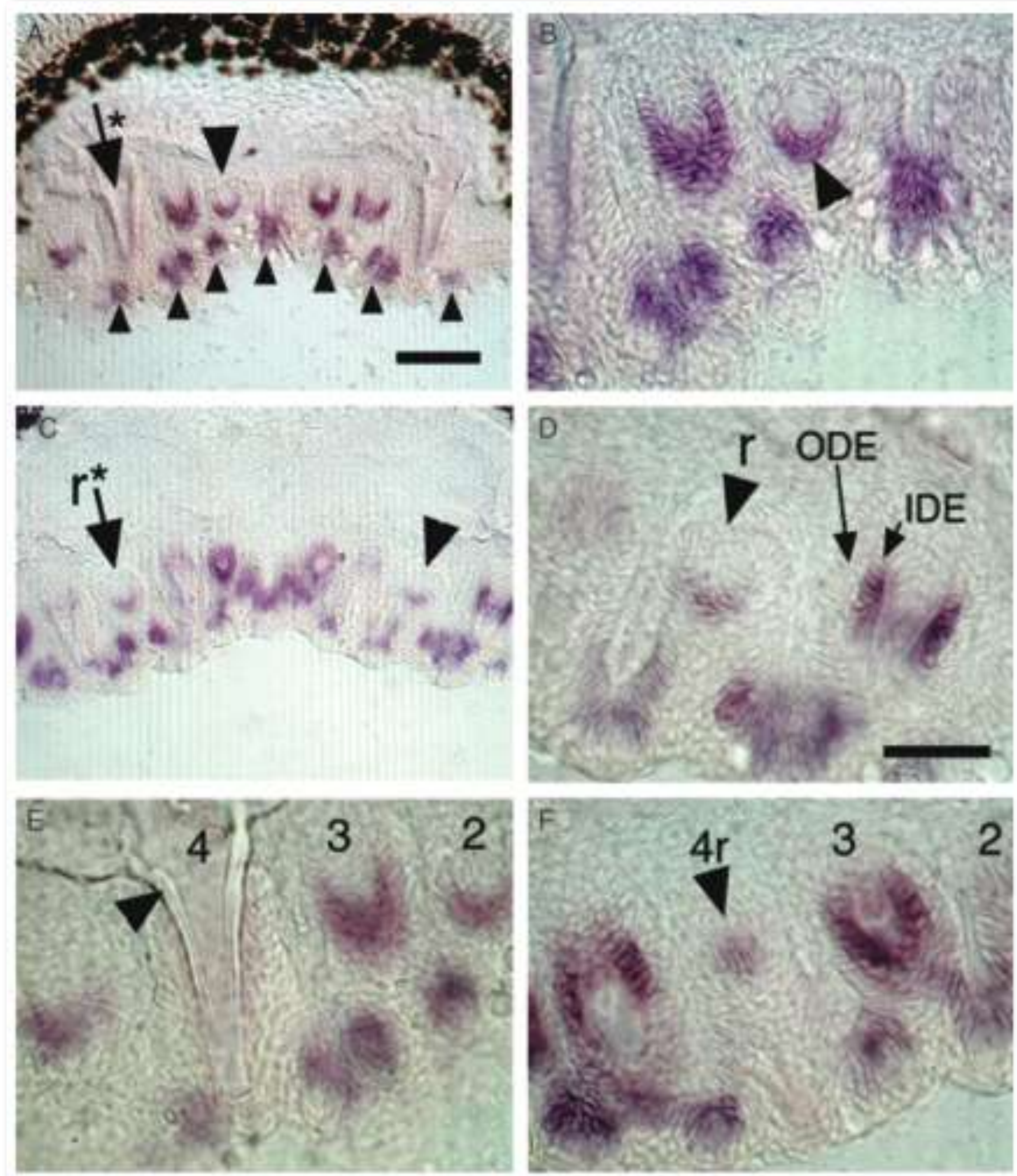




myš: *Shh, Pitx*

Dentální lamina
(*kontinuální)*
vs.
Dentální plakoda
(*diskontinuální)*

pstruh: *Shh*



Ryby + jiní ozubení obratlovci: jednotlivé dentální plakody = diskontinuální dentální lamina?

-zde vznik náhradního zubu z ODE (*outer-dental-epithelium*)

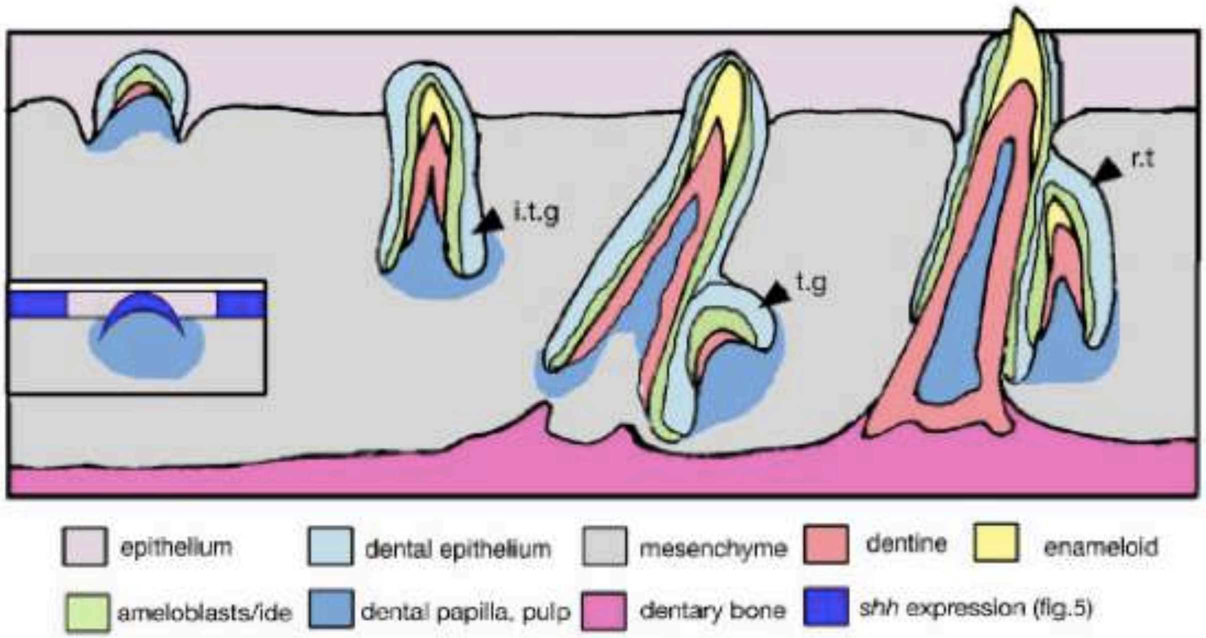
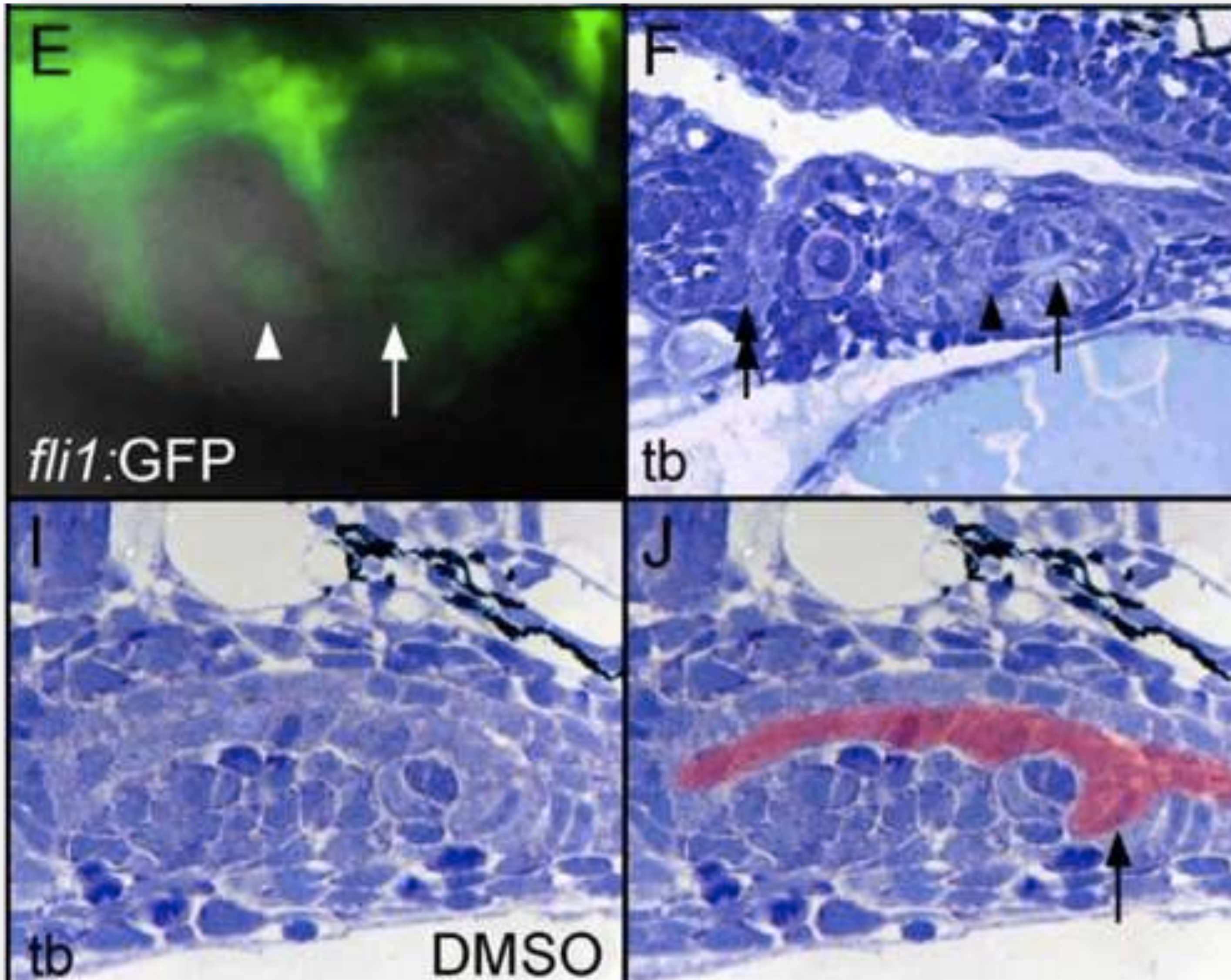
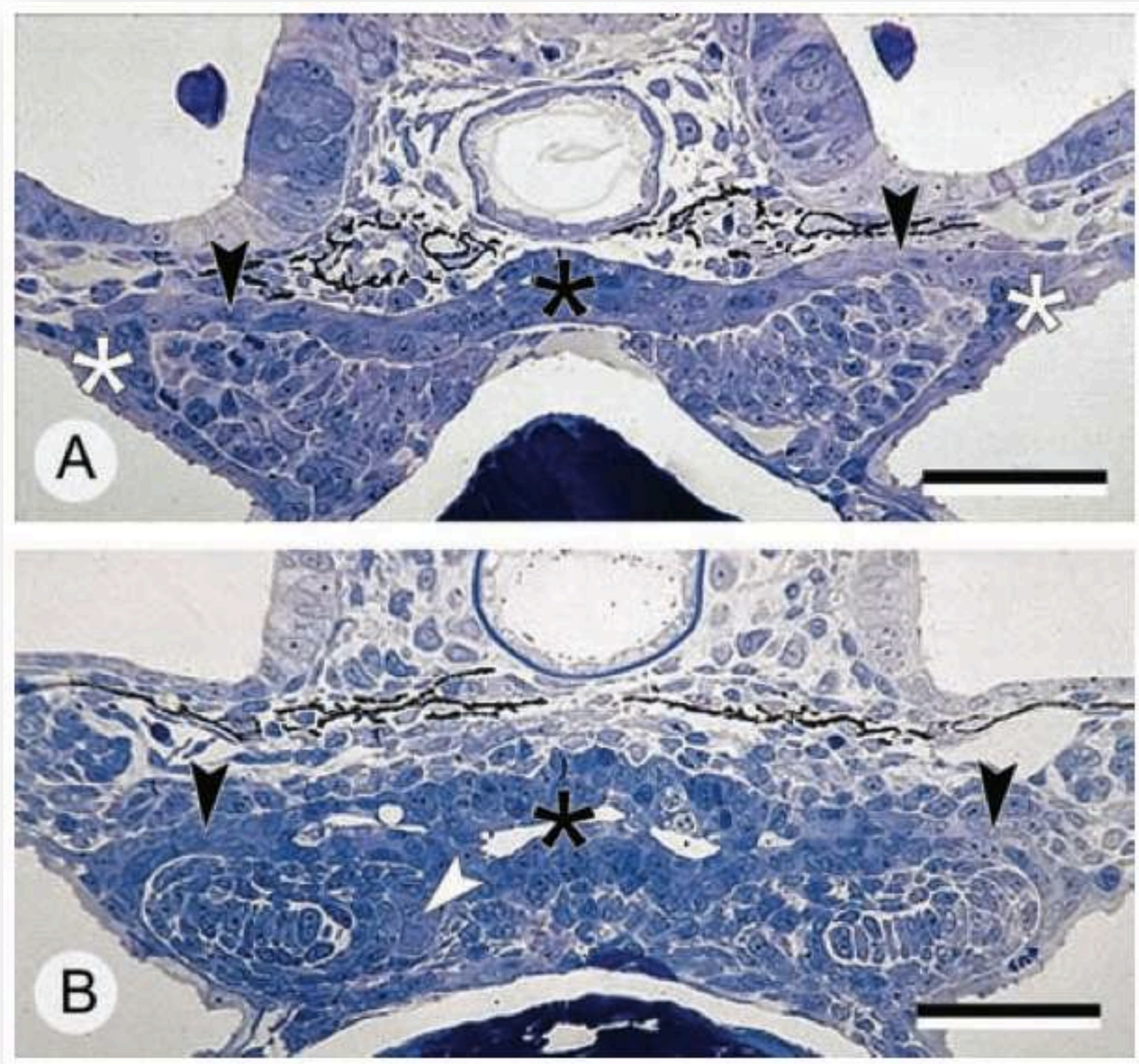


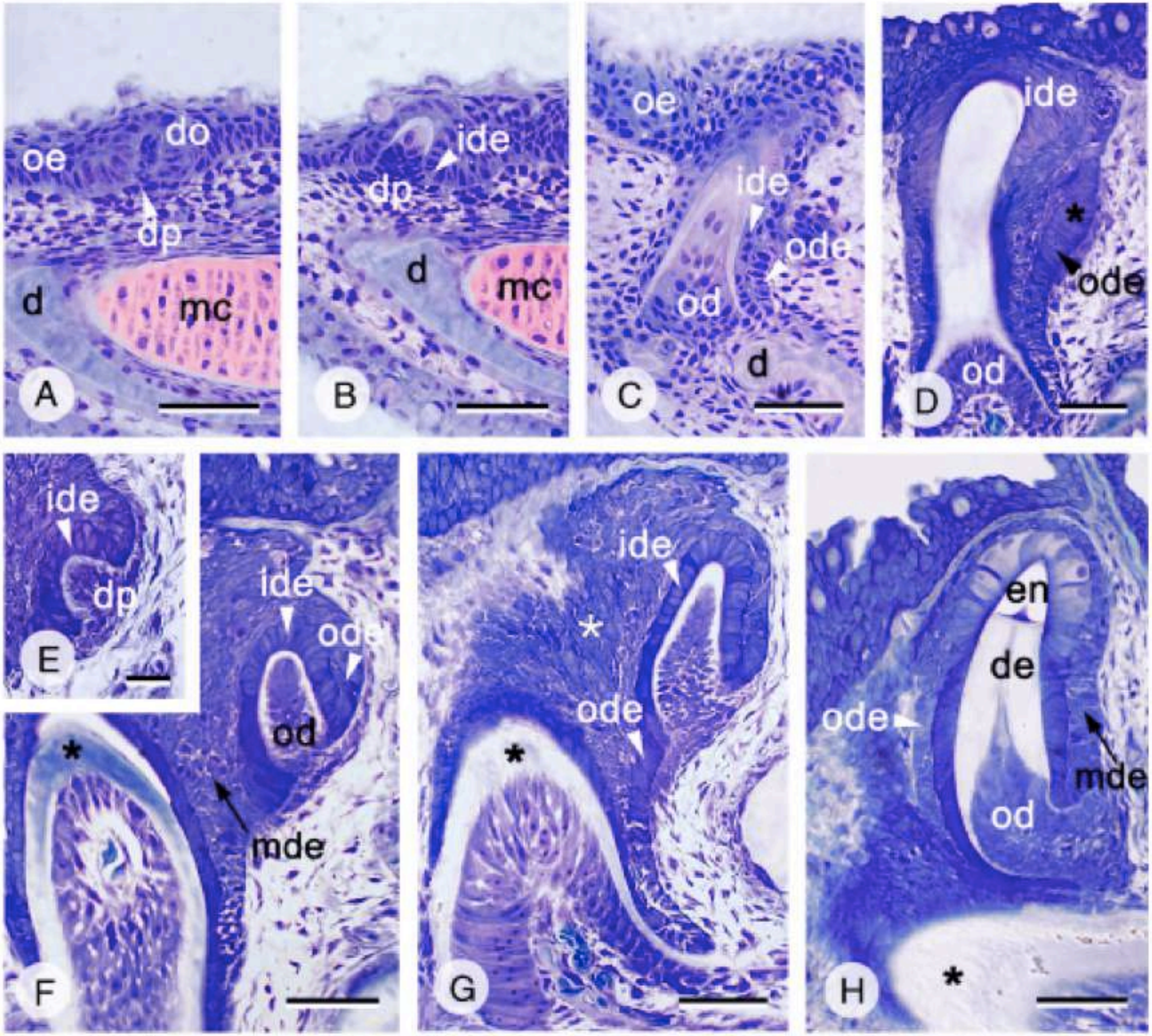
Fig. 9. Diagram of osteichthyan tooth renewal from the dental organ. This depicts the site of secondary tooth initiation (Δ) known from the gene expression in the outer dental epithelium of a prior tooth germ (see Fig. 5). Four stages of the primary tooth are shown from superficial initiation; inset is the stage with *shh* expression to eruption and attachment to the bone. The incipient site for tooth renewal (i.t.g) is in the thickened ODE of the previous tooth germ where the tooth germ (t.g) for the replacement tooth (r.t) develops. The putative site for stem cells (∇) is within the dental epithelium of the preceding tooth germ. Color code for tissues is the same as in Figure 2 but note the absence of a dental lamina. ODE, outer dental epithelium.

zebrafish *Danio rerio*:
histologie snad ani neumožňuje mluvit o DL !
(DL červeně)



zebrafish *Danio rerio*:
histologie snad ani neumožňuje mluvit o DL !
(zub bílá šipka dole)

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Ryby či paryby: Dentální lamina vs. Náhradní d. lamina vs. Middle Dental Epithelium vs. Dentální orgán

- zde srv. MDE [middele DE] vs. ODE

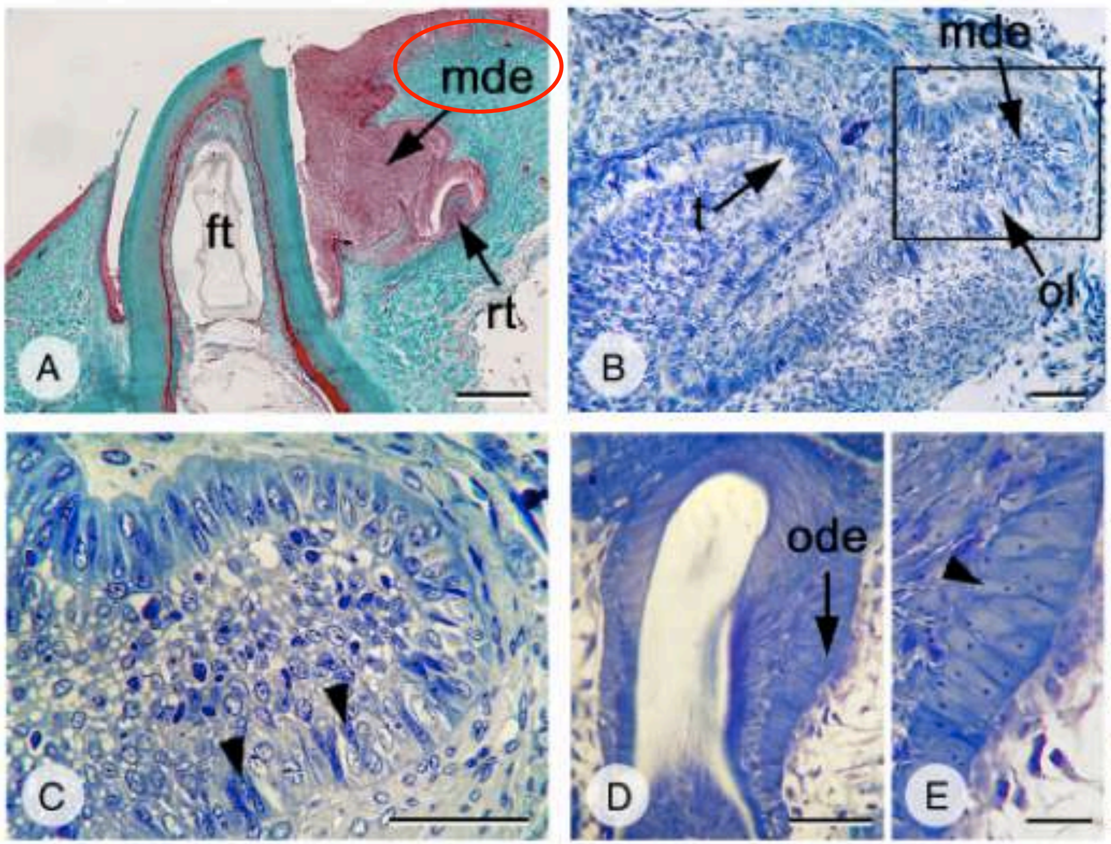

Fig. 3. Light micrographs (sagittal sections) of replacement tooth formation in adult Atlantic salmon (A), juvenile spiny dogfish (*Squalus acanthias*) (B, C), and fry stage Atlantic salmon (D, E). (A) Extensive development of the middle dental epithelium (mde) along the posterior side of a functional dentary tooth (ft) in a female salmon. rt: replacement tooth. Scale bar = 0.5 mm. (B) Aboral end of the dental lamina in an area before formation of a new tooth germ, in an approximately 350 mm spiny dogfish; note that the outer layer (ol) is not clearly segregated from the middle dental epithelium (mde). Scale bar = 100 µm. (C) Larger magnification of the area boxed in (B), showing that cells from the middle and the outer dental epithelium are imbricated (arrowheads). Scale bar = 100 µm. (D) Outer dental epithelium (ode) in a dentary tooth of a 48.4 mm FL Atlantic salmon before formation of the placode of the successor. Scale bar = 50 µm. (E) Larger magnification of the outer dental epithelium shown in (D); note that the outer dental epithelium is not yet clearly separated from the underlying cell population, and that cells of the two layers are imbricated (arrowhead). Scale bar = 15 µm.

