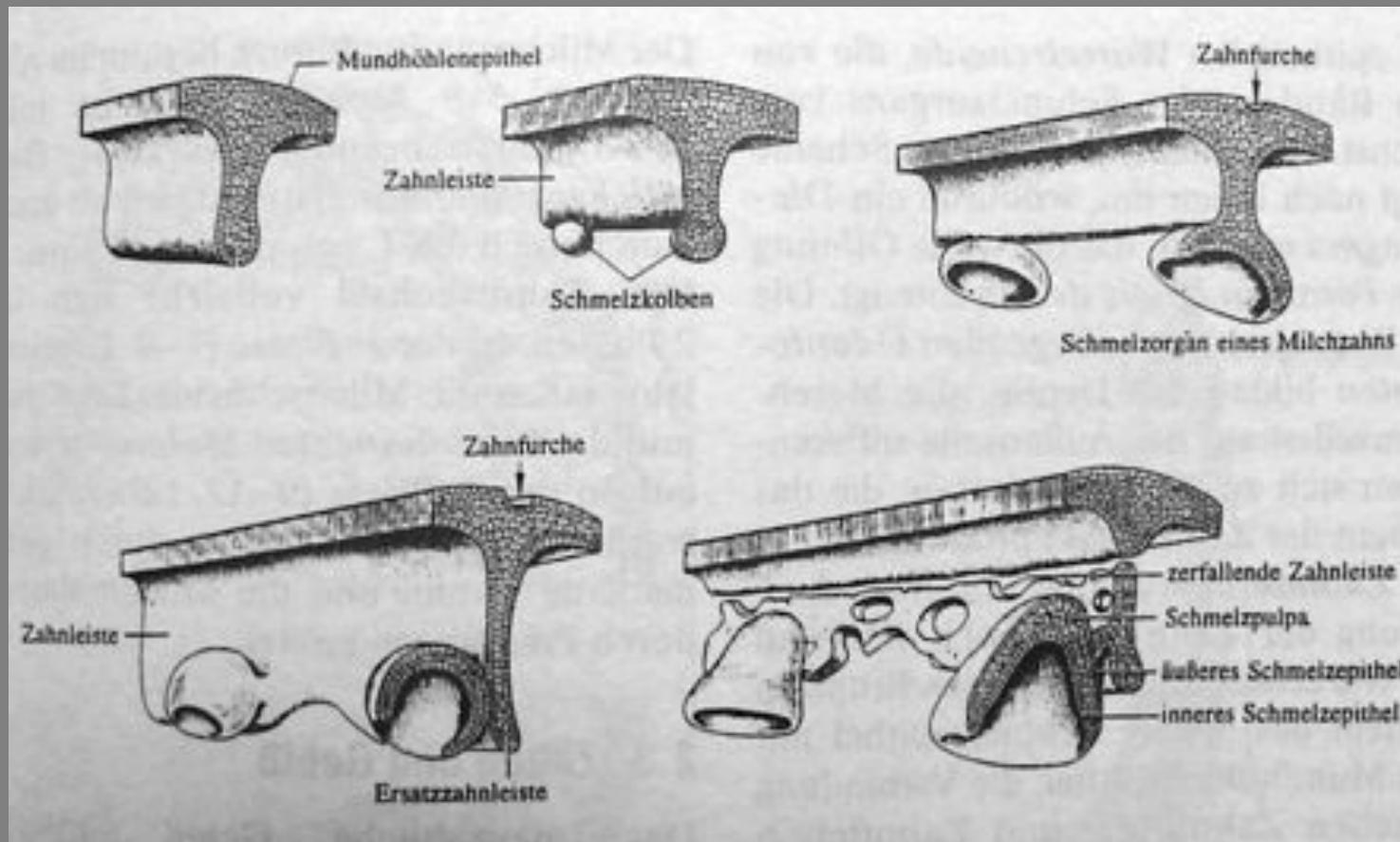




Vývojové souvislosti I: vznik a vývoj zuba jako produkt genetických regulačních kaskád

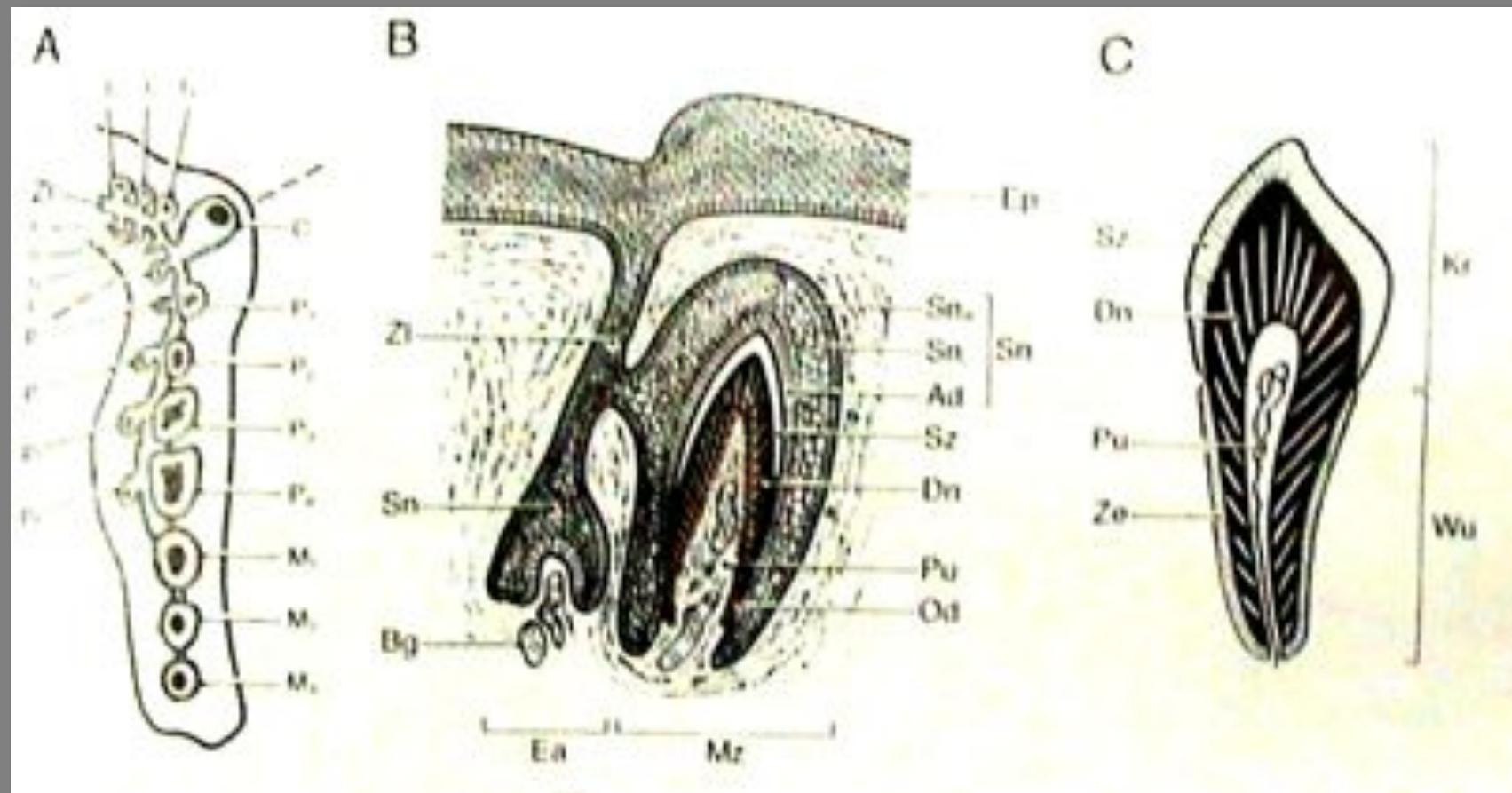
***Vývojové souvislosti II:* d. lamina, zubní epitel a mesenchym; teorie o evoluci zuba/dentice**

D e n t á l i a r i a m i n a



Z u b o t v o r n ý e m b r y o n á l n í o r g á n ; p r o d u k u j e z u b y ; d e f n u j e a
z a k l á d á j e j i c h p o z i c i a v ý m ě n u . E K T (i E N T ?) z t l u š t ě n i n a ;
ř p r i t o m n o s t b u n ě k N L ?

D e n t á l n í l a m i n a



Z u b y j s o u i n t e g r o v à n y d o d e n t i c e :

Integra čním prvkem, který během ontogenese
uspořádává zuby, je zubní lišta (dentální lamína)

Pouze u Amniota?

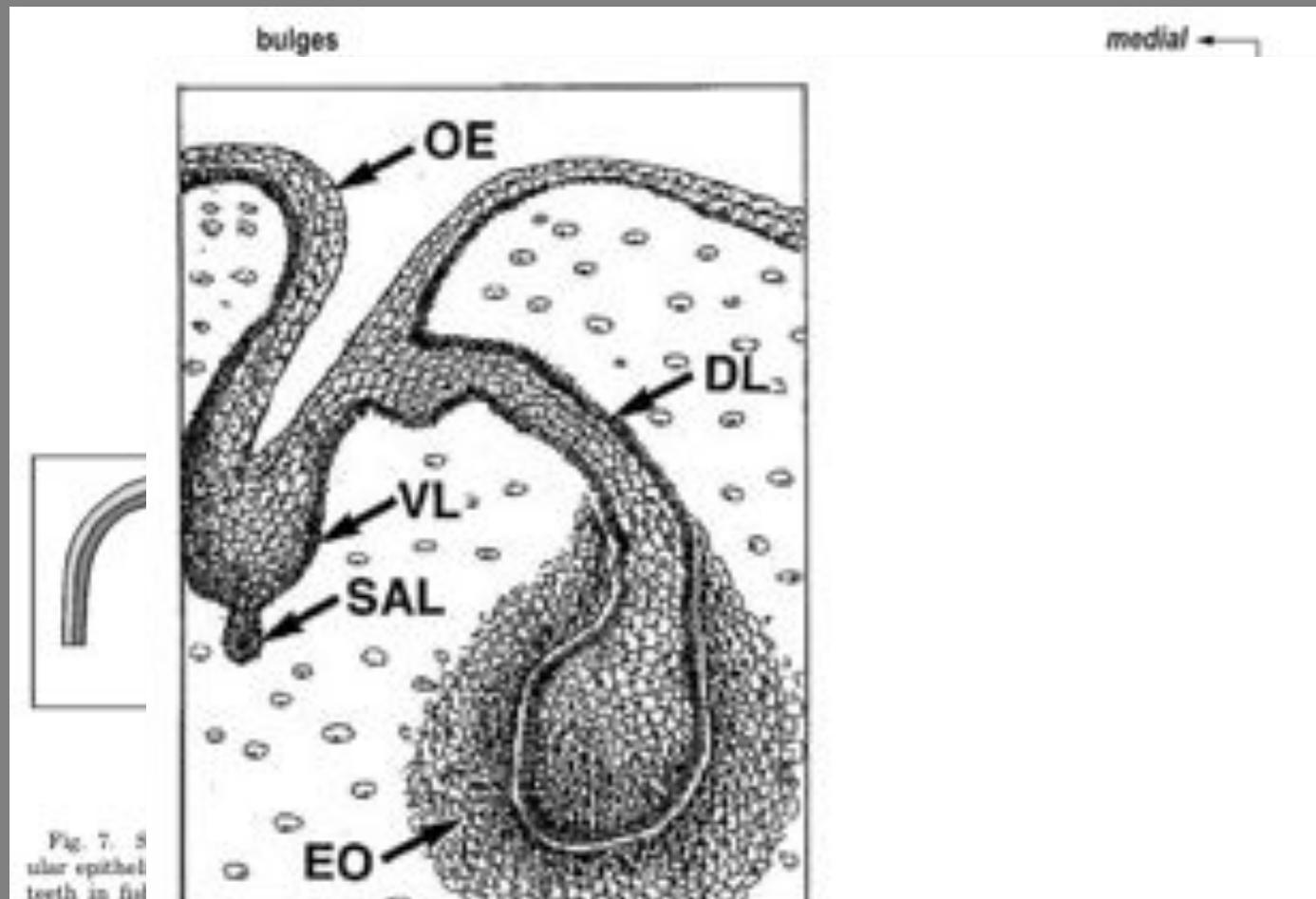


Fig. 7. Similar epithelial teeth in fish parallel U-a '80; DL—dental lamina (according to VI) and VI—oral vestibular epithelium documented

set of discontinuous epithelial structures (ridges and bulges) transiently occurs externally to the dental lamina (according to Horváthová et al., 2005). Dark grey—dental epithelium. Light grey—vestibular epithelium. DC—the deciduous canine,

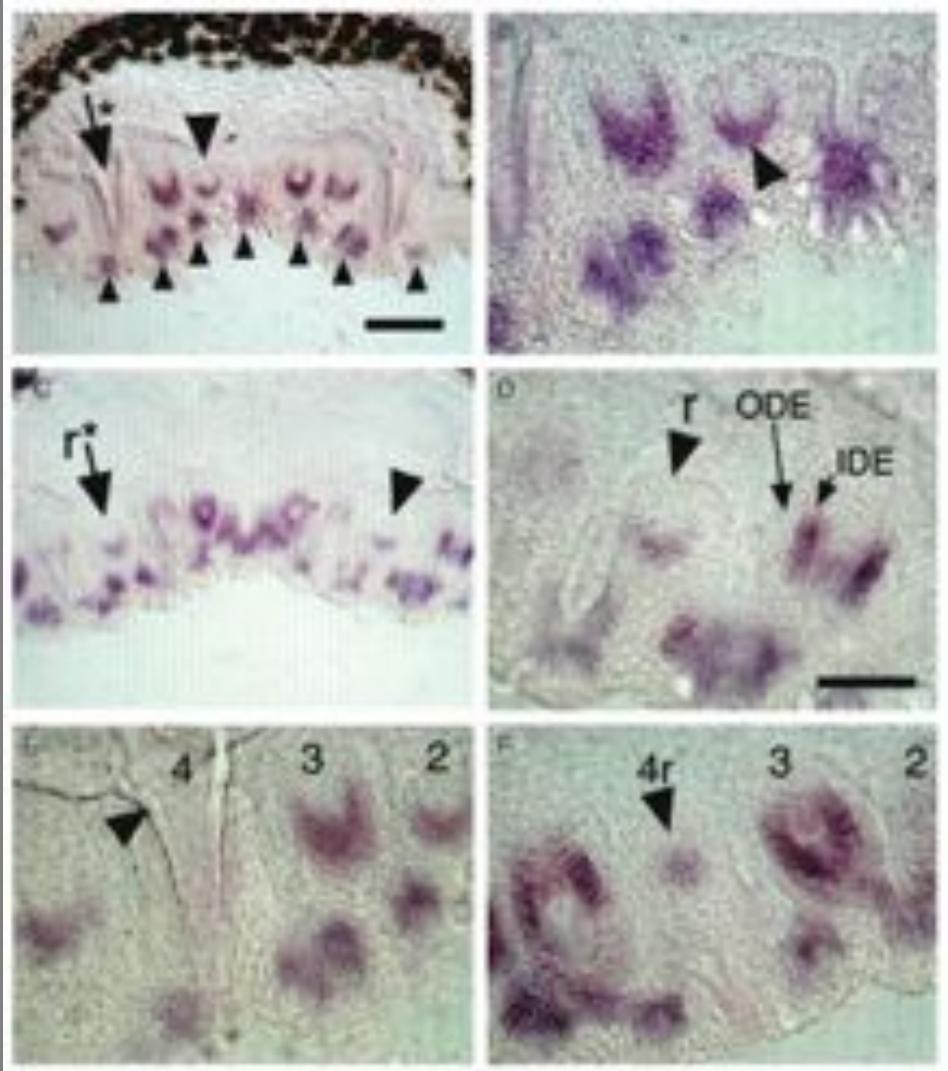
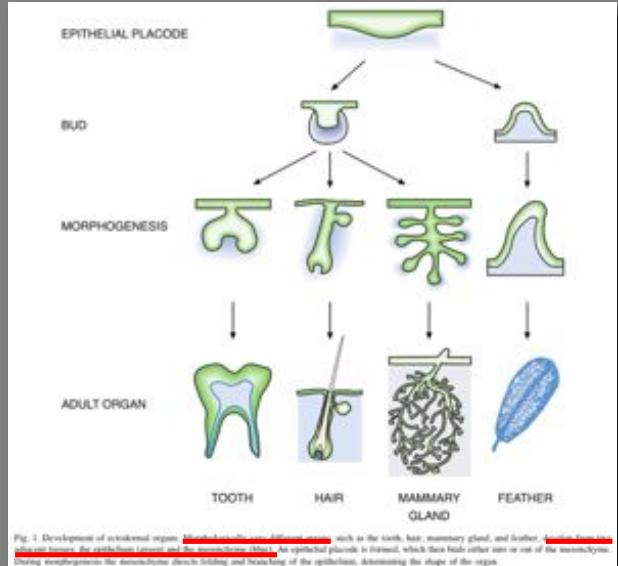
Fig. 1 An epithelial bud (enamel organ, EO) has formed at the end of the dental lamina (DL). Notice, cavitation of vestibular lamina (VL) as the first step towards formation of a vestibule. At the bottom of VL, an initial epithelial proliferation leading to the formation of accessory salivary glands (SAL) (Figs. 1-3 modified after Myr and Fejerskov (1979)).

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.

D e n t á l n i l a m i n a (k o n t i n u á l n i v s . d i s k o n t i n u á l n i -

D e n t á l n i l a m i n a (k o n t i n u á l n i v s . d i s k o n t i n u á l n i -

M . M . S m i t h !) ; d . p l a k o d a



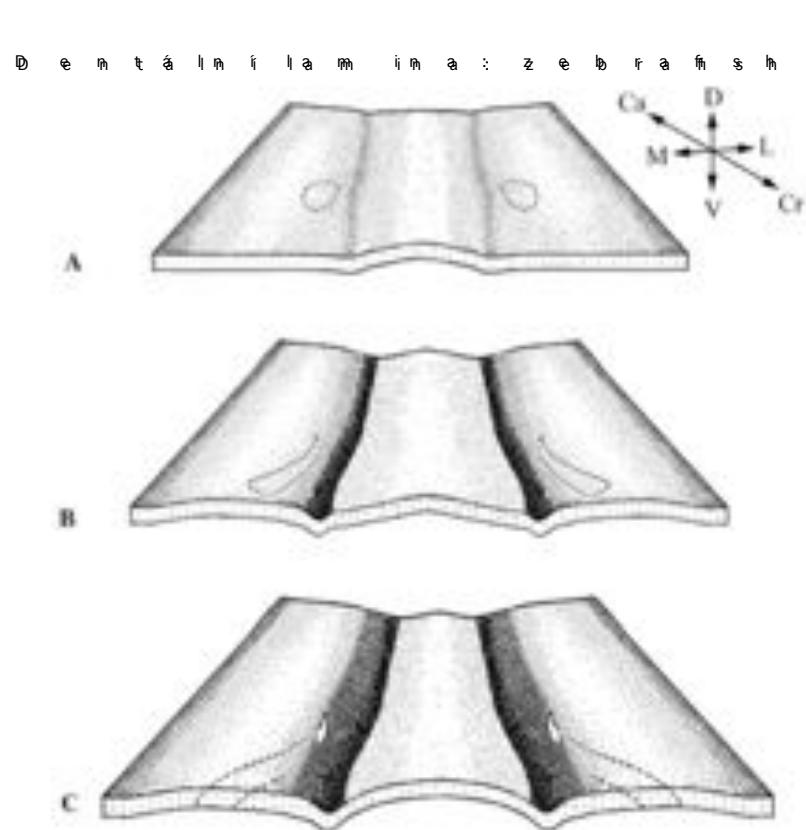


Fig. 1A–C Drawings based on 3D reconstructions of the ventral pharyngeal epithelium and of the first developing teeth in larval zebrafish. Different shades of grey reflect surfaces that lie more superficially (more dorsally, turned towards the pharyngeal cavity: white or light grey), or deeper (more ventrally, turned away from the pharyngeal cavity: darker grey). **A** 56 hPP: the pharyngeal epithelium is fairly smooth; a shallow depression is present at this stage but is not very pronounced yet; tooth $4V^1$ has some matrix deposited (not pictured); **B** 72 hPP: anlagen of the primary crypts are forming medial to the two $4V^1$ teeth, which are still unerupted; **C** 80 hPP: the primary crypts are now well pronounced and both $4V^1$ teeth have erupted (their tip pierces the lateral-facing wall of the crypt). Orientations as indicated: *Ca* caudal, *Cr* cranial, *D* dorsal, *L* lateral, *M* medial, *V* ventral; eruption of the tooth tip follows a medially and dorsally directed orientation

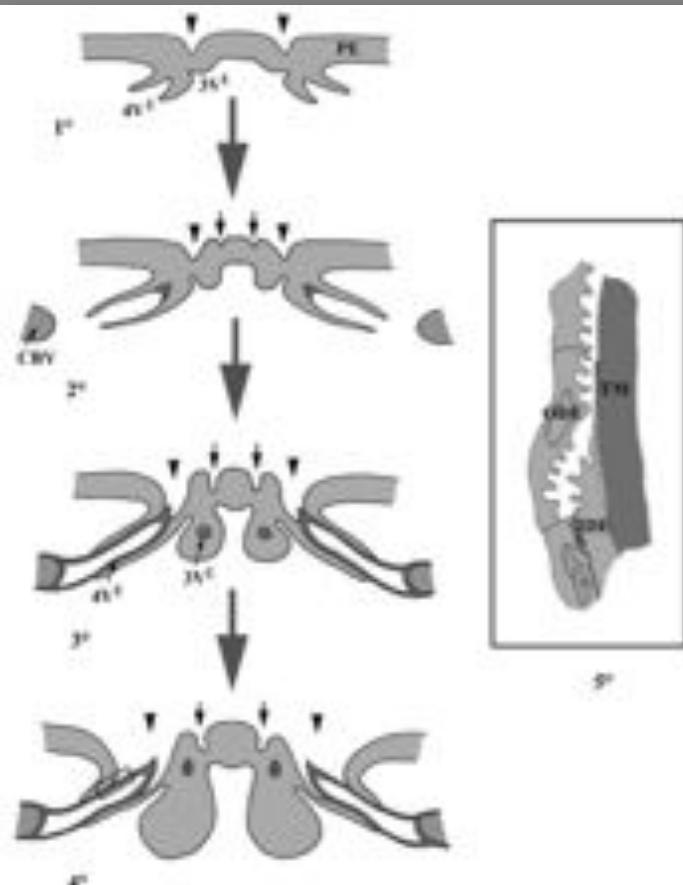


Fig. 2A Interpretative scheme of events associated with the eruption of a first-generation tooth in larval zebrafish. The drawings represent four (1'–4') successive stages in the formation and eruption of tooth $4V^1$ and $3V^1$; large arrows show the succession of these stages. The boxed area in 4' is enlarged in 5'.

1' Formation of primary crypts (arrowheads) in the ventral pharyngeal epithelium opposite the boundary between the developing tooth germs $4V^1$ and $3V^1$ (labelled; tooth $4V^1$ is in a stage of morphogenesis). 2' Deepening of primary crypts (arrowheads) and onset of formation of secondary crypts (small arrow); matrix has been deposited for tooth $4V^1$; tooth $3V^1$ is in a stage of morphogenesis. 3' Eruption of teeth $4V^1$ in the primary crypts (arrowheads) and deepening of the secondary crypts (arrows); matrix has been deposited for tooth $3V^1$. 4' Further exposure of tooth $4V^1$. Lighter shade of grey epithelium, darker shade of grey tooth matrix. *CBV* ceratobranchial V cartilage (cartilage light grey, surrounded by perichondrial bone, darker grey, in 3' and 4'); *IDE* inner dental epithelium, *ODE* outer dental epithelium, *PE* ventral pharyngeal epithelium, *TM* tooth matrix.

Continuous tooth replacement: the possible involvement of epithelial stem cells

Ann Huyssenne^{1*} and Irma Thesleff²

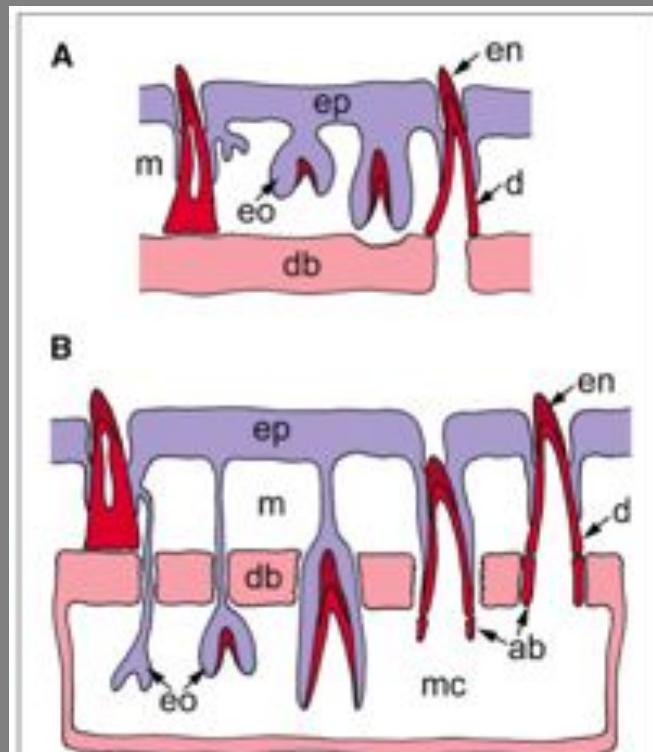


Figure 1. Schematic representation of replacement tooth formation in **A**: extramedullary or **B**: intramedullary situation, as observed in teleost fishes. In both schemes, successive stages of development of the tooth germ are shown from left to right. The predecessor (functional tooth) is only represented 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.

