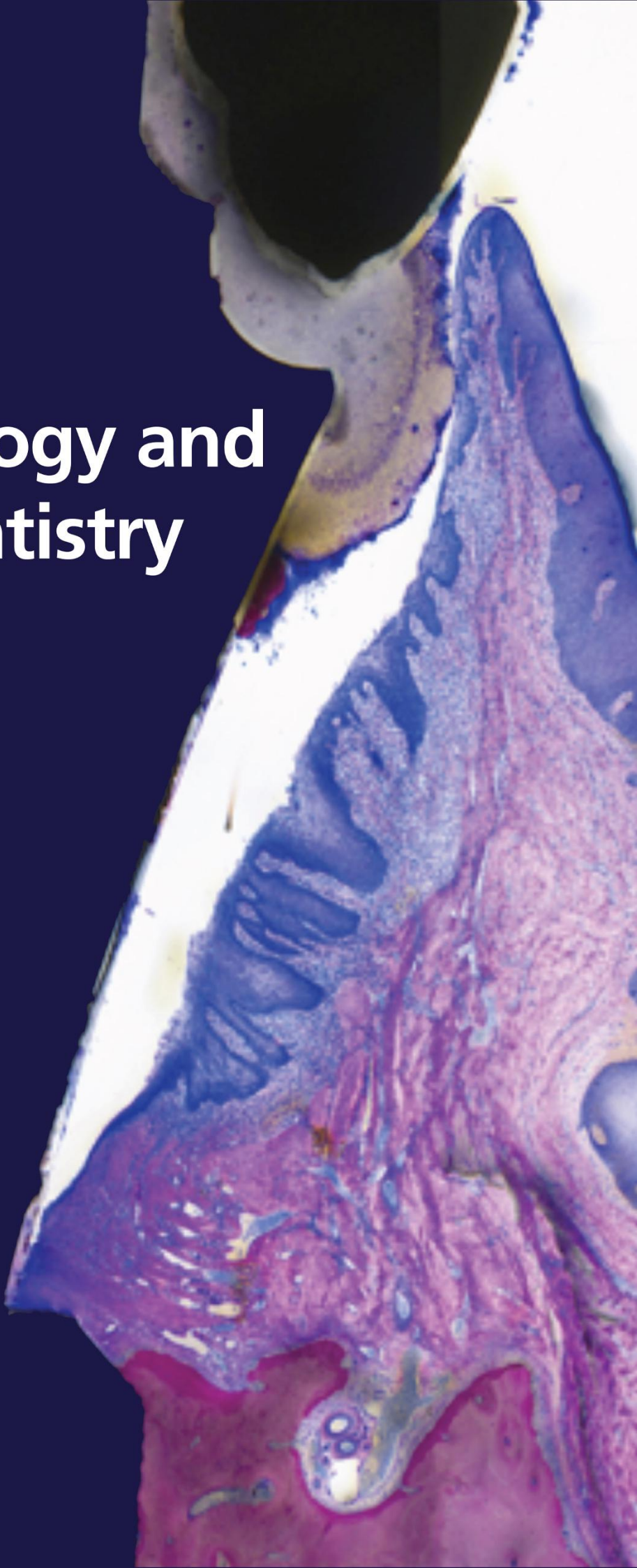
TWO-VOLUME SET

Clinical Periodontology and Implant Dentistry

SIXTH EDITION

Edited by
Niklaus P. Lang
Jan Lindhe



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Sixth Edition

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Niklaus P. Lang
and
Jan Lindhe

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Tord Berglundh
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Volume 1
BASIC CONCEPTS

Edited by

Jan Lindhe
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Preface

In an age when the internet is providing numerous options of treatment based on not always properly validated concepts presented by clinicians of sometimes unclear background, the practitioner is left with a confusing image of the profession. The questions of what is right and what is a professional error are becoming increasingly difficult to determine. It is evident that such online education – while occasionally having its undisputed benefits – bears the danger of distributing treatment philosophies that are most likely not scientifically scrutinized and, hence, may even be detrimental to the patient.