Huysseune and Witten

Salmon tooth development and replacement

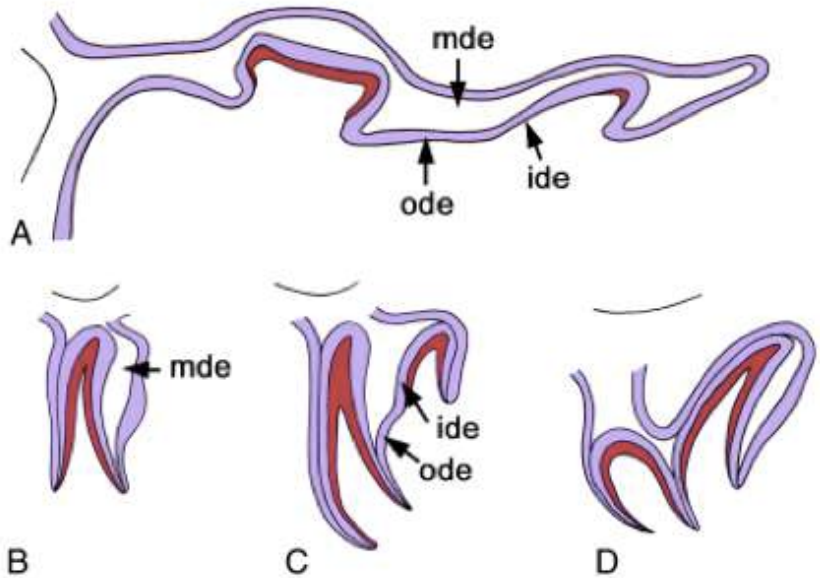

Fig. 4. Interpretative drawing of tooth replacement in sharks (A) and Atlantic salmon (B–D). (A) Semischematic drawing of a tooth family in a 100 mm embryo of a spiny dogfish (*Squalus acanthias*) (after Peyer 1968, Plate 8a). Two replacement teeth, at different stages of development, are present simultaneously (in adults this number is higher, Peyer 1968). Note continuation of outer dental epithelium of predecessor (ode) with the inner dental epithelium of successor (ide). mde, middle dental epithelium. (B–D) Semischematic representation of successive stages of formation of a replacement tooth in wild Atlantic salmon (*Salmo salar*). In contrast to the spiny dogfish (A), these stages are present consecutively rather than simultaneously. Similar to the spiny dogfish, the dental organs of successive teeth are broadly interconnected by the middle dental epithelium (mde), which builds along the posterior, lingual side of a tooth as it develops, and the outer dental epithelium of the predecessor (ode) is continuous with the inner dental epithelium (ide) of the successor. Although in salmon the outer dental epithelium is pictured as a single, well-demarcated layer of cells, it becomes segregated from the middle dental epithelium only just before the initiation of the new replacement tooth germ. The same holds for the spiny dogfish.

☺ ←

Ryby a paryby:

"definice" Middle vs. Outer či Inner Dental Epithelium

Huysseune and Witten

Salmon tooth development and replacement

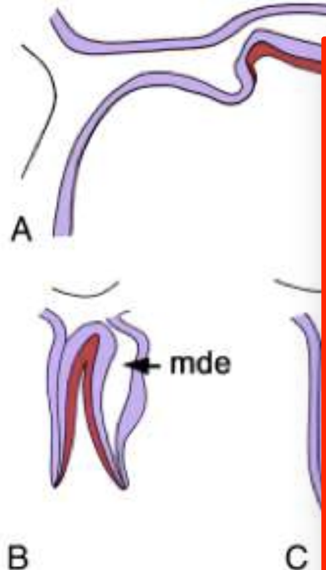

Fig. 4. Interpretative draw
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Concluding remarks

Screening teleosts from very different lineages has revealed that the spatial and temporal relationship of formation of a replacement tooth with respect to its predecessor can differ widely. Although the replacement tooth always appears to derive from the dental organ of the predecessor before eruption, or from the reduced enamel epithelium after eruption, the connection to the latter can vary from an extremely long to a very short and hardly noticeable epithelial strand (successional lamina). The absence of a discrete successional dental lamina in Atlantic salmon stands in sharp contrast to other teleost species, even those that share with salmon the extra-osseous formation of replacement teeth. The mode of tooth replacement in Atlantic salmon bears striking similarities to that observed in sharks. Studies on basal osteichthyans, such as *Polypterus*, *Amia*, or *Lepisosteus*, should reveal whether this represents an ancient way of replacement tooth initiation. The possibility that an elaborate population of epithelial cells functionally substitutes a successional lamina and that this population could be a source of stem cells, whose descendants subsequently contribute to the placode of the new replacement tooth, needs to be explored.

by:

s. Outer či
thelium

Trvalá (permanentní) DL u obojživelníků

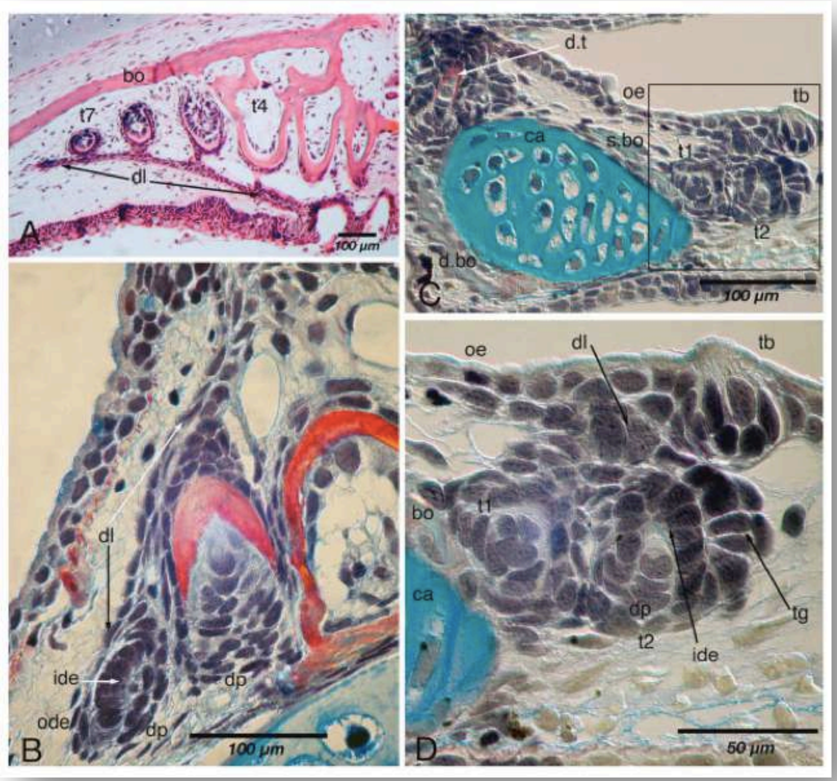
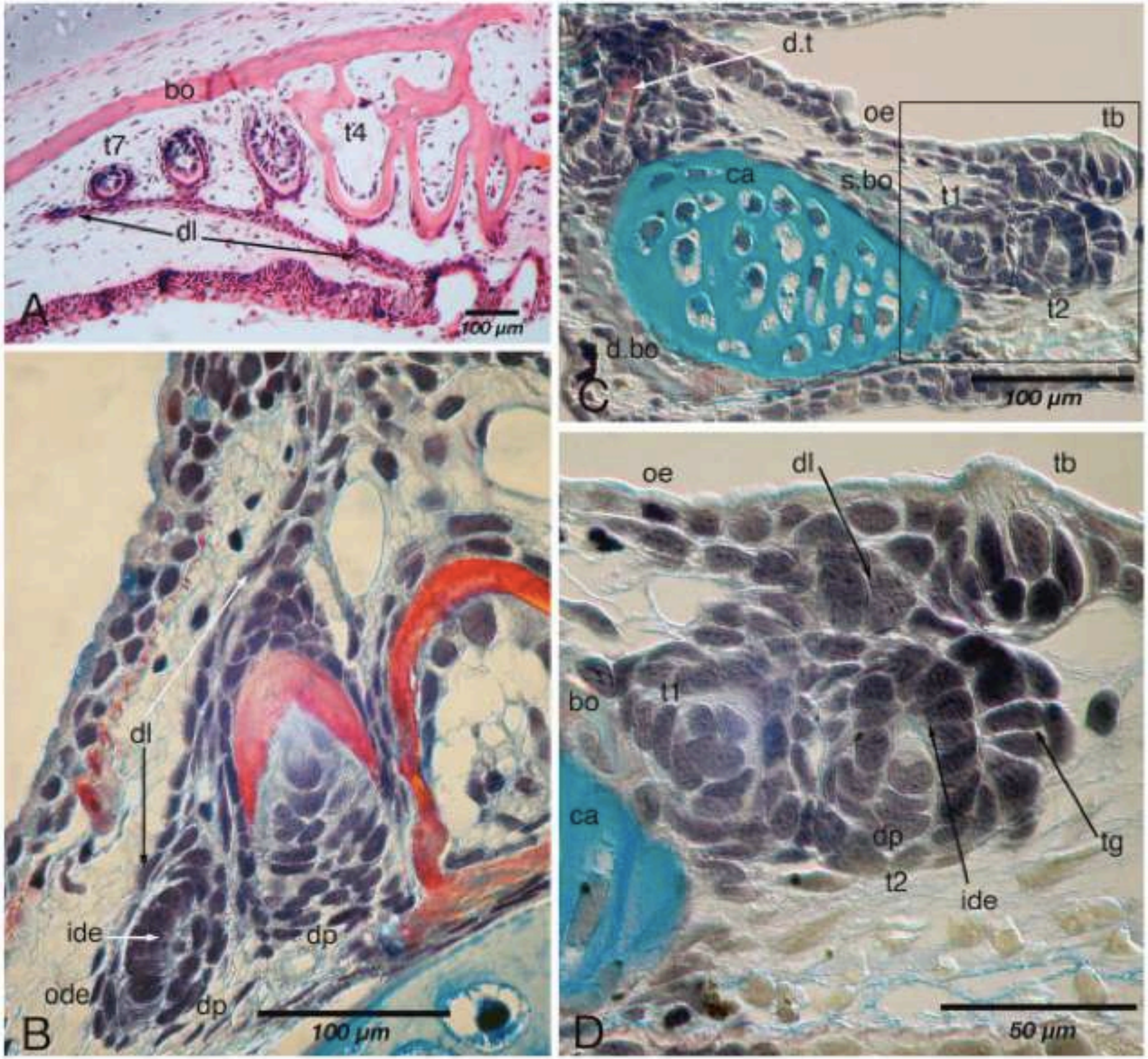


Fig. 7. Permanent dental lamina in amphibian tooth replacement. (**A**, **B**) Three-month juvenile stage of *Ambystoma mexicanum*, sections cut vertically along the tooth row, medial is left. (**C**, **D**) Twelve millimeter larval stage, vertical sections through lower jaw, medial is right. (A) Palatine tooth field with seven teeth (t_4–t_7) all connected to the dental lamina (dl), only three of them are attached to the bone (bo) with one erupted tooth, the distal end of the dental lamina is quiescent (left arrow). (B) Splenial tooth row of lower jaw through two tooth germs, one bud stage with columnar ide cells and new ode cells at the free end of the dental lamina (dl) with dental papilla cells (dp) and one attached tooth base. (C) Early tooth development prior to attachment to the dentary and splenial bones (d.bo, s.bo), Meckel's cartilage (ca), tooth germs (t_1, t_2) distinct from the oral epithelium (oe) and the taste bud (tb). (D) Dental lamina cells (dl) joining two tooth germs below the oral epithelium (oe) all separate from taste bud (tb), ameloblasts (ide) of new germ (t_2), differentiated dental papilla (dp), with thickened outer epithelium as site of next tooth germ (tg).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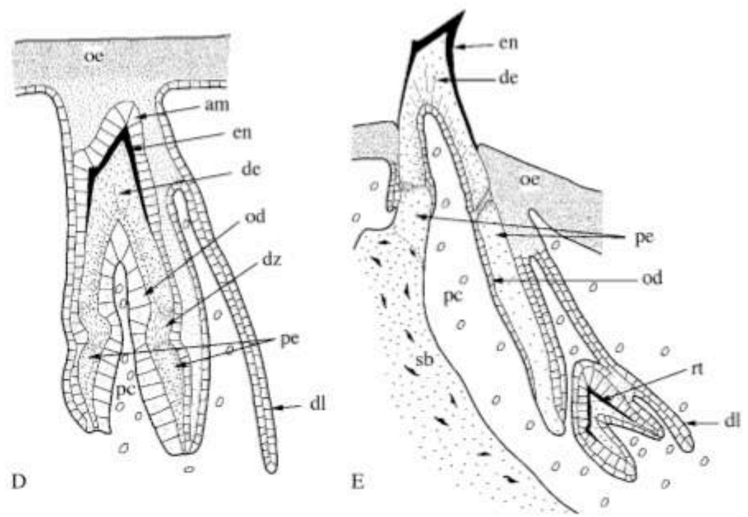


Fig. 8. Schematic representation of the development of a tooth and its successor in a generalised lissamphibian. Anterior is to the left. (A) Morphogenesis and early cytodifferentiation. Originating from the basal epidermal layer of the oral epithelium, the primary dental lamina extends into the subjacent mesenchyme. The distal region of the dental lamina interacts with mesenchymal cells and forms a cup. The epithelial cells differentiate into an enamel organ, which further differentiates into an inner and an outer dental epithelium. (B) Late cytodifferentiation. Mesenchymal cells have differentiated into odontoblasts, which deposit an unmineralised matrix, predentine. The latter mineralises to become dentine. Facing the latter the inner dental epithelium cells differentiate into preameloblasts. (C) The preameloblasts differentiate into ameloblasts and deposit the enamel matrix on the dentine surface. The dentine cone elongates due to the activity of the odontoblasts and the pulp cavity starts to form. A secondary dental lamina, originating from the upper region of the outer dental epithelium of the enamel organ at the posterior side of the tooth, extends into the mesenchyme. (D) The tooth has elongated and its tip is close to the oral epithelium. The pedicel has started to form at the base of the crown. The pedicel is separated from the dentine cone by an unmineralised region, the dividing zone. The secondary dental lamina has extended deeply into the mesenchyme. (E) The tooth has attached to the supporting bone through its pedicel and its tip has pierced the oral epithelium. The tooth is now functional and its replacement tooth has started to form. Note that in caudate larvae the development of the first-generation tooth differs in that enameloid is the first matrix deposited by the odontoblasts, before dentine. Modified from Kerr (1960) and Casey & Lawson (1981). am: ameloblast; de: dentine; dl: dental lamina; dz: dividing zone; en: enamel; ide: inner dental epithelium; od: odontoblast; ode: outer dental epithelium; oe: oral epithelium; pc: pulp cavity; pde: predentine; pe: pedicel; rt: replacement tooth; sb: supporting bone.

žebrovník: tzv. sekundární dentální lamina, vznikající odštěpením z ODE...

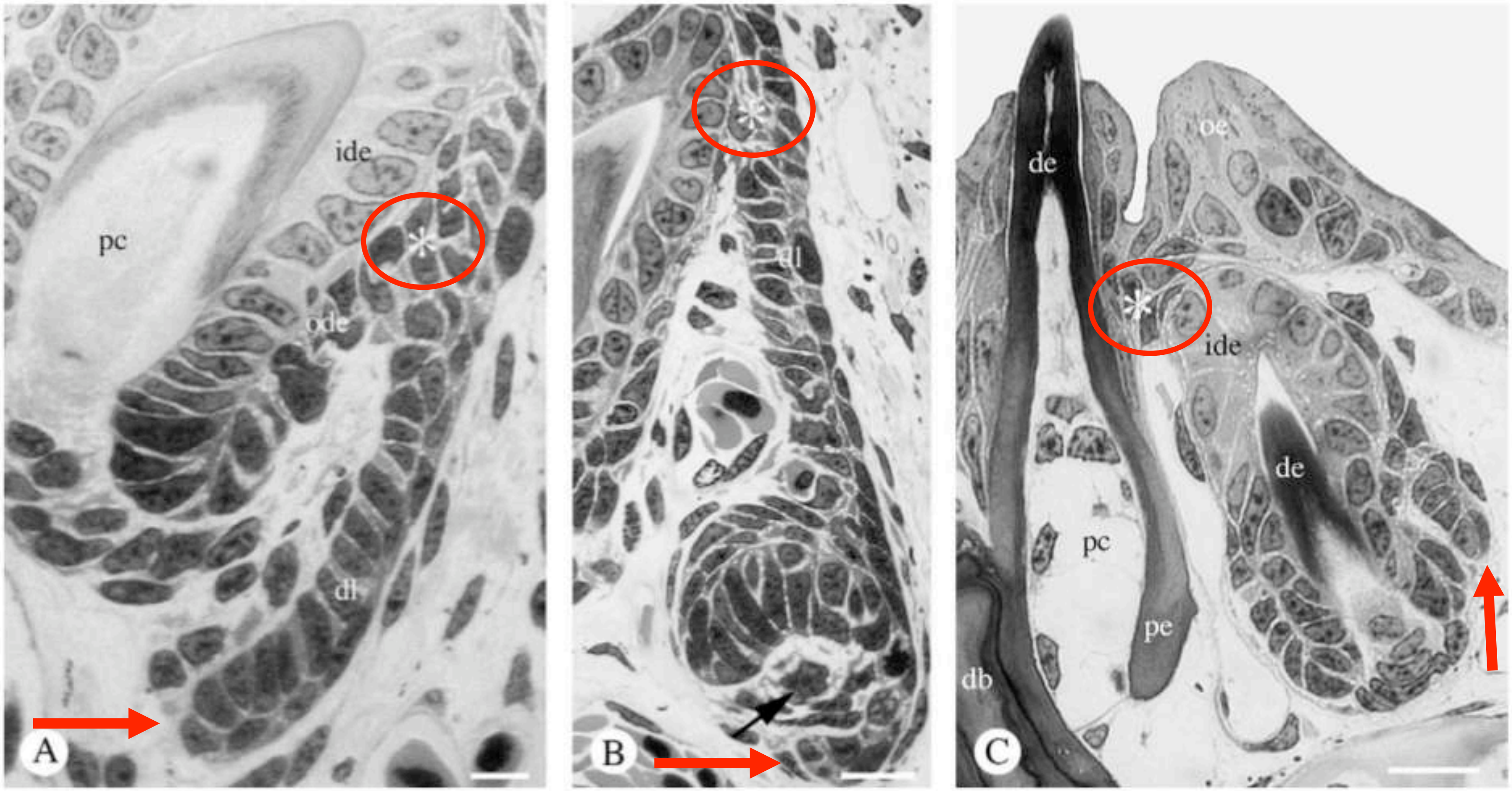


Fig. 12. Tooth replacement in *Pleurodeles waltl.* (A) Larva, stage 56. A secondary dental lamina, originating from the upper region (*) of the outer dental epithelium of the previous tooth, has extended into the mesenchyme. This dental lamina is composed of two layers, the cells of which are differently arranged: flat and elongated at the posterior side and tall and polarized at the anterior side. (B) Larva, stage 56. The cells located at the anterior side and at the extremity of the dental lamina have proliferated and have formed a cup, which surrounds mesenchymal cells (arrow). The asterisk indicates the origin of the secondary dental lamina. (C) Larva, stage 49. A replacement tooth is well formed, but still attached to the functional first-generation tooth by means of the secondary dental lamina (*). Scale bars: A = 10 µm; B, C = 20 µm. db: dentary bone; de: dentine; dl: dental lamina; ide: inner dental epithelium; ode: outer dental epithelium; oe: oral epithelium; pc: pulp cavity; pe: pedicel.

žába drápatka: superficiální vznnik zubů, DL asi přítomna, detekce složitá...