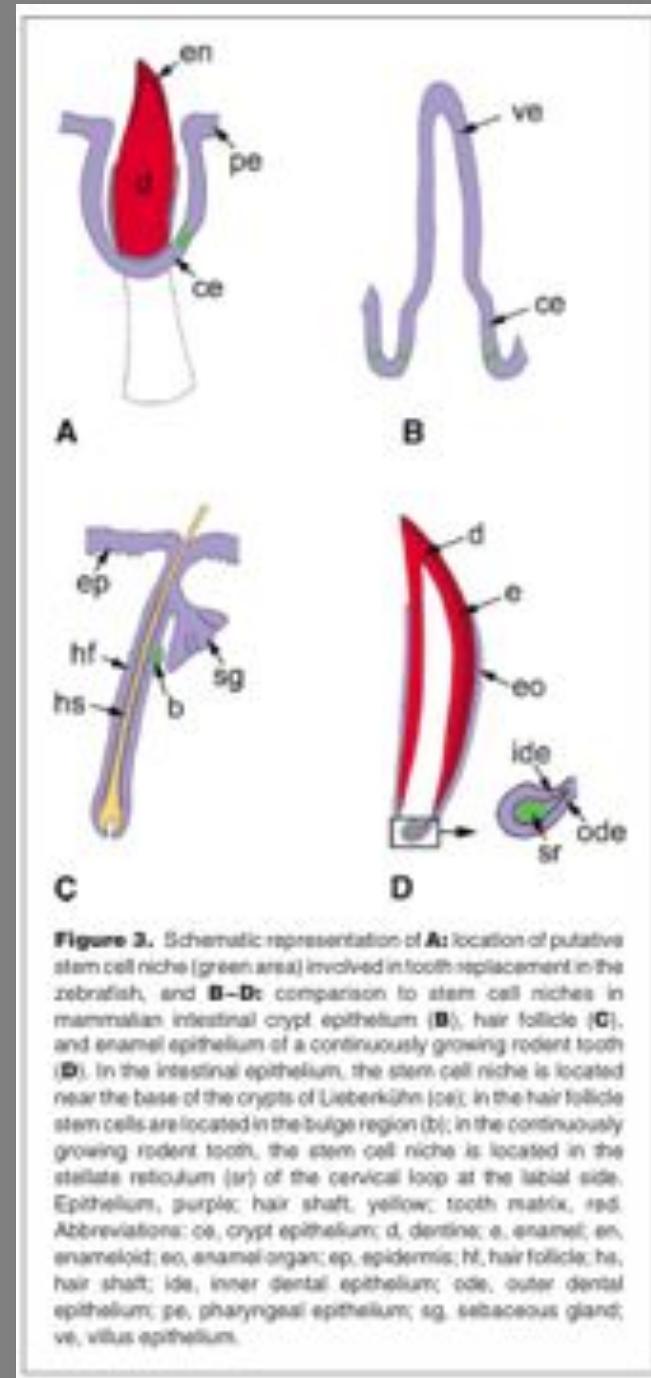
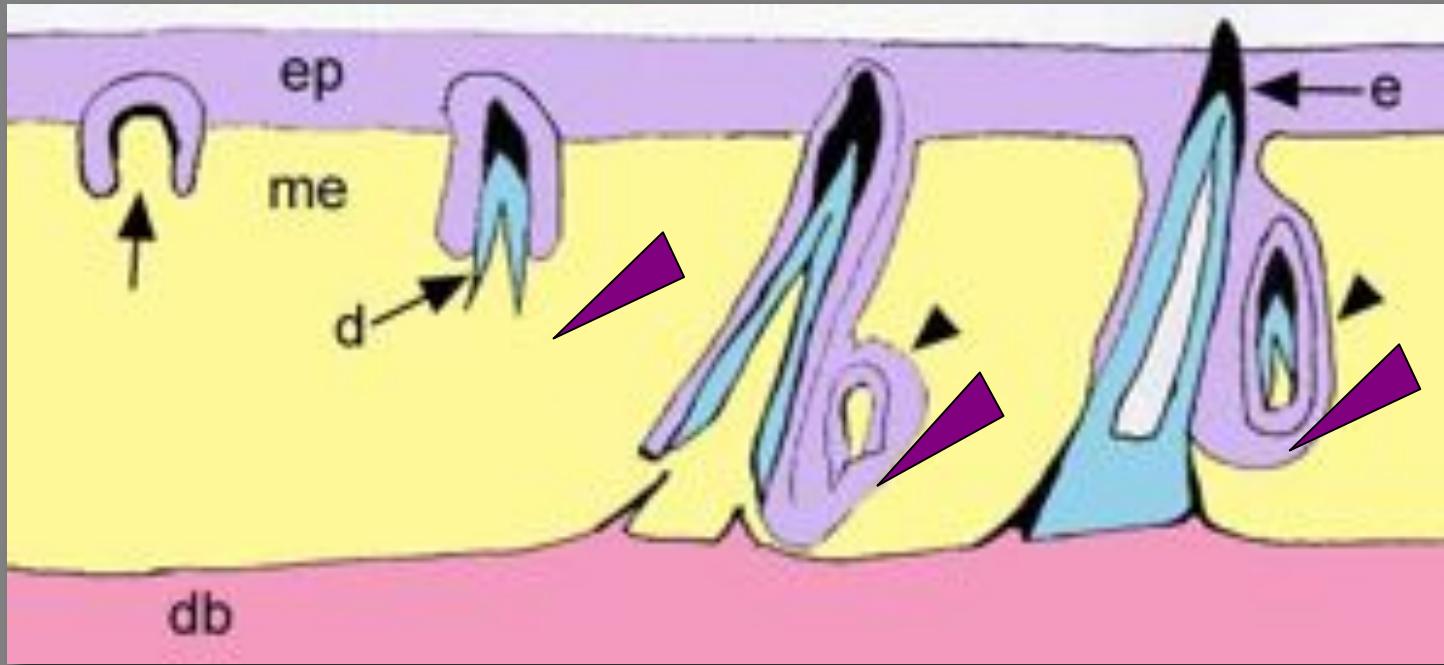


Figure 3. Schematic representation of **A**: location of putative stem cell niche (green area) involved in tooth replacement in the zebrafish, and **B–D**: comparison to stem cell niches in mammalian intestinal crypt epithelium (**B**), hair follicle (**C**), and enamel epithelium of a continuously growing rodent tooth (**D**). In the intestinal epithelium, the stem cell niche is located near the base of the crypts of Lieberkühn (eo); 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: eo, crypt epithelium; d, dentine; en, enamel; en, enameloid; eo, enamel organ; ep, epidermis; hf, hair follicle; hs, hair shaft; idc, inner dental epithelium; odc, outer dental epithelium; pe, pharyngeal epithelium; sg, sebaceous gland; v̄, villus epithelium.



- transient dental lamina is dental epithelium of the tooth
- at the appositional growth stage of preceding tooth germ
- it is site specific and time specific for each dentate bone
- the ODE is site of upregulation of *pitx2* at the bud stage
- *bmp4* is synchronously upregulated in the dental papilla

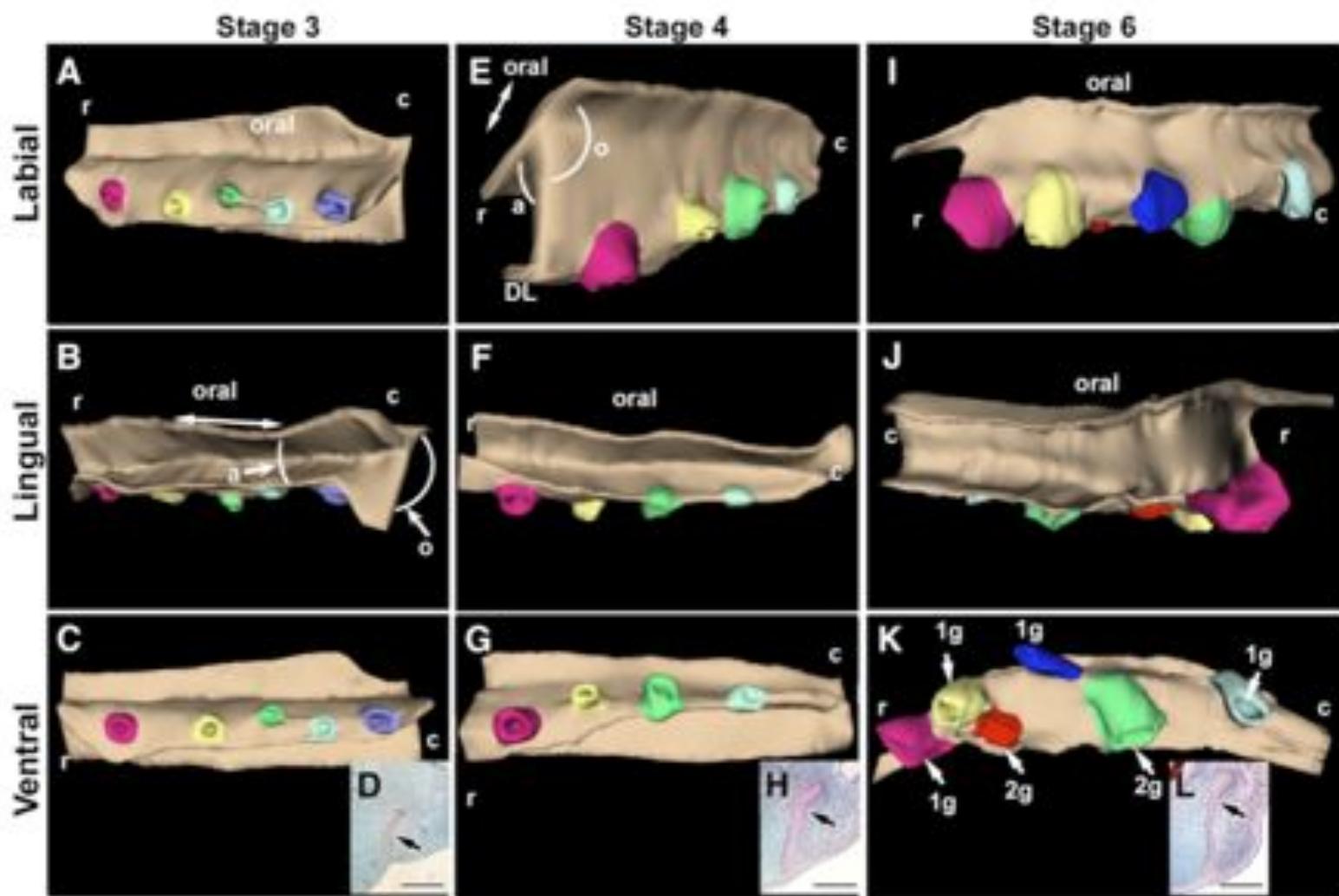
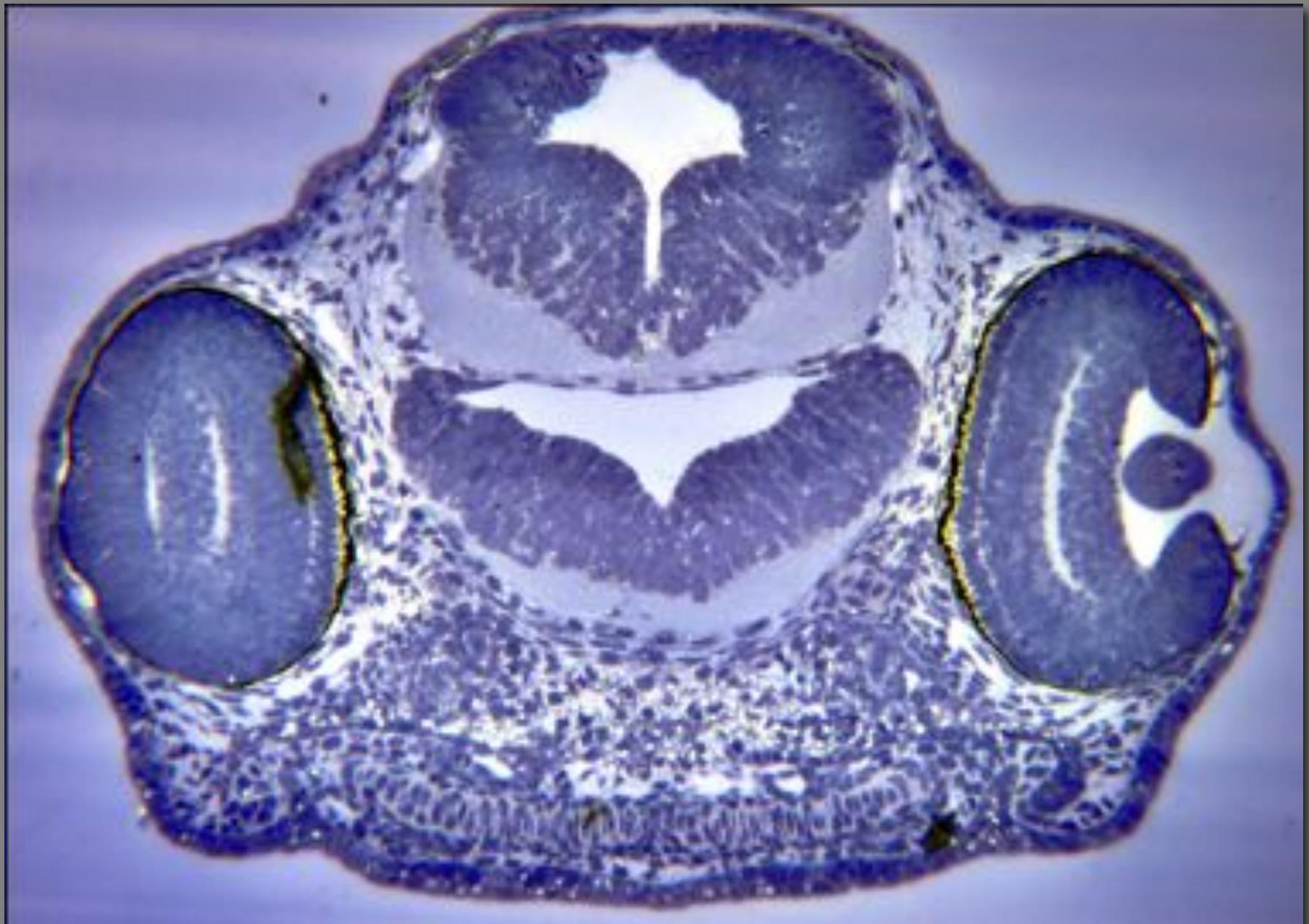
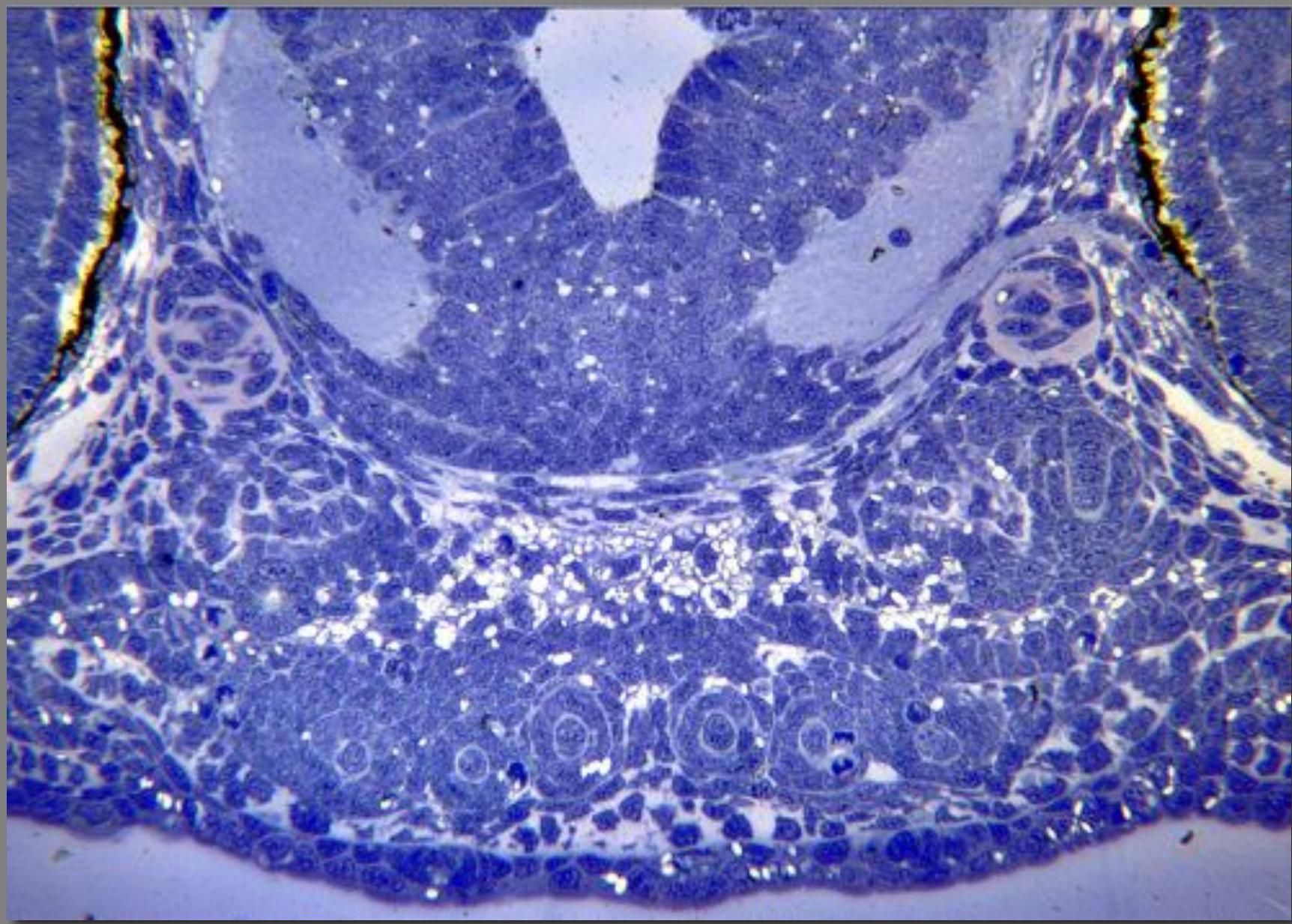
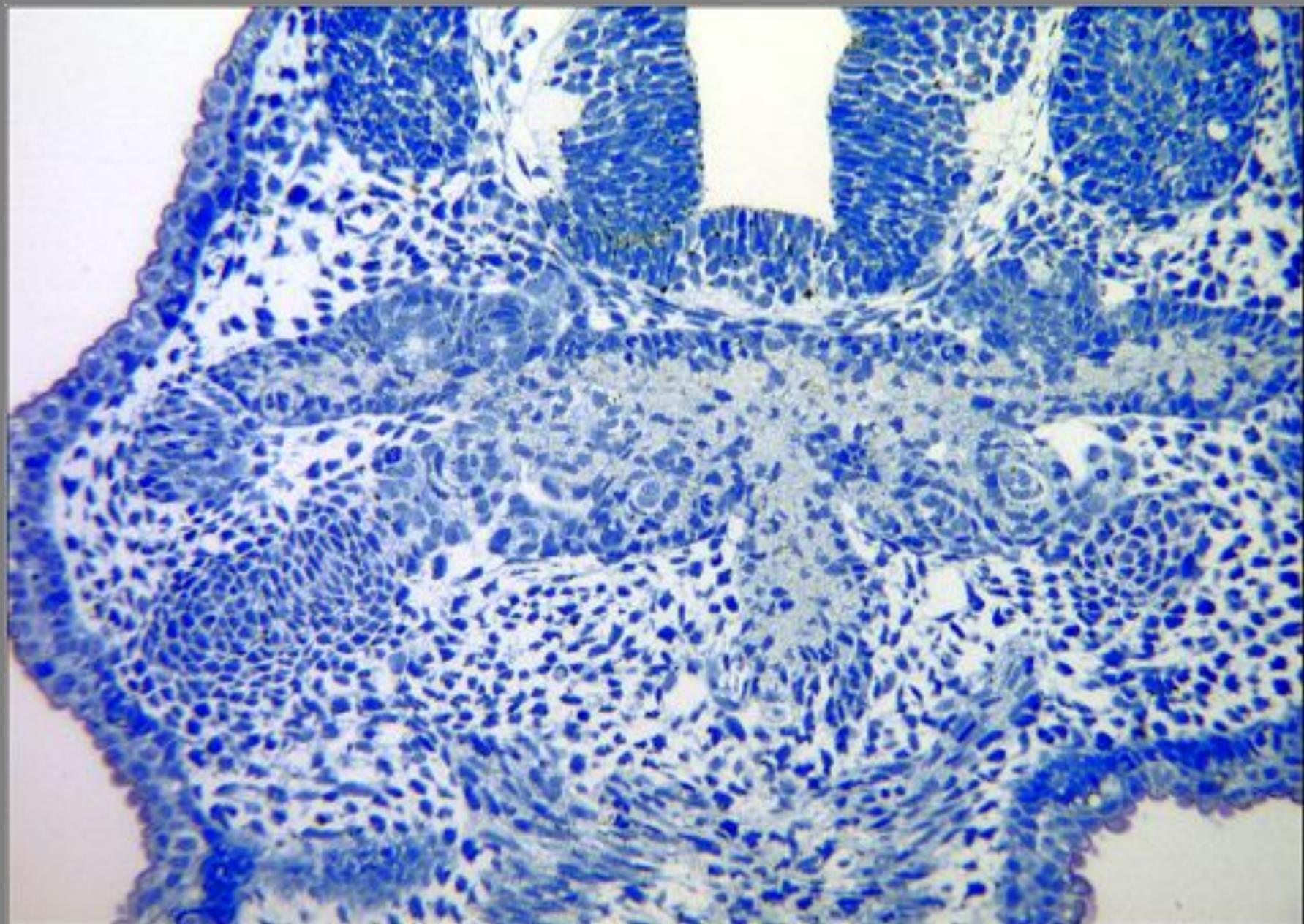


Fig. 3. Continuity of the maxillary dental lamina in *P. sebæ*. Reconstruction of the maxillary dental lamina. There are no gaps between sections and only epithelium was traced. Examples of sections traced are in panels D,H,L (A–C) 1840 μm was reconstructed. The dental lamina is continuous and cap stage 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 .

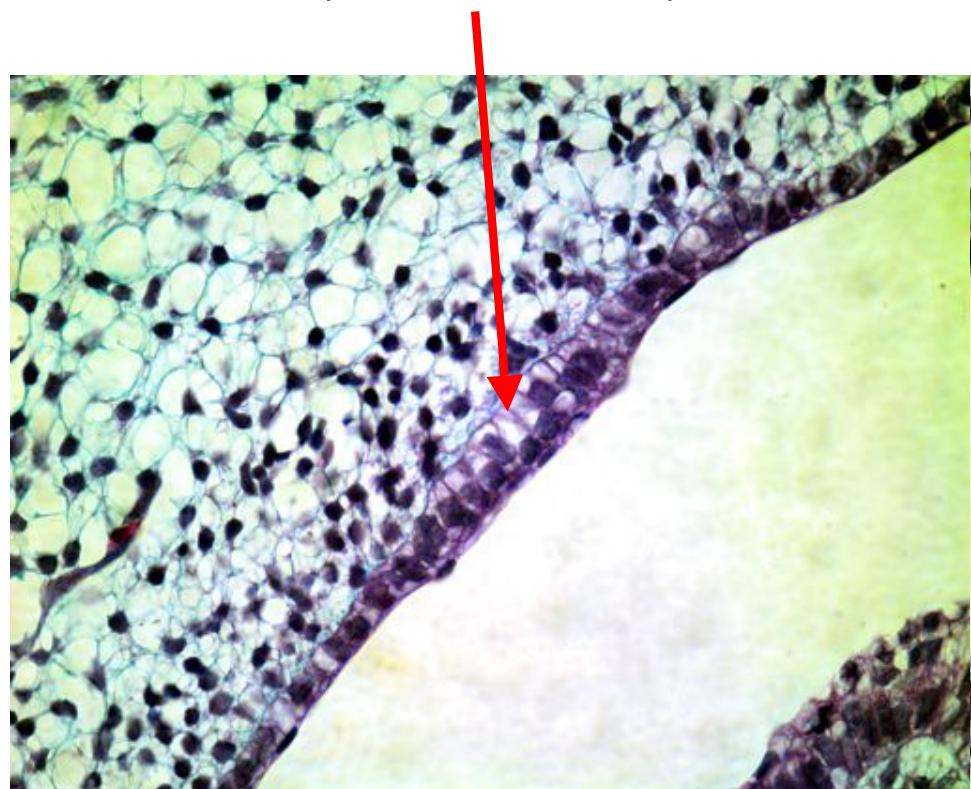




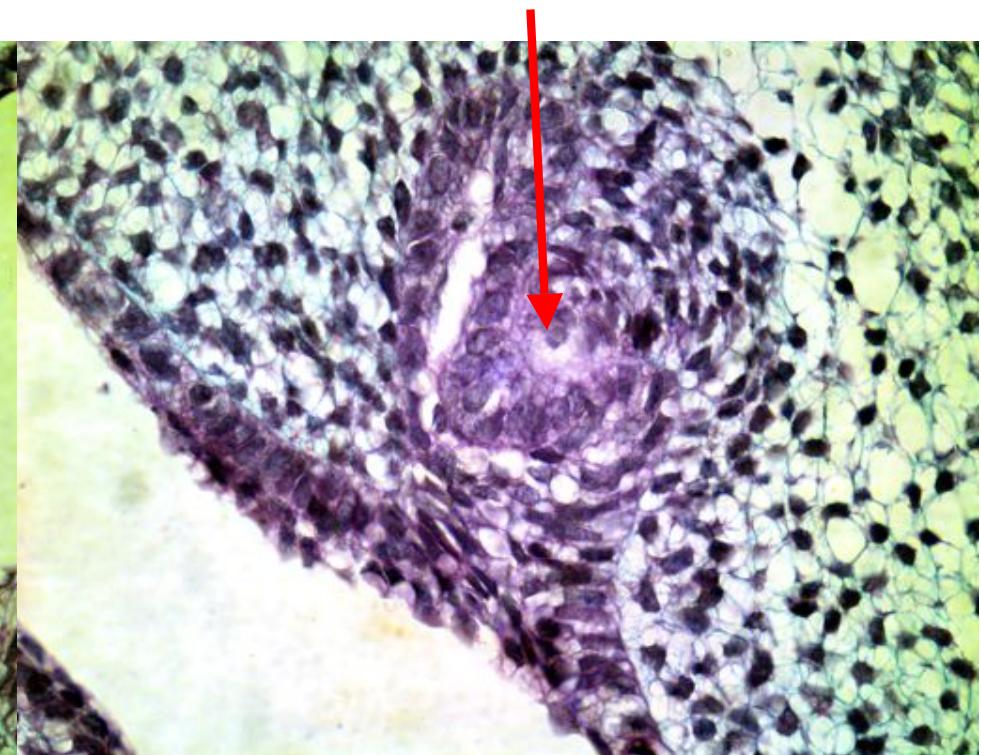


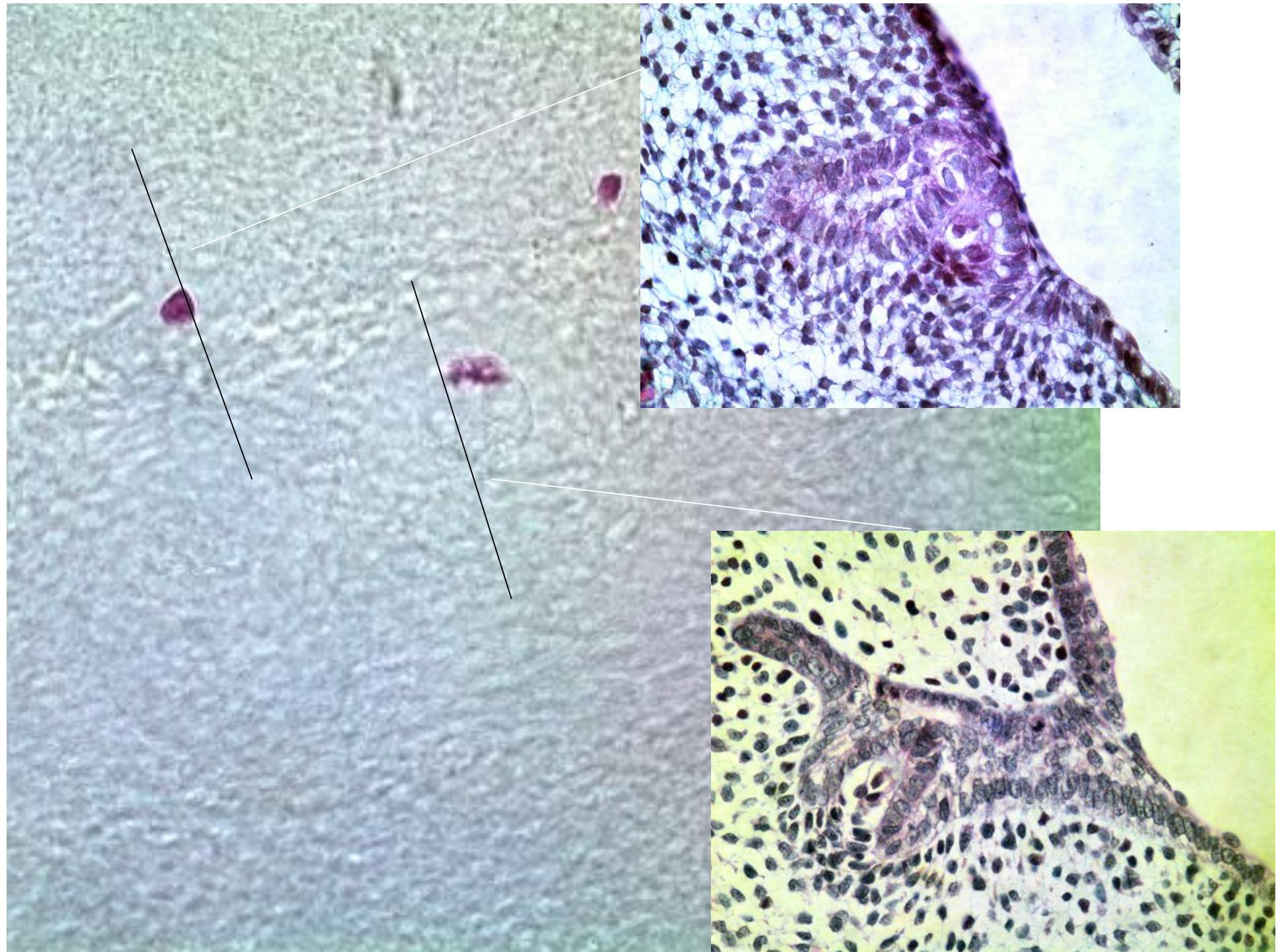
Paroedura

Placodal thickenings randomly distributed over the epithelium
(cf. Odontodes)

