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Enamel Prism of Mammalian Tooth

By

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Abstract

The growth lamellae of enamel are first secreted as TOMES' process, and are gradually calcified in relation to the formation of enamel prisms. The pattern of enamel prisms itself is of little use for phylogenetic and taxonomic purpose, as it is essentially circular, so far in the numerous genera examined. On the other hand, the structural pattern of enamel prisms is recommended to be systematically studied for the same purpose, following up KORVENKONTIO and BOYDE.

Introduction

Since SMREKER (1903), many specialists were concerned with a dispute about prism pattern of enamel. Their examinations, based mainly on rather thick ground sections by means of light microscope, could have come to a resonable conclusion on the dispute. But almost all specialists sided gradually with SMREKER, and offered further data that the enamel prisms show characteristic patterns that may be used as taxonomic indicators for mammals. Recent transmission electron microscopy (TEM) and scanning electron microscopy (SEM) have rivived the dispute.

The present work aims to examine the prism pattern of mammalian tooth, and to discuss the potential of enamel prisms for phylogenetic and taxonomic deduction. The following materials were tentatively checked: *Trichosurus, Sorex, Urotrichus, Tupaia, Simias, Macaca, Hylobates, Homo, Oryctolagus, Sciurus, Petaurista, Cricetus, Microtus, Mus, Rattus, Apodemus, Neotoma, Phenacomys, Cavia, Hystrix, Dugong, Stegodon, Elephas,* rhinocerotids, *Sus, Cervus, Ursus, Canis, Vulpes, Nyctereutes* and other genera.

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Outline of Enamel Prism

In the enamel of mammalian tooth, there are accumulated numerous growth lamellae with boundaries, which are corresponding to RETZIUS' lines in ground section. The growth lamellae are centrifugally arranged throughout all stages of growth, and completely involved in the earlier stages, but partly evolved in the later stages. The growth lamellae are usually about 20 microns in thickness, nearly the same as those of other calcified organs. Their thickness is, however, remarkably variable from portion to portion of tooth. Finally, due to their successive accumulation, change of thickness, bifurcation, folding and other factors, the growth lamellae build up various external forms of tooth.

The growth lamellae are mainly constructed from innumerous enamel prisms and interprismatic bundles or sheets, these consist of elongated crystallites. In a labial-lingual section of a first lower incisor of a macaque adult, the enamel prisms are only rudimentarily present near the evolved parts of growth lamellae, while they are rather well developed in the involved parts (see Pl. 1, Fig. 1a). The enamel prisms are provided with several cross-striations within the thickness of a growth lamella, as if they were periodically built up, and are often fused to each other across the boundaries of lamellae (see Pl. 1, Figs. 1b, c). As a reuslt, RETZIUS' lines become fainter from the enamel surface to the inner part (see Pl. 1, Fig. 1a), although this tendency is more or less emphasized by artificial factors.

On the surface of a third lower premolar of a prenatal macaque individual, TOMES' process is hexagonally or polygonally framed, and other minor structures are also seen in the process pits, but neither crystallites nor enamel prisms are formed at all (see Pl. 3, Fig. 1). A lot of hydroxyapatite pellets, some microns in size, are often secreted in the process pits. They may be recrystallized so as to be crystallites. All these facts mentioned above, as well as the description and illustration of BOYDE (1978), show that the growth lamellae are first framed as TOMES' process and gradually calcified in relation to the formation of enamel prisms.

Pattern of Enamel Prism

SMREKER (1903) observed the enamel prisms of *Homo sapiens*, and named their characteristic pattern "Arkadenform" (arcade-shape): one side of a prism is corresponding to a convex arch in cross section, and the other side to one or two concave arches. WALKHOFF (1903) regarded, however, the arcade-shape as apparent. Then, many specialists were concerned with a dispute about prism pattern. CARTER (1922), SHOBUSAWA (1952) and others offered further data that the enamel prisms show characteristic patterns to be utilized as taxonomic indicators of mammals.

Using TEM or SEM, KAIBARA (1968) pointed out the arch-, slate- and lemon-shaped patterns of *Elephas* teeth, SAHNI (1979) the horseshoe-shaped pattern of the Cretaceous *Stygimys*, and so on. GANTT *et al.* (1977) reported that *Homo sapiens* and the Miocene *Ramapithecus* are provided with keyhole-shaped pattern, and the pongids with circular or hexagonal pattern. But VRBA and GRINE (1978) argued that the prism pattern is essentially similar in all modern and extinct hominoid species.