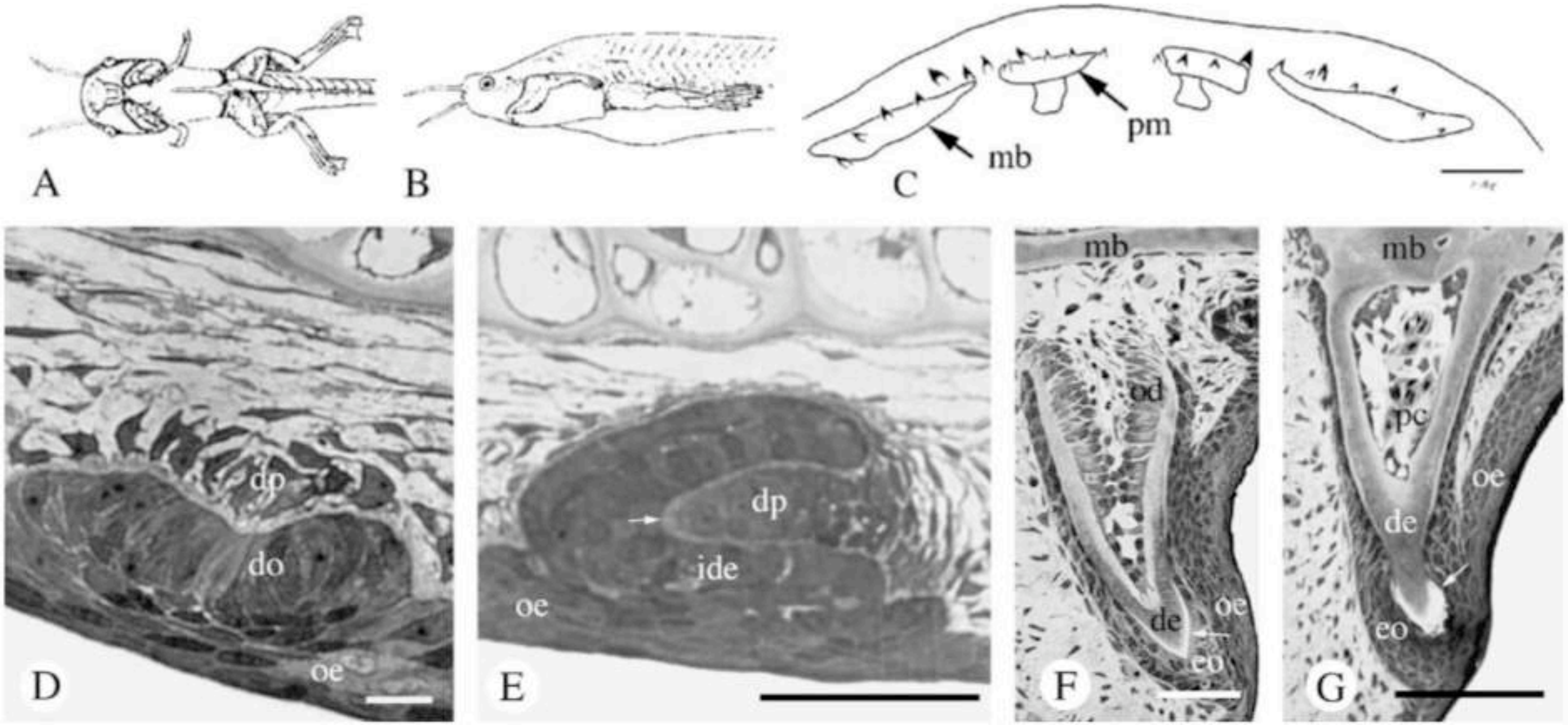
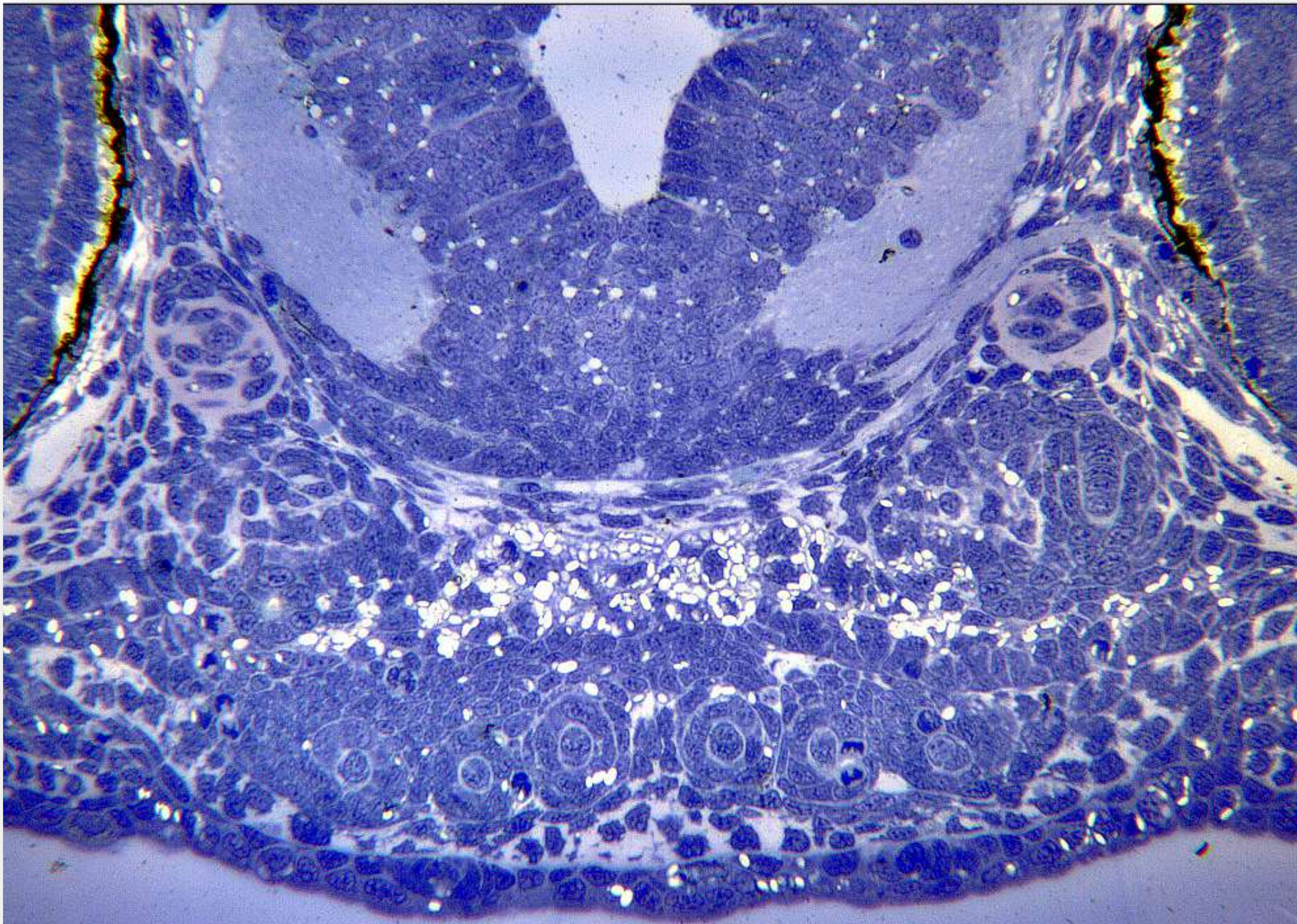


Fig. 11. Tooth development in an anuran, the pipid *Xenopus laevis*. In contrast to most anuran species, the teeth develop long before metamorphosis. (A, B) Tadpole, stage 59, ventral and lateral views, respectively. The first-generation teeth are already well developed at this stage. (C) Tooth pattern in a tadpole, stage 59. As in most anuran species teeth are only present on the upper jaw. (D-G) One µm-thick vertical sections of the upper jaw of tadpoles (stages 54, 58, 63 and 65, respectively) showing various developmental stages of first-generation teeth, from initiation (D) to attachment (G). The arrow in E indicates to the first deposition of the tooth matrix. The arrows in F and G indicate the previous location of the enamel in these samples which were decalcified with EDTA. Developmental stages are as in Nieuwkoop & Faber (1956). A, B modified from Nieuwkoop & Faber (1956), C from Cambray (1976). Scale bars: C = 250 µm; D = 10 µm; E-G = 50 µm. de: dentine; do: dental organ; dp: dental papilla; eo: enamel organ; ide: inner dental epithelium; mb: maxillary bone; od: odontoblast; oe: oral epithelium; pc: pulp cavity; pm: premaxillary bone.

ocasatý obojživelník axolotl: vznik zubů a přítomnost DL

ocasatý obojživelník axolotl: vznik zubů a přítomnost DL



gekon Paroedura picta: nejprve vznik jednotlivých superficiálních zubních základů

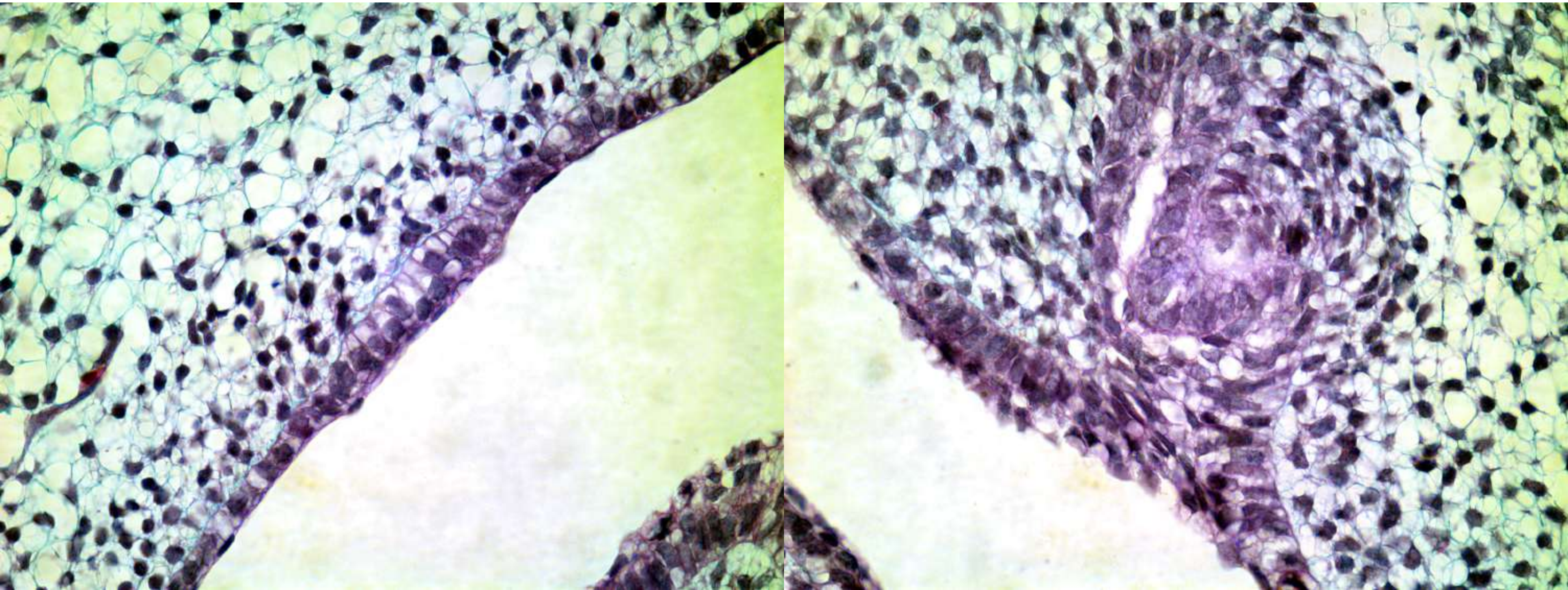
(*O. Zahradníček, I. Horáček*)

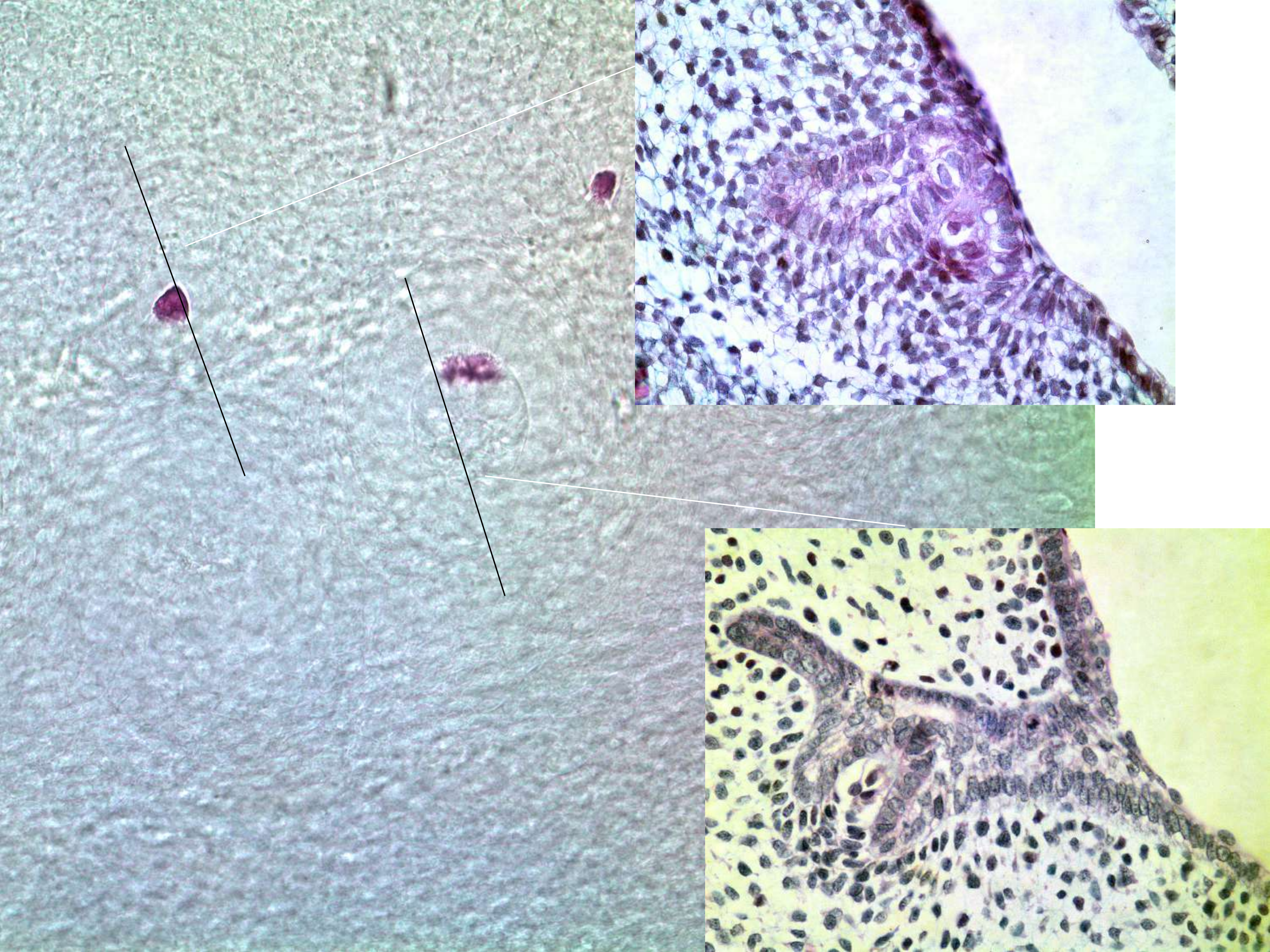
Placodal thickenings randomly distributed over the epithelium

cf. odontodes;

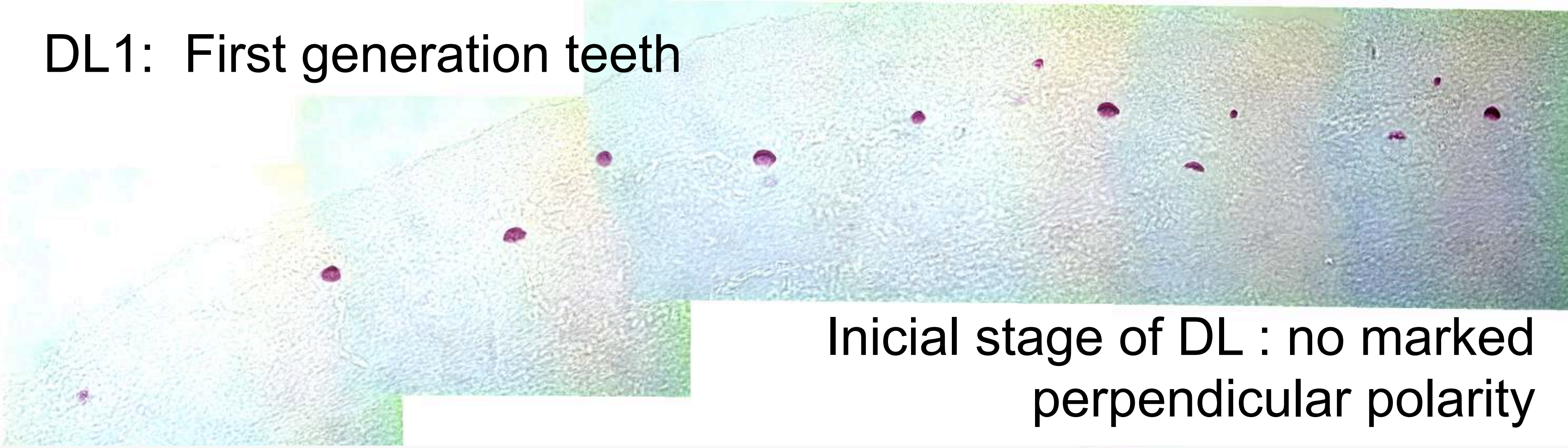
cf. vaječné zuby

Immediatelly differenciated in tooth primordia, most of which do not develop into teeth

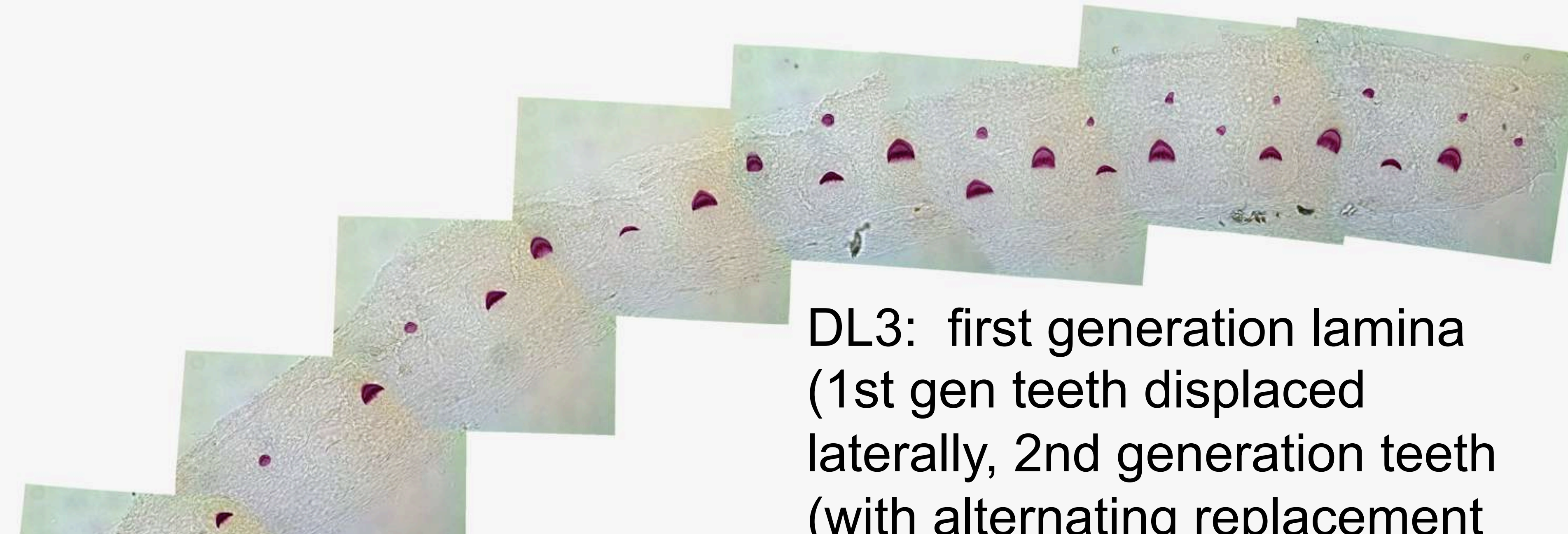




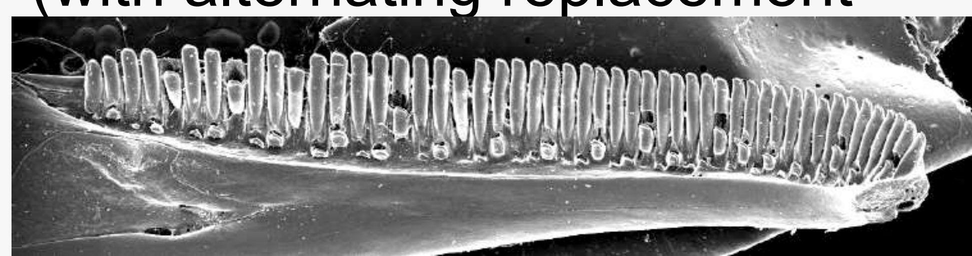
DL1: First generation teeth



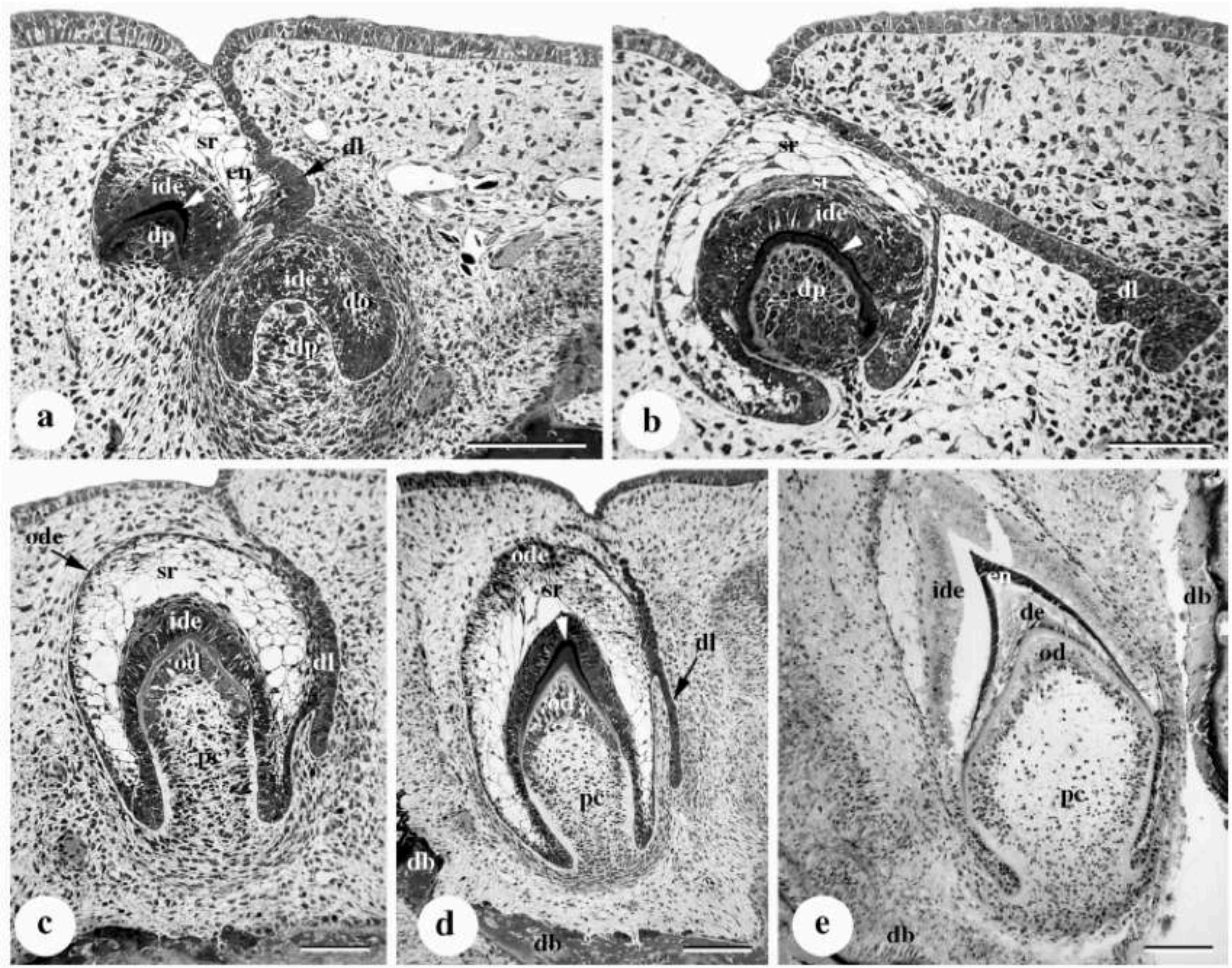
Inicial stage of DL : no marked perpendicular polarity