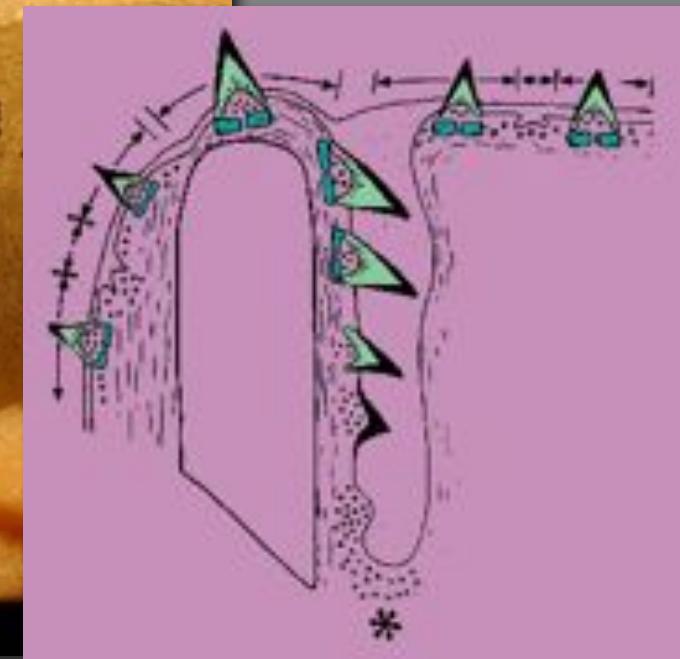


Immediately differentiated in teeth primordia, most of which do not develop into teeth





D e n t á l m i l a m i n a

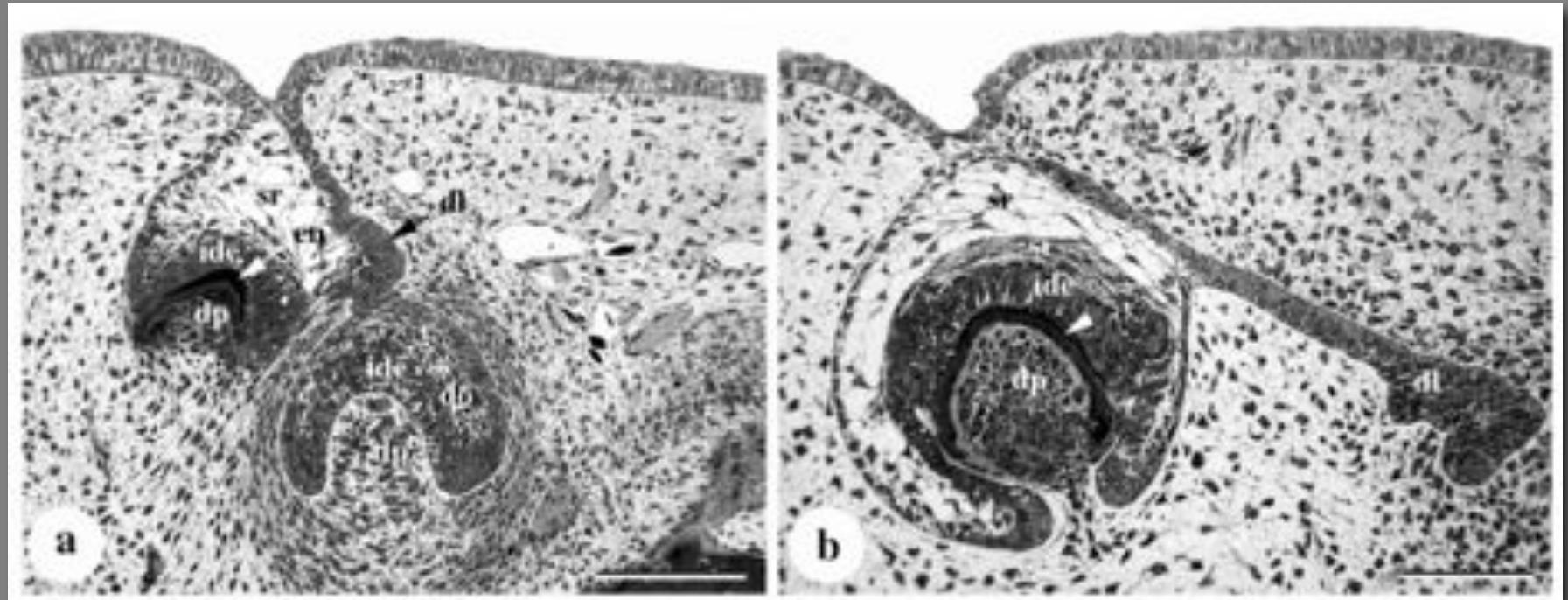


Z u b o t v o r n ý e m b r y o n á ln í o r g á n ;

p r o d u k u j e z u b y ;

d e f i n u j e a z a k l á d á j e j i c h p o z i c i a v ý m ě n u .

D e n t á l i n i l a m i n a : i n v a g i n o v a n y p r u h e p i t e l u



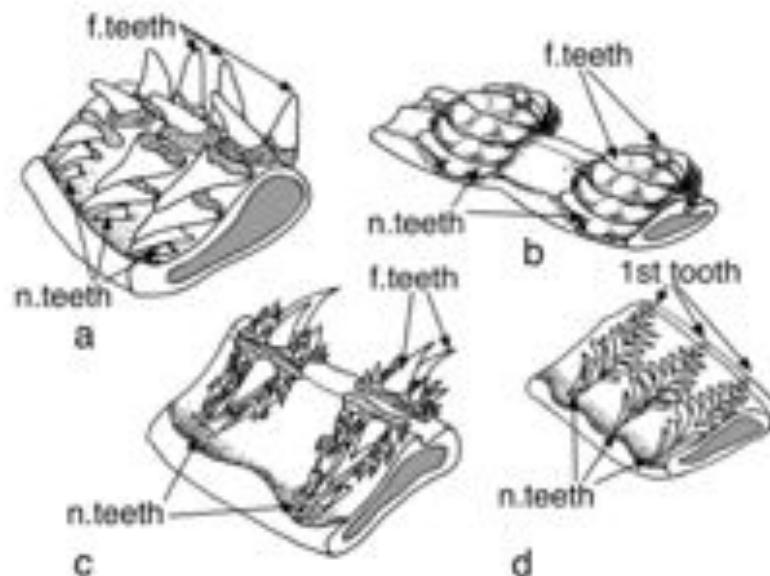


Fig. 6. Representative drawings of tooth files in chondrichthyans, each showing the replacement teeth exposed by removal of the lingual epithelium (a-c) adult and (d) embryo. Alternate tooth files (a, as *Carcharhinus melanopterus*); spaced nonalternate tooth files with teeth in a whorl-like order (c, *Chiloscyllium angustus*), 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 amblyrhynchos*). 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.

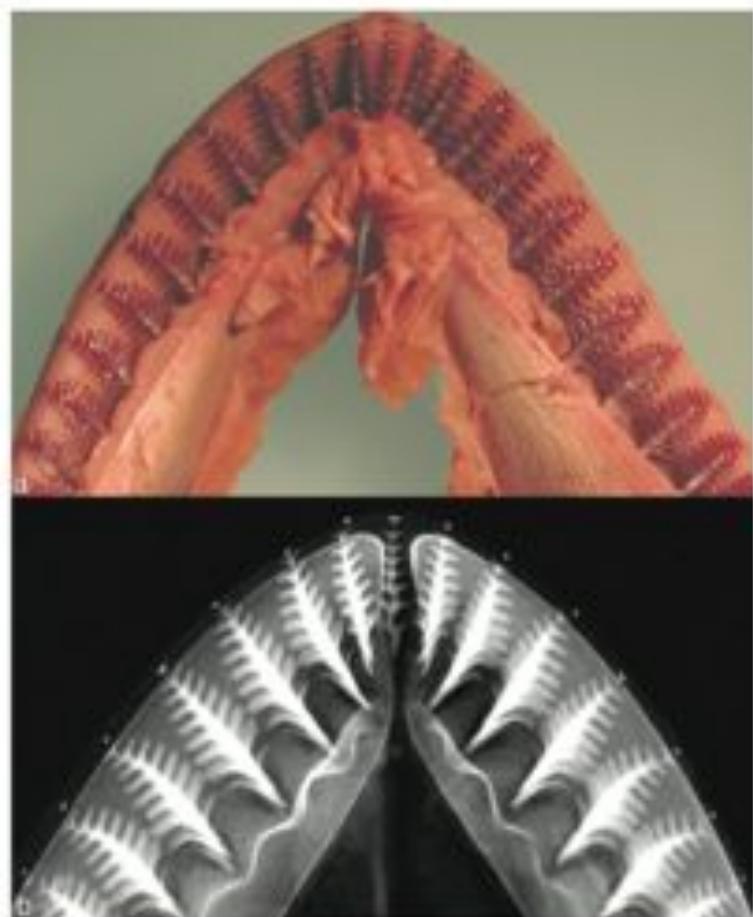


Fig. 9. Lower jaw with epithelium removed (a) and radiograph (b) of the same specimen of embryo gray reef shark (*C. amblyrhynchos*). Regular tooth files are shown each in line with single first rudimentary teeth (tooth shards, beyond the cartilage margin) and space between these used for increase in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

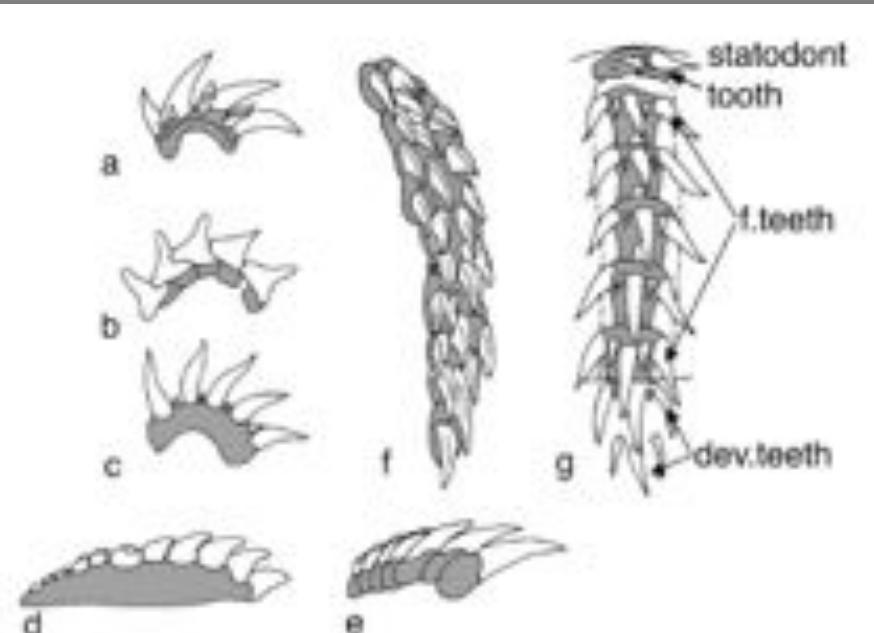


Fig. 2. Representation of tooth whorls in the jaws of fossil and extant fish, anterior to the left in a-d: (a) acanthodian; (b) chondrichthyan, one tooth set in a modern shark with separate tooth bases; (c) sarcopterygian; (d) one row of lungfish tooth-plate. (e) Pharyngeal joined denticle set from early 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).

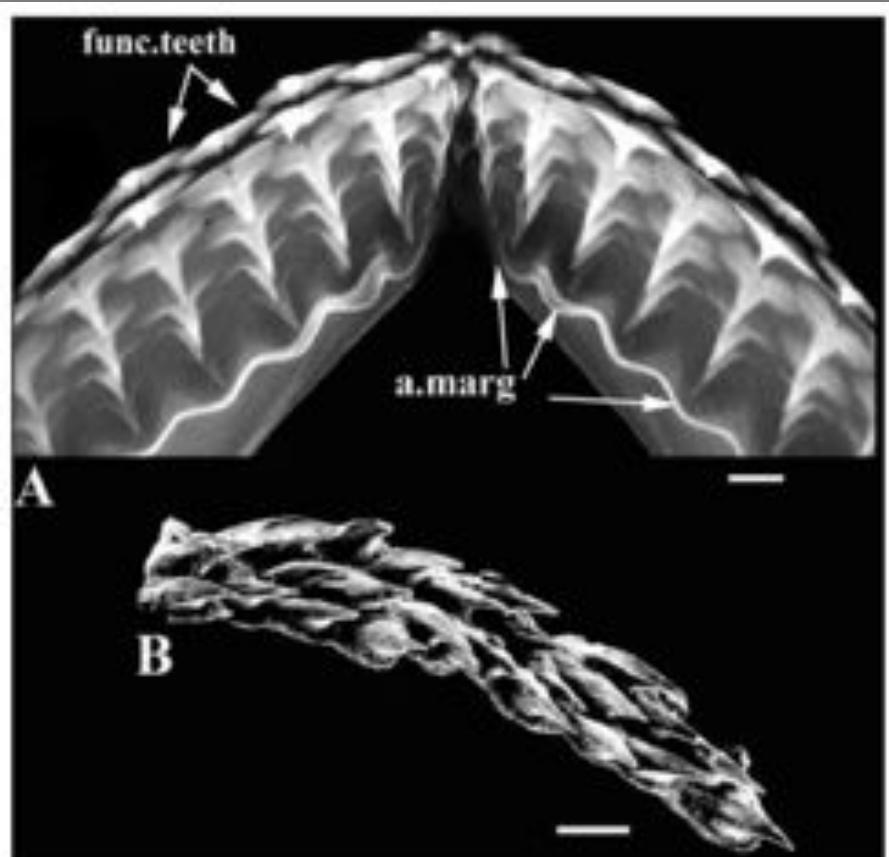
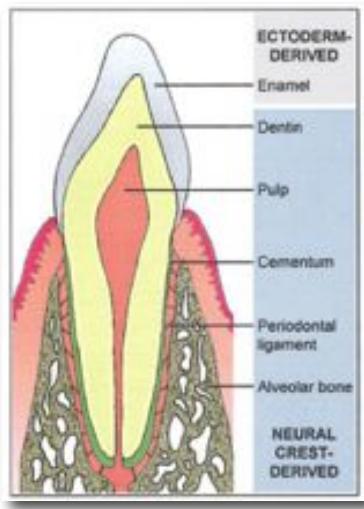


Fig. 2. **A:** Tooth sets along the lower jaw of the chondrichthyan *Carcharhinus melanopterus*. Note staggered or offset positions of tooth sets, particularly with regard to the alternation of the functional teeth at the jaw margin (func.teeth). Scale bar = 1.0 cm. **B:** Denticle whorl of the agnathan (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.

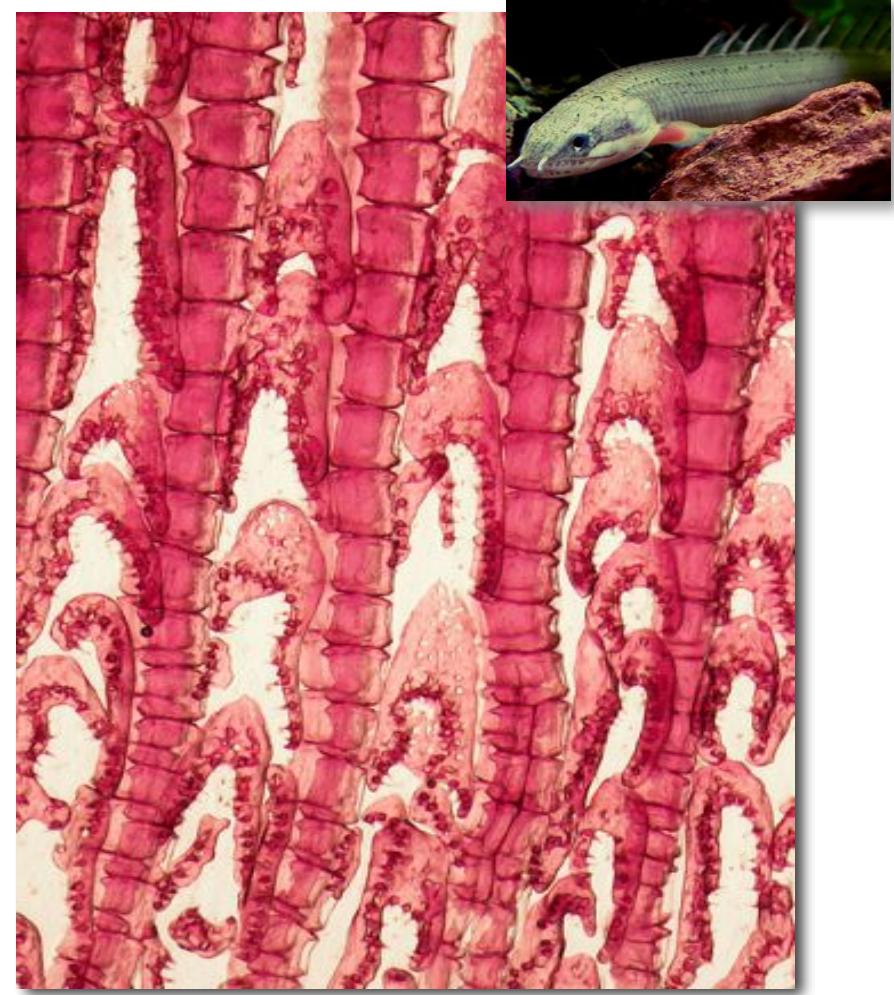
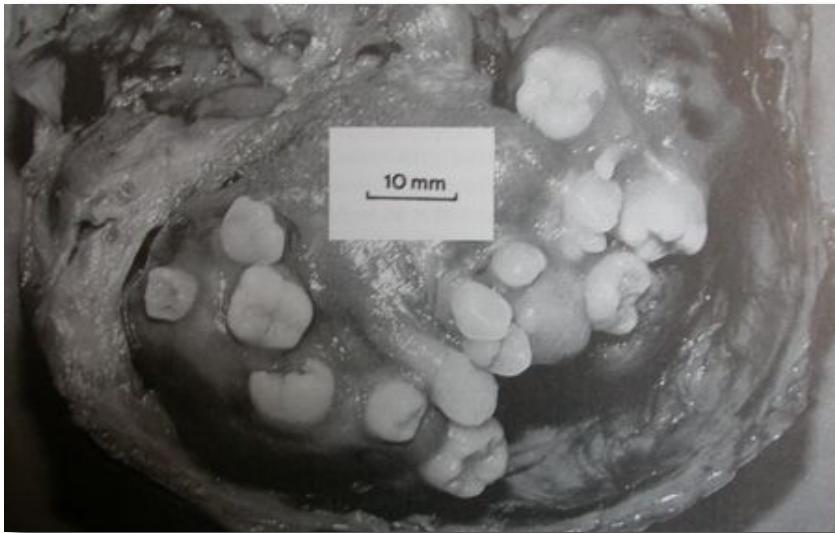
O n t o g e n e z e z u b u :

v z á j e m n é a o p a k u j í c í s e i n t e r a k c e

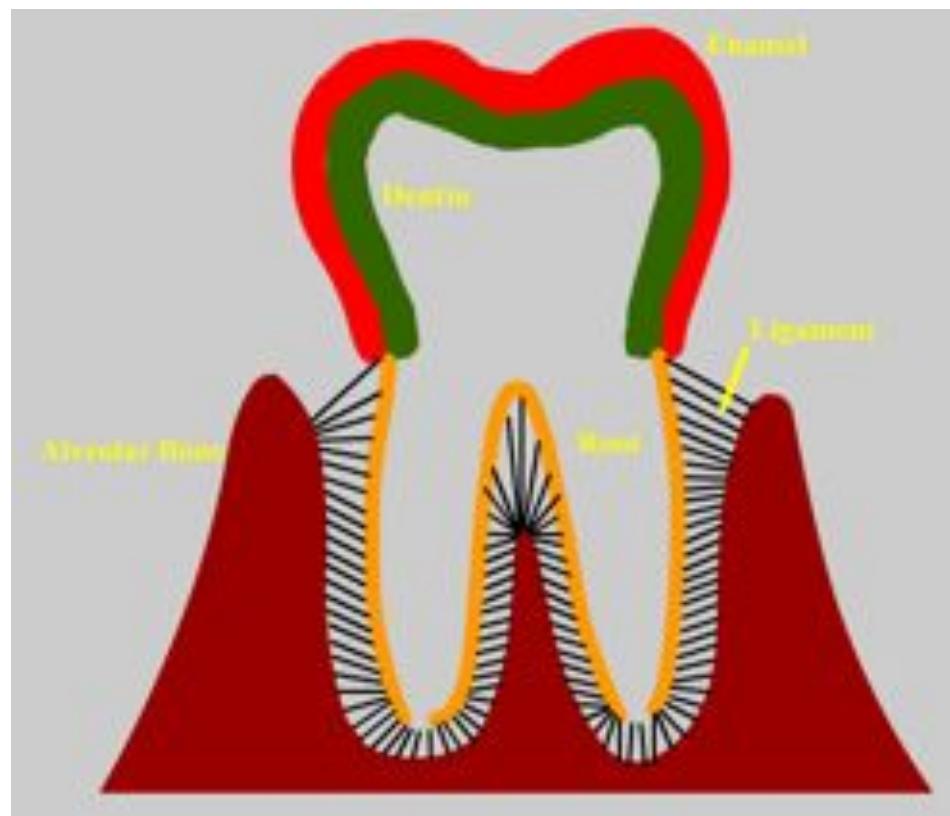
z u b n í h o m e s e m c h y m u a e p i t e l u

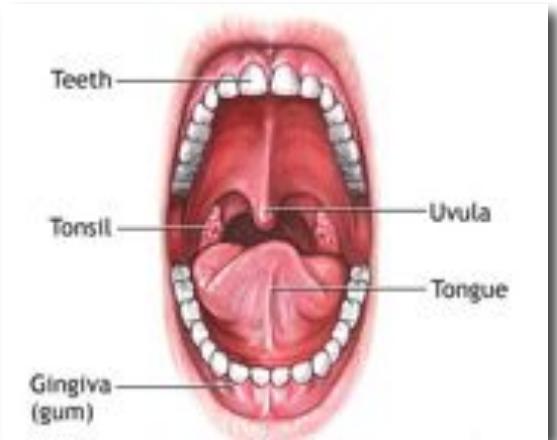


Dle současných definic (*myš, člověk - sic!*) je ontogeneze zuba založena na **orálním ektodermu** a **hlavové neurální liště**.



Dle současných definic (*myš, člověk - sic!*) je ontogeneze zuba založena na **orálním ektodermu** a **hlavové neurální liště**.





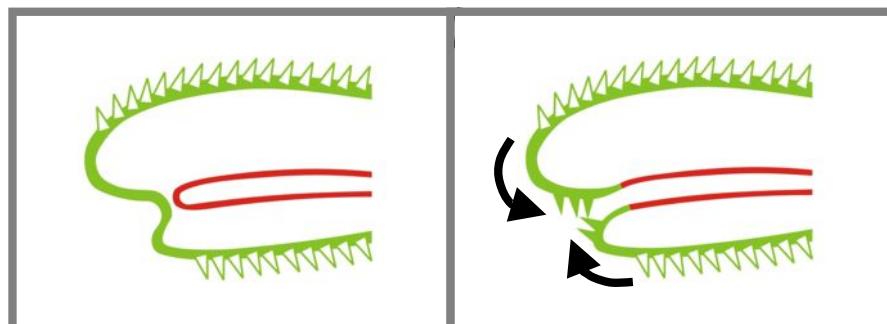
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E p i t e l E K T

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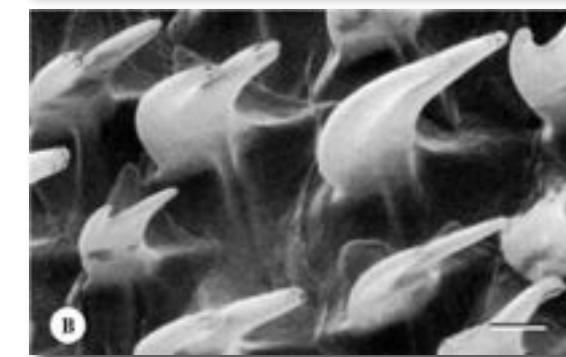
E N T ?