To solve the conflict, whether or not the prism pattern is a potential element for phylogenetic and taxonomic deduction of mammals, a milk incisor of the Pleistocene *Stegodon* yielded from Sangiran in Indonesia was examined at first. In a mesial-distal section, the enamel prisms are indeed arcade-shaped or ginkgo leaf-shaped at a glance (see Pl. 2, Fig. 1a). At greater magnification, however, they look either circular or arcade-shaped (see Pl. 2, Figs. 1b, c). A detailed observation makes clear that the arcade-shaped or ginkgo leaf-shaped pattern is nothing but a compound one, composed of crossly cut outlines of two or three (mostly three) adjacent prisms. The convex arch is corresponding to an outline of a prism, but the both concave arches to those of the second and third prisms. A rhinocerotid molar from the Pleistocene of Sangiran, as well as the same one from the Miocene of Iran, shows the arcade-shaped or ginkgo leaf-shaped pattern at lower magnification, but the circular pattern at greater magnification (see Pl. 2, Fig. 3). Thus, the apparent patterns mentioned above are not limited to *Homo* or *Elephas*.

In a mesial-distal section of a first incisor of an adult *Homo sapiens*, the prism pattern looks either keyhole-shaped, as illustrated by GANTT *et al.* (1977), or arcade-shaped (see Pl. 1, Figs. 2a, b). But an exceedingly magnified figure (Pl. 1, Fig. 2c) shows without doubt that the keyhole-shaped pattern is compound as well as the arcade-shaped pattern. Many other apparent patterns, such as the slate-, lemon-, horseshoe-shape and so on, are seen even in a figure (Pl. 2, Fig. 2), and much better in the figure illustrated by VRBA and GRINE (1978, Fig. 2b).

The enamel prisms are essentially circular in cross section, so far in the numerous genera examined. They are, however, easily variable in shape, depending on their position in the growth lamellae: sometimes elliptical, rectangular, hexagonal or polygonal (see Pl. 3, Fig. 2), and rarely triangular or pentagonal. In addition, the enamel prisms are slightly different from the calcified TOMES' processes (prism sheaths) in chemical composition, more or less strongly twisted, and not uniform in shape, as shown by cross-striations. The crystallites vary remarkably in chemical reaction, depending on their orientation to the etching surface, as illustrated by BOYDE (1978). Therefore, the prism pattern is much emphasized in ground section. All these facts mentioned above suggest that the pattern of enamel prisms itself is of little use as taxonomic indicators for mammals.

Structural Pattern of Enamel Prism

KORVENKONTIO (1934–1935) divided the enamel of mammalian tooth into two structural types: the uniserial type, in which each SCHREGER's band consists of a single row of enamel prisms, and the multiserial type, in which several rows of identically oriented enamel prisms are gathered as a band. The former is specially limited to rodents, while the latter is commonly seen in other mammals. BOYDE (1978) revealed that the enamel of mammalian tooth is mainly constructed from enamel prisms and interprismatic bundles or sheets of crystallites, and that at least three structural patterns of the internal enamel are clearly defined in the rodent incisors. Those results were briefly reviewed in the present work.

In *Sciurus* and *Petaurista* of the suborder Sciuromorpha, the internal enamel of the lower incisor is uniserial, and the interprismatic bundles are almost completely lacking (see Pl. 3, Fig. 4; BOYDE, 1978, Fig. 1). In *Cricetus, Microtus, Rattus, Mus, Apodemus, Neotoma, Phenacomys* and other genera of the suborder Myomorpha, the internal enamel of the lower incisor is also uniserial, but quite different from that of the suborder Sciuromorpha in having well grown interprismatic bundles or sheets of crystallites (see Pl. 3, Fig. 5, 6; BOYDE, 1978, Figs. 2–5). In *Cavia* and *Hystrix* of the classical suborder Hystricomorpha, the internal enamel of the lower incisor is multiserial, only two to five rows of identically oriented prisms are gathered as a band (see Pl. 3, Fig. 3; BOYDE, 1978, Figs. 11, 12), and the interprismatic bundles or sheets are well developed so as to be inter-row sheets. These reviews show that three classical suborders of the order Rodentia are surely separated from each other by the structural pattern of enamel prisms.