DL3: first generation lamina (1st gen teeth displaced laterally, 2nd generation teeth (with alternating replacement



krokodýl: vznik zubů a přítomnost d. laminy



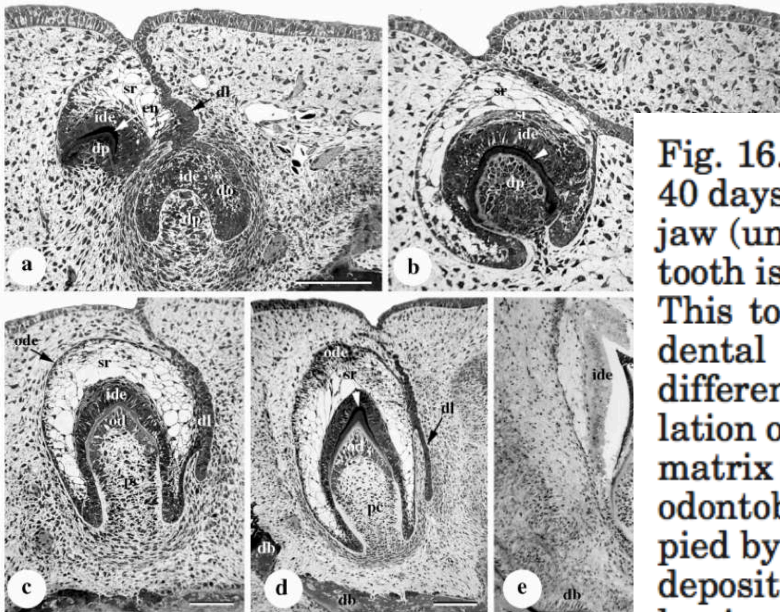
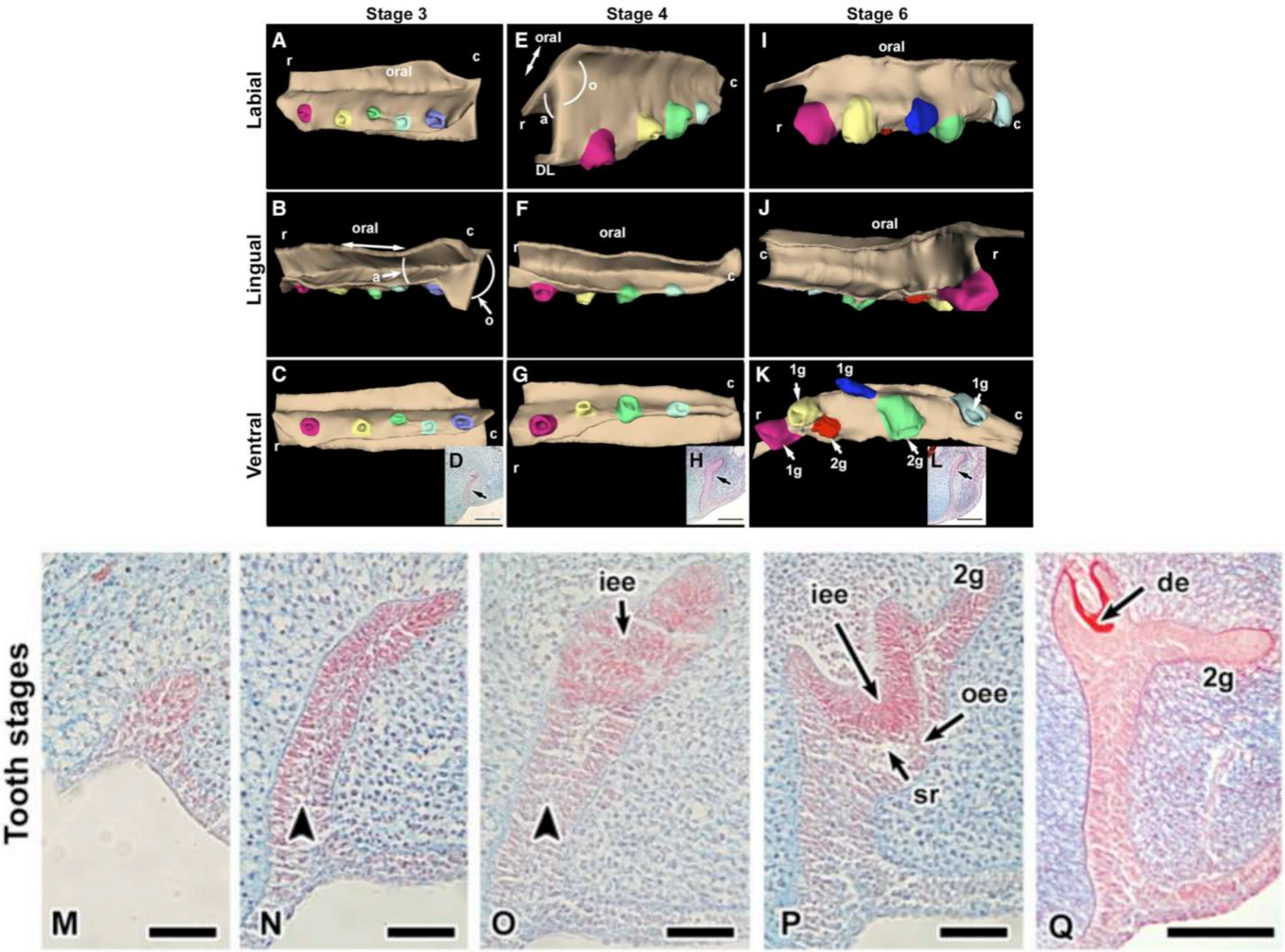


Fig. 16. *Crocodylus niloticus*. **a,c:** 34-day-old embryo; **b:** 28 days; **d:** 40 days; **e:** 70 days; **f–h:** 50 days. Transverse sections of the left lower jaw (undecalcified). **a–f:** 1 μm-thick sections; **g–h:** thin sections. **a:** A tooth is differentiating and enamel and dentine matrix are deposited. This tooth is linked to a young replacement tooth by means of the dental lamina. In the replacement tooth, the epithelial cells have differentiated and the dental organ has folded around a loose population of mesenchymal cells, which form the dental papilla. **b:** Dentine matrix is mineralized and predentine is deposited centripetally by the odontoblasts. The pulp cavity is 10–15 cells wide and entirely occupied by densely packed mesenchymal cells. Polarized ameloblasts are depositing the first layer of enamel matrix (arrowhead). A dental lamina, connected to the surface of the dental organ, extends deep into the mesenchyme. **c:** The dental organ is well differentiated and surrounds a pulp cavity, in which odontoblasts have differentiated and deposited the first elements of the predentine matrix. Some small blood vessels have entered the pulp cavity. **d:** The pulp cavity is well delimited and the odontoblasts located in its upper region synthesize the predentine. The outer layer of predentine has mineralized to give dentine. Enamel matrix (arrowhead) has been deposited by the ameloblasts. The base of the tooth lies close to the dentary bone surface. **e:** The dentine layer has thickened and predentine is still deposited towards the base of the tooth. Both the dentine and the deeper region of the enamel are well mineralized, while the outer region of the enamel matrix is only slightly mineralized. The tooth is not yet attached to the dentary bone, which can be seen on both sides of the tooth. **f:** Upper region of a well-formed tooth at the start of enamel matrix maturation. **g:** Detail of the enamel matrix. The crystallites are perpendicular to the tooth surface. **h:** Detail of the dentine and predentine showing the presence of numerous cell processes embedded in the matrix. Scale bars: **a–e** = 100 μm; **f** = 10 μm; **g** = 1 μm; **h** = 5 μm.

krajta: kontinuální dentální lamina odštěpující jednotlivé dentální plakody /zuby

M. Buchtová et al. / Developmental Biology 319 (2008) 132–145 137



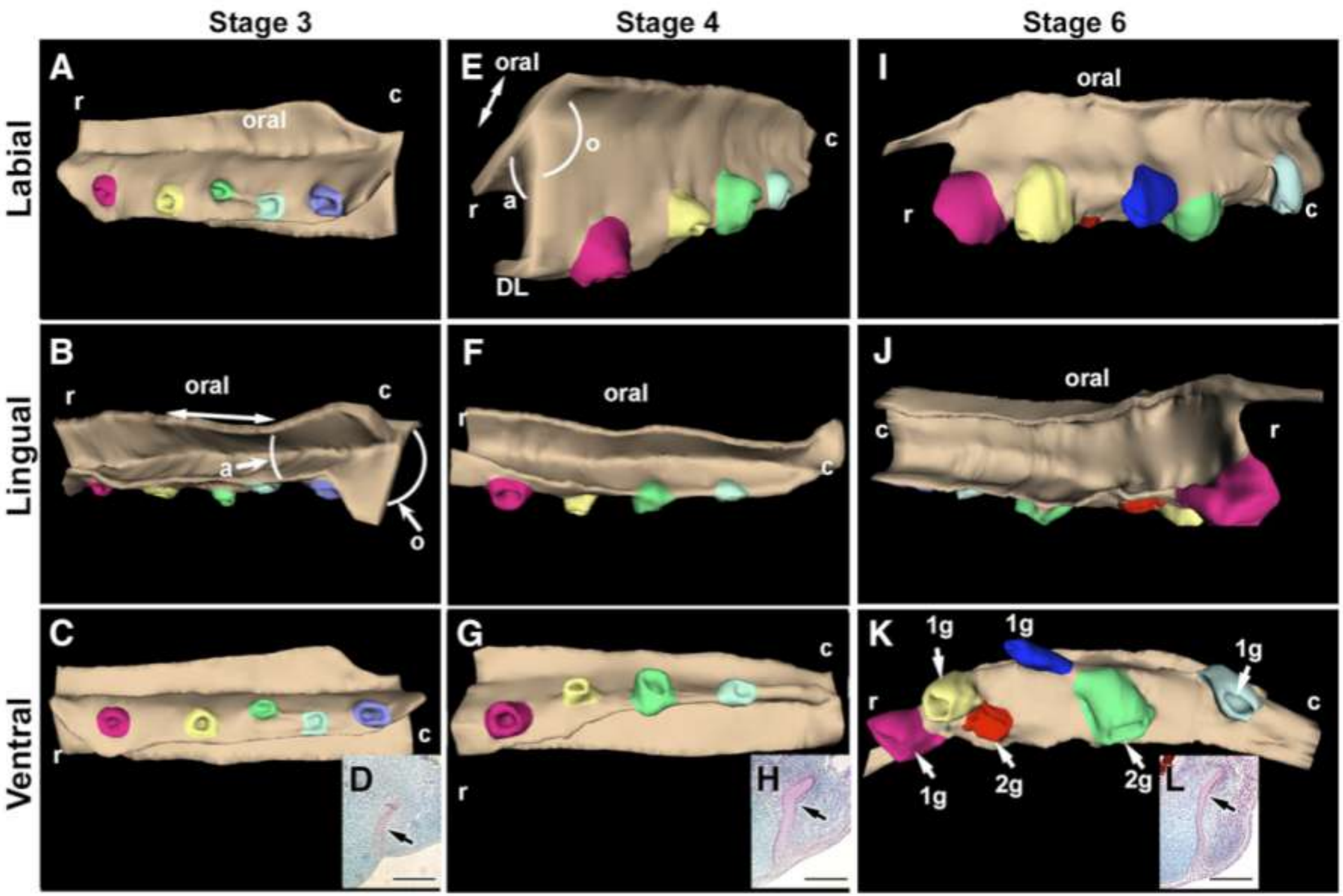


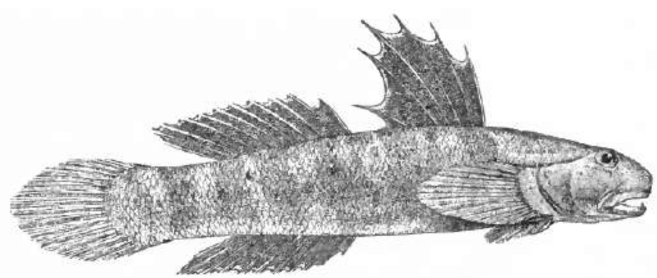
Fig. 3. Continuity of the maxillary dental lamina in *P. sebae*. Reconstruction of the maxillary dental lamina. There are no gaps between sections and only epithelium was traced. Examples of sections traced are in panels D,H,L. (A–C) 1840 μm was reconstructed. The dental lamina is continuous and cap stage primary or first generation teeth are present at regular intervals. The angle of the dental lamina with respect to the oral epithelium is indicated in panel B. (E–G) 1440 μm was reconstructed. The tip of the dental lamina is bent at 90° to the rest of the dental lamina. First generation bell stage teeth bud off the labial side or obtusely angled side of the lamina (E,F). (I–K) 1197 μm was traced. Several tooth families (first and second generation) can be seen. The pink, green, yellow and dark blue anlagen are bell-stage, whereas the red and turquoise teeth are cap stage. The second-generation teeth are closest to the growing tip of the dental lamina. The dental lamina has an S shape (I,J). Key: a — acute angle, c — caudal, DL — dental lamina, o - obtuse angle, r — rostral, 1g — first generation tooth, 2g — second generation tooth. The reconstructions are not to scale. Scale bar for sections = 200 μm.

Cell Tissue Res (2010) 340:189–200
DOI 10.1007/s00441-010-0935-2

REGULAR ARTICLE

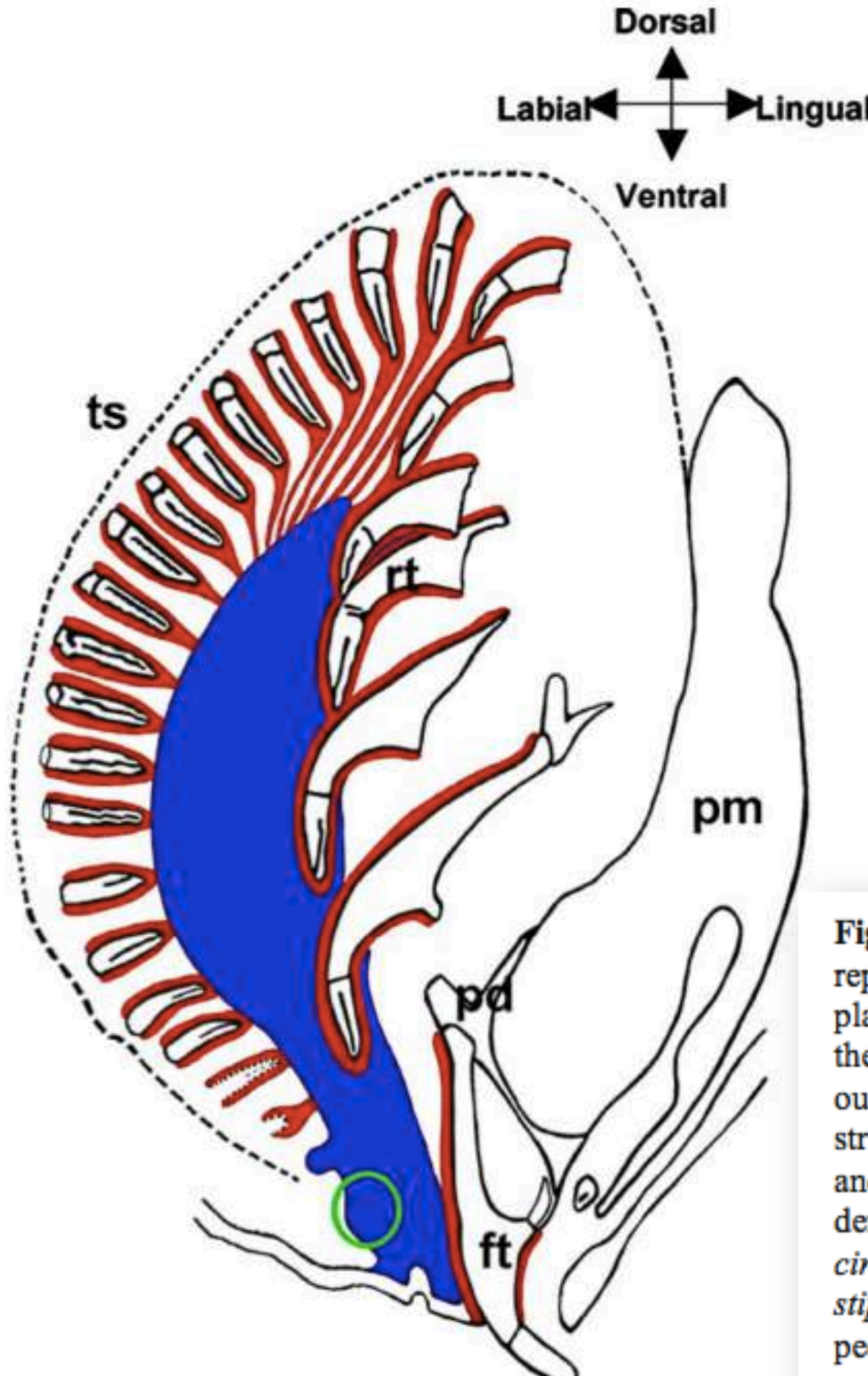
Plate-like permanent dental laminae of upper jaw dentition in adult gobiid fish, *Sicyopterus japonicus*

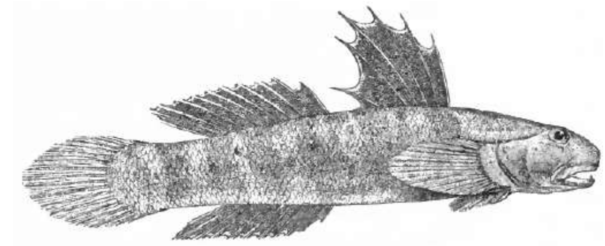
Keita Moriyama · Shun Watanabe · Midori Iida · Noriyuki Sahara



Sicydium fasciatum.

Abstract *Sicyopterus japonicus* (Teleostei, Gobiidae) possesses a unique upper jaw dentition different from that known for any other teleosts. In the adults, many (up to 30) replacement teeth, from initiation to attachment, are arranged orderly in a semicircular-like strand within a capsule of connective tissue on the labial side of each premaxillary bone. We have applied histological, ultrastructural, and three-dimensional imaging from serial sections to obtain insights into the distribution and morphological features of the dental lamina in the upper jaw dentition of adult *S. japonicus*. The adult fish has numerous permanent dental laminae, each of which is an infolding of the oral epithelium at the labial side of the functional tooth and forms a thin plate-like structure with a wavy contour. All replacement teeth of a semicircular-like strand are connected to the plate-like dental lamina by the outer dental epithelium and form a tooth family; neighboring tooth families are completely separated from each other. The new tooth germ directly buds off from the ventro-labial margin of the dental lamina, whereas no distinct free end of the dental lamina is present, even adjacent to this region. Cell proliferation concentrated at the ventro-labial margin of the dental lamina suggests that this region is the site for repeated tooth initiation. During tooth development, the replacement tooth migrates along a semicircular-like strand and eventually erupts through the dental lamina into the oral epithelium at the labial side of the functional tooth. This unique thin plate-like permanent dental lamina and the semicircular-like strand of replacement teeth in the upper jaw dentition of adult *S. japonicus* probably evolved as a dental adaptation related to the rapid replacement of teeth dictated by the specialized feeding habit of this algae-scraping fish.





Sicydium fasciatum.

Fig. 8 Distribution of the dental lamina and dental epithelium of replacement teeth in the upper jaw dentition of adult *S. japonicus*. The plate-like dental lamina (*blue*), an infolding of the oral epithelium at the labial side of the functional tooth (*ft*), invades deeply and spreads out labio-lingually within a tooth sac (*ts*), forming a thin plate-like structure. Each replacement tooth (*rt*) is aligned against the dental sac and is connected to the plate-like permanent dental lamina independently by means of the dental epithelium (*brown*). The *green open circle* represents the repeated formation site of replacement teeth. The *stippled line* indicates the approximate position of the tooth sac (*pd* pedicel, *pm* premaxillary bone)

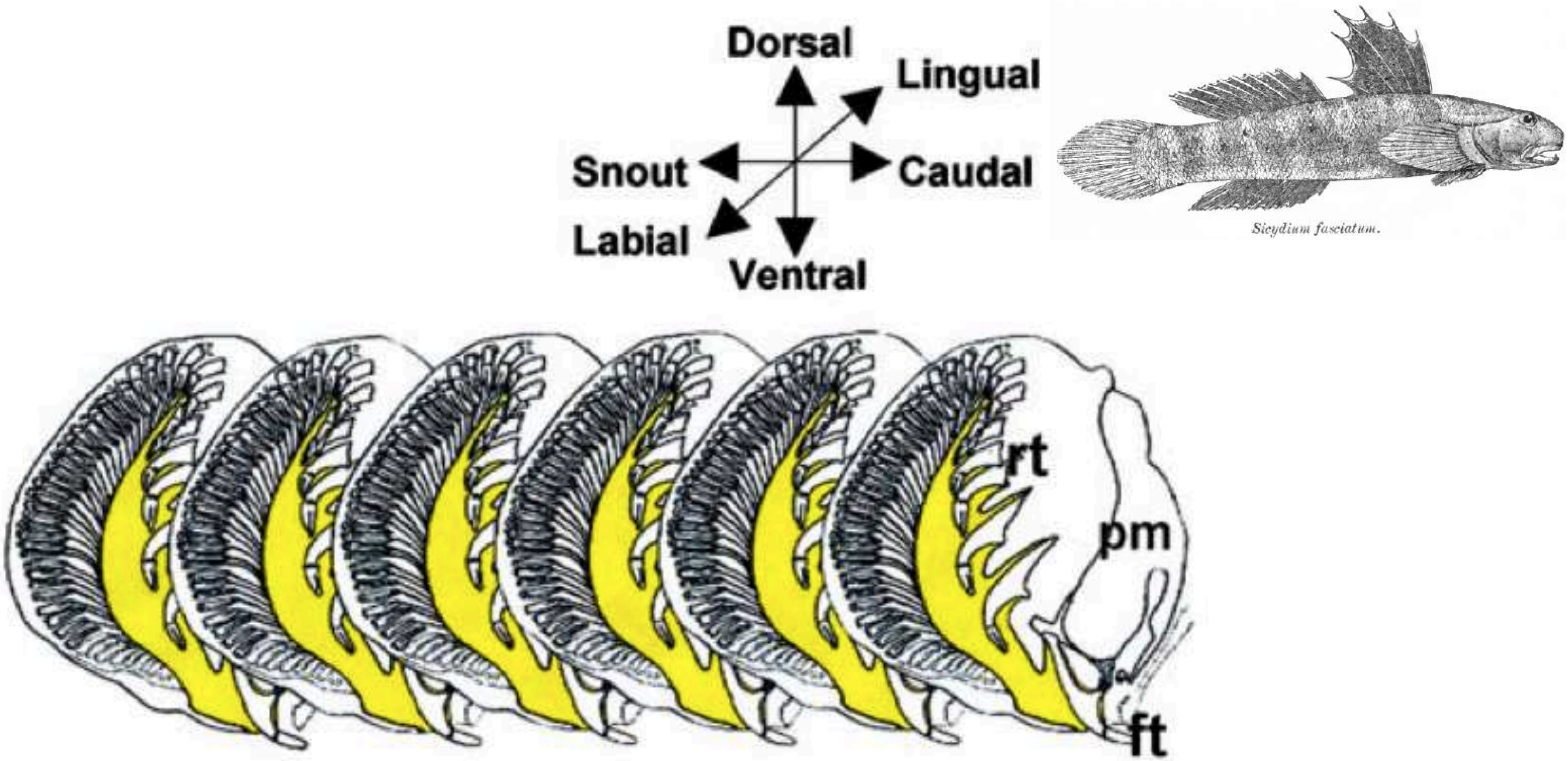


Fig. 9 Representation of the distribution of the dental laminae in the upper jaw dentition of adult *S. japonicus*. More than 30 replacement teeth and tooth germs in a semicircular-like strand within the tooth sac are associated with a thin plate-like dental lamina (*yellow*), thereby forming a tooth family. The dental lamina of each tooth family is formed by its own epithelial invagination. The laminae are completely separated from each other (*ft* functional tooth, *pm* premaxillary bone, *rt* replacement tooth)