Zuby (obecně?!!) umístěny ve
stomodeu, epitel EKT původu



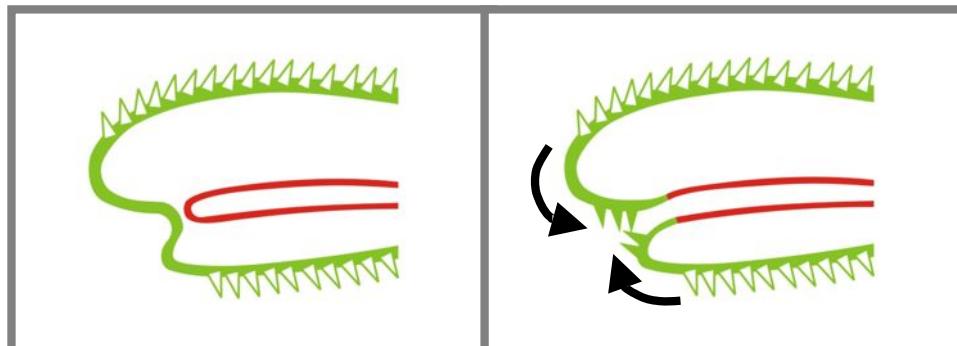
Povrchové (**EKT**) šupiny, dentikly (viz. plakoidní šupiny) vmigrovaly do **stomodea**, kde se postupně navázaly do čelistí a staly se **zuby s. str.**

- zuby z EKT ontogeneticky i evolučně;;
 - odontoda jakožto EKT struktura;
 - založeno na situaci u žraloka
- Homologizační předpoklad:
gradient šupina - zub



Tooth evolution: „OUT-IN“ theory

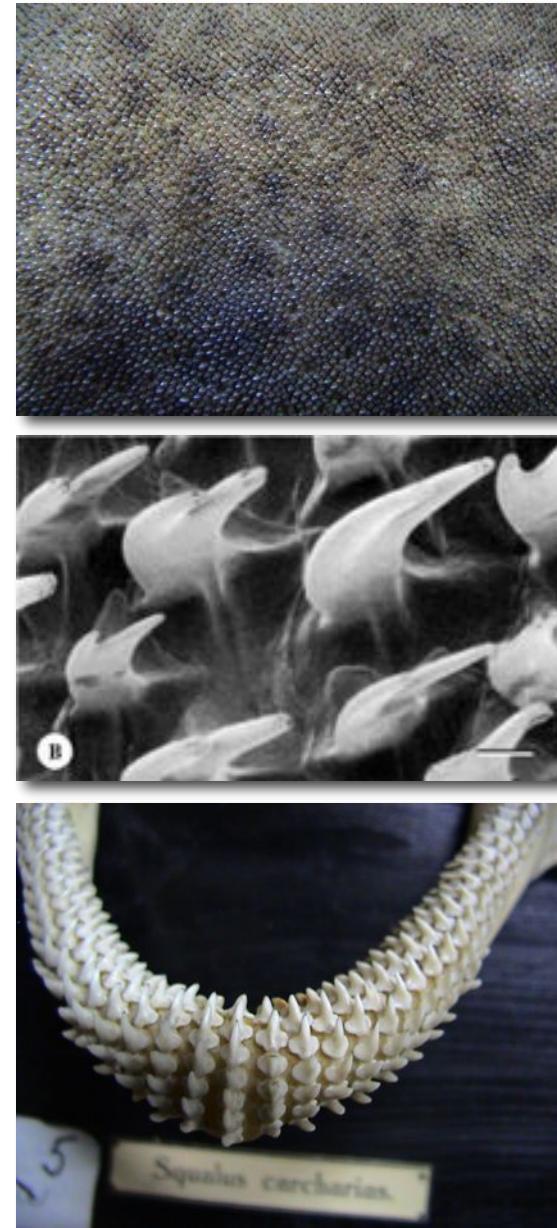
Teeth from ECTODERM
(e.g. *sensu* W.E. Reif)



Dermal denticles of ECT origin migrated into the stomodeum, where they became teeth

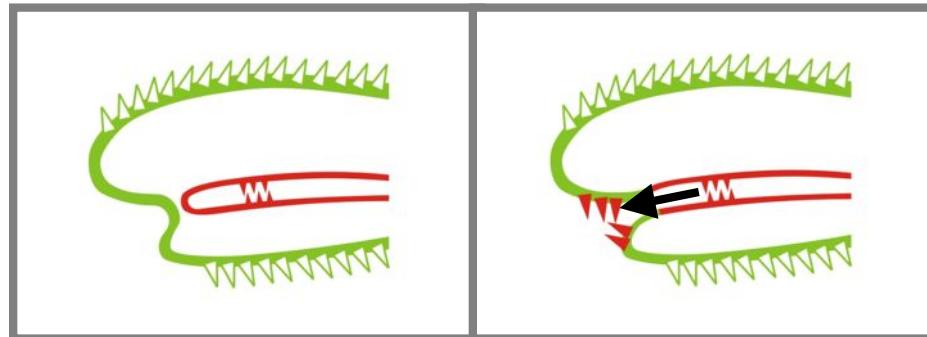
Tooth =

ECTODERM
+
NEURAL CREST

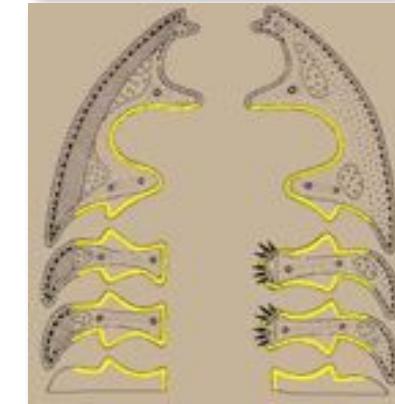
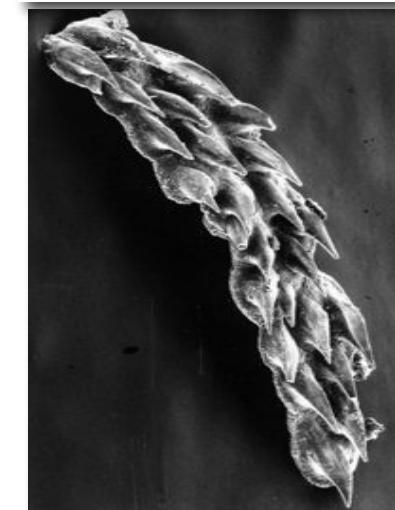
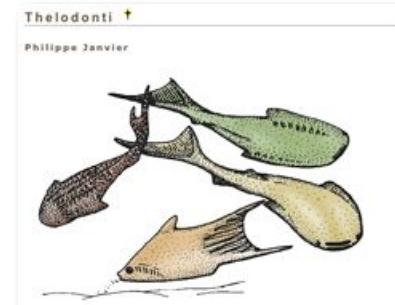
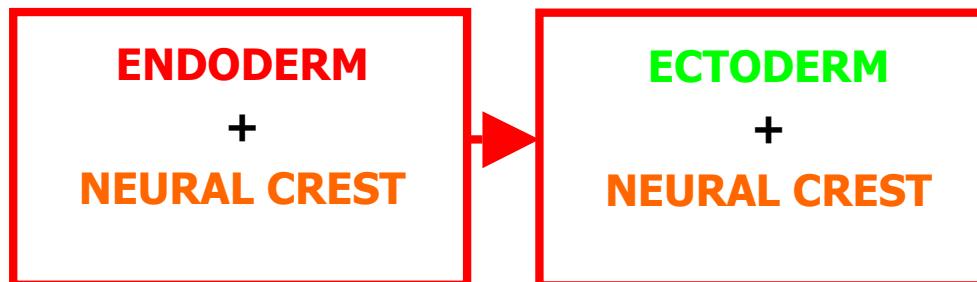


Tooth evolution: „IN-OUT“ theory

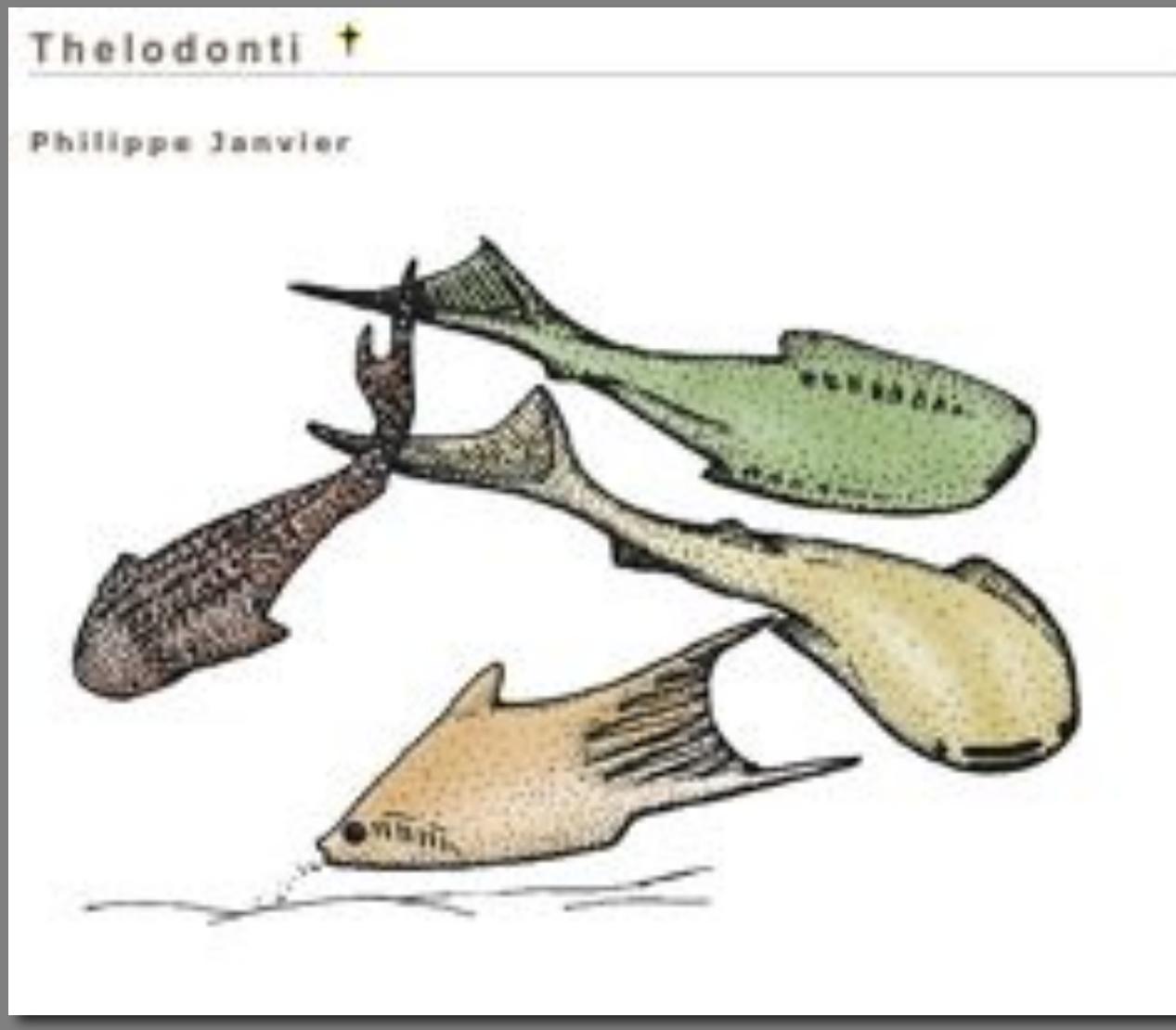
Teeth from **ENDODERM**
(*sensu* M.M. Smith)



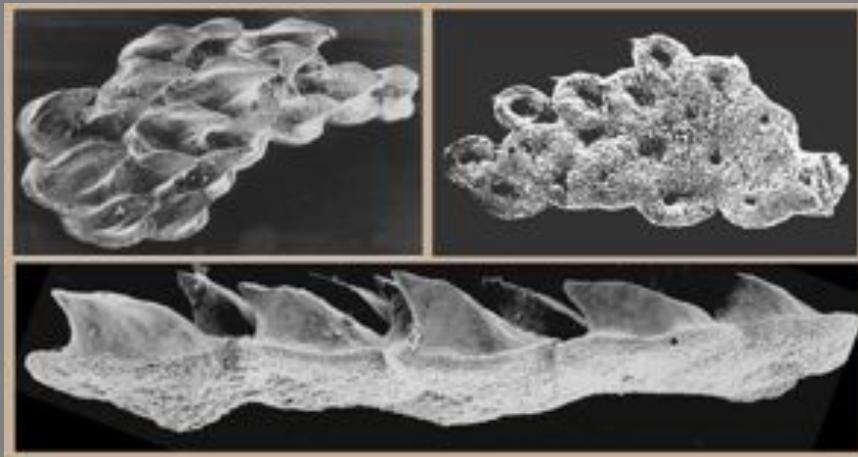
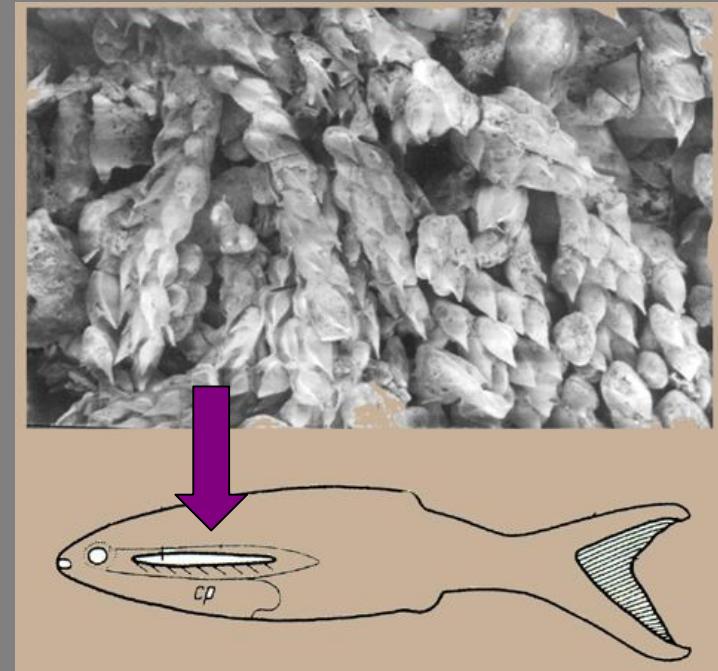
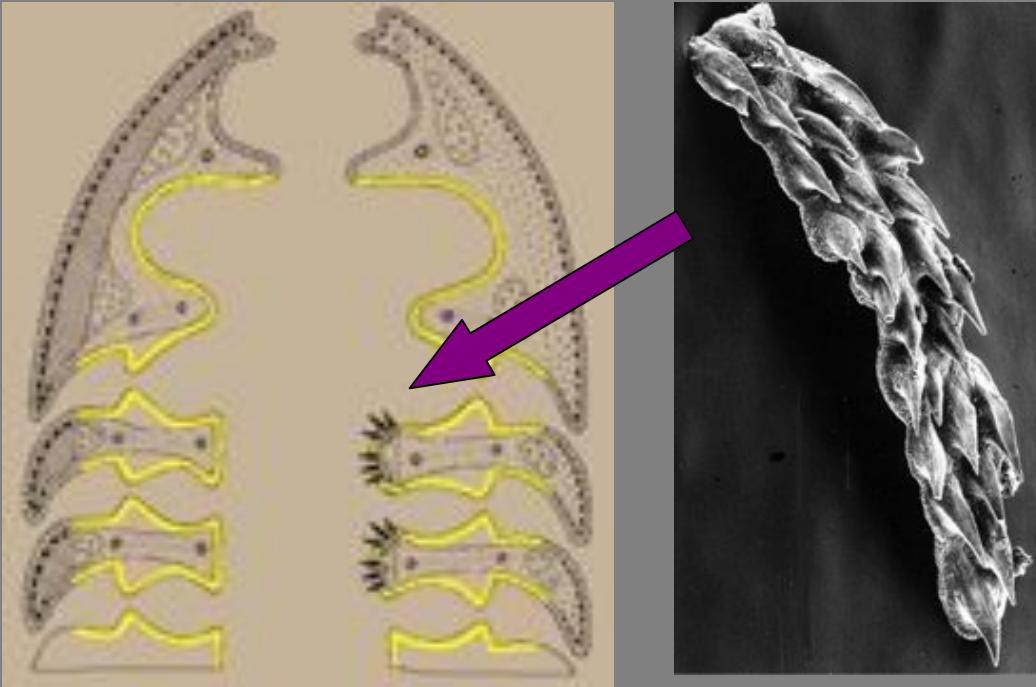
Pharyngeal denticles of **END** origin were later co-opted for **ECT** areas



Thelodont pharyngeal denticles - agnathan



Thelodont pharyngeal denticles - agnathan



Internal branchial denticle whorls

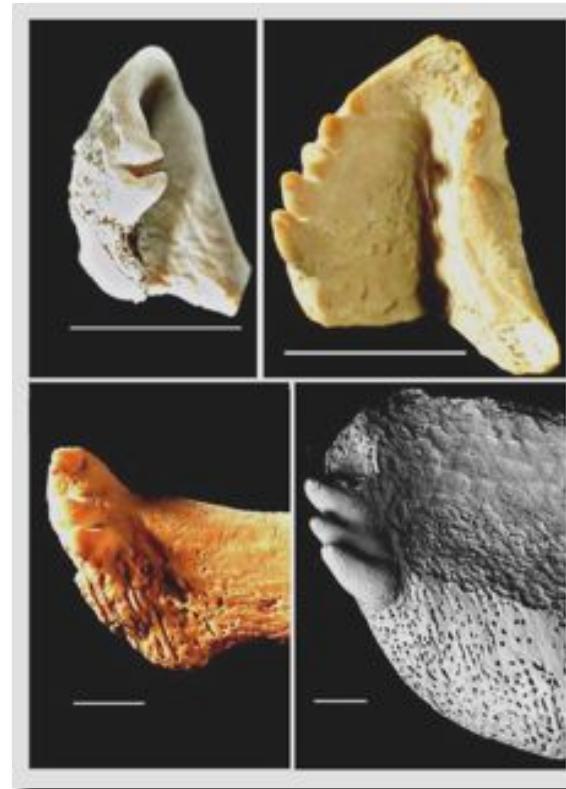
Timed sequential formation

Thick basal bone joins them

Different from outer denticles

Tooth evolution:

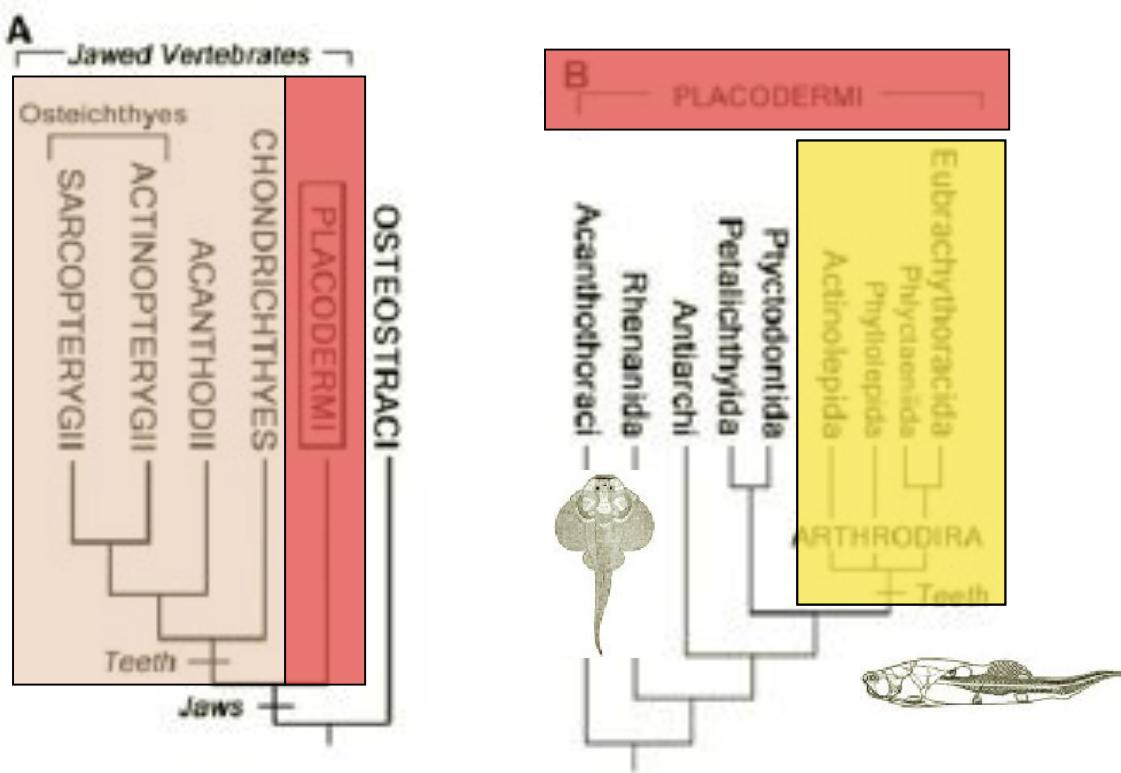
... several times, independently?



- (Smith & Johansson, 2003): ...teeth may have evolved independently, several times, through a mechanism of convergent evolution.
- (Tucker & Sharpe, 2004): ...diversity of dentitions might have been explained by combinatorial derivation of teeth from both external (ECT), as well as internal (END) denticles and teeth.

Separate Evolutionary Origins of Teeth from Evidence in Fossil Jawed Vertebrates

Moya Meredith Smith^{1*} and Zerina Johanson²

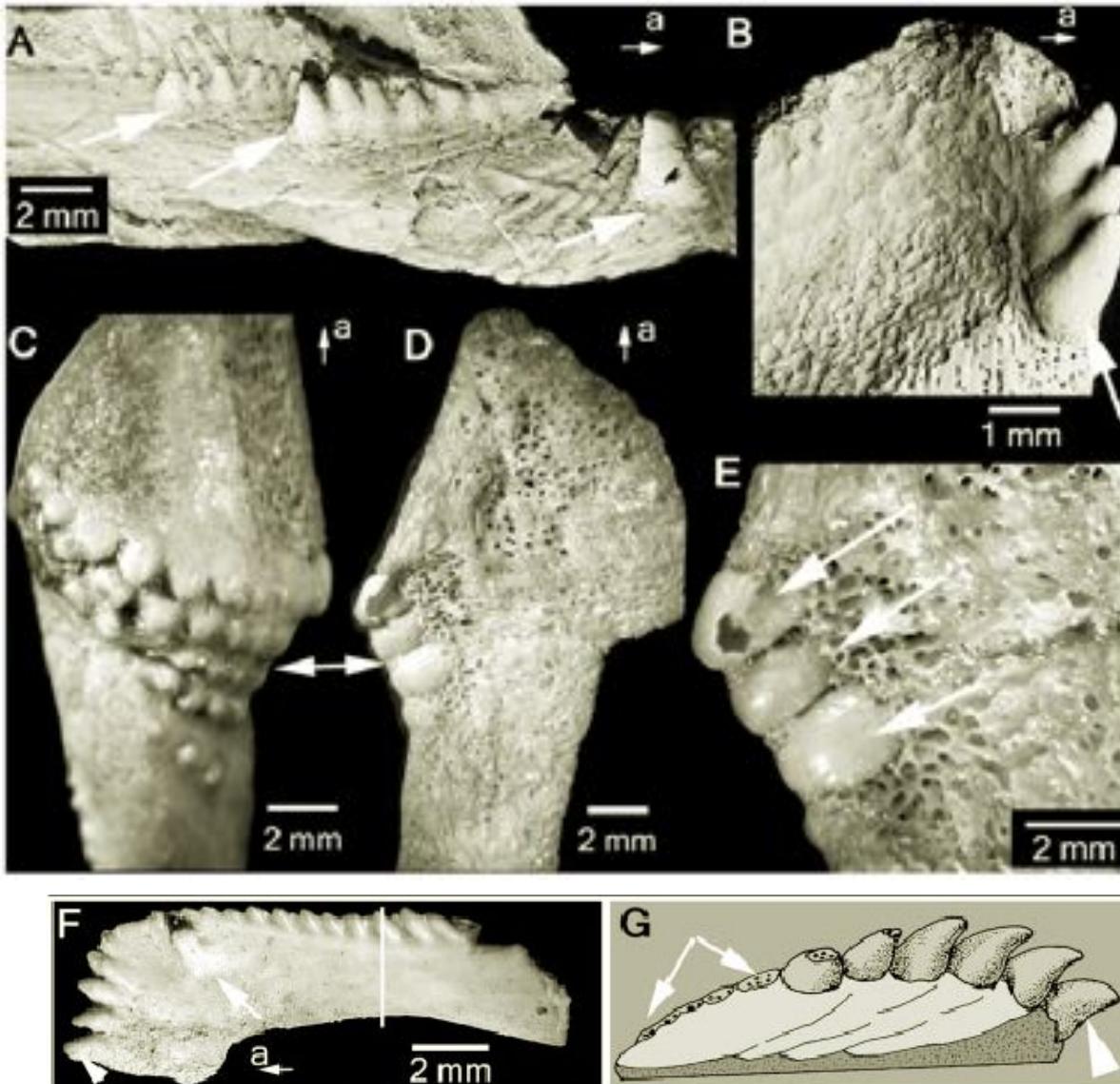


Dual origin of teeth ?!?

In derived placoderms,
teeth developed independently and thus
are not homologous to
other teeth of jawed
vertebrates

Some placoderms have upper and lower dental plates with teeth

Placodermi: Actinolepida (*Aethaspis* sp., *Incisoscutus* sp., *Bullerichthys* sp.)



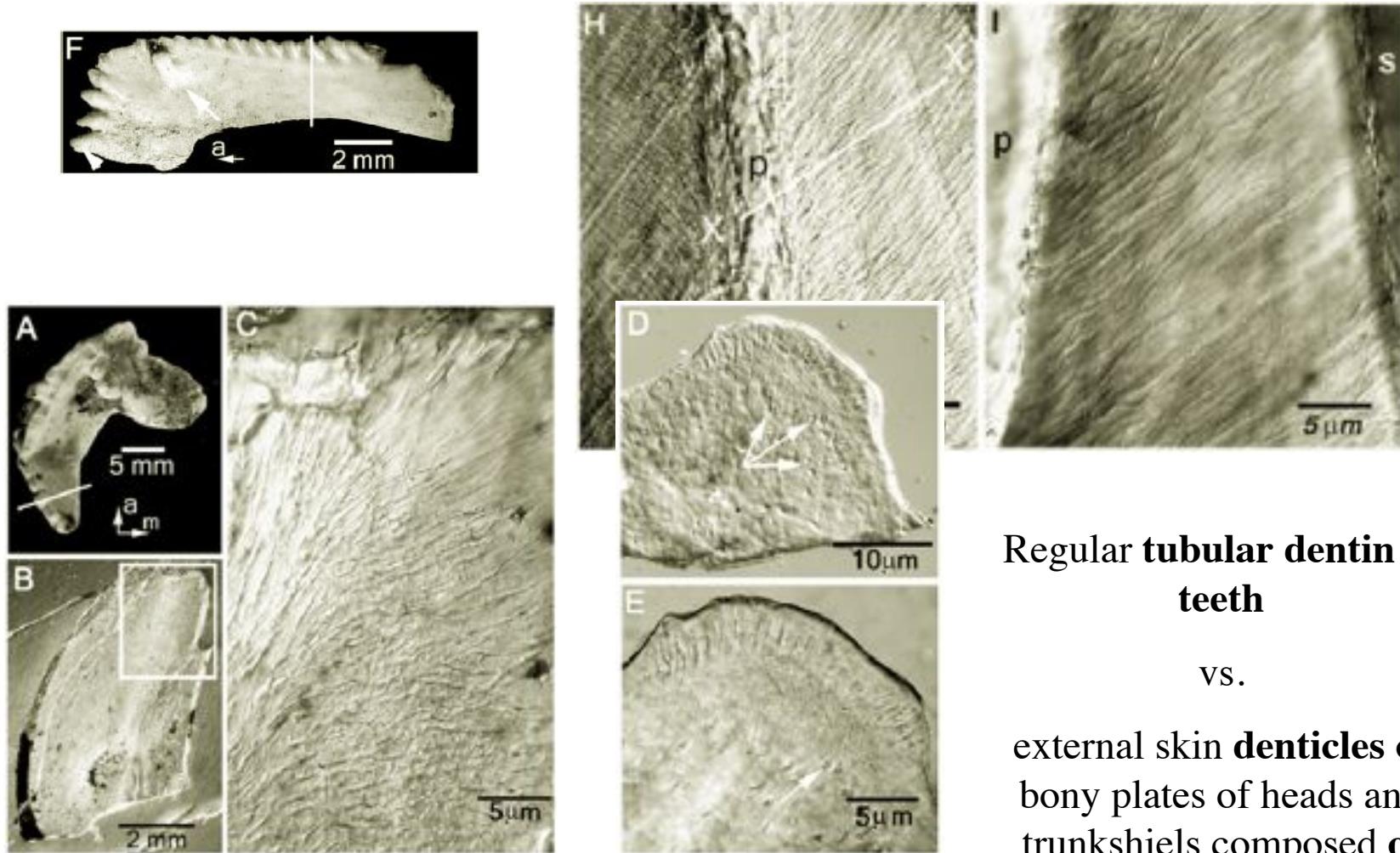
New teeth arose in an organized way being added to recognizable rows on each dental plate...

...thus, tooth development was patterned and regulated...

... therefore, teeth develop from tooth-primordia, regulated in space and time by tooth-specific tissues...

... DENTAL LAMINA ?!?

These teeth are composed of **regular** (=gnathostome type) **dentine** formed from cells within a pulp cavity (contrary to accepted opinions)



Regular **tubular dentin** of
teeth

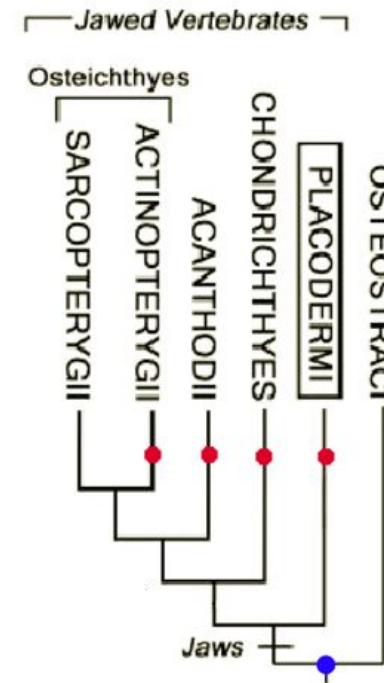
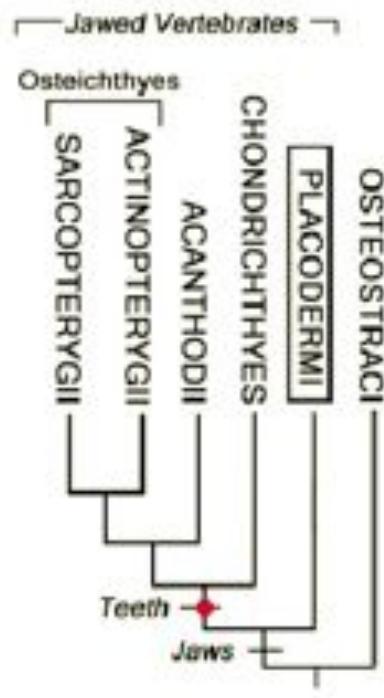
vs.

external skin **denticles** or
bony plates of heads and
trunkshields composed of
semidentine/mesodentine

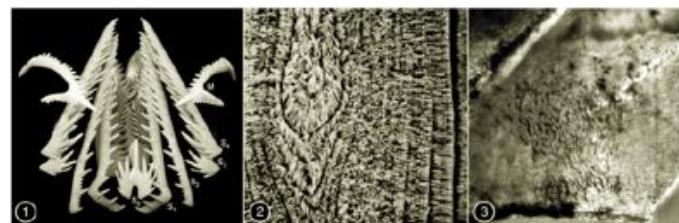
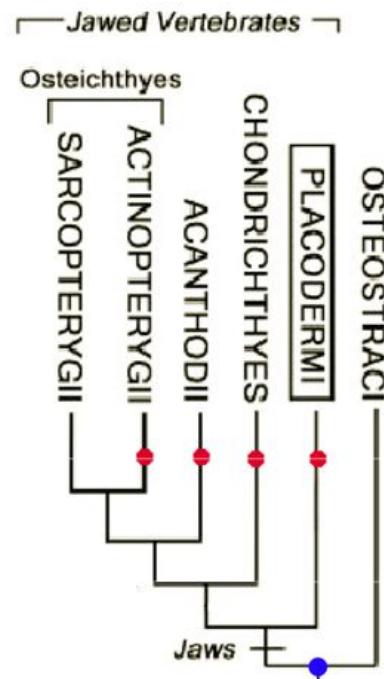
Teeth of Arthrodira develop and are regulated **as in other jawed vertebrates**

Because Arthrodira are derived forms of placoderms, **teeth evolved at least twice**

How many times did teeth develop ?!?