Further characteristic features are found in the structural pattern of enamel prisms. For example, in *Macaca, Simias, Sus, Cervus* and others, the interprismatic sheets are markedly grown to be regared as inter-row sheets, which define a boundary between two adjacent rows of enamel prisms (see Pl. 3, Fig. 2). On the other hand, *Trichosurus* seems to have another kind of arrangement: the interprismatic bundles are fairly developed between two adjacent prisms within a single row. Each SCHREGER's band found in the rhinocerotid molars is constructed from numerous rows of prisms, and is hardly twisted from the enamel-dentine junction to the enamel surface. Thus, the appearance of SCHREGER's bands may be utilized as taxonomic indicators for mammals, as stated by KAWAI (1955). Namely, the pattern of enamel prisms itself is of little use, but the structural pattern of enamel prisms is recommended to be systematically studied for phylogenetic and taxonomic deduction of mammals.

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Explanation of Plate 1

Fig. 1. Labial-lingual section of a first lower incisor of *Macaca*, adult.

a) Showing the growth lamellae, enamel prisms and SCHREGERS' bands, incisal left, enamel surface bottom, × about 350.
b) Enlarged detail showing RETZIUS' lines and emamel prisms, the latter being partly fused across the former, × about 1300.
c) Highly enlarged detail showing the enamel prisms with cross-striations, × about 3000.

Fig. 2. Mesial-distal section of a first lower incisor of *Homo sapiens*, adult.

a) Showing various apparent patterns of enamel prisms, × about 1300.
b) Enlarged detail showing the "keyhole-shaped" and "arcade-shaped" patterns, × about 3000.
c) Highly enlarged detail showing the "keyhole-shaped" pattern as an apparent one, × about 6000.

Explanation of Plate 2

Fig. 1. Mesial-distal section of a milk incisor of *Stegodon*, Pleistocene.

a) Showing the "ginkgo leaf-shaped" pattern of enamel prisms, × about 1500.
b) Enlarged detail showing the "ginkgo leaf-shaped" pattern, × about 3000.
c) Enlarged detail showing the "arcade-shaped" pattern, × about 3000.
d) Highly enlarged detail showing the circular pattern, × about 6000.

Fig. 2. Mesial-distal section of a milk incisor of *Stegodon*, Pleistocene, same as the specimen illustrated in Fig. 1, but another section, showing various patterns of enamel prism, the "horseshoe-shaped" pattern in bottom right, "ginkgo leaf-shaped" in left, true pattern in center, and so on, × about 1500.

Fig. 3. Mesial-distal section of a rhinocerotid molar, Pleistocene, showing the "ginkgo leaf-shaped" and circular patterns of enamel prisms, × about 3500.

Explanation of Plate 3

Fig. 1. Surface of a third lower premolar of *Macaca*, prenatal, showing TOMES' process and other minor structures in the process pit, × about 10000.

Fig. 2. Labial-lingual section of a lower incisor of *Cervus*, adult, showing rectangular outline of enamel prisms and interprismatic sheets of crystallites, × about 3000.

Fig. 3. Labial-lingual section of a lower incisor of *Hystrix*, showing the multiserial pattern of the internal enamel, enamel-dentine junction top, × about 1000.

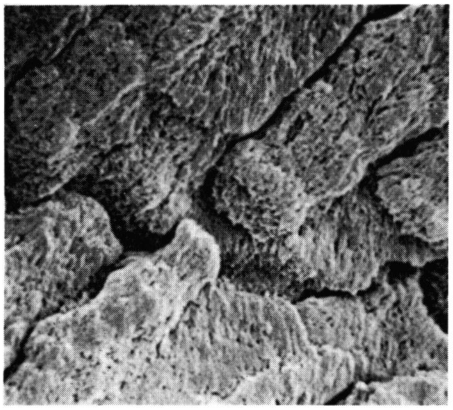
Fig. 4. Labial-lingual section of a lower incisor of *Sciurus*, showing the uniserial pattern of the internal enamel, enamel-dentine junction left, × about 3000.

Fig. 5. Labial-lingual section of a lower incisor of *Neotome*, showing the uniserial pattern and interprismatic sheets, × about 4000.

Fig. 6. Labial-lingual section of a lower incisor of *Rattus*, showing the uniserial pattern and interprismatic sheets, × about 5000.