Given these facts, one may wonder what the role of a textbook becomes, when everything is so easily accessible through electronic media. Obviously, a textbook still represents a unique source of professional information containing a treatment philosophy that must be based on scientific evidence rather than on trial and error or personal preference. *Clinical Periodontology and Implant Dentistry* has always emphasized the evidence-based treatment approach.

The textbook originated from Scandinavia and documented various treatment procedures with clinical research data. In later years, the authorship became more international, which led to the success of the text throughout the world. In the fourth edition some aspects of implant dentistry were incorporated, and by the time that fifth edition was prepared implant dentistry had become an important part of clinical periodontology. Owing to the increased content, the first of the now two volumes presented the basic aspects, applying biological principles to both periodontal and peri-implant tissues, whereas the second volume was devoted to treatment aspects. It had become evident that periodontology also affects the biology of implants.

Consequently, these two fields of dentistry have become merged and married to each other. The new sixth edition of this textbook incorporates the important topic of the strictly prosthetic aspects of treating mutilated dentition. An essential part of comprehensive therapy is treatment planning according to biological principles, to which special attention has been given. The installation of oral implants and their healing are covered in detail, and novel concepts of tissue integration are also addressed. Last, but not least, clinical experience from latter years has revealed that biological complications occur with oral implants. The sixth edition gives special attention to coping with such adverse events and also to issues related to the maintenance of periodontal and peri-implant health. All in all, the sixth edition represents a thoroughly revised syllabus of contemporary periodontology and implant dentistry.

If a textbook is to maintain its role as a reference source and guide for clinical activities it has to be updated at regular intervals. The sixth edition follows the fifth edition by 7 years, and 90% of the content has been revised in the last 2 years. Several chapters have been reconceived or completely rewritten by a new generation of internationally recognized researchers and master clinicians. As we thank our contributors to this new masterpiece for their enormous effort in keeping the text updated, we hope that the sixth edition of *Clinical Periodontology and Implant Dentistry* will maintain its status as the master text of periodontology and implant dentistry for the entire profession worldwide.

We express our gratitude to the numerous coworkers at Wiley, our publisher, who contributed to the realization of the project, and special thanks go to Nik Prowse (freelance project manager), Lucy Gardner (freelance copy-editor) and Susan Boobis (freelance indexer).

However, most of our thanks go to you, as reader, student, colleague, specialist clinician or researcher in clinical periodontology and implant dentistry. We hope that you enjoy this new edition, with its new clothes and new outline.

Niklaus P. Lang

Jan Lindhe

February 2015

Part 1: Anatomy

Chapter 1

Anatomy of Periodontal Tissues

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Introduction

This chapter provides a brief description of the characteristics of the normal periodontium. It is assumed that the reader has prior knowledge of oral embryology and histology.

The periodontium (peri = around, odontos = tooth) comprises the following tissues: (1) *gingiva* (G), (2) *periodontal ligament* (PL), (3) *root cementum* (RC), and (4) *alveolar bone proper* (ABP) (Fig. 1-1). ABP lines the alveolus of the tooth and is continuous with the alveolar bone; on a radiograph it may appear as *lamina dura*. The *alveolar process* that extends from the basal bone of the maxilla and mandible consists of the alveolar bone and the *alveolar bone proper*.

The main function of the periodontium is to attach the tooth to the bone tissue of the jaws and to maintain the integrity of the surface of the masticatory mucosa of the oral cavity. The periodontium, also called "the attachment apparatus" or "the supporting tissues of the teeth", constitutes a developmental, biologic, and functional unit which undergoes certain changes with age and is, in addition, subjected to morphologic changes related to functional alterations and alterations in the oral environment.