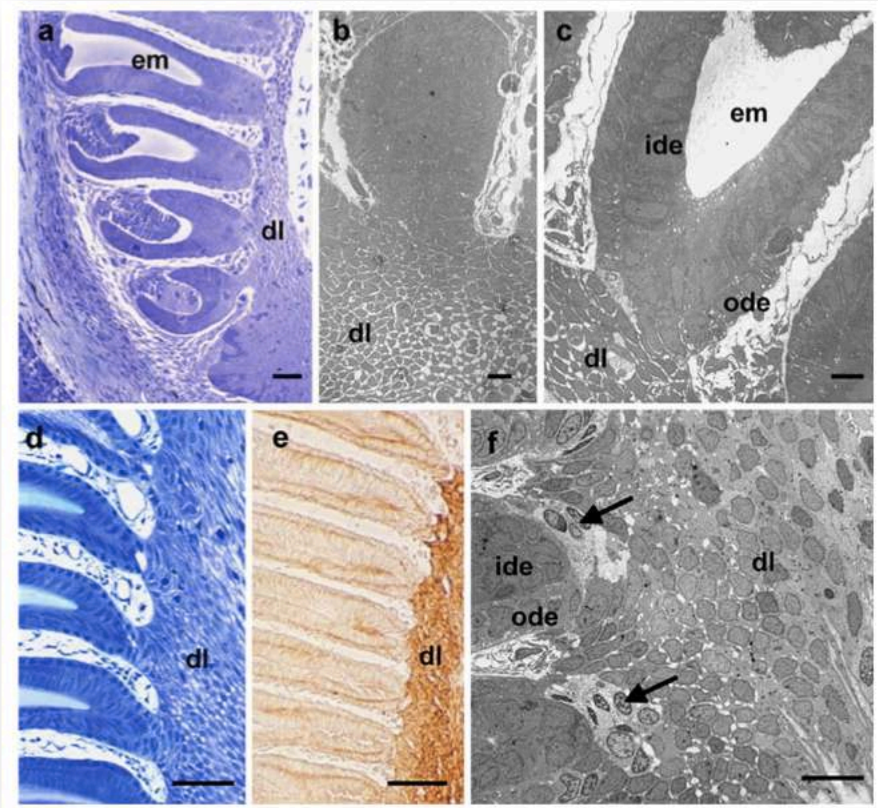
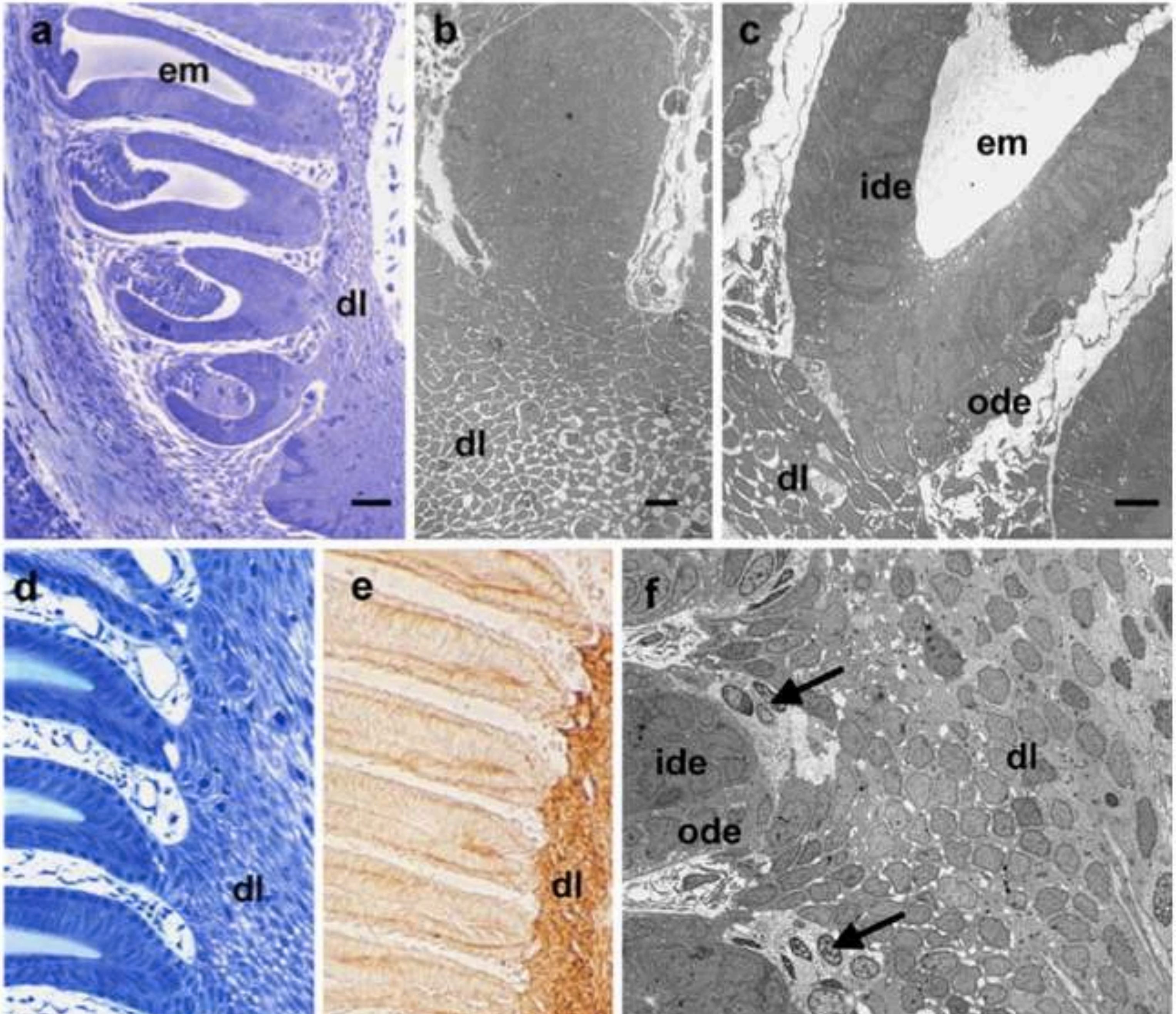


Fig. 3 Morphological features of the connection between the dental lamina and replacement teeth at the initiation and morphogenesis stage (**a**–**c**) and at the enamel matrix deposition and mineralization stage (**d**–**e**). **a** The new tooth germ directly buds off from the dental lamina at the ventro-labial margin of the dental lamina (*dl*). The developmental stages of replacement teeth are orderly arranged in the dorsal aspect (*em* enameloid matrix). **b** Initial stage. No significant morphological difference can be found between the tooth germ and dental lamina. **c** Morphogenesis stage. The dental epithelium has differentiated into two distinct layers: the inner (*ide*) and outer (*ode*) dental epithelia. The tooth germ is connected to the dental lamina by mean of the outer dental epithelium. **d** Enameloid matrix deposition and mineralization stage. The connection area between the outer dental epithelium and dental lamina has become smaller. **e** Immunostaining for cytokeratin reveals a difference in staining between the dental epithelium and dental lamina. **f** Some degenerating cells can be observed in the outer dental epithelium of the connection regions (*arrows*). *Bars* 50 μm (**a**), 100 μm (**d**, **e**), 10 μm (**b**, **c**, **f**)



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REGULAR ARTICLE

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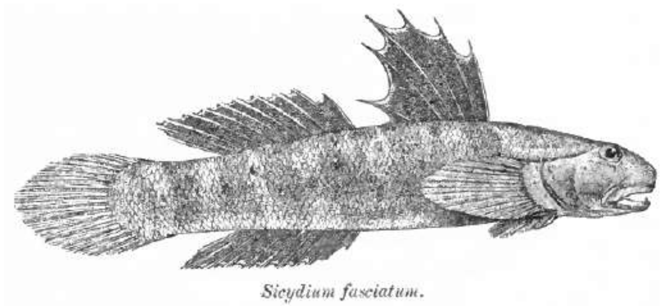
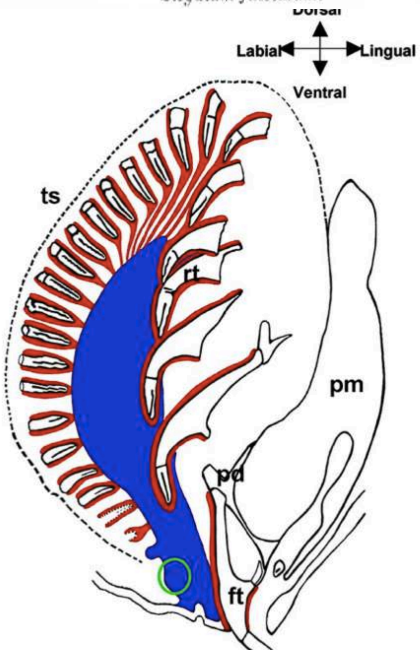
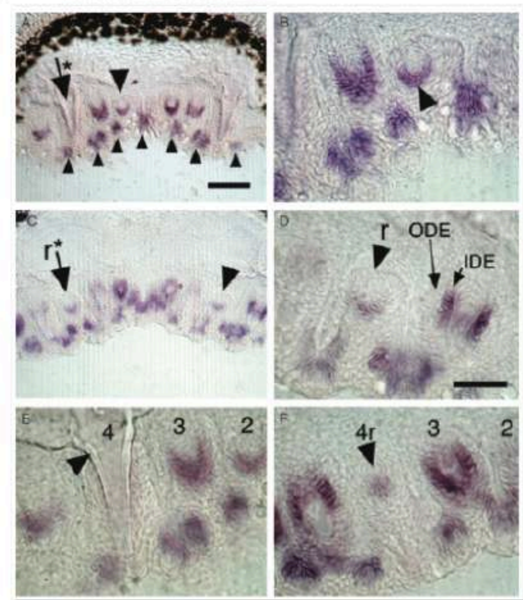




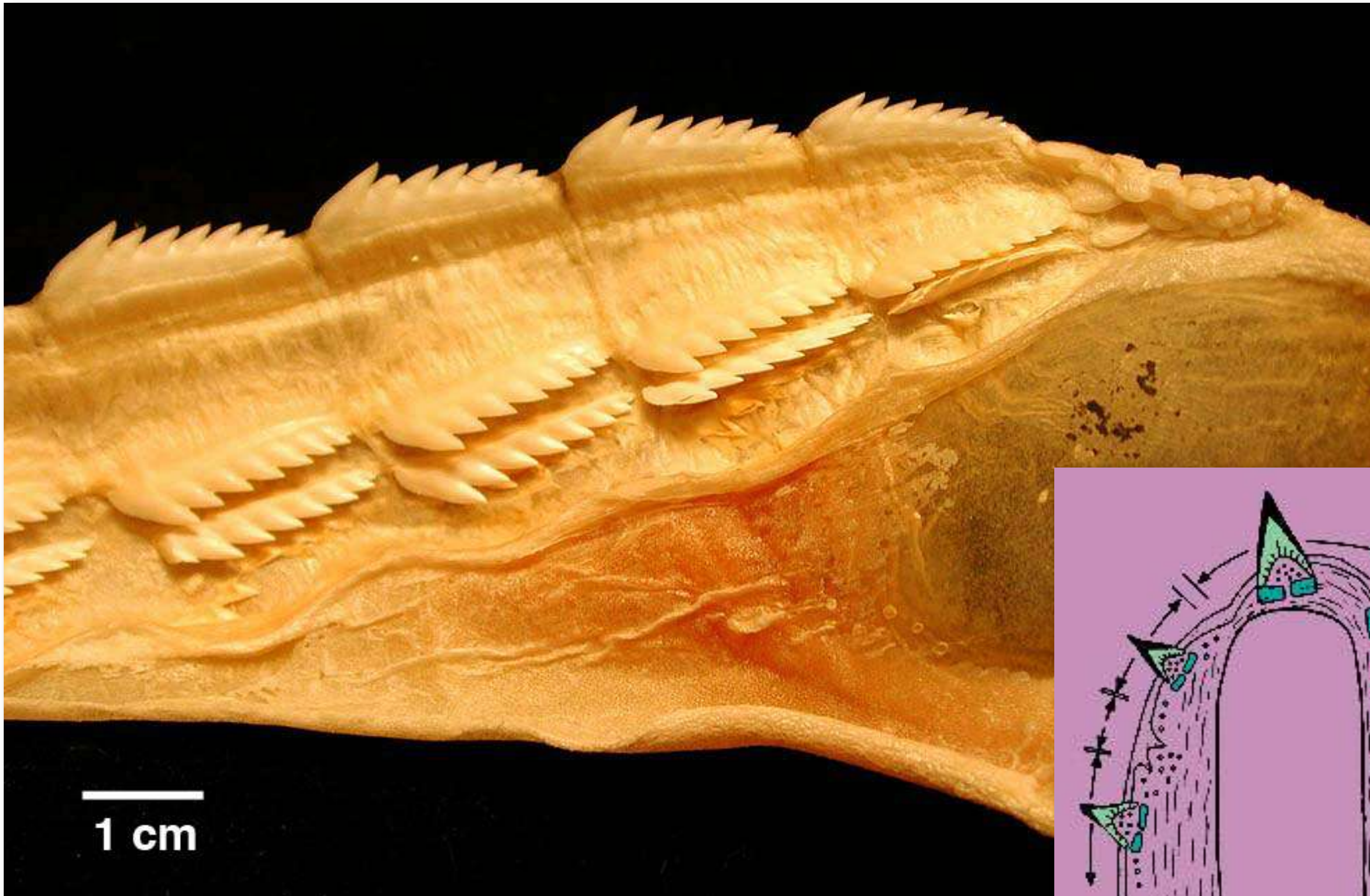
Dentální plakoda vs. dentální lamina:
kontinuální vs. *diskontinuální*

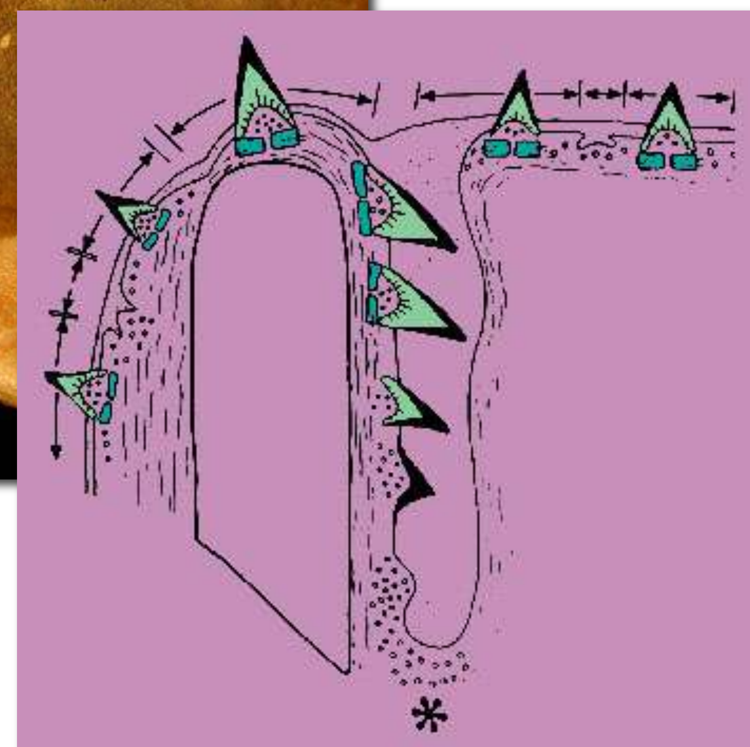
pstruh: *Shh*



cf: "klasická" situace u ryb!

Dentální lamina žraloka: "klasická" DL





Zubotvorný embryonální orgán;
produkuje zuby;
definuje a zakládá jejich pozici a výměnu

Patrnost zubů (*patterned and regulated teeth*) ukazuje na přítomnost DL, srv. tzv. *tooth whorls*

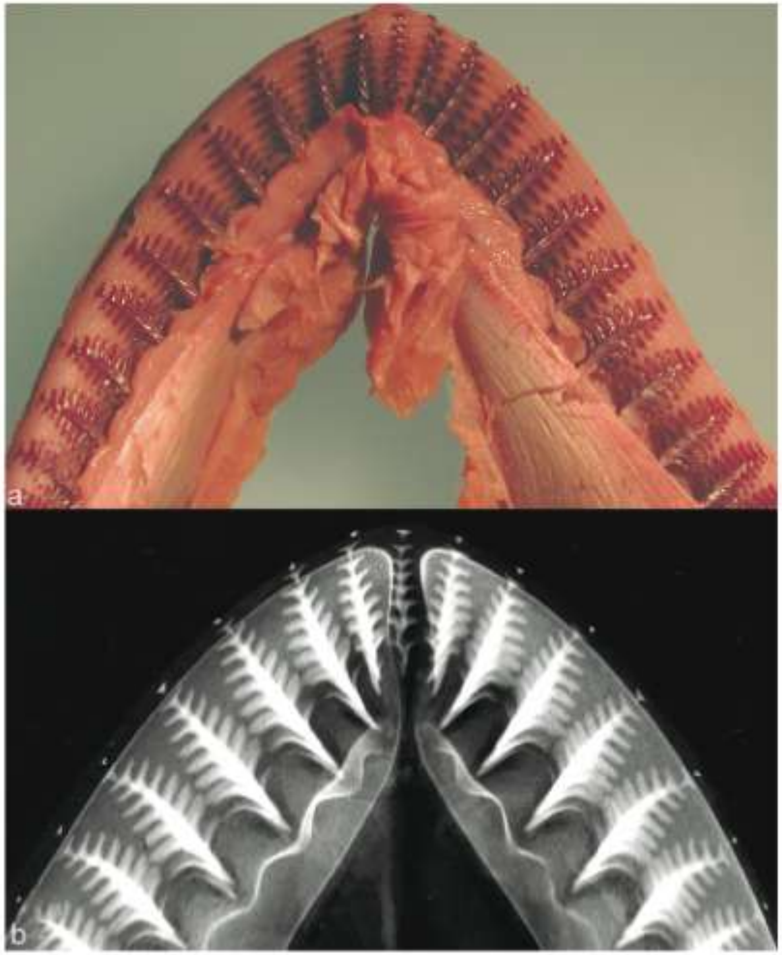


Fig. 9. Lower jaw with epithelium removed (a) and radiograph (b) of the same specimen of embryo gray reef shark (*C. amblyrhyncus*). Regular tooth files are shown each in line with single first rudimentary teeth (tooth shards, beyond the cartilage margin) and space between these used for increase in size of later tooth bases, but nonalternation of teeth.

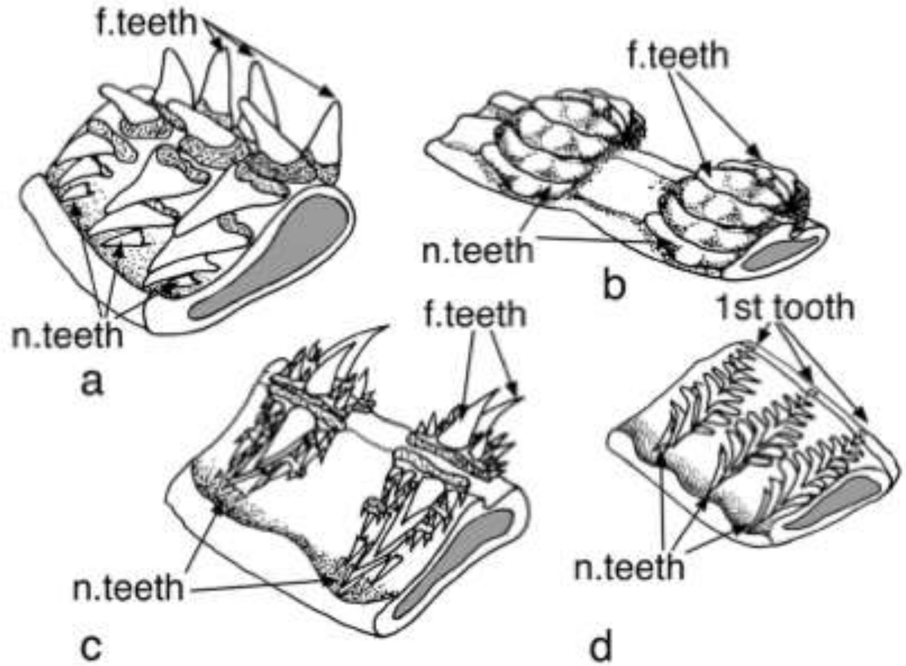


Fig. 6. Representative drawings of tooth files in chondrichthyans, each showing the replacement teeth exposed by removal of the lingual epithelium (a–c) adult and (d) embryo. Alternate tooth files (a, as *Carcharhinus melanopterus*); spaced nonalternate tooth files with teeth in a whorl-like order (c, *Chlamydoselachus anguineus*), also seen in primitive fossil examples; spaced nonalternate tooth files of crushing dentition (b, chimaeroid as *Helodus simplex*); close but nonalternate files (d, embryo gray reef shark *Carcharhinus amblyrhynchus*). f.teeth, functional teeth at the jaw margin may be several in each file (b, c), or a single one (a). n. teeth, newest tooth to form from permanent tooth primordium.

Srv. zubní řady či rodiny u ryb vs. "tooth whorls"!!!