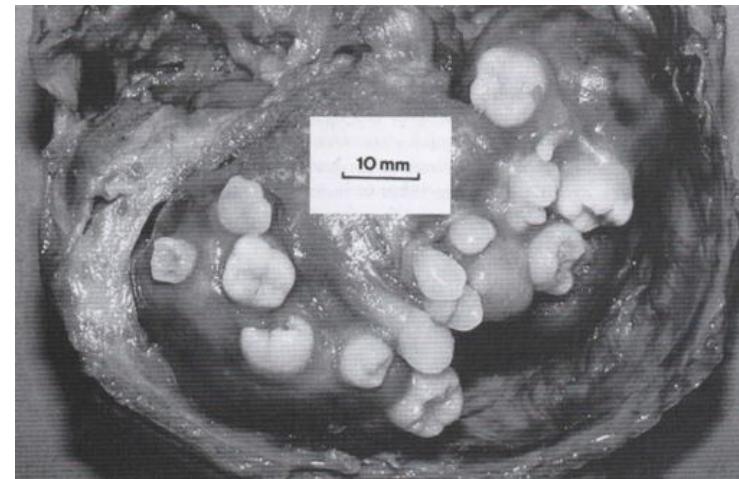


“Teeth” evolution: from skin denticles or pharyngeal denticles ?!?



“*Teeth from pharyngeal denticles*” means that developmental regulatory mechanisms responsible for tooth patterns on jaw **are co-opted from the pharyngeal region** and not from the skin as classically thought

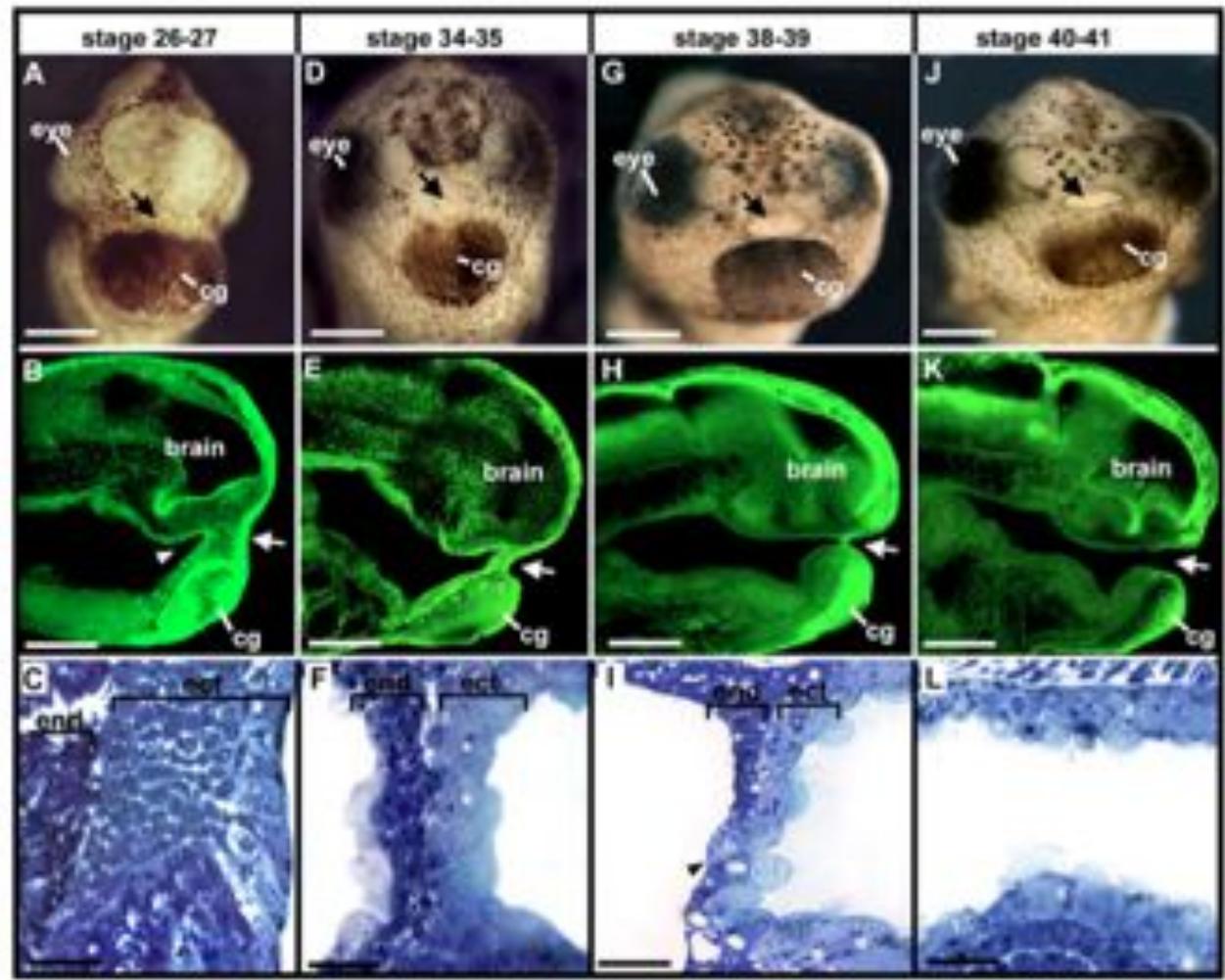
This strongly implies embryonic **ENDODERM** as opposed from **ECTODERM** in the genetic control of dentition patterning



Ectopic teeth in human ovarian teratoma

Oral opening development: ECT vs. ENT

A.J.G. Dickinson, H. Sive / Developmental Biology 295 (2006) 700–713

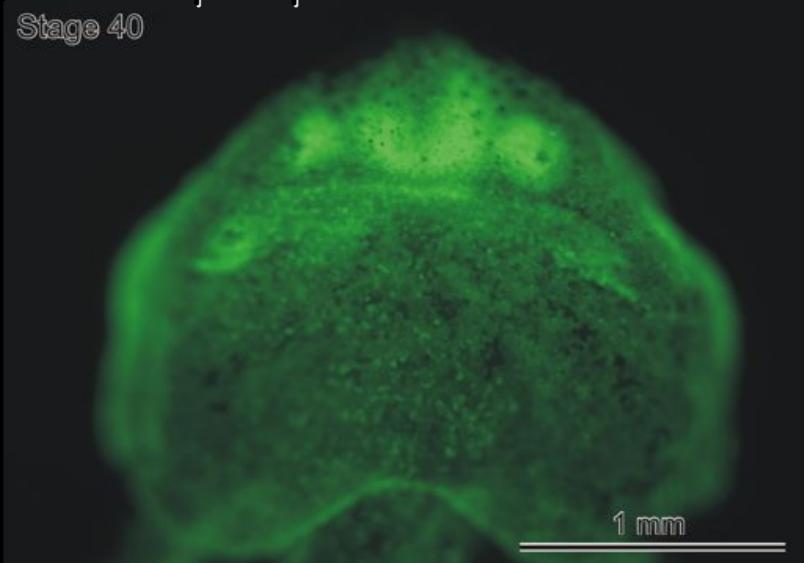
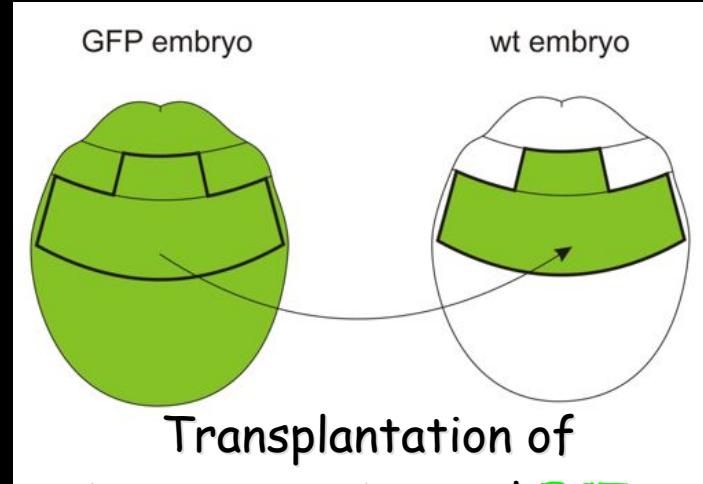
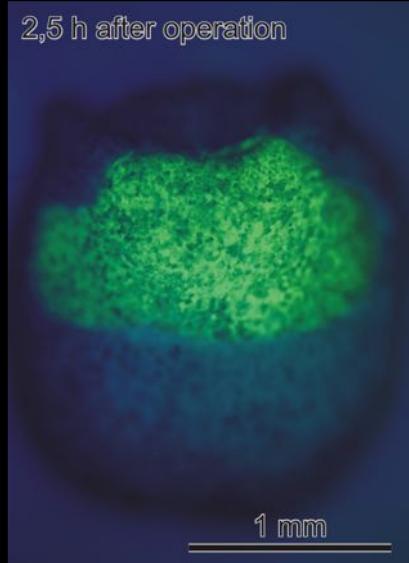


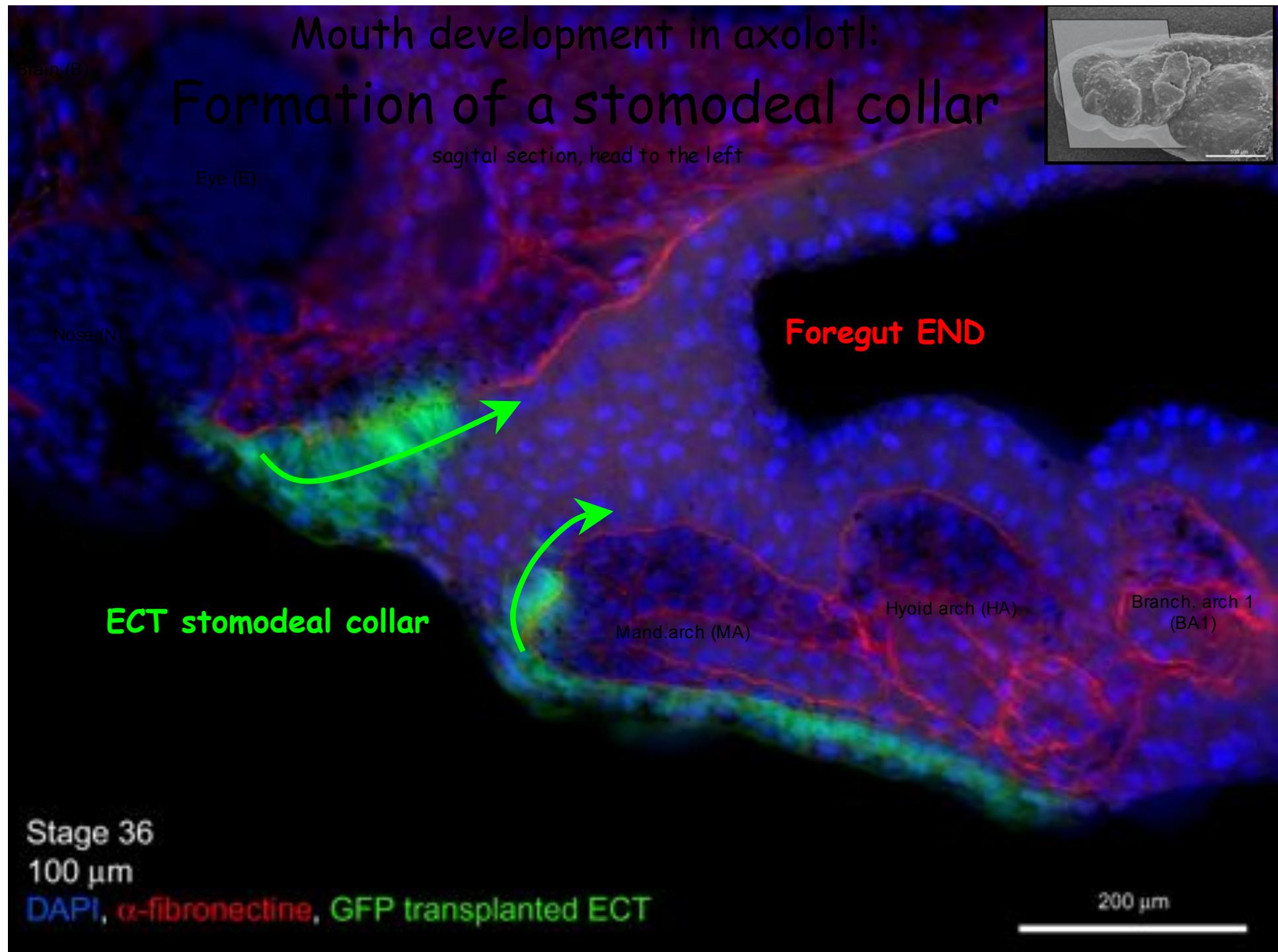
Mouth development in axolotl



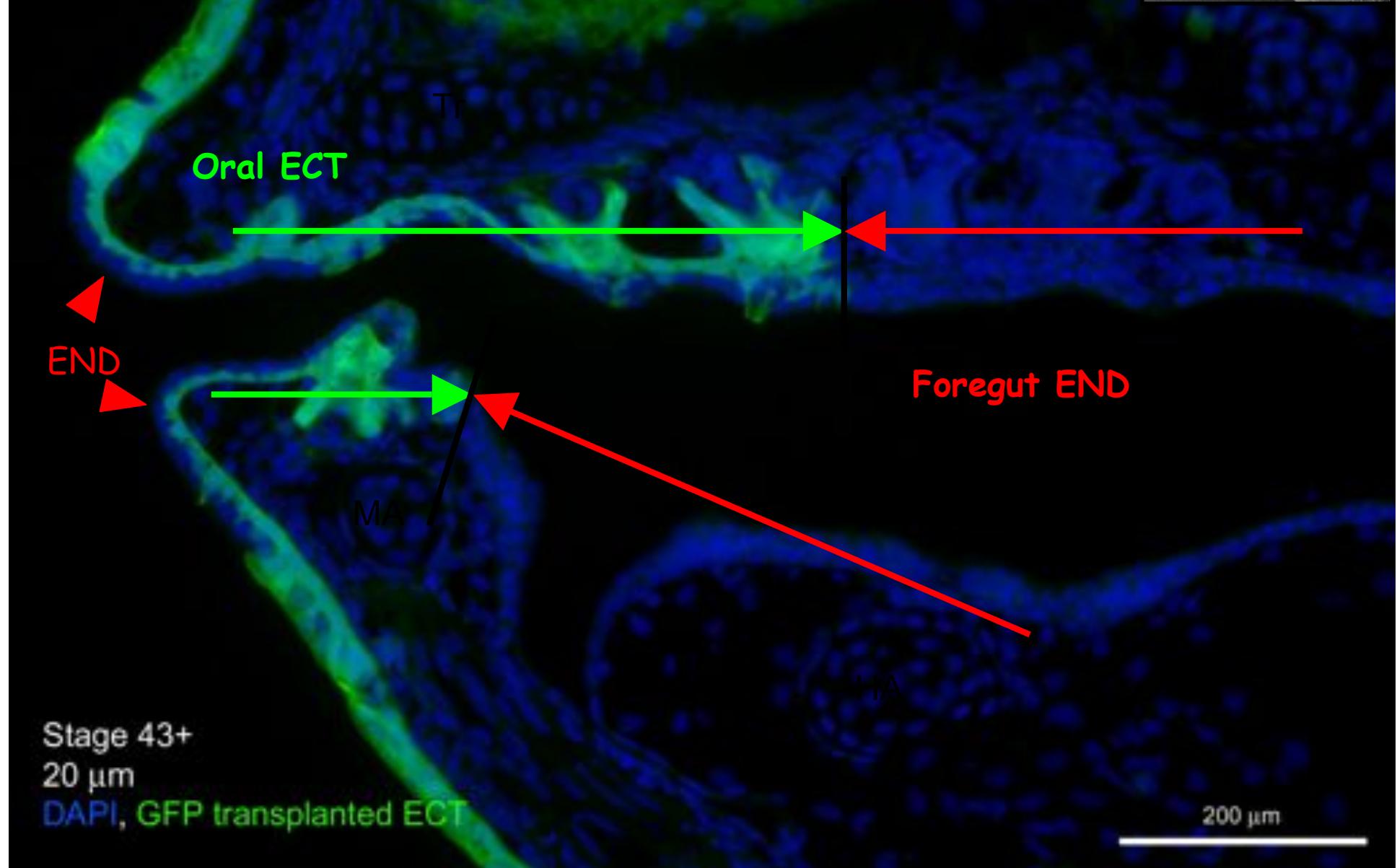
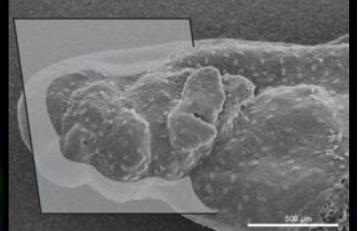
Axolotl embryos:

Transplantation of oral ECT during mouth and tooth formation

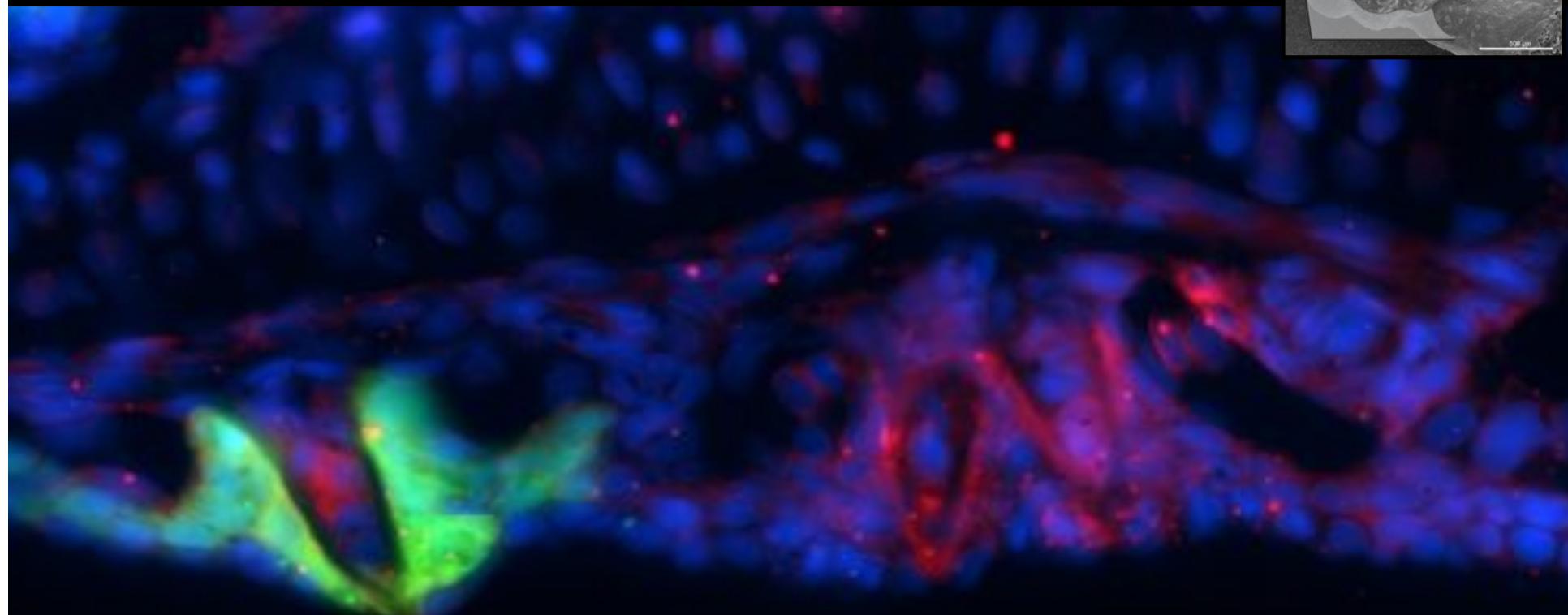
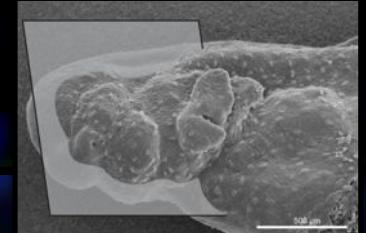




Mouth development in axolotl positioning of ECT in



Teeth on the palate



Stage 43+

20 μ m

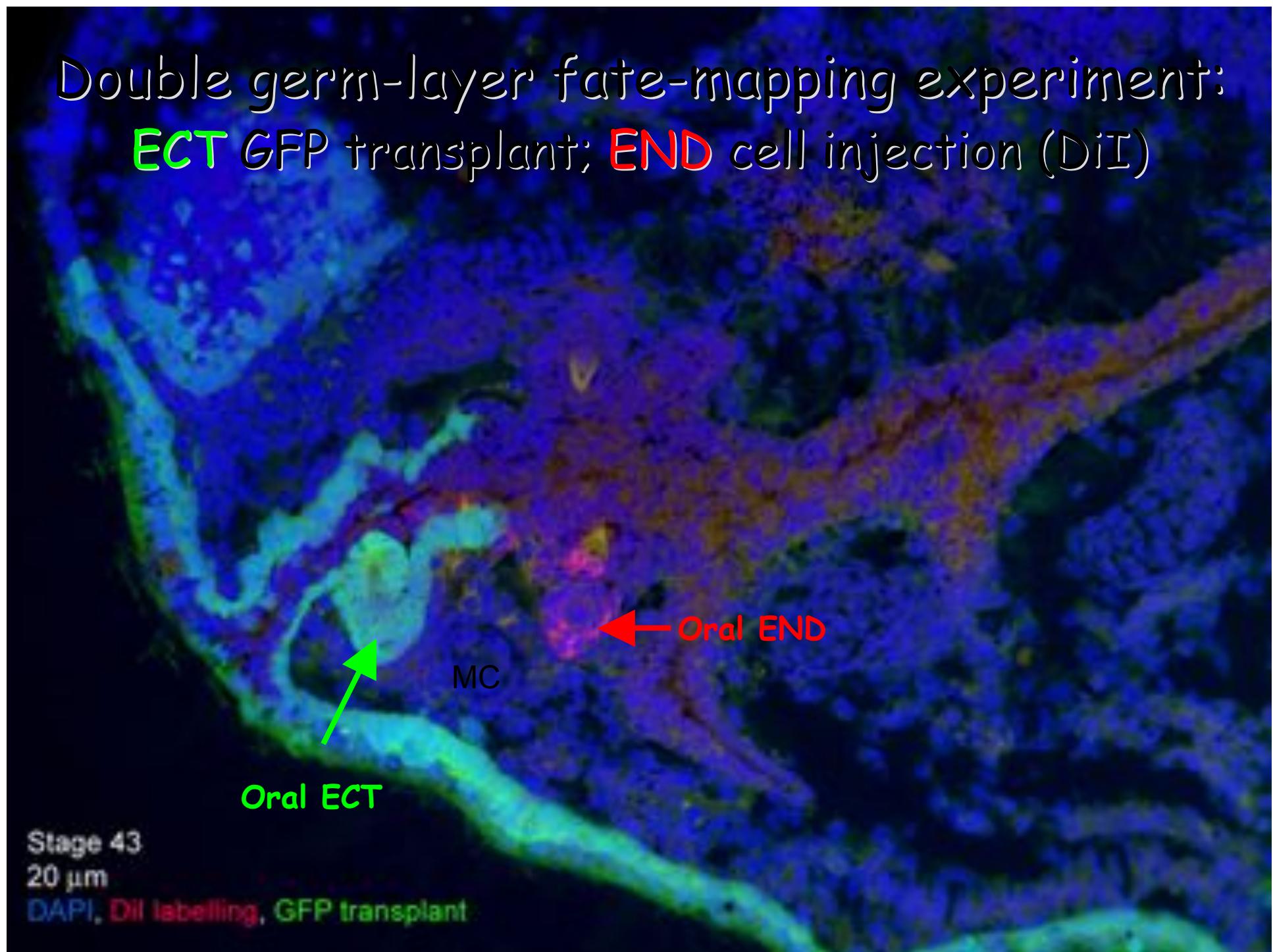
DAPI; α -calbindin, GFP transplanted ECT

20 μ m

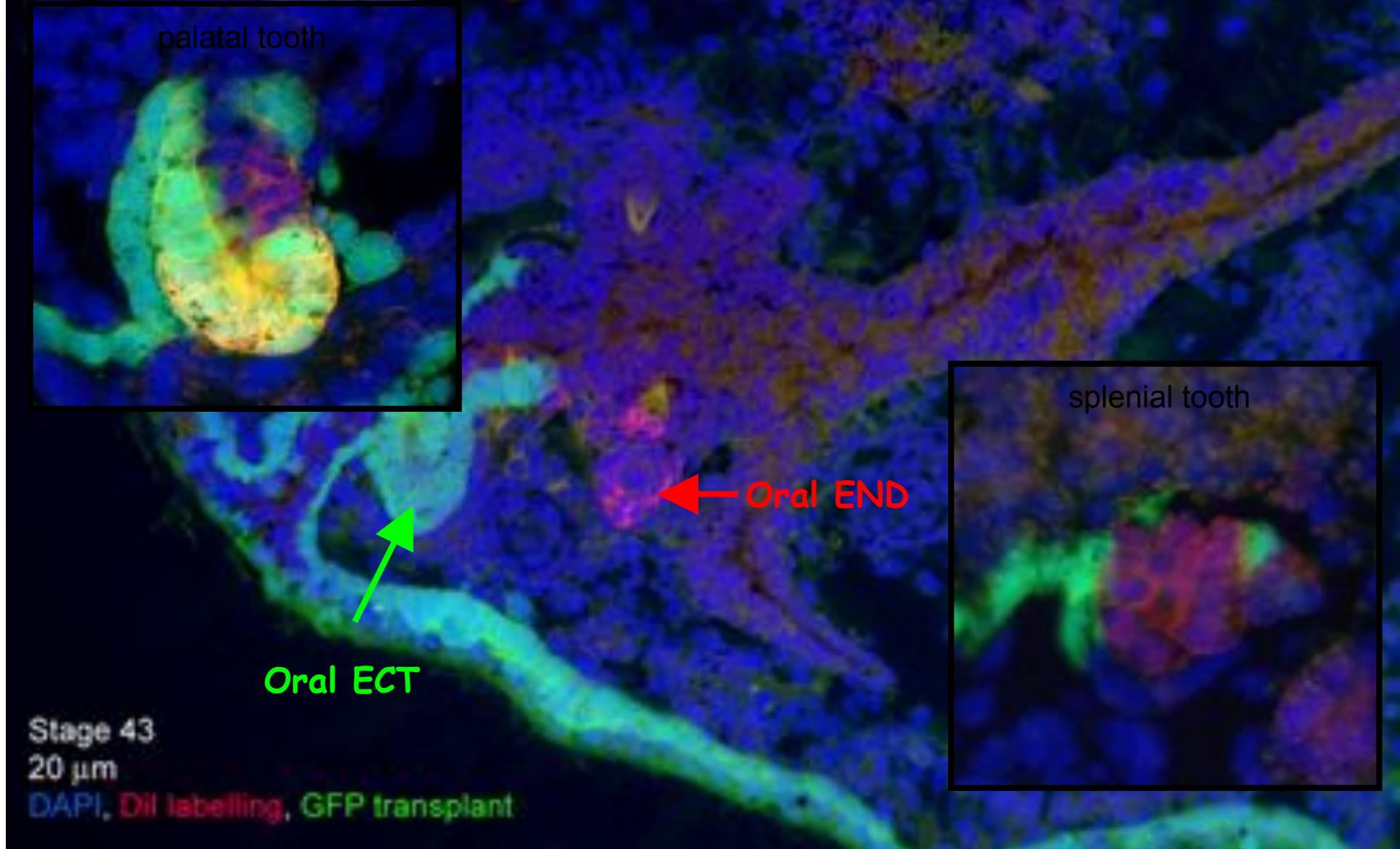
DAPI, GFP transplanted ECT

200 μ m

Double germ-layer fate-mapping experiment:
ECT GFP transplant; **END** cell injection (DiI)