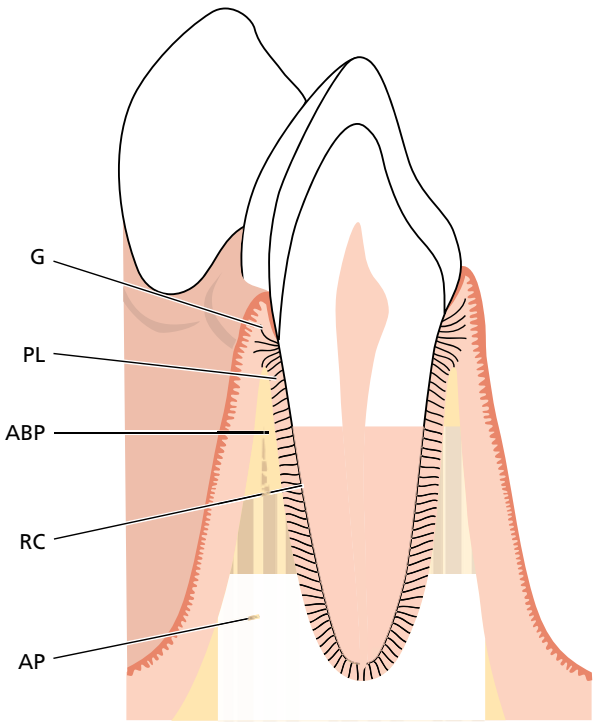


Fig. 1-1

Clinical Periodontology and Implant Dentistry, Sixth Edition. Edited by Niklaus P. Lang and Jan Lindhe.

The development of the periodontal tissues occurs during the development and formation of teeth. This process starts early in the embryonic phase when cells from the neural crest (from the neural tube of the embryo) migrate into the first branchial arch. In this position, the neural crest cells form a band of *ectomesenchyme* beneath the epithelium of the stomatodeum (the primitive oral cavity). After the uncommitted neural crest cells have reached their location in the jaw space, the epithelium of the stomatodeum releases factors which initiate epithelial–ectomesenchymal interactions. Once these interactions have occurred, the ectomesenchyme takes the dominant role in the further development. Following the formation of the *dental lamina*, a series of processes are initiated (bud stage, cap stage, bell stage with root development) which result in the formation of a tooth and its surrounding periodontal tissues, including the alveolar bone proper. During the cap stage, condensation of ectomesenchymal cells appears in relation to the dental epithelium (the dental organ [DO]), forming the *dental papilla* (DP) that gives rise to the dentin and the pulp, and the *dental follicle* (DF) that gives rise to the periodontal supporting tissues (Fig. 1-2). The decisive role played by the ectomesenchyme in this process is further established by the fact that the tissue of the dental papilla apparently also determines the shape and form of the tooth.

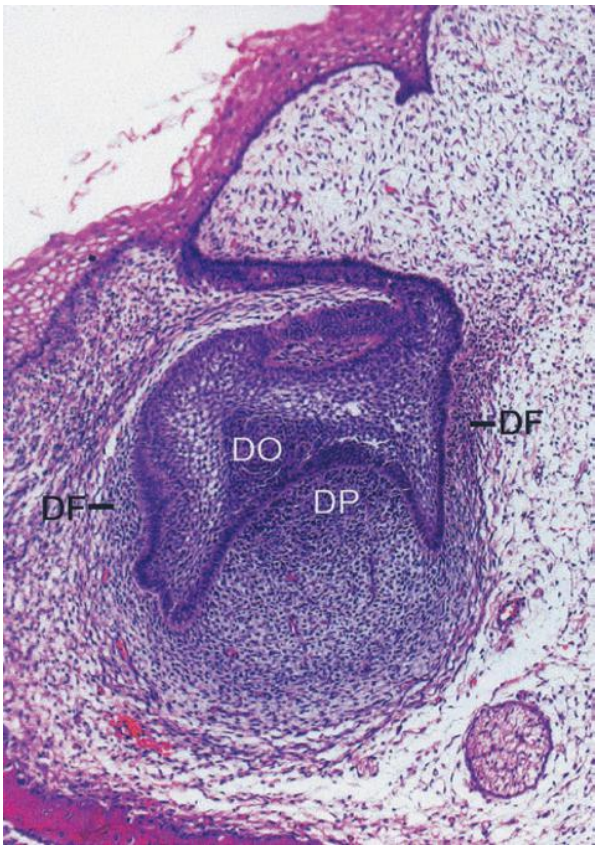


Fig. 1-2

If a tooth germ in the bell stage of development is dissected and transplanted to an ectopic site (e.g. the connective tissue or the anterior chamber of the eye), the tooth formation process continues. The crown and the root are formed, and the supporting structures (i.e. cementum, periodontal ligament, and a thin lamina of alveolar bone proper) also develop. Such experiments document that all information necessary for the formation of a tooth and its attachment apparatus resides within the tissues of the dental organ and the surrounding ectomesenchyme. The dental organ is the formative organ of enamel, the dental papilla is the formative organ of the dentin–pulp complex, and the dental follicle is the formative organ of the attachment apparatus (cementum, periodontal ligament, and alveolar bone proper).