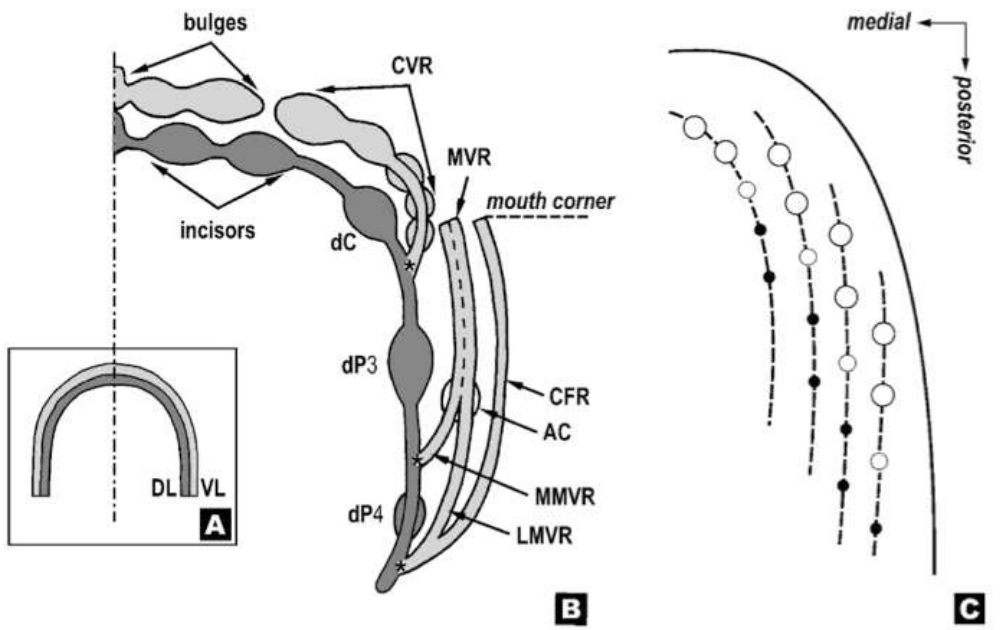
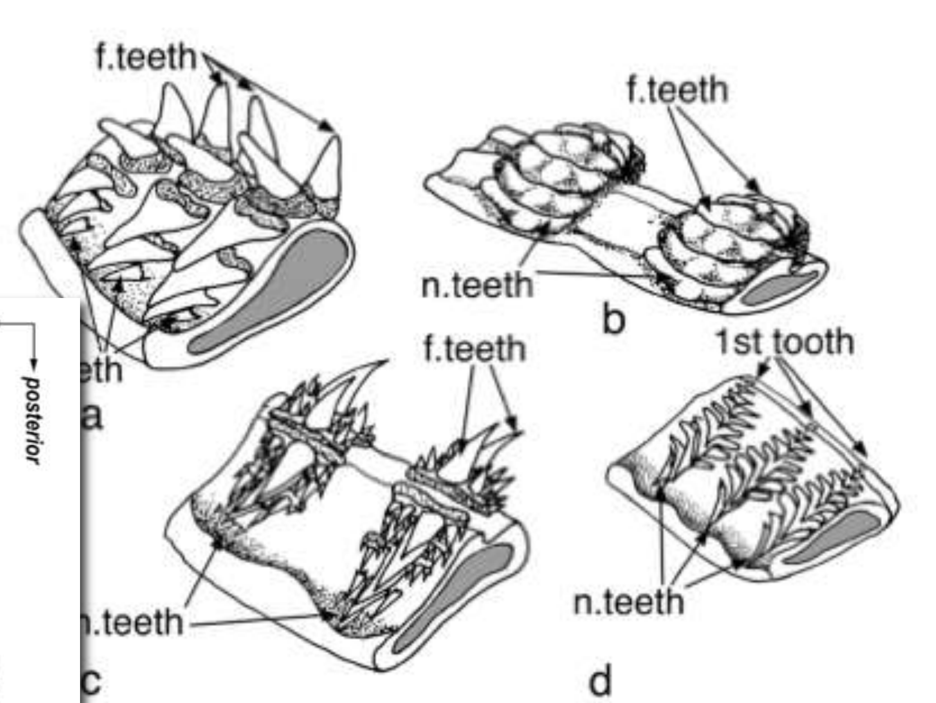


Fig. 7. Schemes of the pattern of the dental and vestibular epithelium in human embryos (A, B) and of developing teeth in fishes (C). (**A**) A textbook concept presenting two parallel U-shaped ridges in human embryos (e.g., Bhaskar, '80): DL—dental lamina (giving rise to the deciduous dentition) and VL—vestibular lamina or labio-gingival band (where oral vestibule will form). (**B**) The 3D reconstructions have documented that no continuous vestibular lamina exists but a set of discontinuous epithelial structures (ridges and bulges) transiently occurs externally to the dental lamina (according to Hovorakova et al., 2005). Dark grey—dental epithelium. Light grey—vestibular epithelium. dC—the deciduous canine; dP3—the first milk molar (corresponding to the deciduous third premolar); dP4—the second milk molar (corresponding to the deciduous fourth premolar). CVR—the canine vestibular ridge; MVR—the molar vestibular ridge splitting in its medial and lateral branch (MMVR and LMVR, respectively); CFR—the cheek furrow ridge. AC—the accessory cap-shaped structure. The star indicates the places of fusion between the dental lamina and vestibular ridges. (**C**) The schematic pattern of tooth rows (Zahnreihen) in fishes (according to data by Edmund, '60). The empty rings and black spots indicate the older and younger teeth, respectively. New teeth are formed at the posterior end of each Zahnreihen.



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... vs. DL jako apomorfie savců?

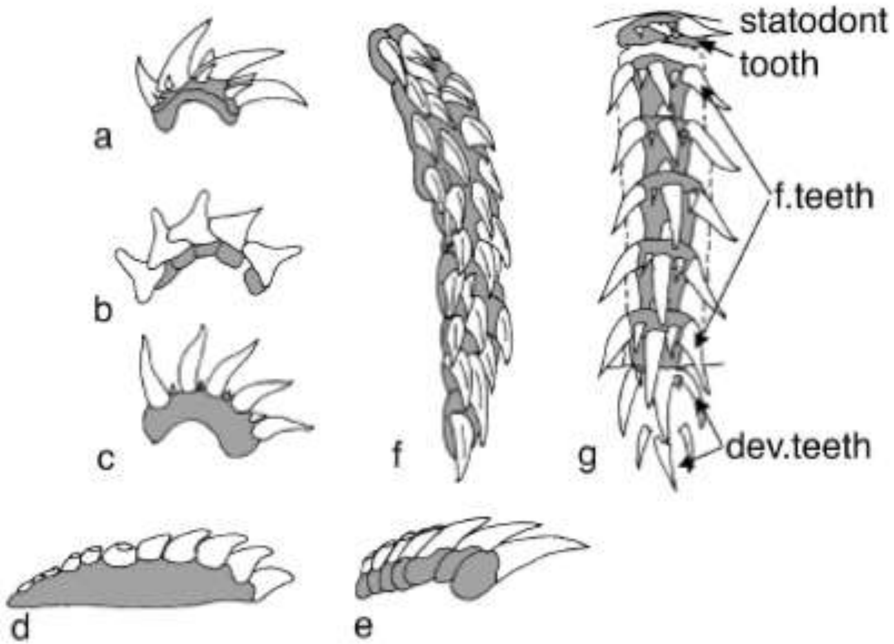


Fig. 2. Representation of tooth whorls in the jaws of fossil and extant fish, anterior to the left in a–d: (a) acanthodian; (b) chondrichthyan, one tooth set in a modern shark with separate tooth bases; (c) sarcopterygian; (d) one row of lungfish tooth-plate. (e) Pharyngeal joined denticle set from early stethacanthid *Akmonistion zangerli*, a primitive chondrichthyan. (f) Pharyngeal joined denticle set of an agnathan, the thelodont *Loganellia scotica*. (g) One tooth set from the frilled shark *Chlamydoselachus anguineus*, five functional teeth (f. teeth) are locked together with special attachment region, one is outside the edge of the jaw (statodont tooth), two developing teeth are below the lingual epithelium (see Fig. 7). Sources for drawings in a–e are Denison (1979), Reif (1976), Moy-Thomas and Miles (1971), Smith (1988), and Smith and Coates (2001).

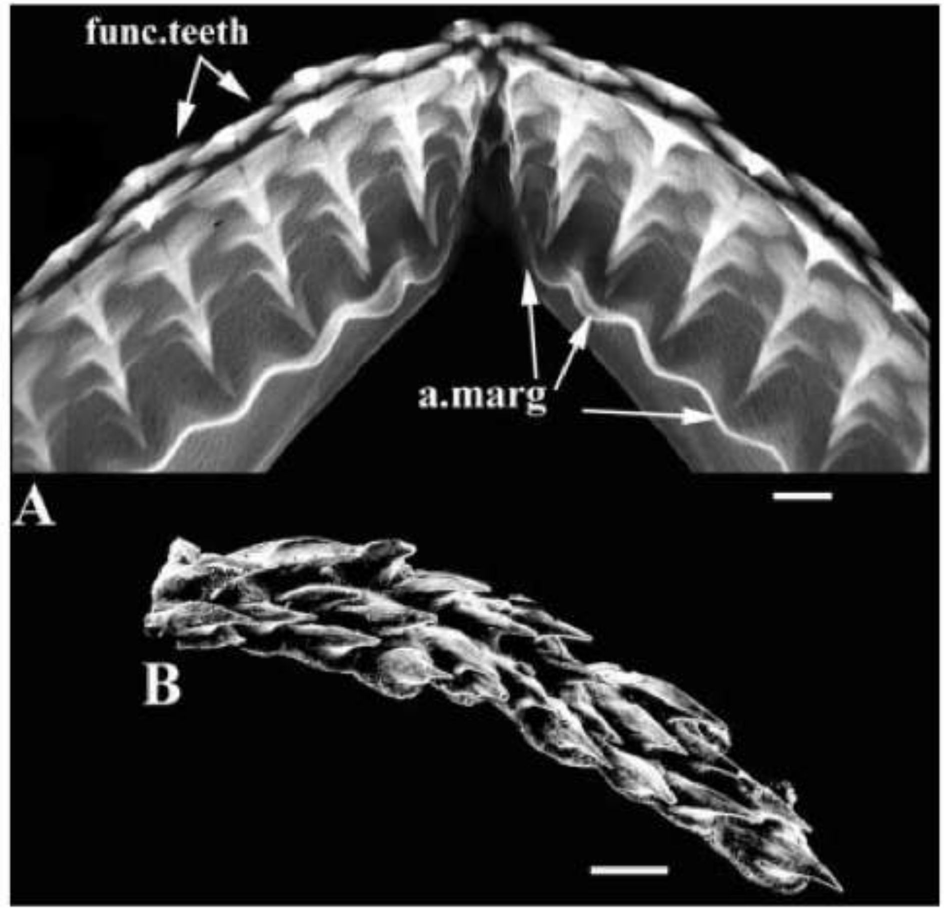


Fig. 2. **A:** Tooth sets along the lower jaw of the chondrichthyan *Carcharhinus melanopterus*. Note staggered or offset positions of tooth sets, particularly with regard to the alternation of the functional teeth at the jaw margin (func.teeth). Scale bar = 1.0 cm. **B:** Denticle whorl of the agnathan (jawless fish) *Loganellia* (Thelodonti). Scale bar = 1.0 mm. Adapted from Smith and Coates (2001: fig. 14.1H). a.marg, active margin of dental lamina, site of most recent tooth production; small dentine tooth cores.

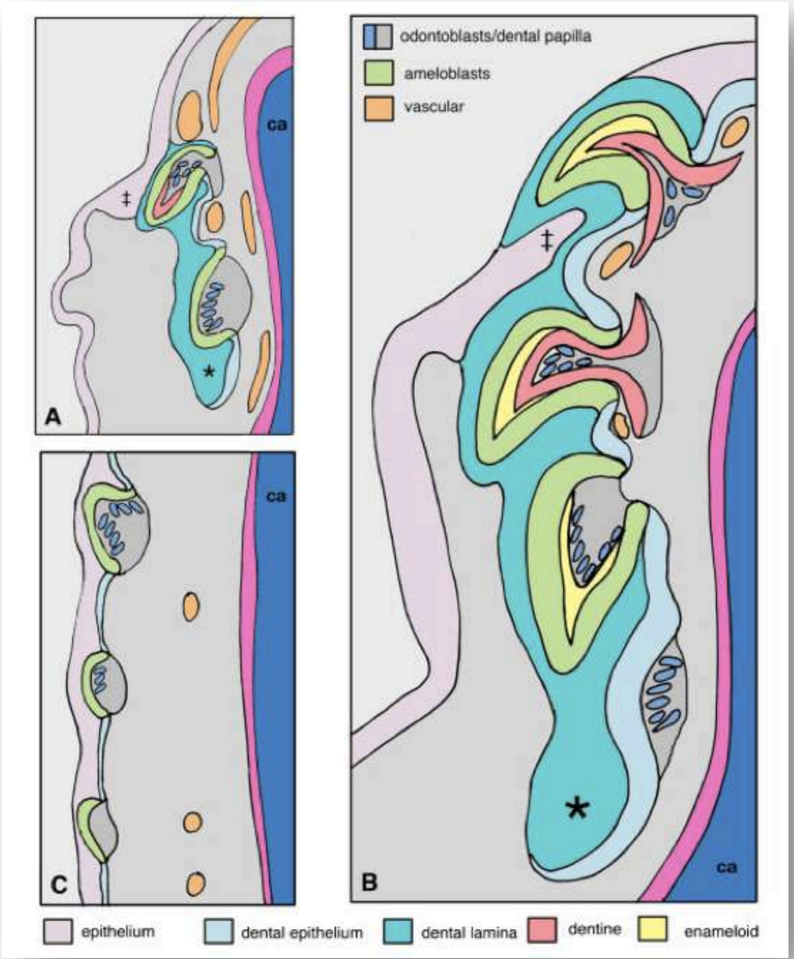
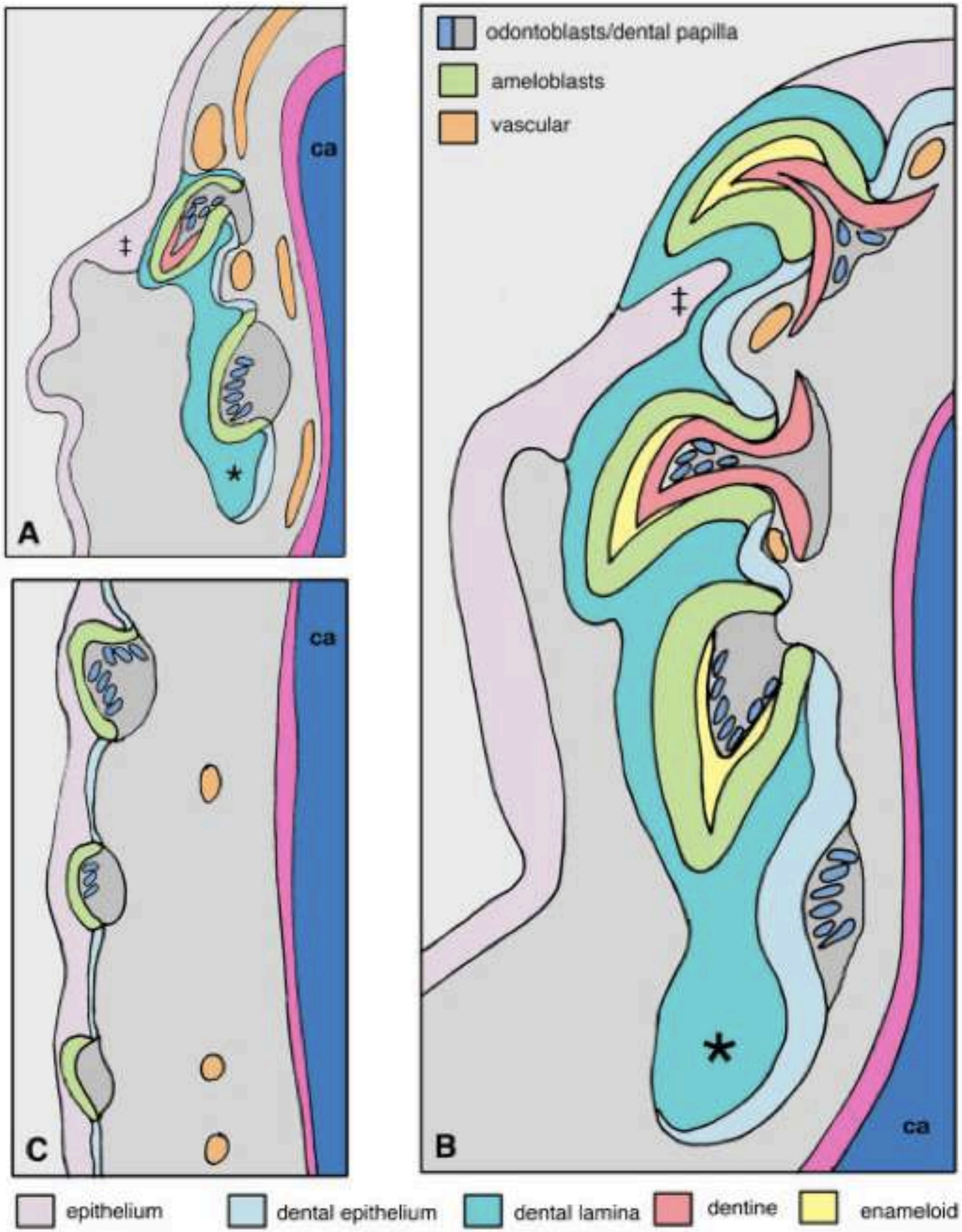


Fig. 2. Development of the dental lamina in chondrichthyans. Comparison of skin denticle (placoid scales) development with teeth in prehatch stages of *Scyliorhynus canicula* embryos. (**A**) Early tooth development with rudimentary tooth at first position and tooth cap stage at the second, both form within a dental lamina (stage 32). (**B**) Hatching stage of tooth development (11.5 cm BL) with three teeth in the family and cells of dental epithelium color coded as in the key; a new tooth bud develops from a region of the outer dental epithelium that lies close to the jaw cartilage and within an expanded region of the dental lamina with many intermediate cells proposed as equivalent to the stem cell niche. Regulation is proposed to occur in the dental lamina cells, either at the oral surface (‡ hypothesis 1) or at the growth extension away from the oral epithelium (* hypothesis 2). ca, cartilage. (**C**) Dorsal surface of the jaw with early epithelial buds and papillae for dermal denticles but no hard tissue formed, stage 32 of development. BL, baseline.



odontoblasts/dental papilla
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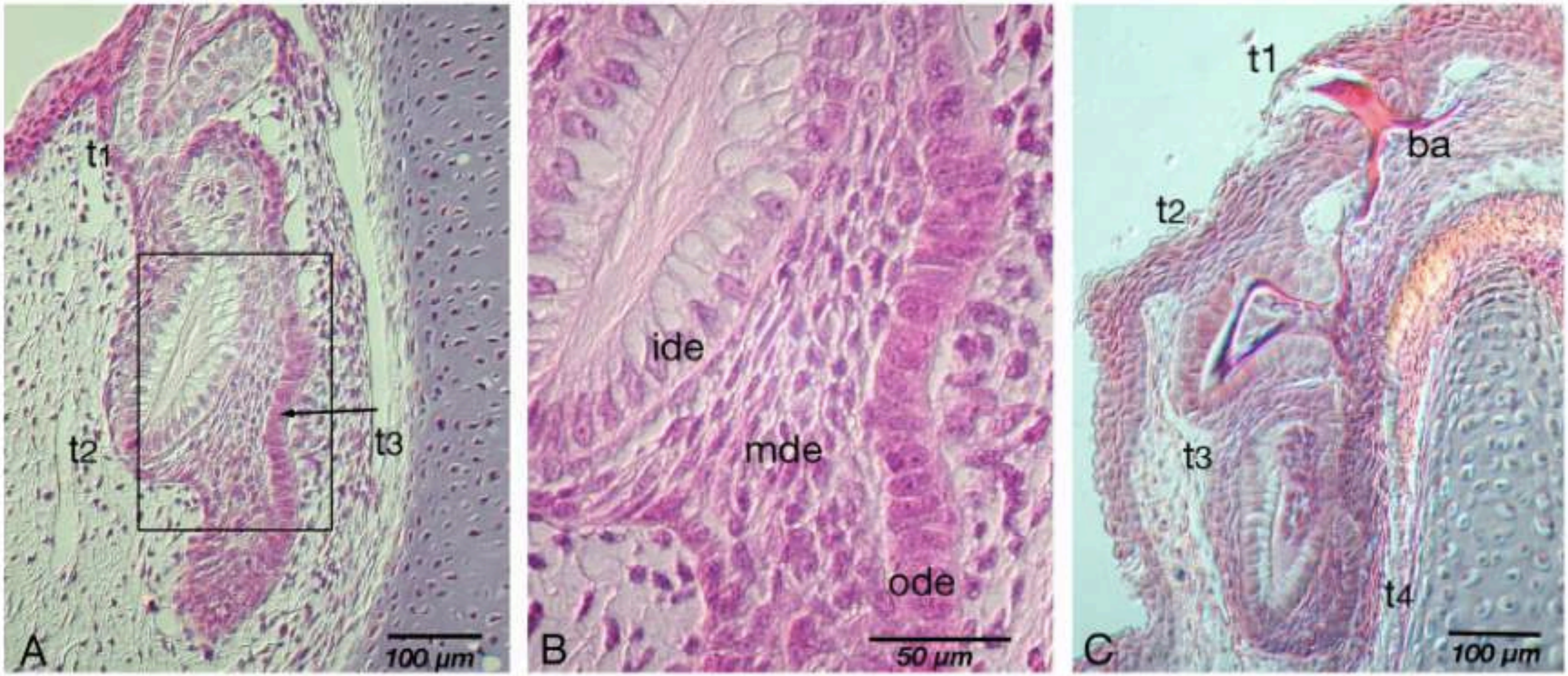

Fig. 4. Tooth family development in chondrichthyans. (**A**, **B**) Prehatch vertical section through lower jaw at two tooth stage *S. canicula*. (**C**) Five-day posthatch at start of tooth eruption. (A) Two teeth in tissue growth stage (ameloblasts, ide) and position of third (t_3) as a thickening (dental placode, arrow) of the outer dental epithelium (ode) as a part of the extension of the dental lamina. (B) Field in (A) (rectangle) to show undifferentiated cells of middle dental epithelium (mde) and dental placode with grouped mesenchyme cells. (C) Three to four tooth family stage (t_1–t_2) with enameloid on tooth crown, pulp tissue and bone of attachment but t_3 with enameloid matrix only and t_4 as a placodal thickening.

DL:
rozdíl mezi plakoidními *šupinami* a *zuby* žraloků…?!?

JOURNAL OF MORPHOLOGY 166:275-288 (1980)

Development of Dentition and Dermal Skeleton in Embryonic *Scyliorhinus canicula*[1]

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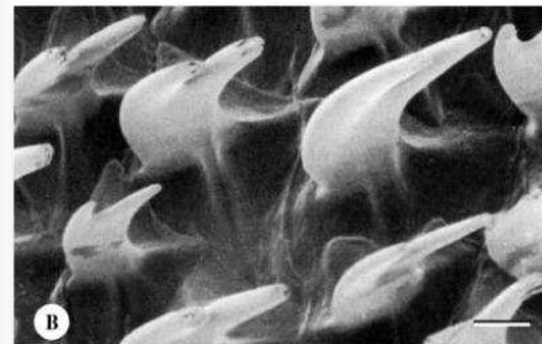
ABSTRACT Serial sections ranging from very young embryos to hatched juveniles and whole embryos of *Scyliorhinus* show that dentition and dermal skeleton belong to two independent secondary developmental fields that differ both developmentally and structurally. The development of the dentition starts very early, with a thickening of the ectoderm in the region of the mouth (stage 04), the invagination of the dental lamina (stage 18), and the formation of the germs of the first generation (stage 20). Tooth replacement movements start only near the end of embryogenesis (stage 35). Scale germs, on the other hand, first begin to form at stage 24. Scales erupt shortly before the animal hatches (stage 43). Only one scale generation is formed during embryogenesis. The forces which erupt the scales may come from fluid pressures in vacuoles of the fibrous layer of the dermis. Those which erupt the teeth probably also result from similar fluid pressures. The crown and upper part of the base of scales and teeth are formed by cells of the inner dental epithelium which are differentiated from the ectoderm. They are also formed by odontoblasts which are derived from the vascular layer of the dermis. However, the basal plates of scales and teeth containing the anchoring fibers are formed by osteoblasts, which are derived from the fibrous layer of the dermis.