**ECT GFP transplant + END cell injection (DiI):
Teeth of double-layer origin**



gin of tooth enamel epithelia the Mexican axolotl

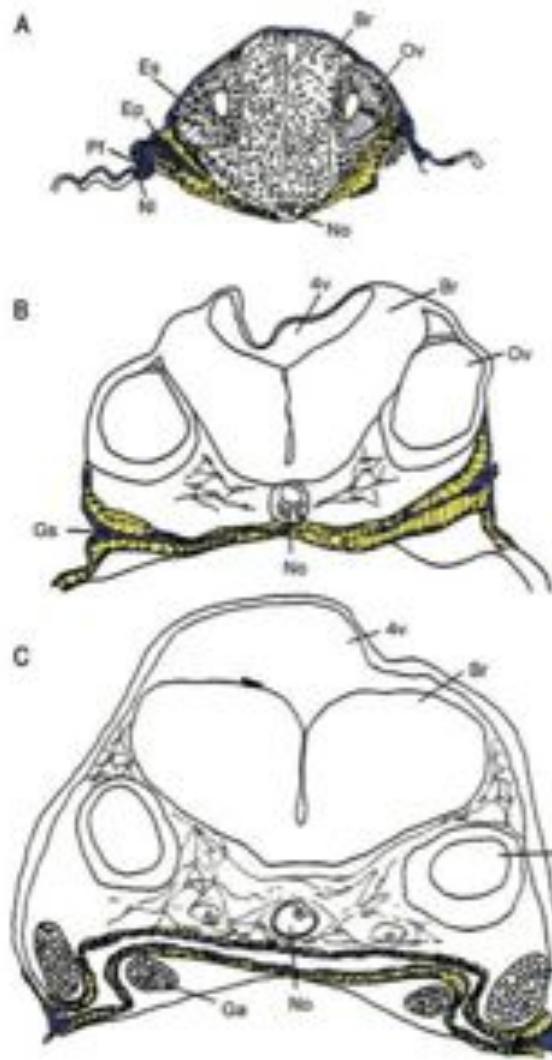
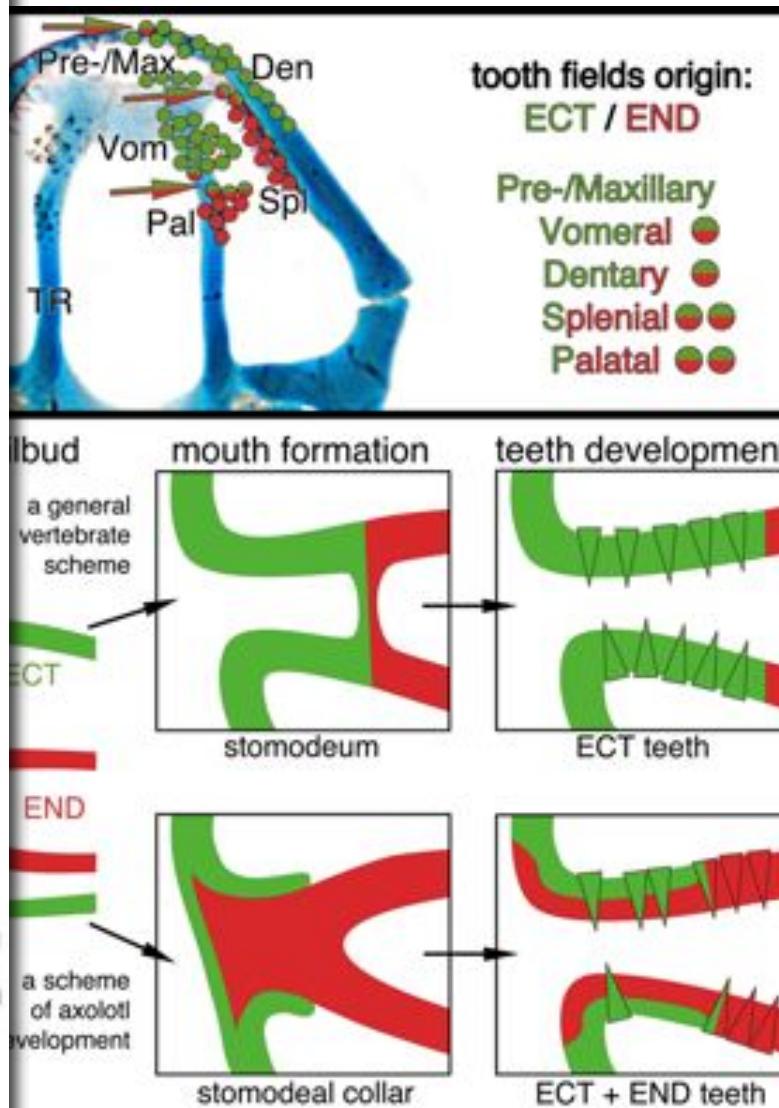


Fig. 3 Three stages in the development of the gill slits and pharynx of the carp (*Cyprinus carpio*). (A-C) respectively 36, 56 and 78 h post-fertilization. An ectodermal plug (blue) invaginates the endodermal pharyngeal folds (yellow) (A) and forms a layer of flattened (ectoderm-derived) cells (blue) on top of the columnar (endoderm-derived) epithelial cells (yellow) (B,C). The latter produce the enamel organs of the teeth. Av, fourth ventricle; Br, brain; Ep, proliferating ectodermal plug; Es, epidermal stratum; Ga, gill arch; Gs, gill slit; Ha, hyoid arch; Ni, inner layer of ectoderm; No, notochord; Ov, otic vesicle; Pl, pharyngeal fold (modified after Edwards, 1929).

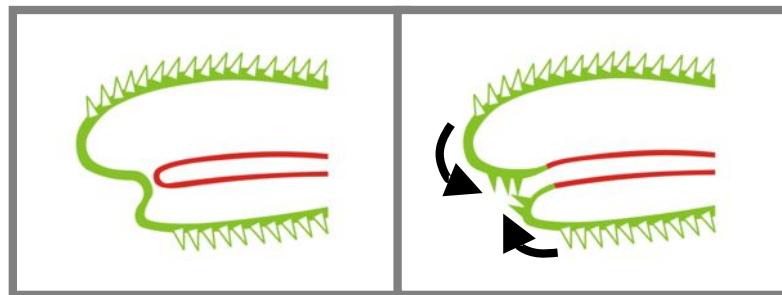


Implications for development and evolution

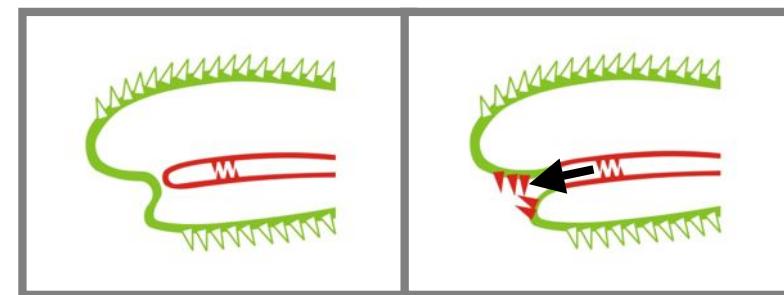
The germ-layer origin of epithelium doesn't seem to matter at all - mesenchyme cells can apparently interact both with ECT and END and such teeth look very identical > homology?

We stress the role of NC-mesenchyme in tooth development & evolution because then odontodes/teeth/denticles can form when in the oral/pharyngeal cavity or even on the skin surface.

Teeth evolution from **ECTODERM**



Teeth evolution from **ENDODERM**

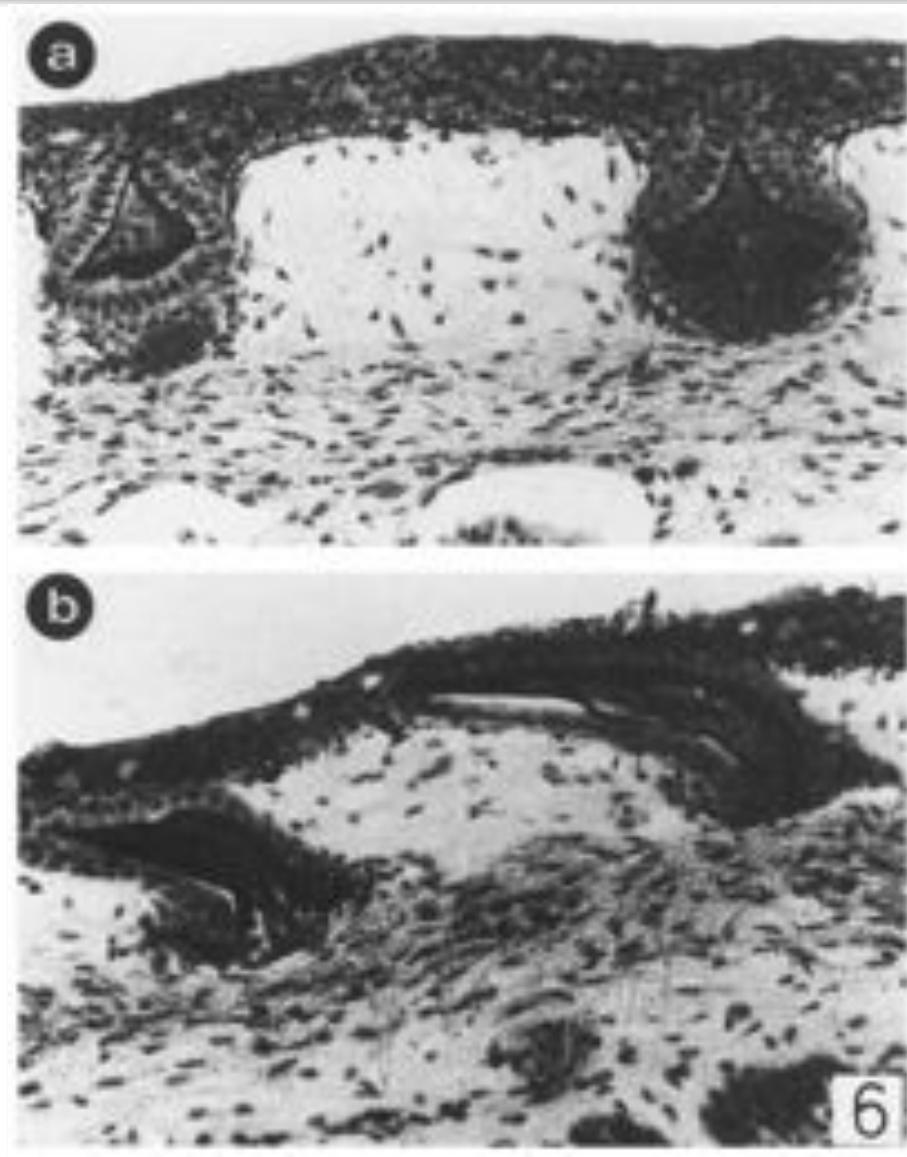
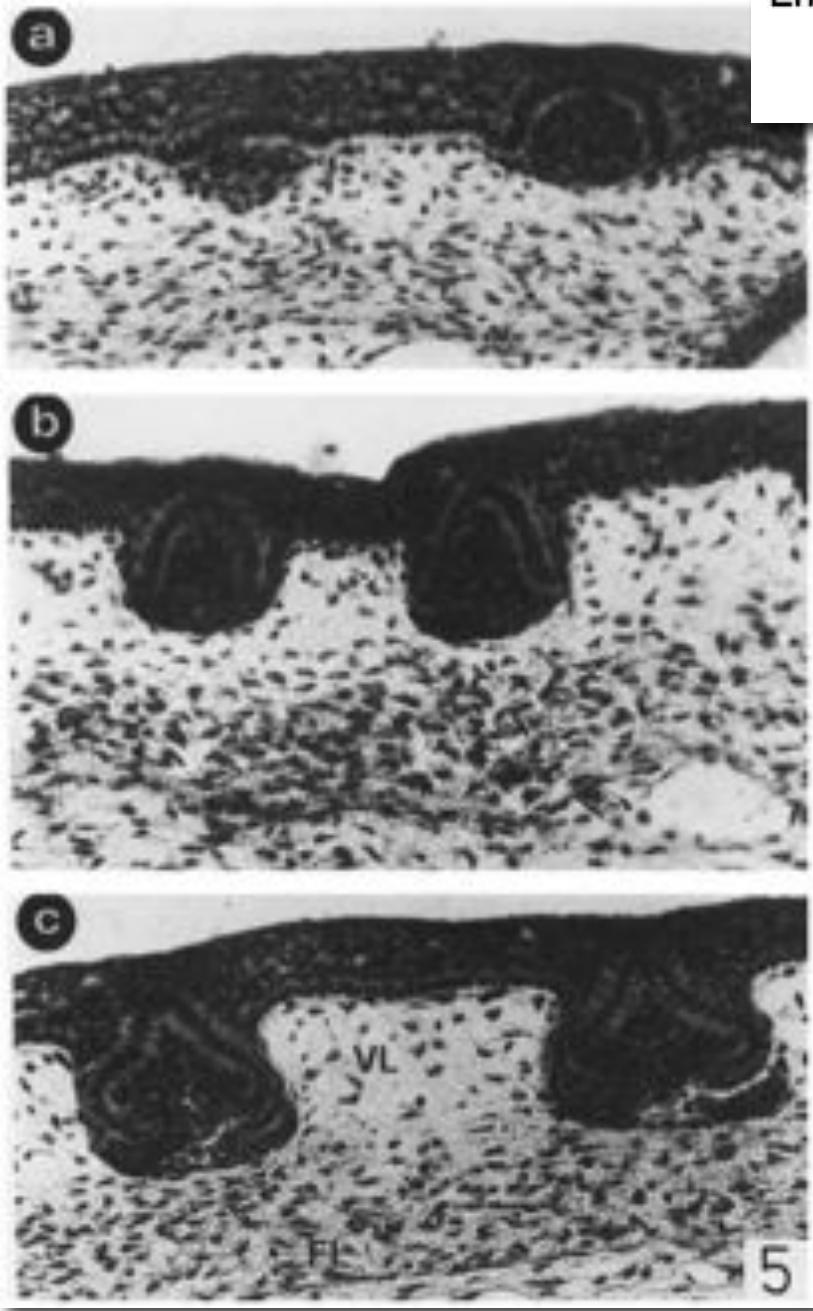


Teeth origin can be seen as evolution of odontogenic capacity in neural crest-derived mesenchyme

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

WOLF-ERNST REIF

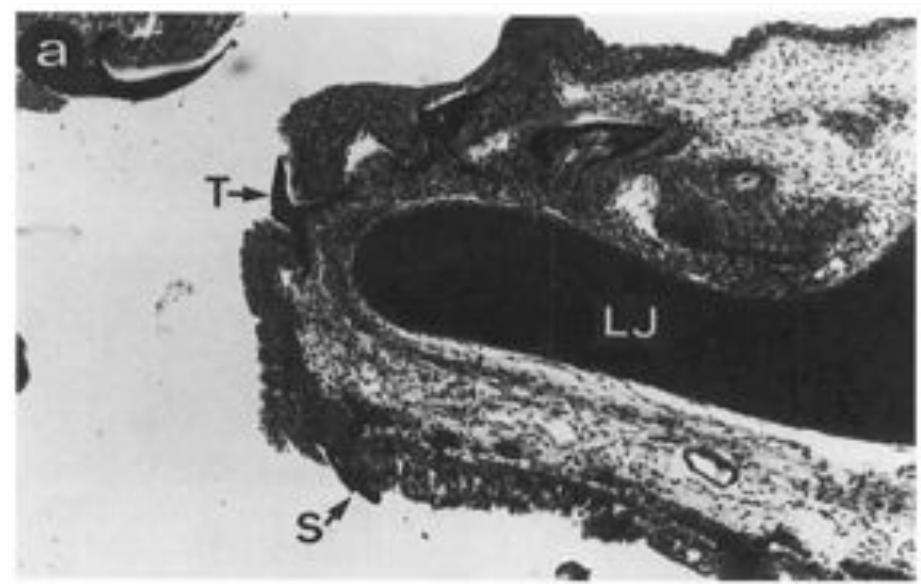
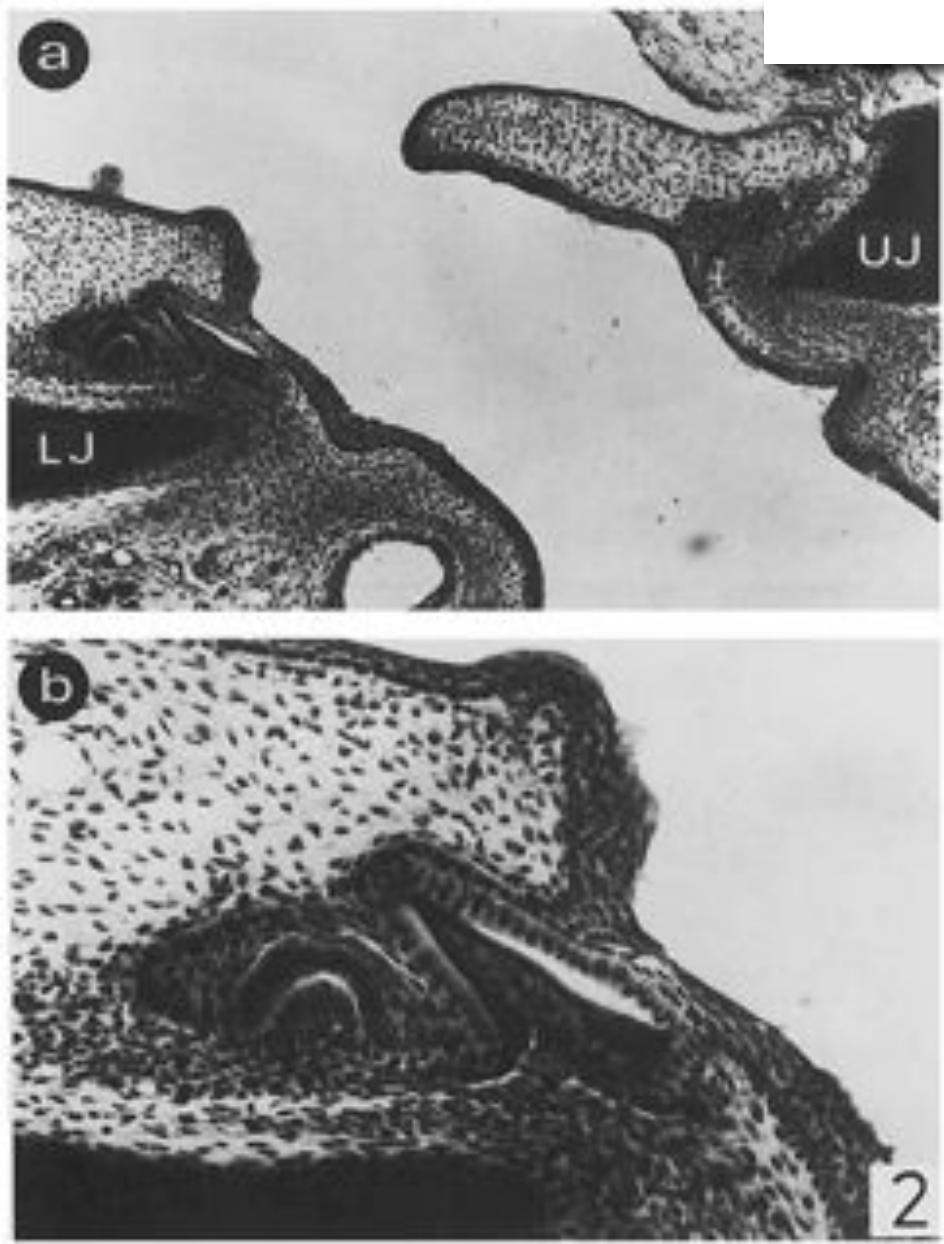
Institut für Geologie und Paläontologie der Universität Tübingen, Sigwartstr.10, D-7400
Tübingen-1, West Germany



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

WOLF-ERNST REIF

Institut für Geologie und Paläontologie der Universität Tübingen, Sigmaringerstr. 10, D-7400
Tübingen-1, West Germany



Several authors have assumed that in the postembryonic stages of Recent sharks, scales can morphologically grade into teeth (see, e.g., Smith, '37). This cannot, however, be confirmed. Scales do not grade morphologically into teeth during any postembryonic stage in a living shark; nor do they grade into each other with respect to their locus of formation (in the skin versus on the dental lamina), or with respect to their mode of eruption (Reif, '74a, '76a).

Dentition and dermal skeleton of *S. canicula* (and all other elasmobranchs) thus seem to develop rather independently from one another. This is shown by the difference in timing of the developmental processes; although these processes may sequentially be connected with reference to an "overall" biological clock-like regulation process. The difference is also

It is not known when scales of the second generation start to form in *S. canicula* and when the replacement of scales begins. Most sharks studied so far have scales both on the body surface and in the mouth cavity. As a rule, the formation of scales in the mouth cavity starts much later than on the body surface. It begins either at the end of embryonic development or in the first months of postembryonic development. As far as can be determined from the specimens available (up to 70 cm total length), *S. canicula* never develops scales in the mouth cavity.

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

WOLF-ERNST REIF

Institut für Geologie und Paläontologie der Universität Tübingen, Sigwartstr. 10, D-7400 Tübingen-1, West Germany

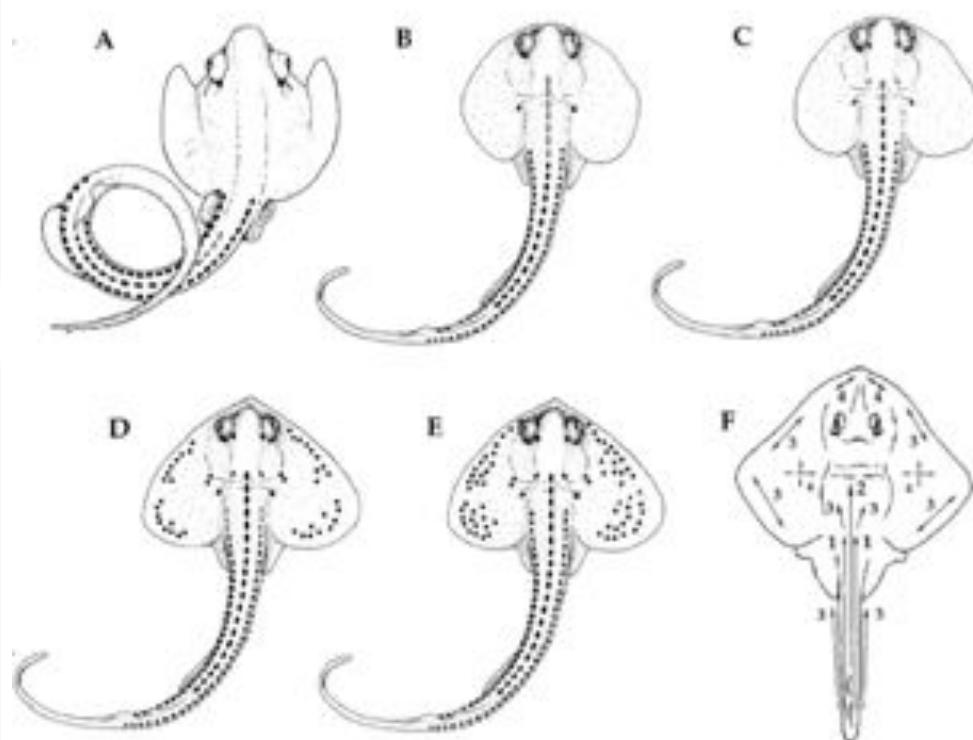
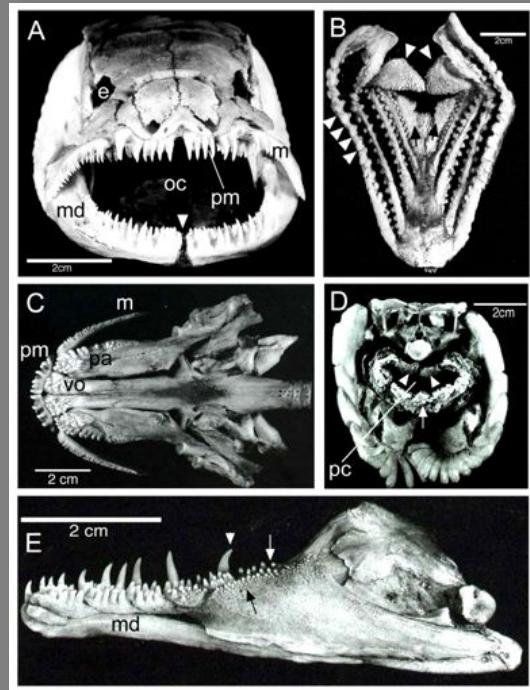


Fig. 4. *Leucoraja erinacea*. Patterns of dermal denticle development. Denticles which are externally visible are shown as black symbols; those which will be visible later are shown as open symbols. All embryos are shown at the same scale (A-E). F: A summary of the order and direction (1 to 9) of denticle development in the body. A: 12.5 mm in snout to cloaca (SVL). B: 15.6 mm in SVL. C: 15.8 mm in SVL. D: 19.2 mm in SVL. E: 20.0 mm in SVL.

Kde všude jsou zuby?

Případně jsou "orální" zuby z EKT a "faryngeální" z ENT?