The development of the root and the periodontal supporting tissues follows that of the crown. Epithelial cells of the external and internal dental epithelium (the dental organ) proliferate in an apical direction, forming a double layer of cells called *Hertwig's epithelial root sheath* (RS). The odontoblasts (OBs) forming the dentin of the root differentiate from ectomesenchymal cells in the dental papilla under the inductive influence of the inner epithelial cells (Fig. 1-3). The dentin (D) continues to form in an apical direction, producing the framework of the root. During formation of the root, the periodontal supporting tissues, including the acellular cementum, develop. Some of the events in cementogenesis are still unclear, but the following concept is gradually emerging.

At the start of dentin formation, the inner cells of Hertwig's epithelial root sheath synthesize and secrete enamel-related proteins, probably belonging to the amelogenin family. At the end of this period, the epithelial root sheath becomes fenestrated and ectomesenchymal cells from the dental follicle penetrate through these fenestrations and contact the root surface. The ectomesenchymal cells in contact with the enamel-related proteins differentiate into cementoblasts and start to form cementoid. This cementoid represents the organic matrix of the cementum and consists of a ground substance and collagen fibers, which intermingle with collagen fibers in the not yet fully mineralized outer layer of the dentin. It is assumed that the cementum becomes firmly attached to the dentin through these fiber interactions. The formation of the cellular cementum, which often covers the apical third of the dental roots, differs from that of acellular cementum in that some of the cementoblasts become embedded in the cementum.

The remaining parts of the periodontium are formed by ectomesenchymal cells from the dental follicle lateral to the cementum. Some of them differentiate into periodontal fibroblasts and form the fibers of the periodontal ligament, while