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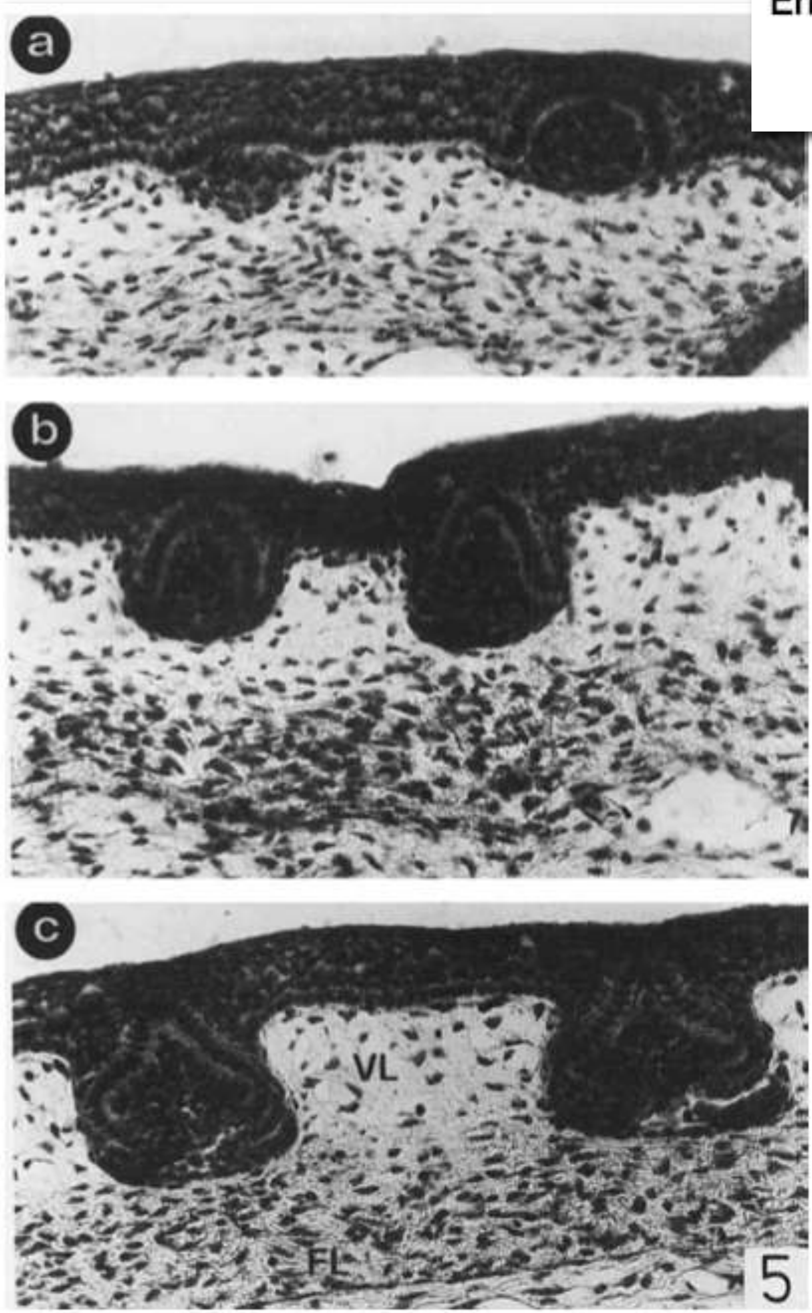
scales



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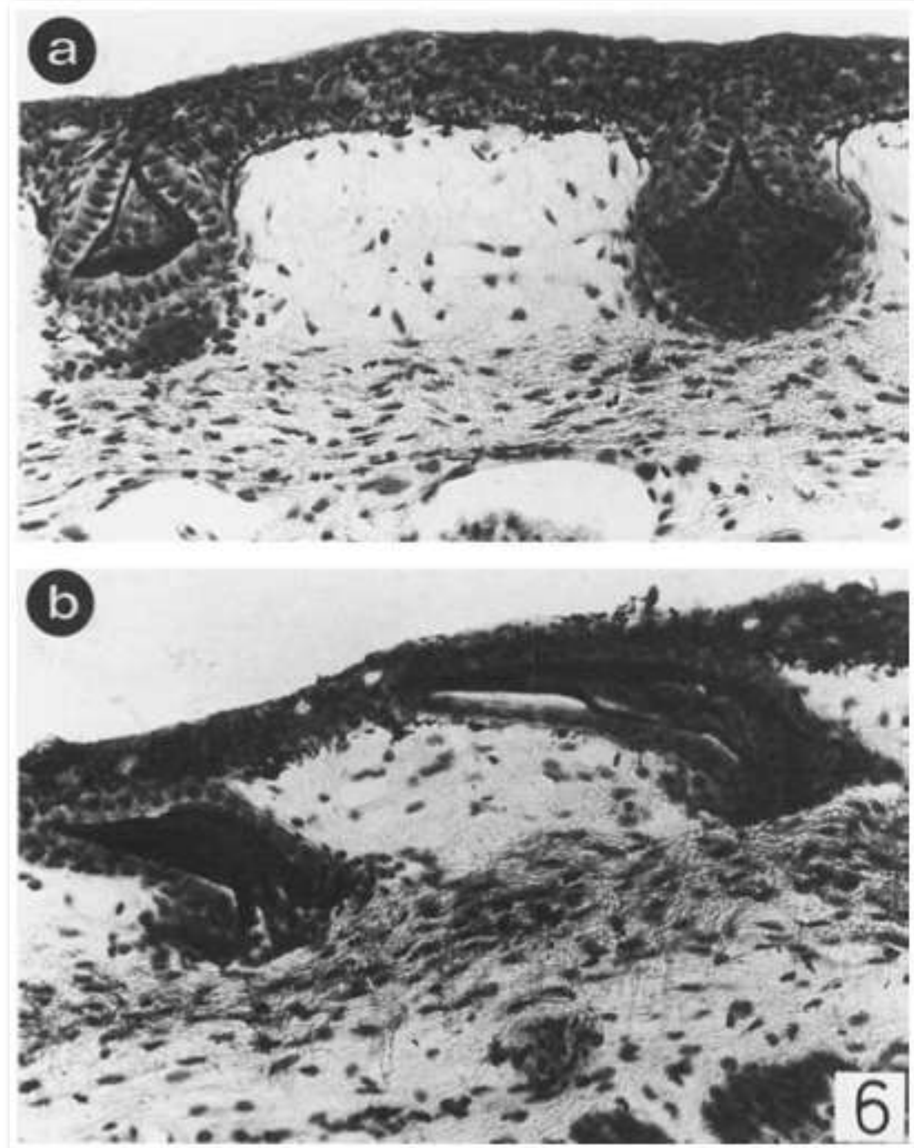

scales

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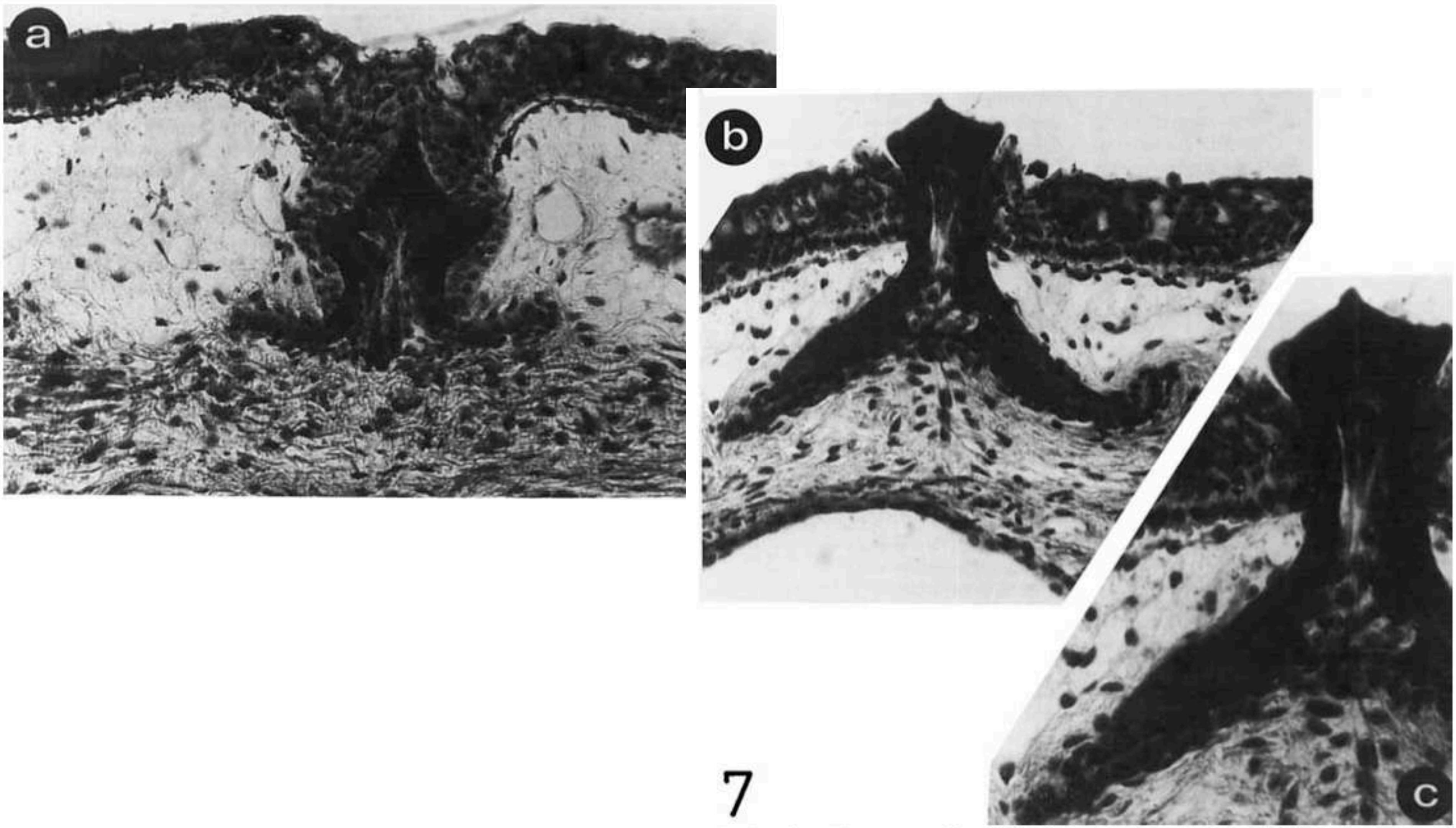

Fig. 7.a. Stage 35, nares area, dorsal body side, transverse section. The scales begin to erupt. × 240. b,c. Stage 45, nares area, dorsal body side, transverse section. The scales have erupted; odontoblasts continue to secrete dentine in the pulp cavity; osteoblasts form the basal plate. b, × 240; c, × 350.

teeth

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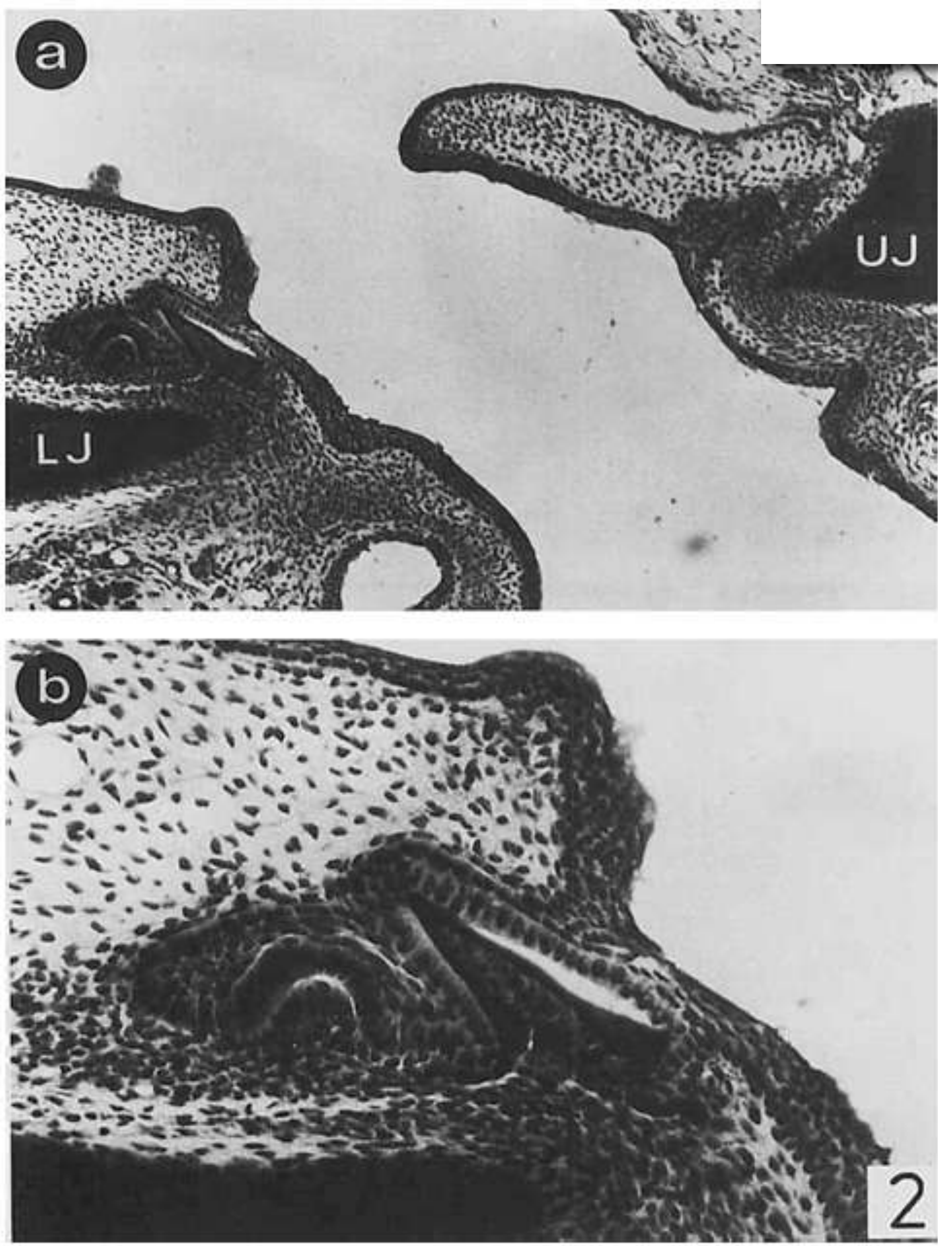

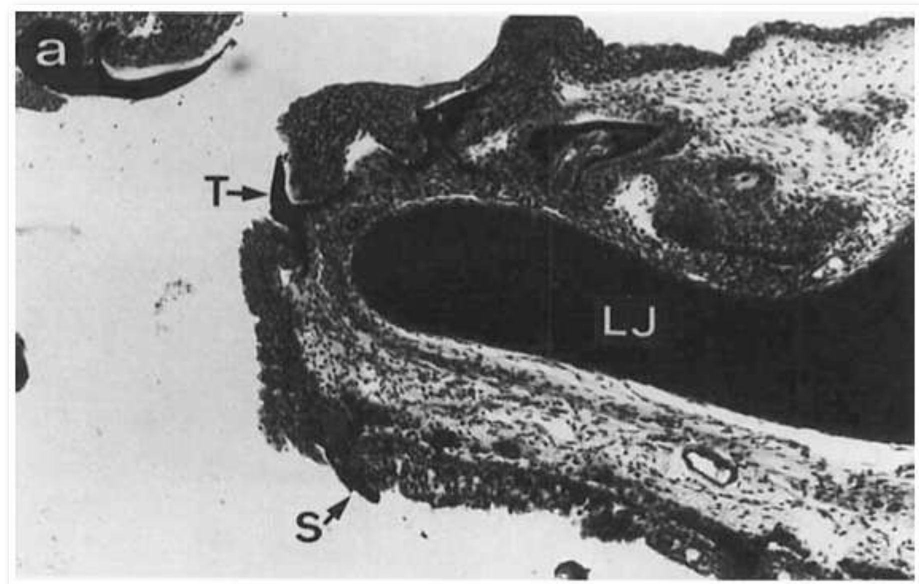

teeth

Development of Dentition and Dermal Skeleton in Embryonic *Scyliorhinus canicula*[1]

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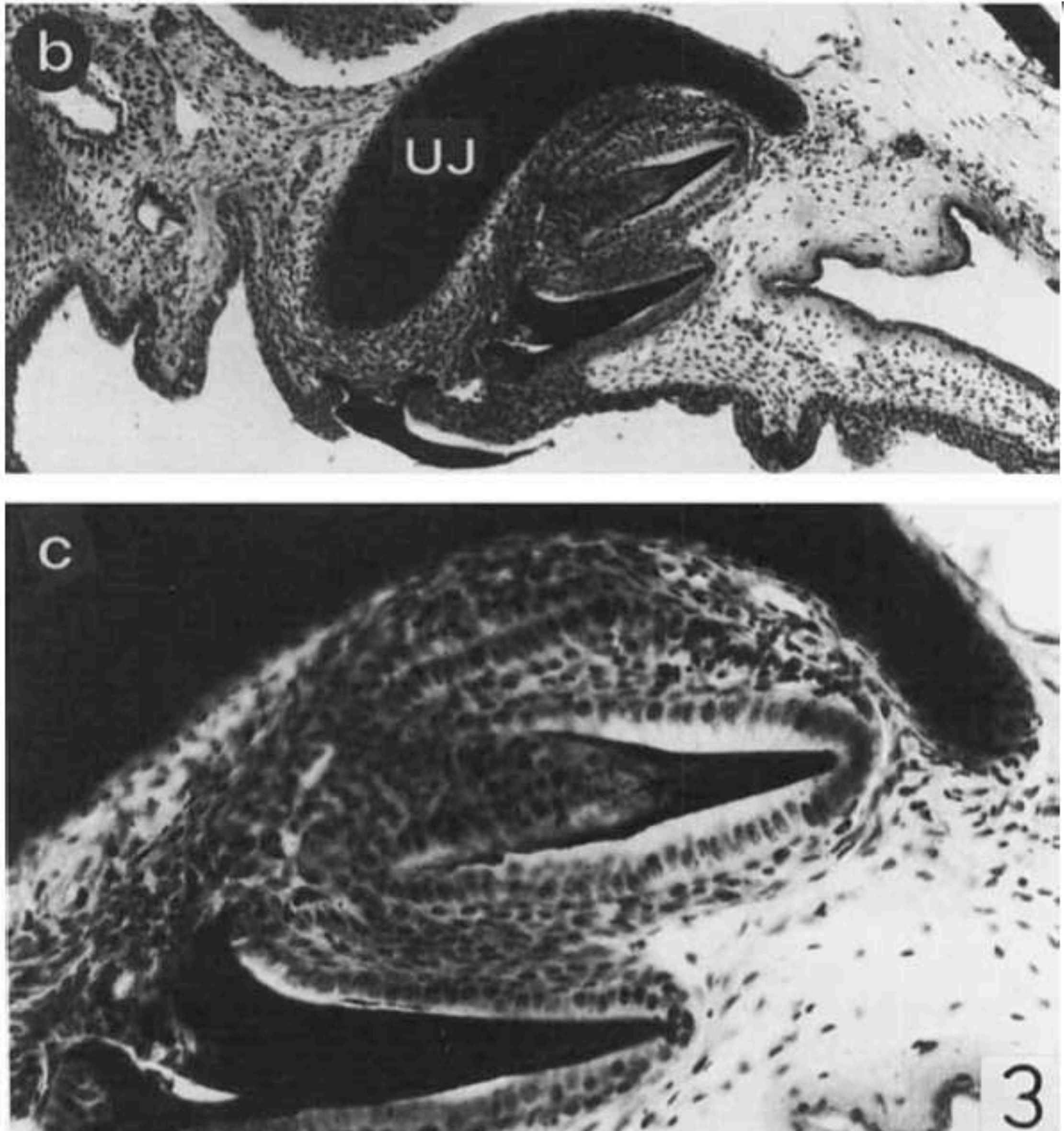

JOURNAL OF MORPHOLOGY 166:275-288 (1980)

Development of Dentition and Dermal Skeleton in Embryonic *Scyliorhinus canicula*[1]

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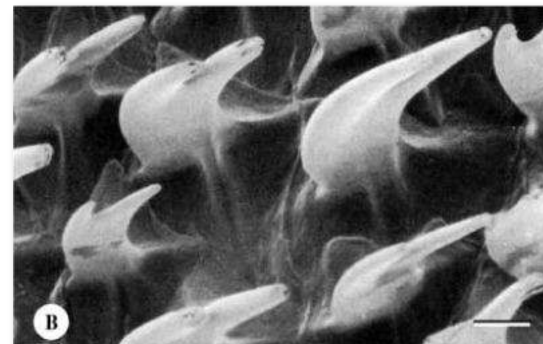
ABSTRACT Serial sections ranging from very young embryos to hatched juveniles and whole embryos of *Scyliorhinus* show that dentition and dermal skeleton belong to two independent secondary developmental fields that differ both developmentally and structurally. The development of the dentition starts very early, with a thickening of the ectoderm in the region of the mouth (stage 04), the invagination of the dental lamina (stage 18), and the formation of the germs of the first generation (stage 20). Tooth replacement movements start only near the end of embryogenesis (stage 35). Scale germs, on the other hand, first begin to form at stage 24. Scales erupt shortly before the animal hatches (stage 43). Only one scale generation is formed during embryogenesis. The forces which erupt the scales may come from fluid pressures in vacuoles of the fibrous layer of the dermis. Those which erupt the teeth probably also result from similar fluid pressures. The crown and upper part of the base of scales and teeth are formed by cells of the inner dental epithelium which are differentiated from the ectoderm. They are also formed by odontoblasts which are derived from the vascular layer of the dermis. However, the basal plates of scales and teeth containing the anchoring fibers are formed by osteoblasts, which are derived from the fibrous layer of the dermis.



Během ontogeneze šupiny postupně morfologicky "nepřecházejí" do zubů; oba systémy jsou v ontogenezi časoprostorově nezávislé!

Evoluce zubů resp. zubního paternování = evoluce DL?!?