1a

1b



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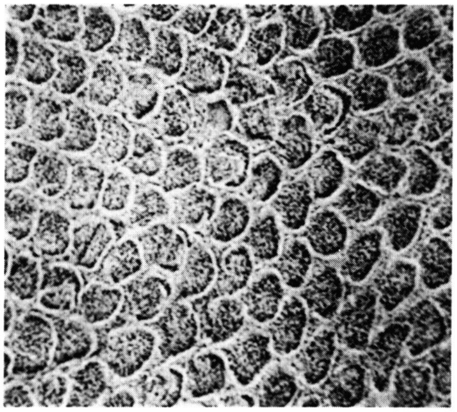

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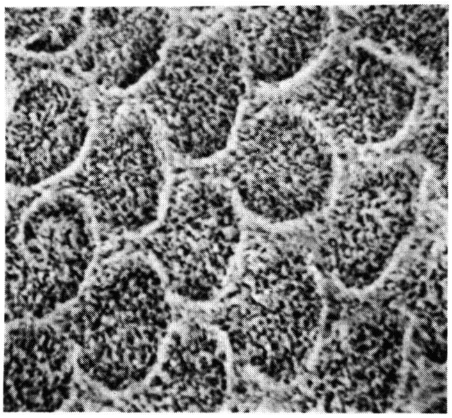

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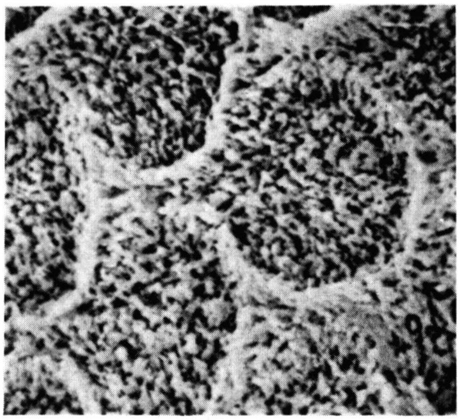

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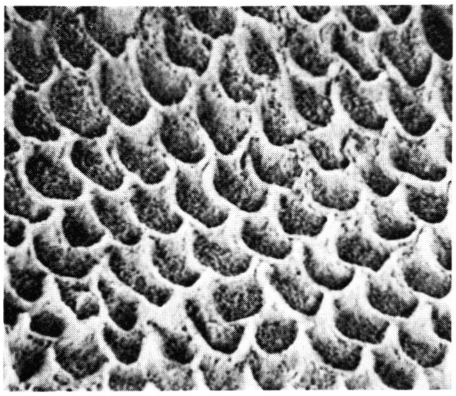

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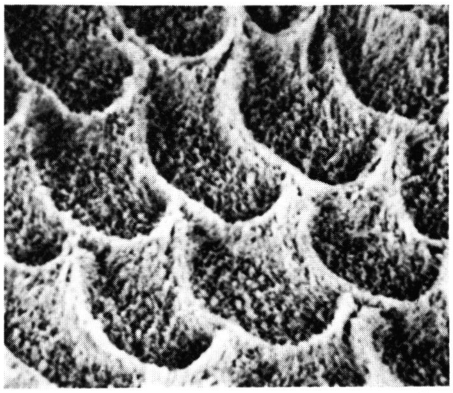

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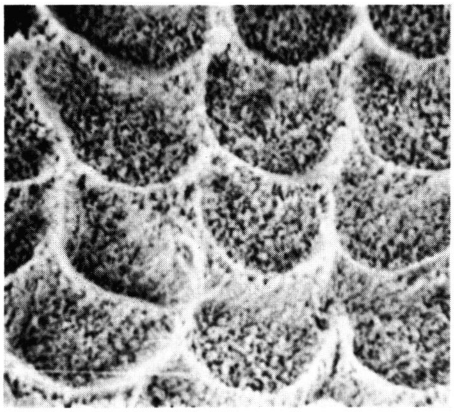

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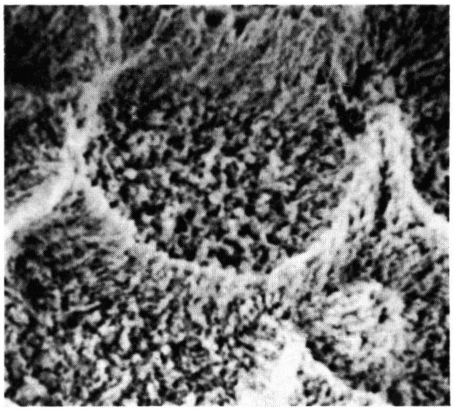