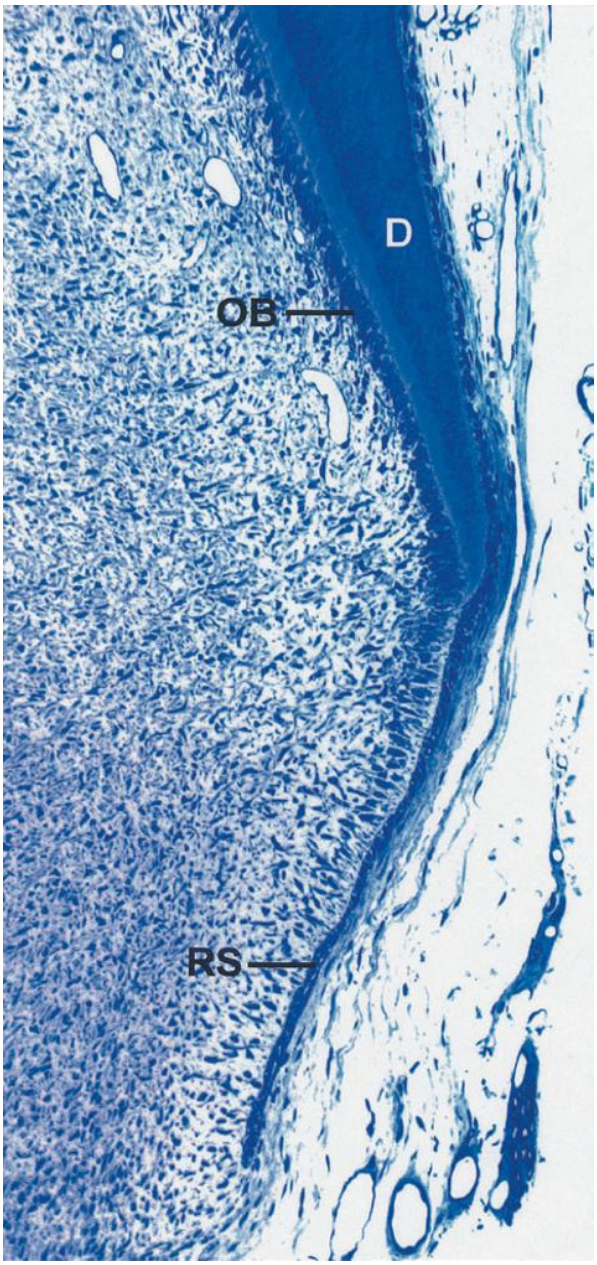


Fig. 1-3

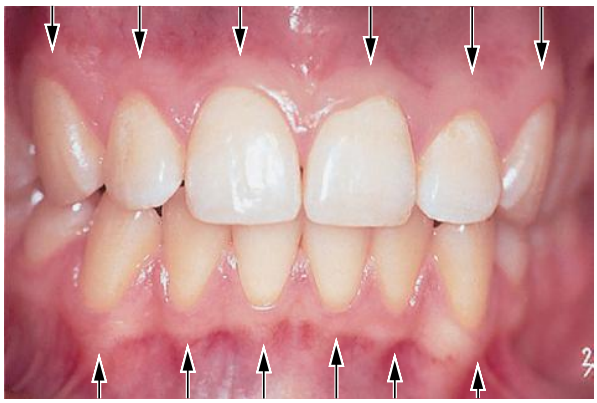


Fig. 1-4

Fig. 1-5

others become osteoblasts and form the alveolar bone proper in which the periodontal fibers are anchored. In other words, the primary alveolar wall is also an ectomesenchymal product. It is likely, but still not conclusively documented, that ectomesenchymal cells remain in the mature periodontium and take part in the turnover of this tissue.

Gingiva

Macroscopic anatomy

The oral mucosa (mucous membrane) is continuous with the skin of the lips and the mucosa of the soft palate and pharynx. The oral mucosa consists of (1) the *masticatory mucosa*, which includes the gingiva and the covering of the hard palate; (2) the *specialized mucosa*, which covers the dorsum of the tongue; and (3) the remaining part, called the *lining mucosa*.

Figure 1-4 The gingiva is that part of the masticatory mucosa which covers the alveolar process and surrounds the cervical portion of the teeth. It consists of an epithelial layer and an underlying connective tissue layer called the *lamina propria*. The gingiva obtains its final shape and texture in conjunction with eruption of the teeth.

In the coronal direction, the coral pink gingiva terminates in the *free gingival margin*, which has a scalloped outline. In the apical direction, the gingiva is continuous with the loose, darker red *alveolar mucosa* (lining mucosa) from which the gingiva is separated by a usually easily recognizable border called either the mucogingival junction (arrows) or the mucogingival line.

Figure 1-5 There is no mucogingival line present in the palate since the hard palate and the maxillary alveolar process are covered by the same type of masticatory mucosa.