Superficiální šupiny vs. zuby na čelistech *uvnitř úst*

Debiais-Thibaud *et al. BMC Evolutionary Biology* 2011, **11**:307
http://www.biomedcentral.com/1471-2148/11/307

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RESEARCH ARTICLE Open Access

The homology of odontodes in gnathostomes: insights from *Dlx* gene expression in the dogfish, *Scyliorhinus canicula*

Mélanie Debiais-Thibaud[1,3,5], Silvan Oulion[1,3,6], Franck Bourrat[4], Patrick Laurenti[1,2], D
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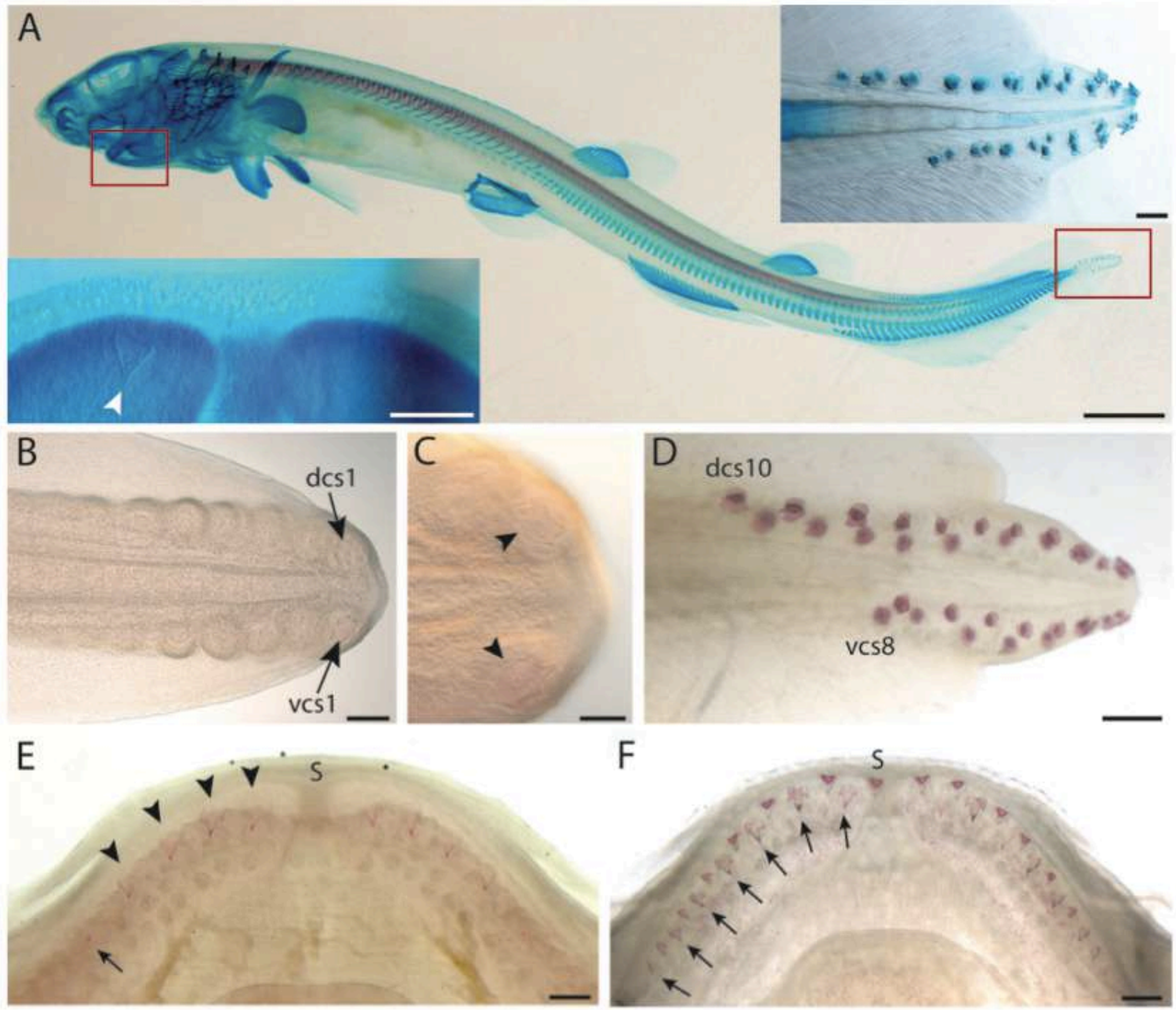

Figure 1 Localization and embryonic development of caudal primary scales and oral teeth in the dogfish. A: ventro-lateral view (anterior

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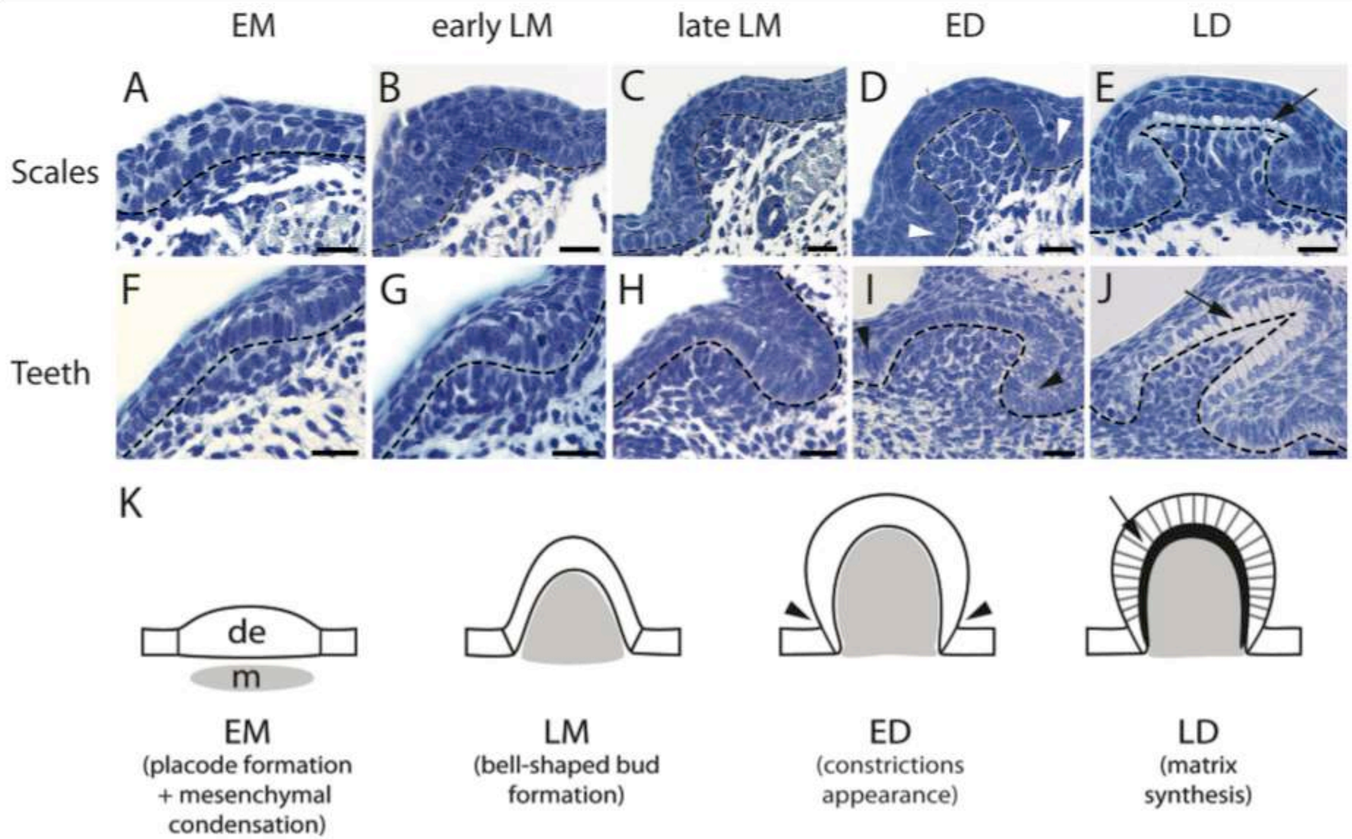

Figure 2 Histological definition of four developmental stages for caudal primary scale and tooth development. Transversal sections of a tail from a 3 cm long embryo (A-E) and of lower jaws from 4 cm (F-H) and 5.5 cm (I-J) long embryos coloured with *Nissl* stain (cresyl violet - *thionin*), scale bar: 25 μm. K: diagram summarising the four common stages for odontode development in the dogfish. EM, early morphogenesis- thickening of the dental epithelium (d.e.), condensation of the mesenchyme (m, coloured grey); LM, late morphogenesis- bell shape bud formation; ED, early differentiation- a constriction appears at the bottom of the bud (arrowheads); LD, late differentiation- matrix secretion (arrow).

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Abstract

Background: Teeth and tooth-like structures, together named odontodes, are repeated organs thought to share a common evolutionary origin. These structures can be found in gnathostomes at different locations along the body: oral teeth in the jaws, teeth and denticles in the oral-pharyngeal cavity, and dermal denticles on elasmobranch skin. We, and other colleagues, had previously shown that teeth in any location were serially homologous because: i) pharyngeal and oral teeth develop through a common developmental module; and ii) the expression patterns of the *Dlx* genes during odontogenesis were highly divergent between species but almost identical between oral and pharyngeal dentitions within the same species. Here we examine *Dlx* gene expression in oral teeth and dermal denticles in order to test the hypothesis of serial homology between these odontodes.

Results: We present a detailed comparison of the first developing teeth and dermal denticles (caudal primary scales) of the dogfish (*Scyliorhinus canicula*) and show that both odontodes develop through identical stages that correspond to the common stages of oral and pharyngeal odontogenesis. We identified six *Dlx* paralogs in the dogfish and found that three showed strong transcription in teeth and dermal denticles (*Dlx3*, *Dlx4* and *Dlx5*) whereas a weak expression was detected for *Dlx1* in dermal denticles and teeth, and for *Dlx2* in dermal denticles. Very few differences in *Dlx* expression patterns could be detected between tooth and dermal denticle development, except for the absence of *Dlx2* expression in teeth.

Conclusions: Taken together, our histological and expression data strongly suggest that teeth and dermal denticles develop from the same developmental module and under the control of the same set of *Dlx* genes. Teeth and dermal denticles should therefore be considered as serial homologs developing through the initiation of a common gene regulatory network (GRN) at several body locations. This mechanism of heterotopy supports the 'inside and out' model that has been recently proposed for odontode evolution.

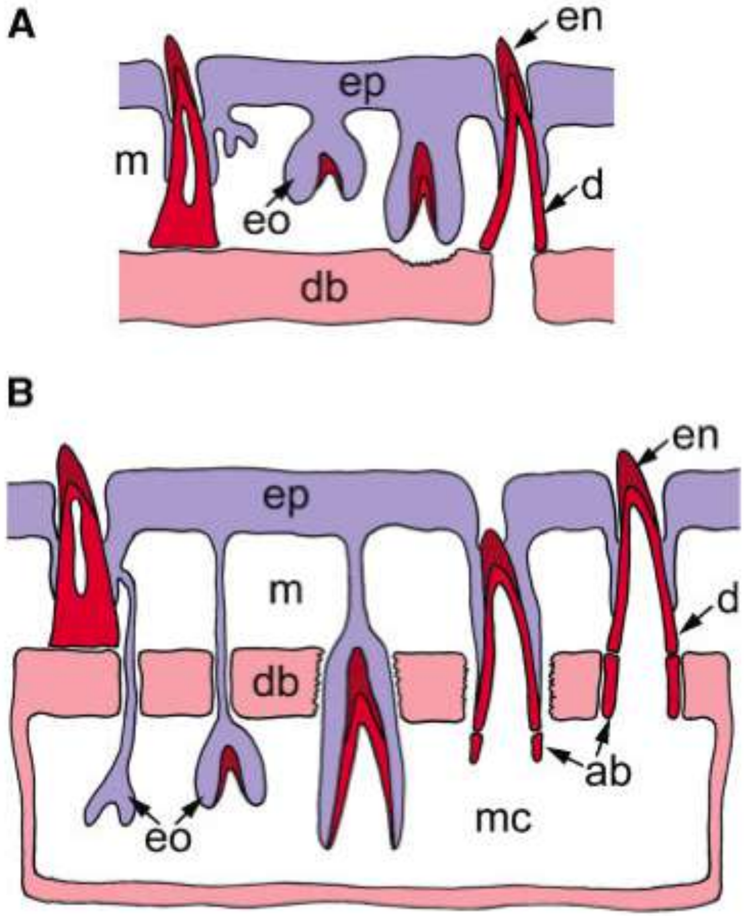


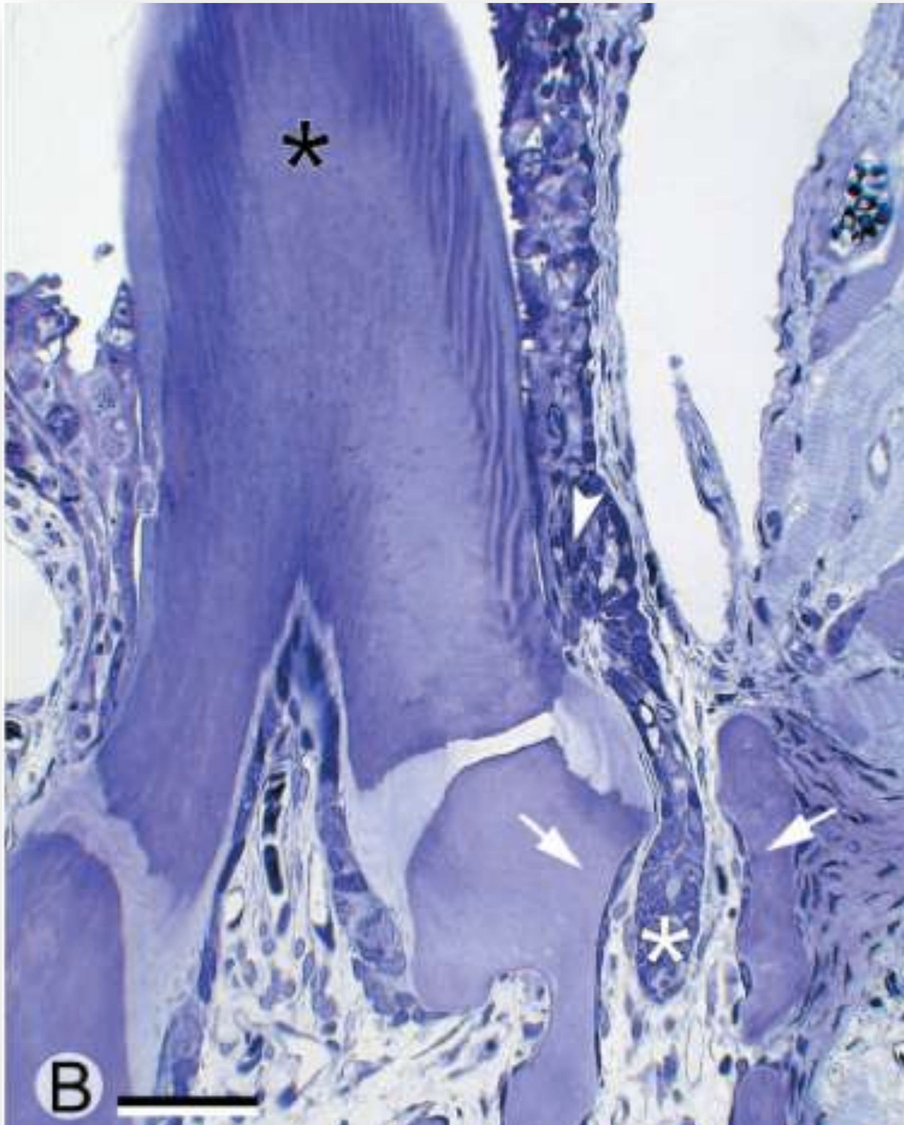
Figure 1. Schematic representation of replacement tooth formation in **A:** extramedullary or **B:** intramedullary situation, as observed in teleost fishes. In both schemes, successive stages of development of the tooth germ are shown from left to right. The predecessor (functional tooth) is only represented once (left of each figure), to show its relationship to the successor (replacement tooth). The zebrafish conforms to the upper scheme; other teleosts, e.g. cichlid fish, to the lower. Bone, pink; epithelium, purple; tooth matrix, red. Abbreviations: ab, attachment bone; d, dentine; db, dentigerous bone; ep, buccal or pharyngeal epithelium; en, enameloid; eo, enamel organ; m, mesenchyme; mc, medullary cavity.

Continuous tooth replacement: the possible involvement of epithelial stem cells

Ann Huysseune[1]* and Irma Thesleff[2]

Summary
Epithelial stem cells have been identified in integumental structures such as hairs and continuously growing teeth of various rodents, and in the gut. Here we propose the involvement of epithelial stem cells in the continuous tooth replacement that characterizes non-mammalian vertebrates, as exemplified by the zebrafish. Arguments are based on morphological observations of tooth renewal in the zebrafish and on the similarities between molecular control of hair and tooth formation. Dissection of the molecular cascades underlying the regulation of the epithelial stem cell niche might open perspectives for new regenerative treatment strategies in clinical dentistry. *BioEssays* 26:665–671, 2004.

Vyprázdnění termínu(?):
dentální lamina ➔ kmenové buňky



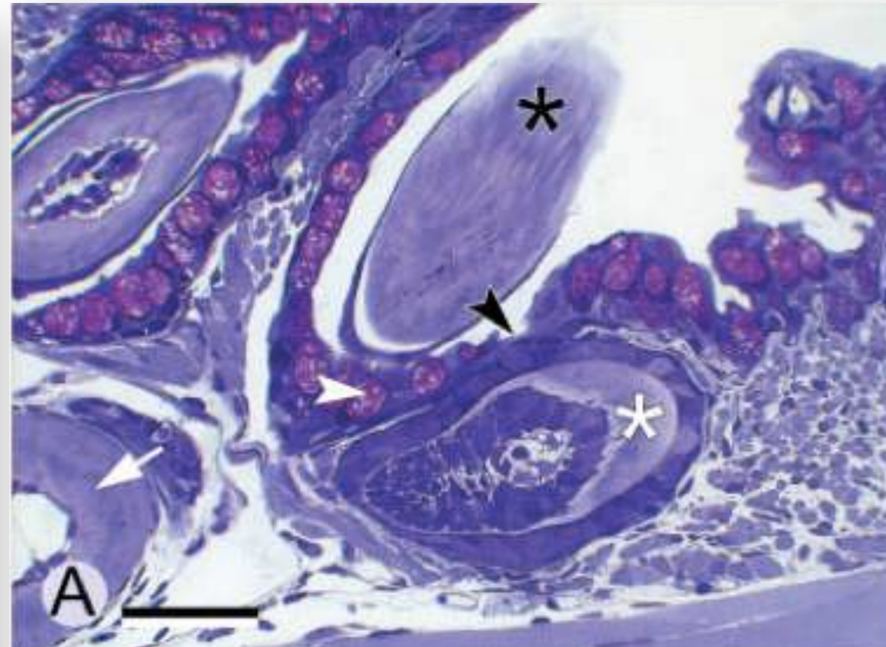


Figure 2. Micrographs of putative stem cell niche involved in **A:** extramedullary replacement tooth formation (zebrafish) and **B:** intramedullary replacement tooth formation (the cichlid fish *Hemichromis bimaculatus*). A pharyngeal tooth is shown in **B**, to match the only tooth type present in zebrafish (**A**). Functional teeth are labeled by a black asterisk; a white asterisk indicates the replacement tooth germ in **A**, and the epithelial strand giving rise to an intramedullary tooth germ in **B**. The dentigerous bone is indicated by a white arrow in **A**; two white arrows in **B** indicate the attachment bone through which a channel allows passage of the epithelial strand. The putative stem cell niche is indicated by a black arrowhead in **A** and a white arrowhead in **B**. A white arrowhead in **A** points to a mucous cell, abundantly present in the crypt epithelium. Scale bar in **A** and **B**: 20 μm.

Continuous tooth replacement: the possible involvement of epithelial stem cells

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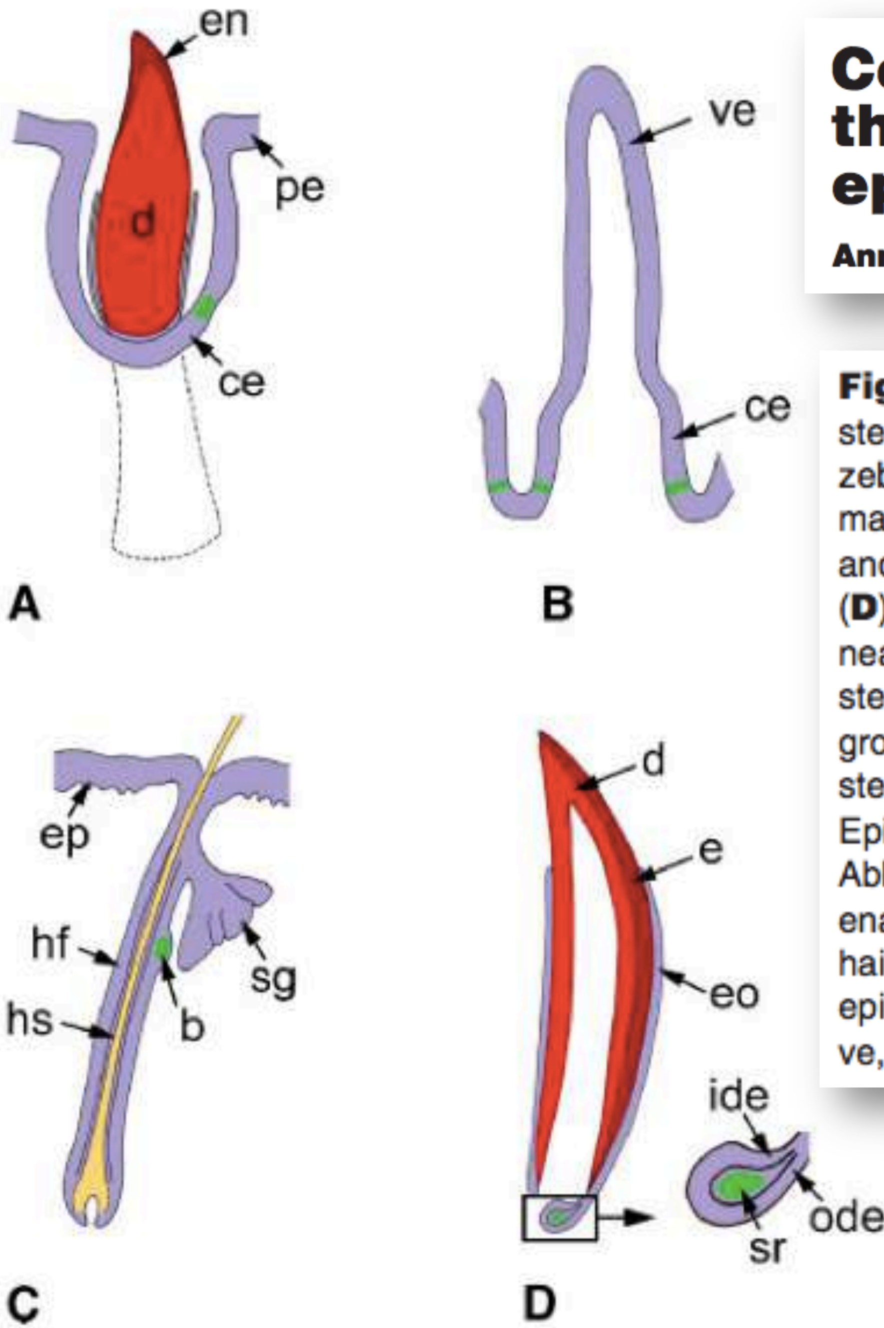

Figure 3. Schematic representation of **A:** location of putative stem cell niche (green area) involved in tooth replacement in the zebrafish, and **B–D:** comparison to stem cell niches in mammalian intestinal crypt epithelium (**B**), hair follicle (**C**), and enamel epithelium of a continuously growing rodent tooth (**D**). In the intestinal epithelium, the stem cell niche is located near the base of the crypts of Lieberkühn (ce); in the hair follicle stem cells are located in the bulge region (b); in the continuously growing rodent tooth, the stem cell niche is located in the stellate reticulum (sr) of the cervical loop at the labial side. Epithelium, purple; hair shaft, yellow; tooth matrix, red. Abbreviations: ce, crypt epithelium; d, dentine; e, enamel; en, enameloid; eo, enamel organ; ep, epidermis; hf, hair follicle; hs, hair shaft; ide, inner dental epithelium; ode, outer dental epithelium; pe, pharyngeal epithelium; sg, sebaceous gland; ve, villus epithelium.

Vyprázdnění termínu(?):
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