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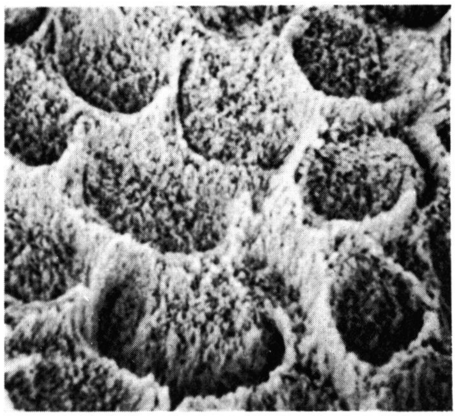

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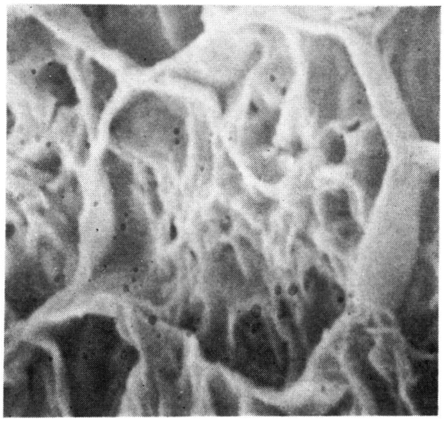
NOGAMI: Enamel Prism of Mammalian Tooth



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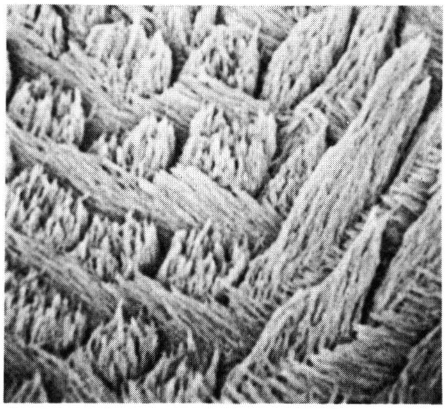

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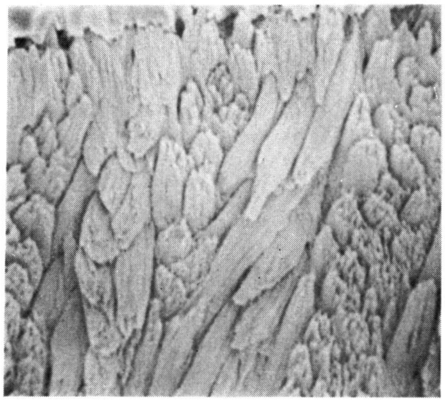

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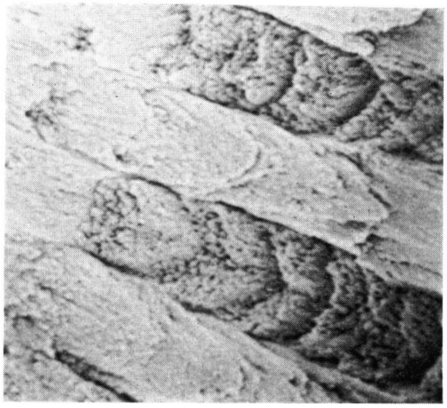

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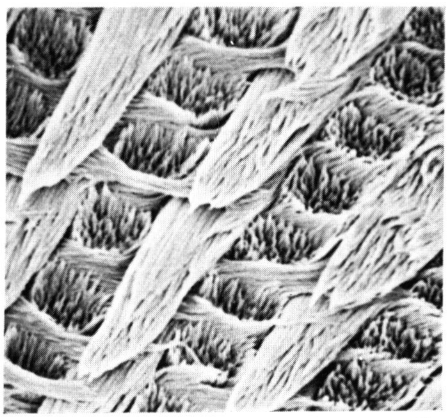

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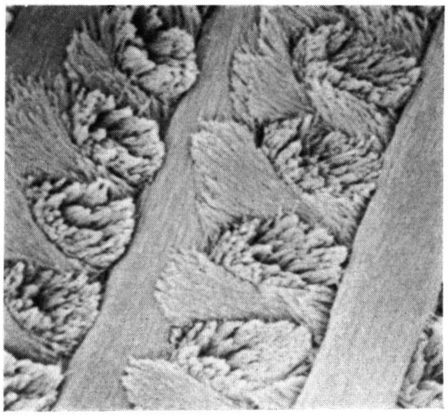

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