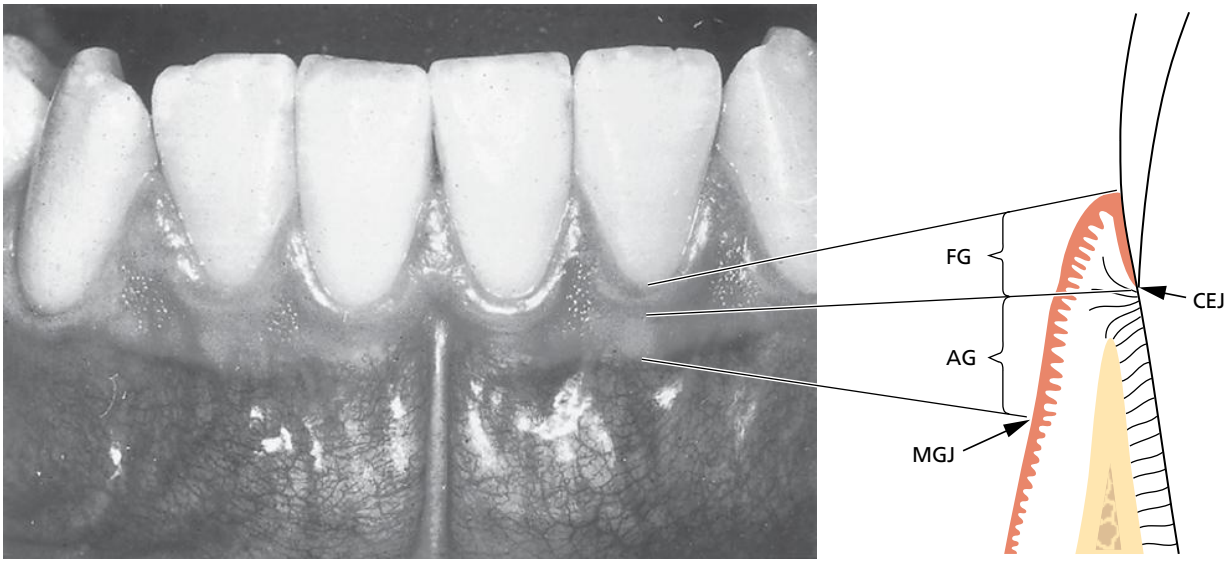


Fig. 1-6

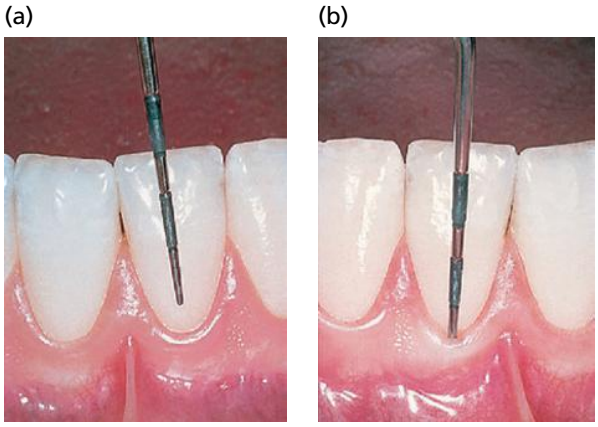


Fig. 1-7

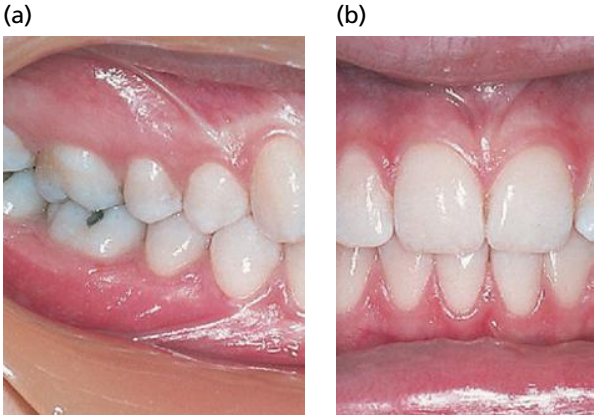


Fig. 1-8

Figure 1-6 Three parts of the gingiva can be identified:

1. Free gingiva (FG)
2. Interdental gingiva
3. Attached gingiva (AG).

The free gingiva is coral pink, has a dull surface and a firm consistency. It comprises the gingival tissue at the vestibular and lingual/palatal aspects of the teeth. On the vestibular and lingual sides of the teeth, the free gingiva extends from the gingival margin in an apical direction to the *free gingival groove*, which is positioned at a level corresponding to the level of the *cementoenamel junction* (CEJ). The attached gingiva is demarcated by the mucogingival junction (MGJ) in the apical direction.

Figure 1-7 The free gingival margin is often rounded in such a way that a small invagination or sulcus is formed between the tooth and the gingiva (Fig. 1-7a).

When a periodontal probe is inserted into this invagination and, further apically, towards the CEJ, the gingival tissue is separated from the tooth and a "*gingival pocket*" or "*gingival crevice*" is artificially opened. Thus, in normal or clinically healthy gingiva there is in fact no "gingival pocket" or "gingival crevice" present, but the gingiva is in close contact with the enamel surface. In Fig. 1-7b, a periodontal probe has been inserted into the tooth–gingiva interface and a "gingival crevice" artificially opened approximately to the level of the CEJ.