Bowfin (*Ammia calva*)
represents a "primitive" dental
system



Rainbow Trout

• Teeth

present in
multiple
locations

• Homodont dentition

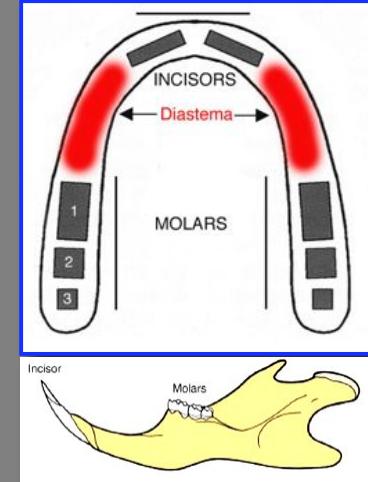
• Single row of
oral teeth



Zebrafish

• Homodont dentition

• No oral
teeth - teeth
restricted to
posterior
pharynx



Mouse

- A well-studied
model for
initiation of
heterodont
odontogenesis
no replacement
teeth

- How applicable
is the mouse
data to

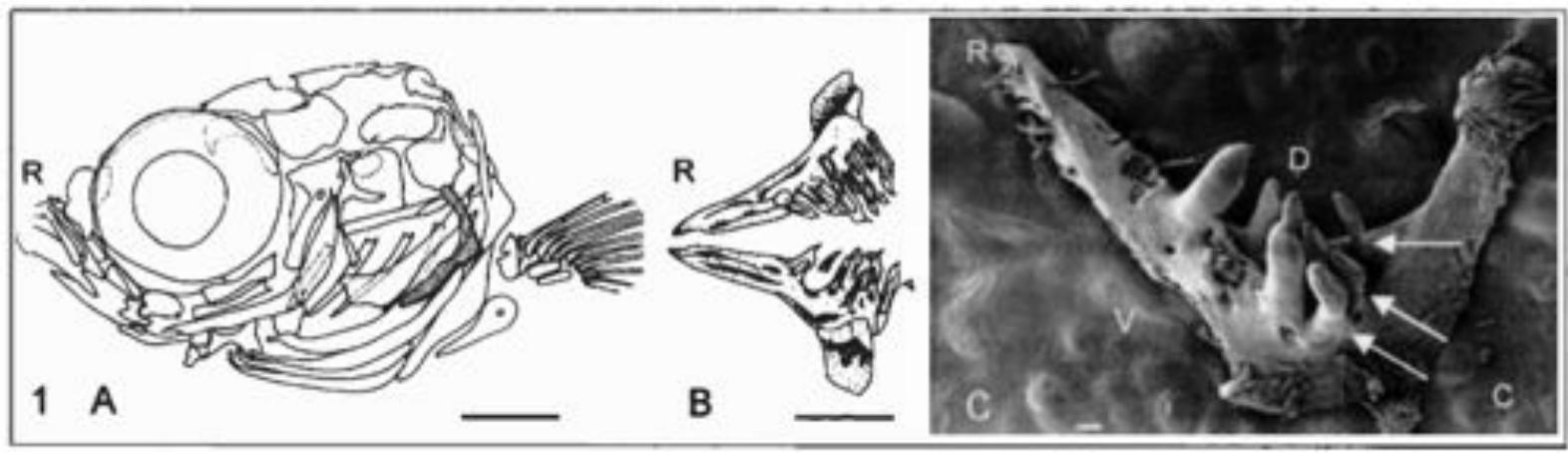
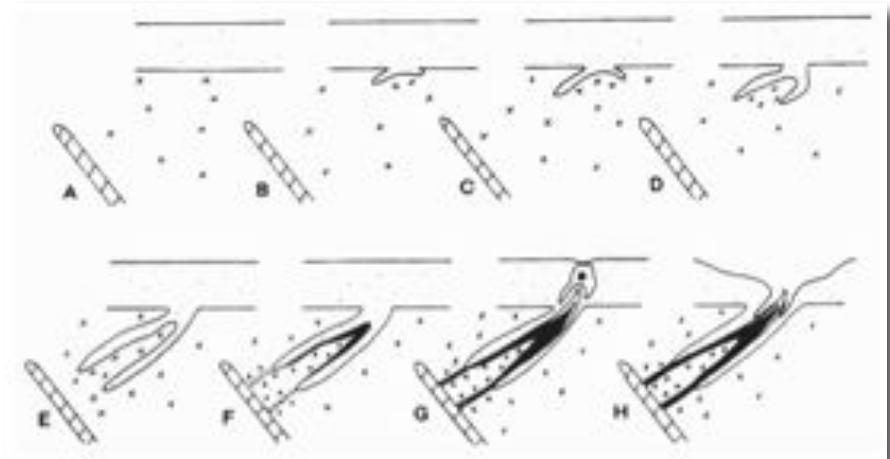


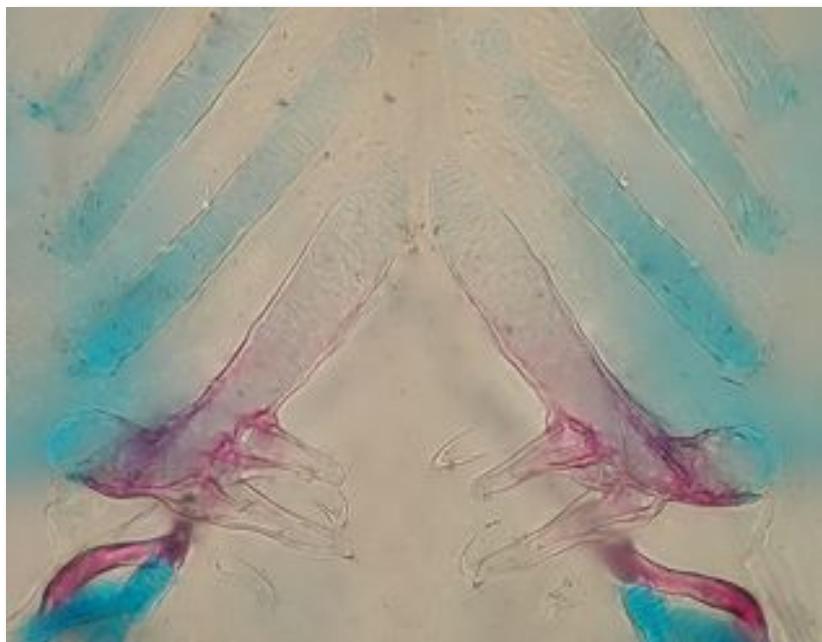
Kde všude jsou zuby?

Cypriniformes: zuby

faryngeální

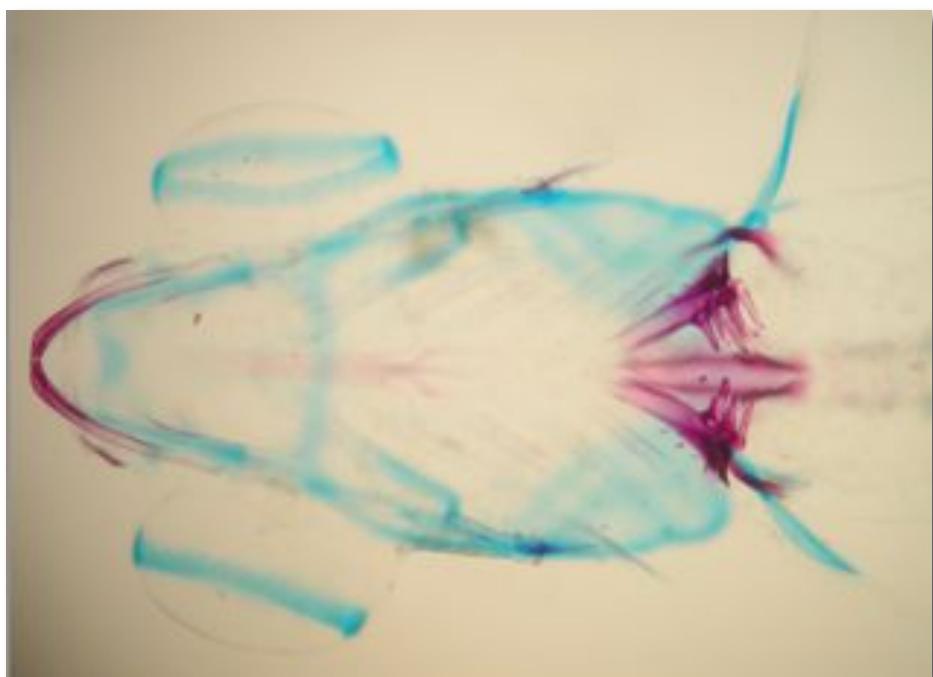
Cypriniformes ztratili orální zuby před cca 50 mil lety;
Přes 5 000 druhů v 5-ti čeledích;

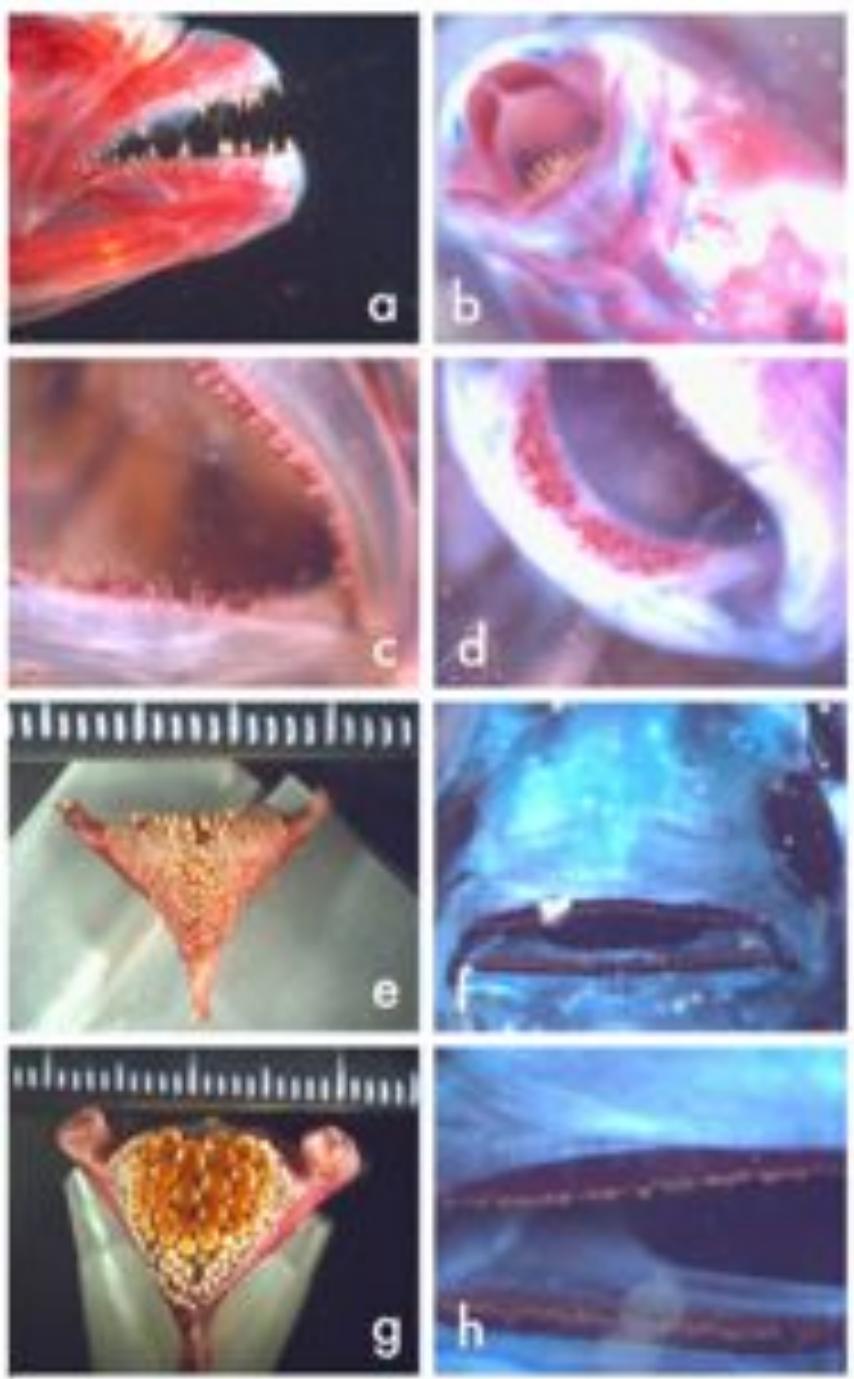




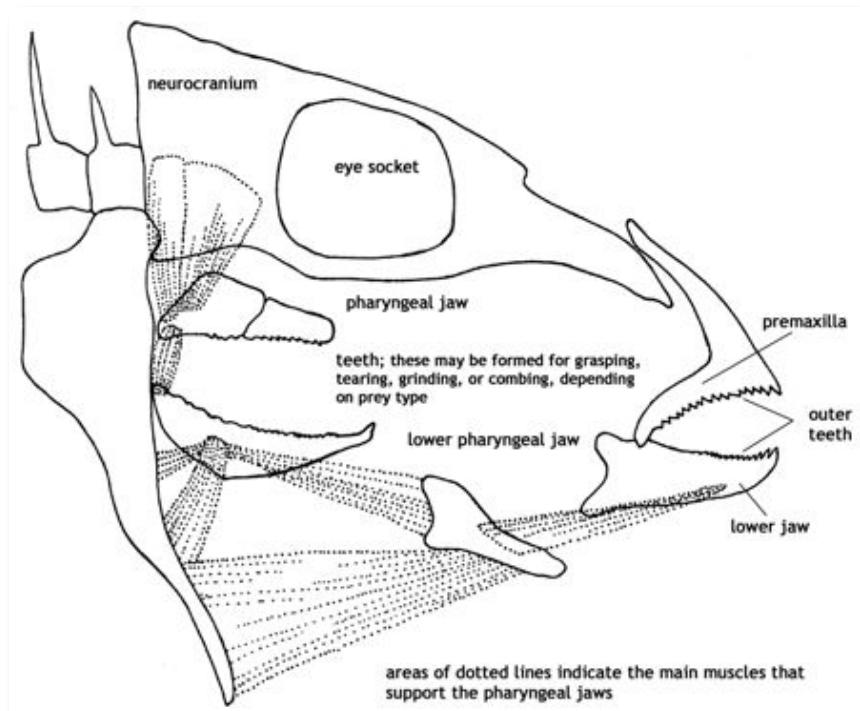
K d e v š u d e j s o u z u b y ?

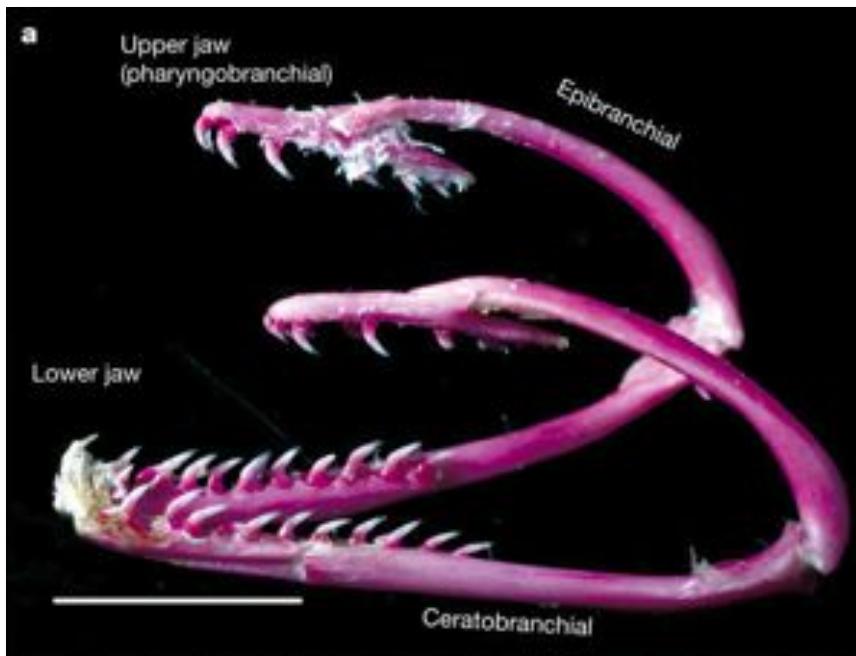
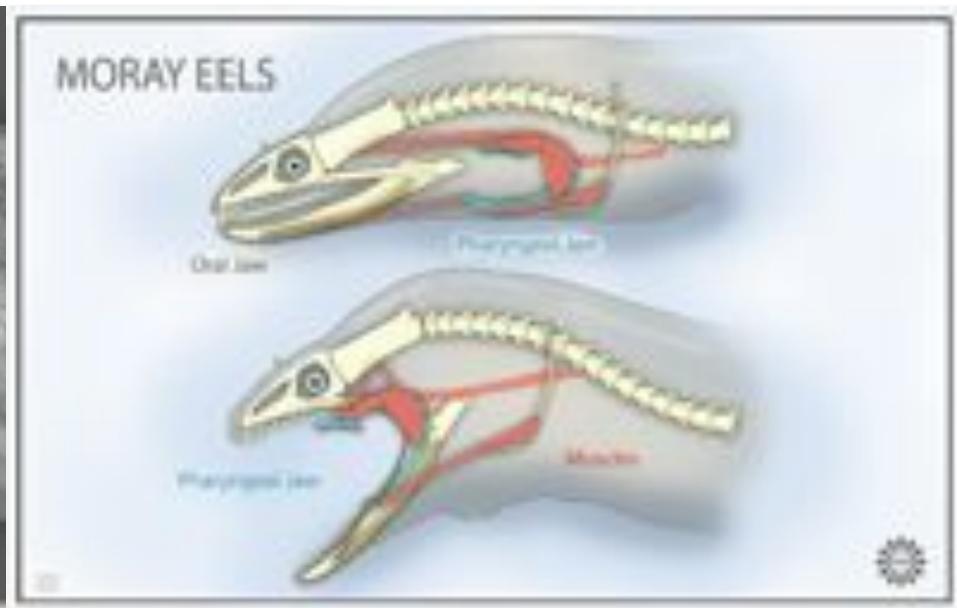
B o l e n i z u b y f a r y n g e á l a i





Kde všude jsou zuby?
Cichlid ycorální faryngeální
čelisti







Comparison of Teeth and Dermal Denticles (Odontodes) in the Teleost *Denticeps clupeoides* (Clupeomorpha)

JEAN-YVES SIRE,* STANISLAS MARIN, AND FRANÇOISE ALLIZARD
Université Paris 7-Denis Diderot and CNRS, URA 1137, Paris, France

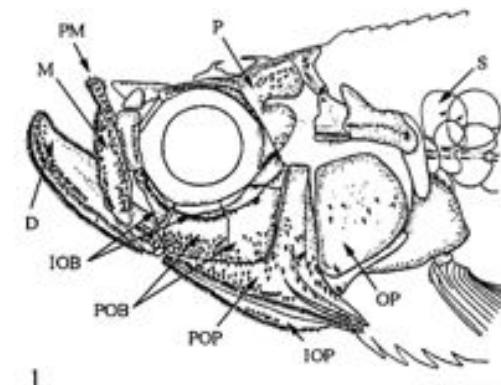
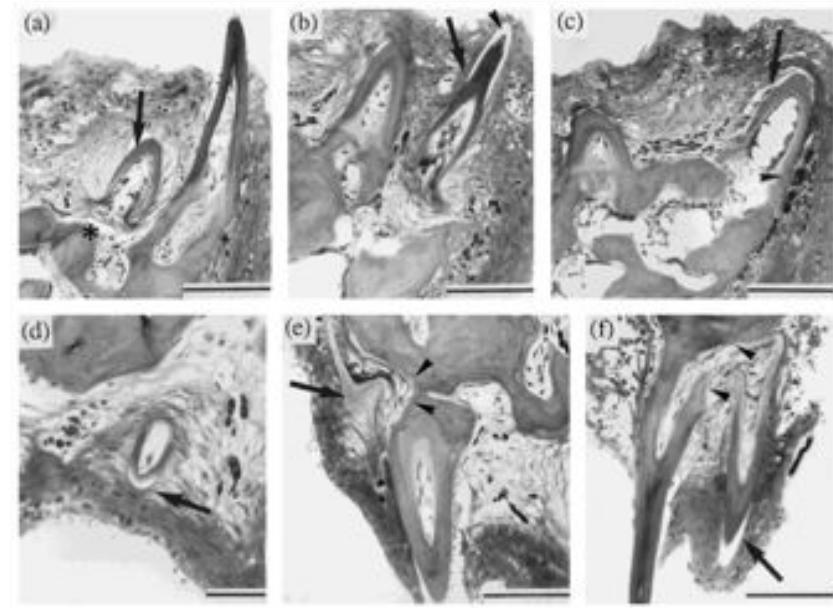
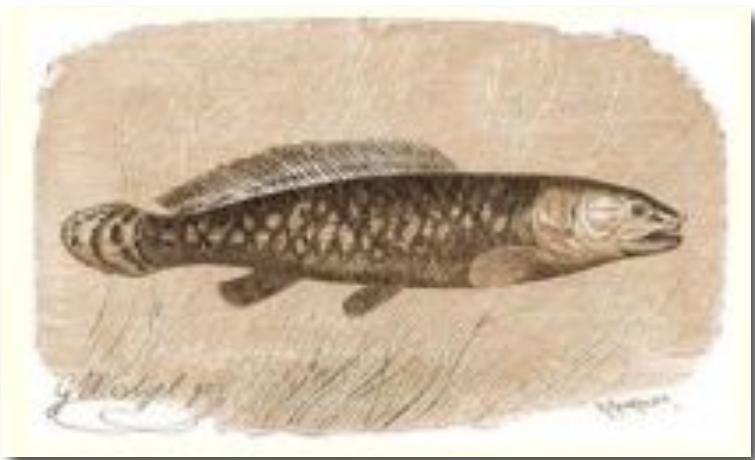


Fig. 1. Lateral view of the anterior part of the body in *Denticeps clupeoides* showing the distribution of the dermal denticles and the bones cited in this study. D, dentary; M, maxilla; IOP, interoperculum; OP, opercu-

lum; P, parietal; PM, premaxilla; POP, operculum; S, scale. Slightly modified after Clausen (59). Scale bar = 0.3 mm.





DEVELOPMENTAL DYNAMICS 18(3):626–636 (2002)

BRIEF COMMUNICATIONS

Tooth Development Is Independent of a Hox Patterning Programme

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Department of Craniofacial Development, IGT Dental Institute, King's College London, Guy's Hospital, London Bridge, London, United Kingdom

ABSTRACT Hox genes have a critical role in controlling the patterning processes of many tissues by imparting positional information in embryogenesis. Patterns of the pharyngula have postulated that the skull (or vertebral column) has been proposed to be influenced by this "Hox code." Recently, it has been shown that Hox genes are associated with the evolution of jaws, loss of Hox gene expression in the first branchial arch being necessary for the transition from the agnathan condition to the gnathostome condition. Teeth develop on the first branchial arch in mammals and, therefore, might be expected to be under the control of the cranial shield elements. However, we show that, unlike cartilage and bone, the development of teeth is not affected by alterations in *Hoxa2* expression. Tooth development in the first arch was unaffected by overexpression of *Hoxa2*, whereas relocalizations of second arch mesenchyme with first arch epithelium led to tooth development within a *Hoxa2*-positive environment. These data demonstrate that teeth develop from local epithelial signals, and that tooth development is not under the axial patterning programme specified by the Hox genes. We propose that the evolutionary development of teeth in the first branchial arch is independent of the loss of Hox expression necessary for the development of the jaw. © 2002 Wiley-Liss, Inc.

Key words: *Hoxa2*; tooth development; pharyngeal patterning; evolution

INTRODUCTION

The evolution of jaws in vertebrates facilitated a wide variety of feeding strategies and marked the onset of an explosion in vertebrate speciation. The exact mechanisms for the transition of the agnathan condition to the gnathostome condition are not fully understood (Maiat, 1996; Kimmel et al., 2001). Recently, it has been shown that in an agnathan group, lampreys, Hox genes are expressed in the first branchial arch,

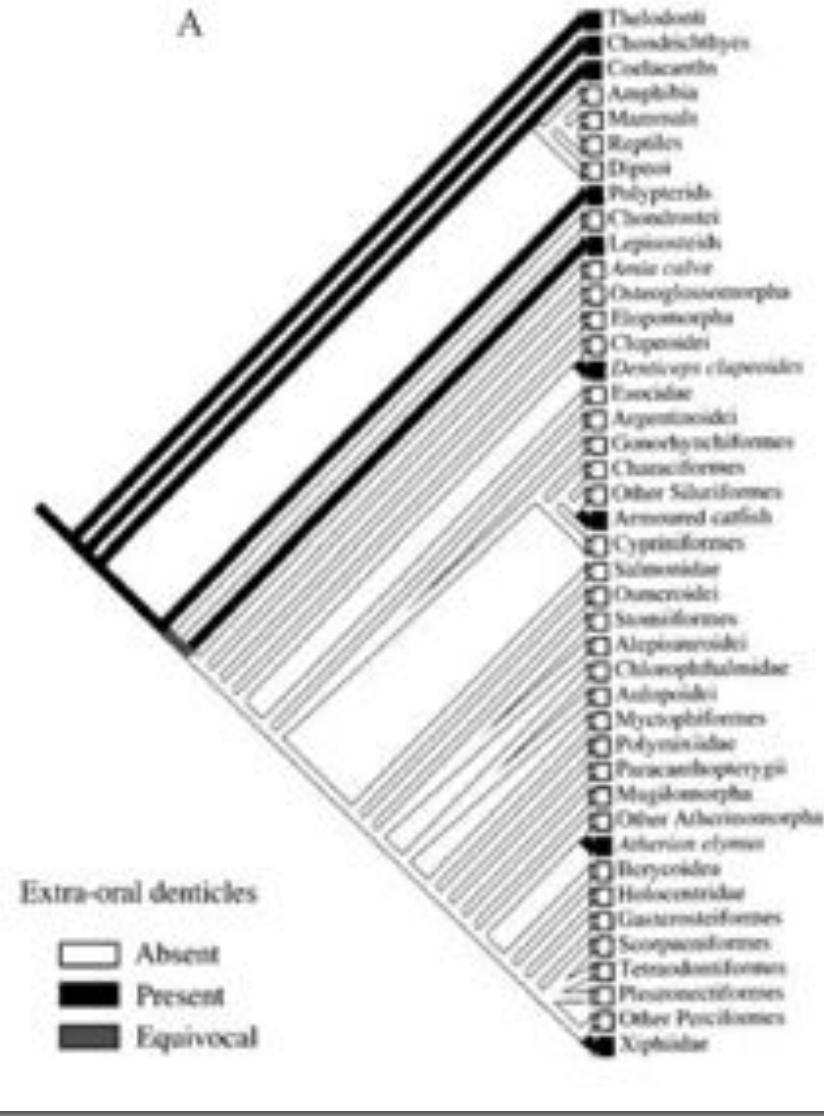
whereas in gnathostomes, Hox genes are not expressed in the corresponding mandibular arch. Indeed in neural crest emerging from the level of the second rhombomere, the mandibular rhombomere for the first branchial arch, *Hoxa2* is expressed (Prince and Lumsden, 1994). Thus, it is postulated that an evolutionary loss of Hox gene expression was essential for the skeletal rearrangement necessary for the development of the jaw (Cohn, 2002). Most of the hard tissues in the cranium are derived from neural crest, and these cells exert a crucial influence on patterning of the complex hard cranial structures and on the muscular connectivity (Blum et al., 1991; Konings and Lumsden, 1996). Overexpression of Hox genes in the first branchial arch neural crest, or grafts of Hox-expressing tissue to the first branchial arch fail to induce formation of the neural crest to differentiate into cartilage and bone (Ondrej et al., 1998; Grunewald-Piro et al., 2000). Hox gene expression, therefore, appears incompatible with lower jaw development. Teeth, like the skeletal elements, are ectomesodermally derived hard tissues and in amniotes are restricted to the first arch; an important question to ask, therefore, is, Are teeth subject to the same axial patterning controls as the visceroskeleton? We have attempted to answer this question by manipulating the expression of *Hoxa2*. *Hoxa2* is the anteriorly most active of the Hox genes and is expressed up to the border of rhombomeres 1 and 2 and in the mid-rostral of the second and many posterior branchial arches (Prince and Lumsden, 1994; Mannochie et al., 1999). Loss of expression of *Hoxa2* by gene knockout leads to duplication of first branchial arch structures (Rigli et al., 1993) and loss of second branchial arch hard tissues, whereas ectopic expression of *Hoxa2* in the first branchial arch leads to a duplication of structures of

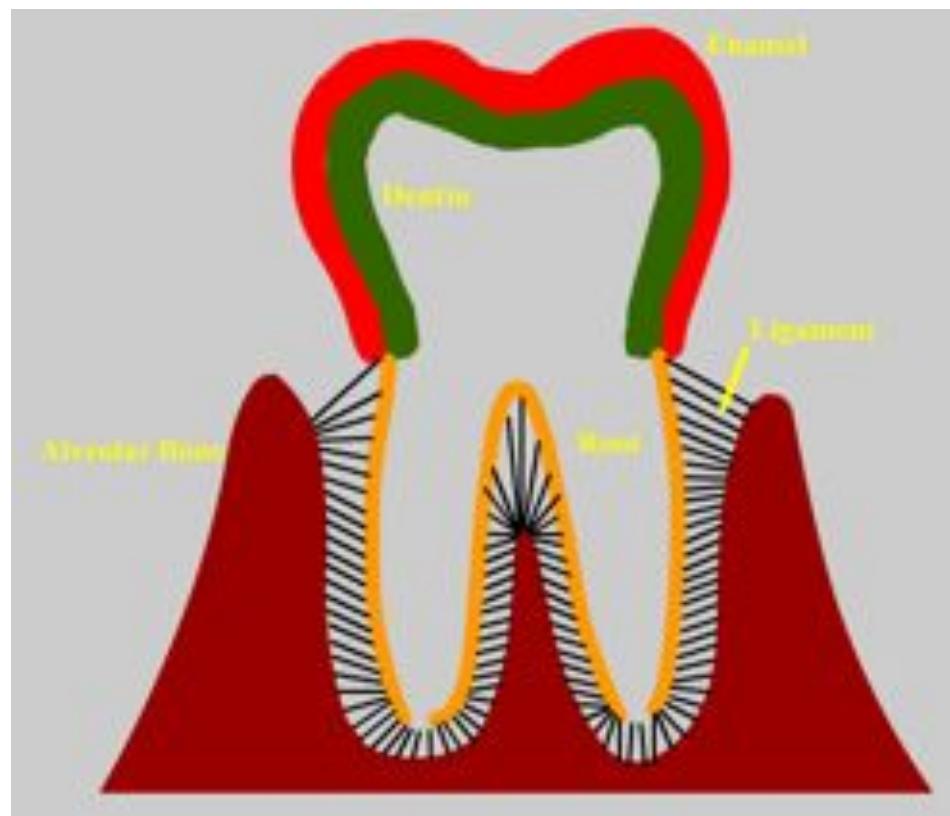
Grant sponsor: Wellcome Trust; Grant sponsor: MRC
*Key dishes and Ogiama have contributed equally to this work.
Correspondence to: Paul T. Sharp, Department of Craniofacial Development, Faculty of Dentistry, Dental Institute, Guy's Hospital, London Bridge, London SE1 8ET UK. E-mail: paul.sharp@kcl.ac.uk
Received 1 July 2002; Accepted 15 August 2002
DOI 10.1002/dvdp.10166

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K d e v i s u d e j s o u z u b y ?

P l e s i o m o r f n i s t a v i z u b y

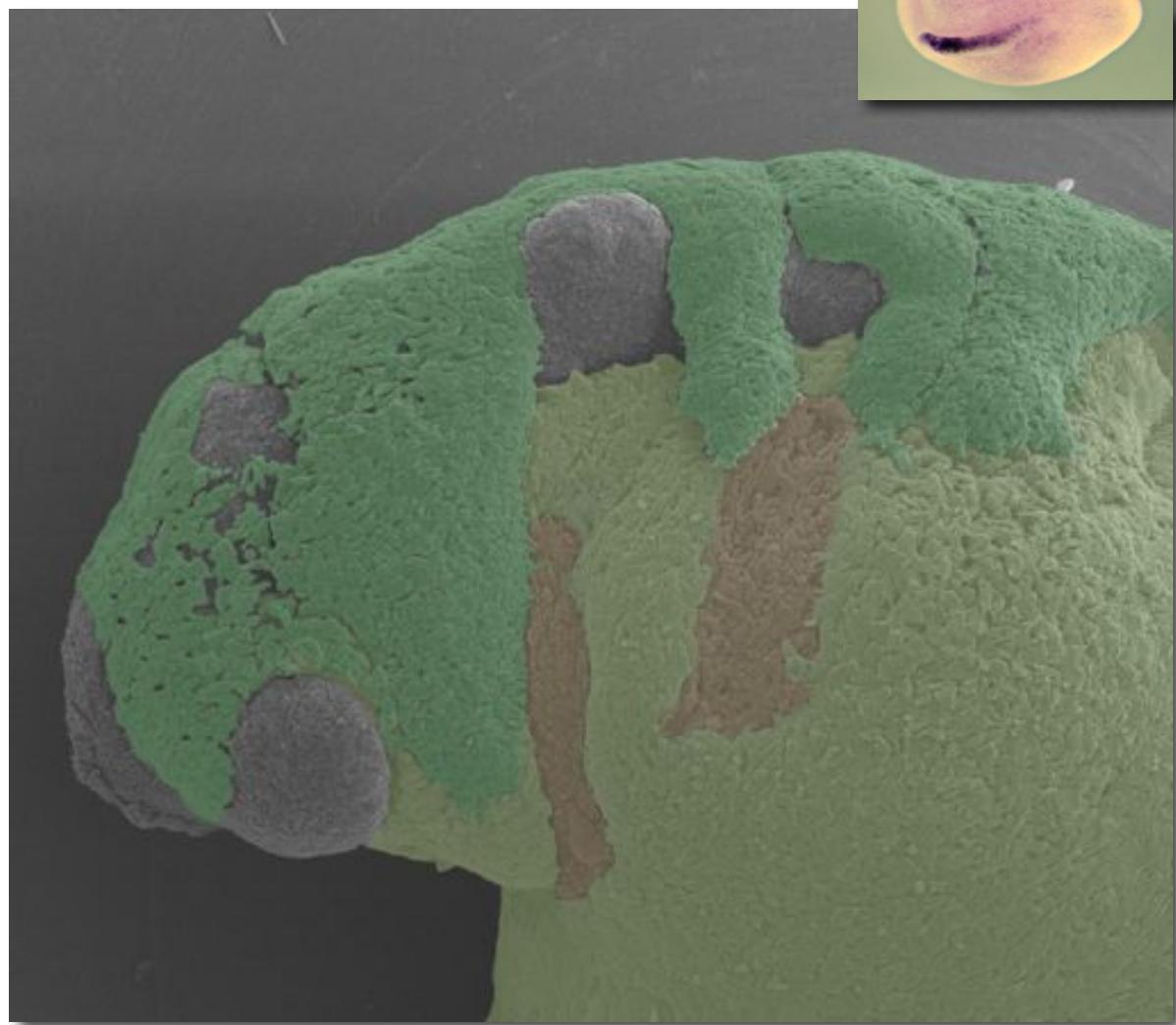
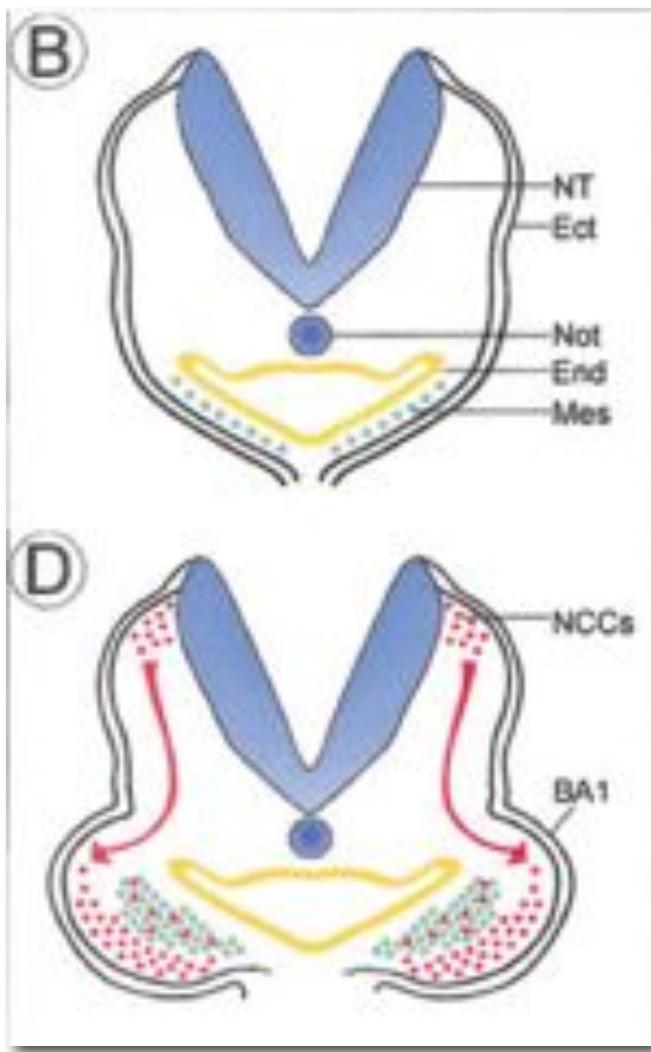




O e m b r y o n á l i n i m v z n i k u z u b u

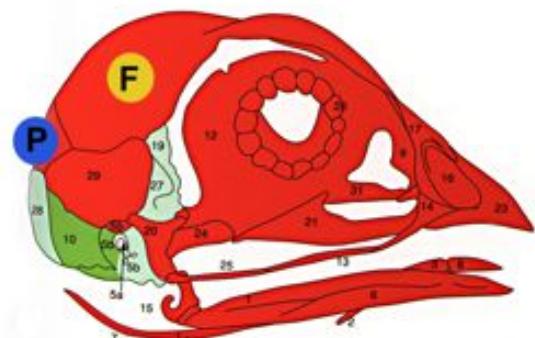
M e s e n c h y m p ū v o d u n e u r á l n í l i š t y

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O embryonálním vzniku zuba
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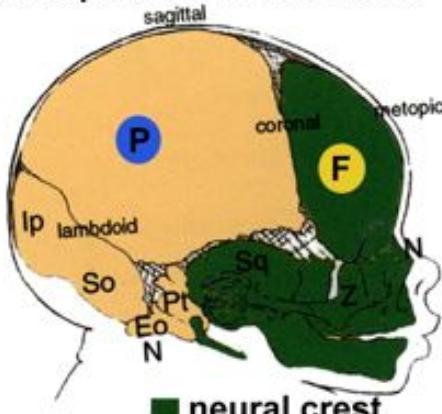
chick skull:



■ neural crest

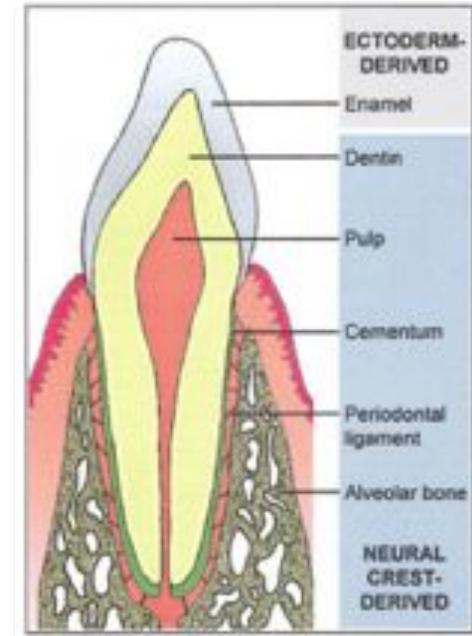
The neural crest (2. nd, 1999)

human skull,
 extrapolated from mouse:



■ neural crest

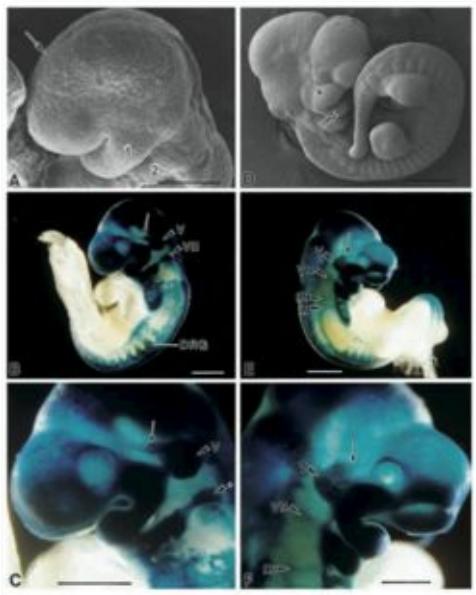
J.Anat. 2001



Příspěvek buněk NL do lebky: myš, kuře, Xenopus;
 Příspěvek buněk NL do zuba: myš, mlok, ...?

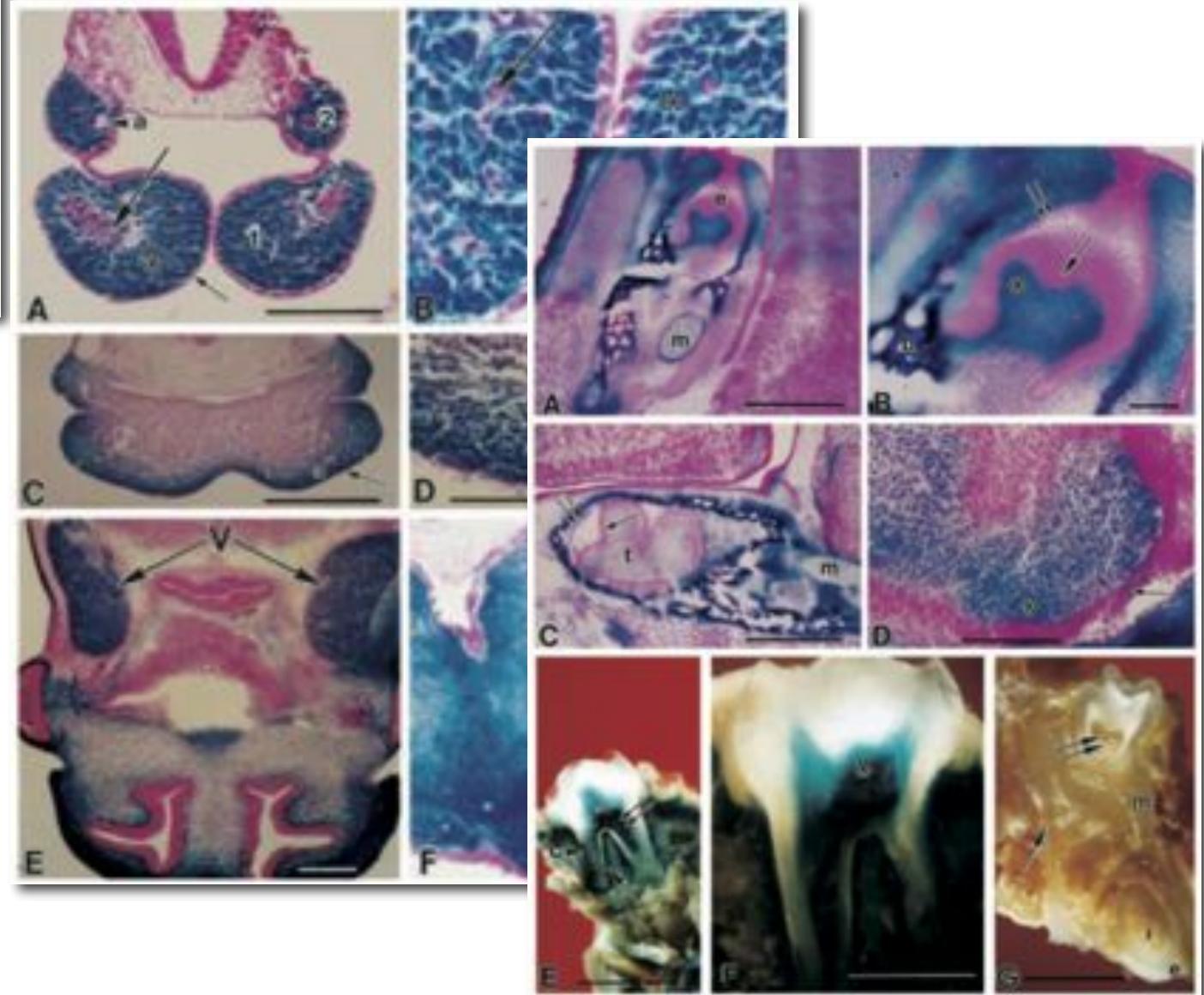
Problém s dermis:
 ekto-mesenchym vs. MES-mesenchym

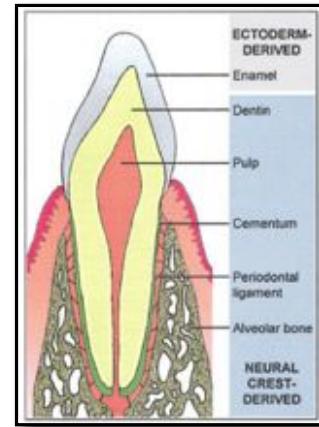
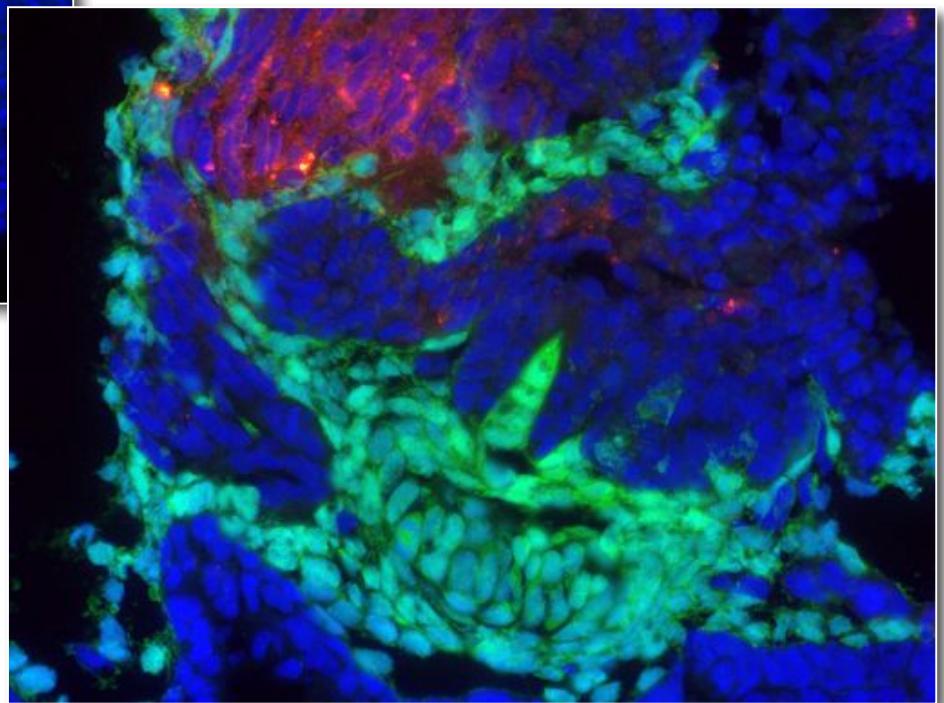
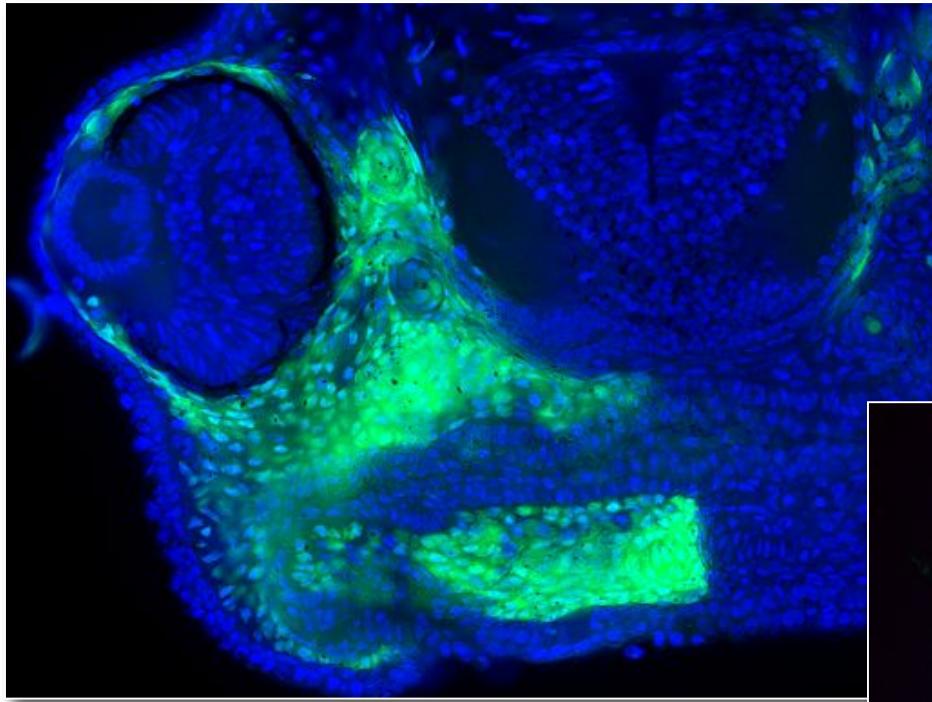




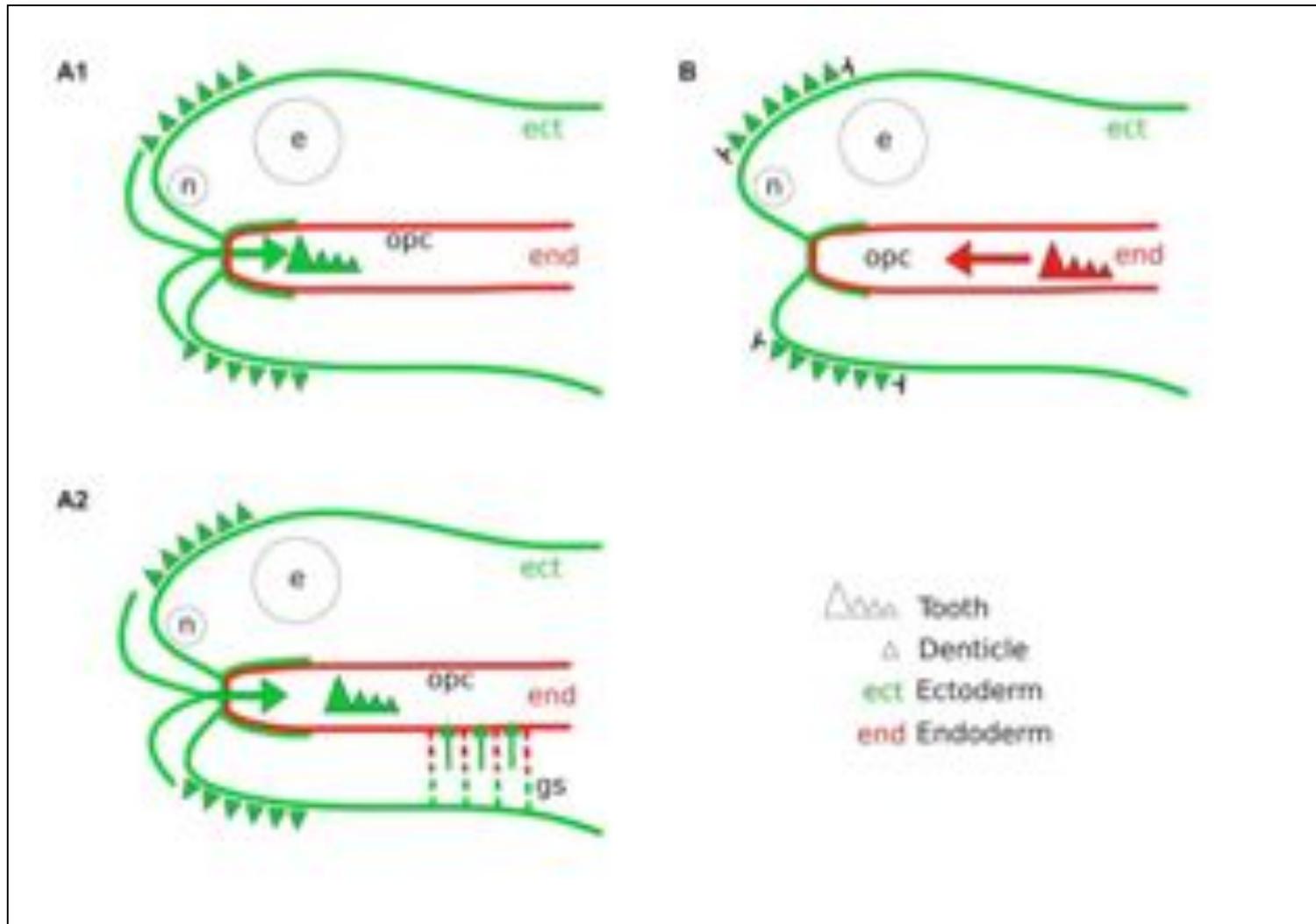
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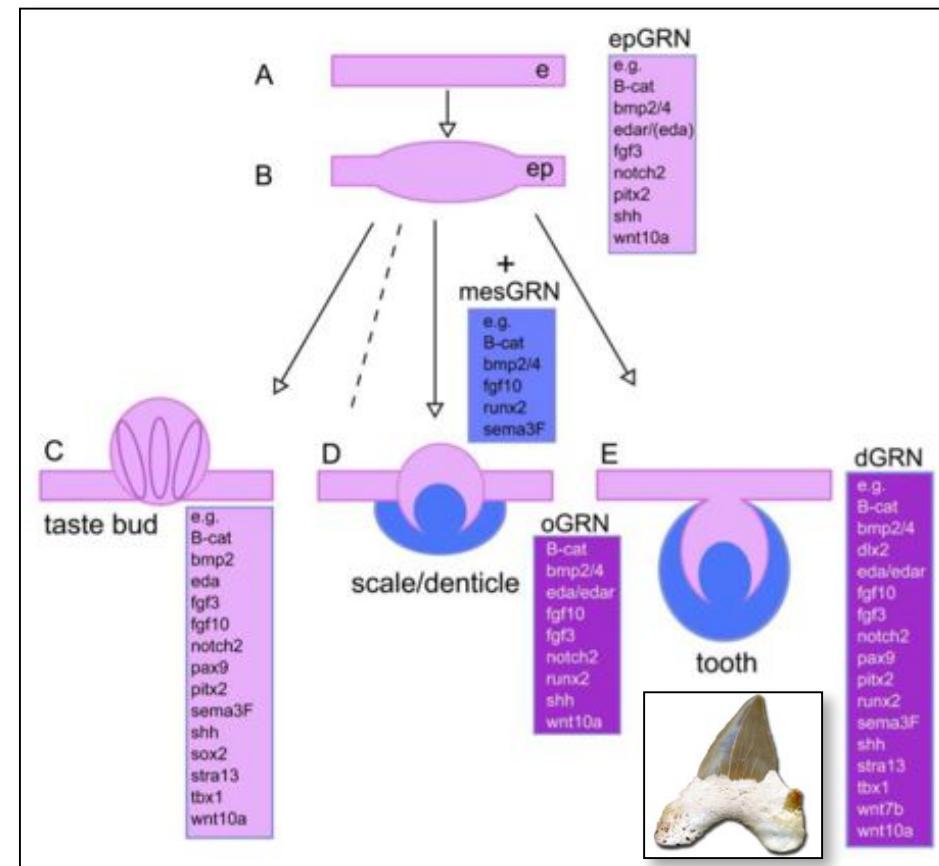
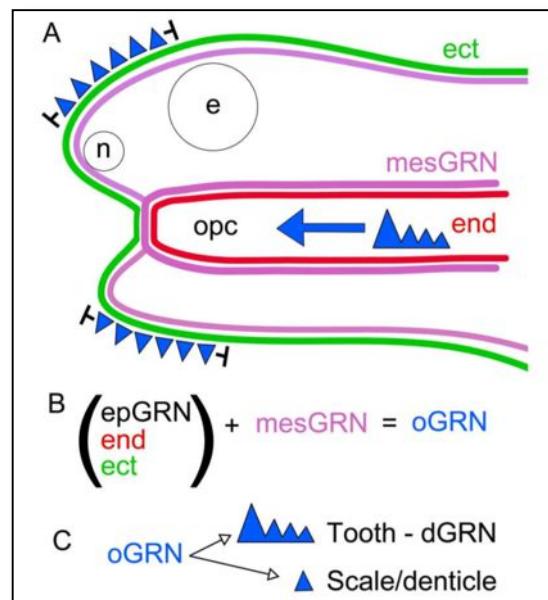




Evoluční původ zuba: EKT vs. ENT



A new perspective: collaborative interactions of ep- & NC-GRN's



Gene networks, neural crest and the advent of vertebrate dentitions

G.Fraser, R.Cerny, V.Soukup, J.Streelman: subm)