After complete tooth eruption, the free gingival margin is located on the enamel surface approximately 1.5–2 mm coronal to the CEJ.

Figure 1-8 The shape of the *interdental gingiva (the interdental papilla)* is determined by the contact relationships between the teeth, the width of the approximal tooth surfaces, and the course of the CEJ. In anterior regions of the dentition, the interdental papilla is of pyramidal form (Fig. 1-8b), while in the molar regions, the papillae are flatter in the buccolingual direction (Fig. 1-8a). Due to the presence of interdental papillae, the free gingival margin follows a more or less accentuated, scalloped course through the dentition.

Figure 1-9 In the premolar/molar regions of the dentition, the teeth have approximal contact surfaces (Fig. 1-9a) rather than contact points. Since the shape of

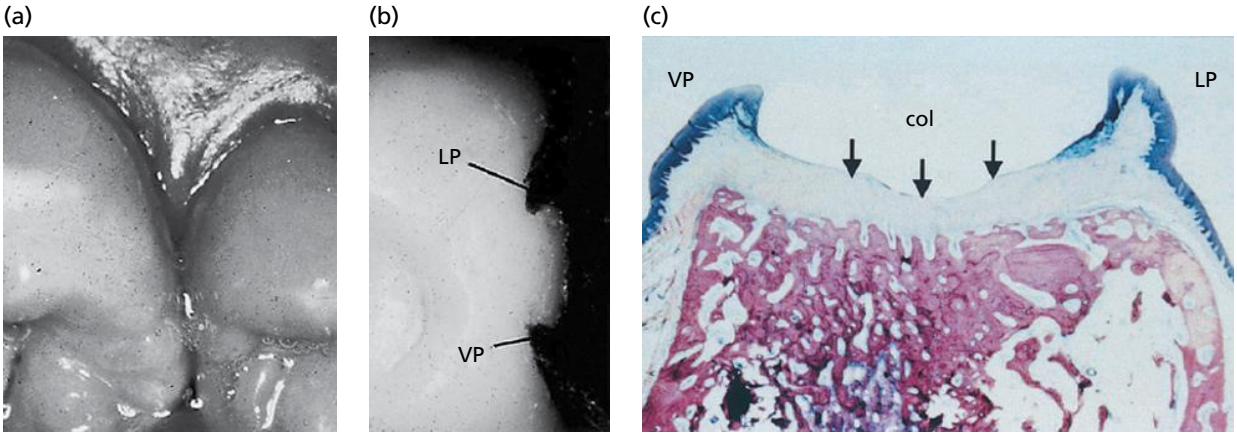


Fig. 1-9

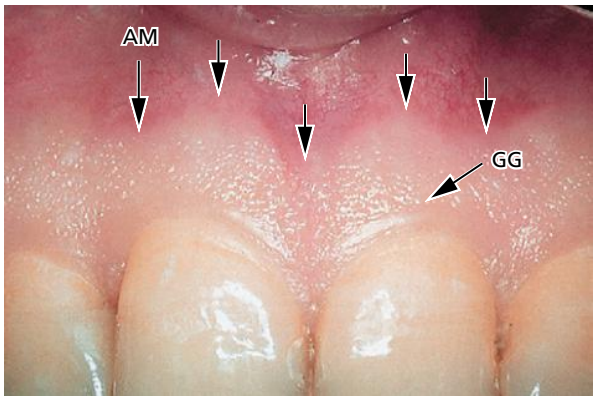


Fig. 1-10

the interdental papilla conforms with the outline of the interdental contact surfaces, a concavity – *a col* – is established in the premolar and molar regions, as demonstrated in Fig. 1-9b, where the distal tooth has been removed. Thus, the interdental papillae in these areas often have one vestibular (VP) and one lingual/palatal portion (LP) separated by the col region. The col region, as demonstrated in the histologic section (Fig. 1-9c), is covered by a thin non-keratinized epithelium (arrows). This epithelium has many features in common with the junctional epithelium (see Fig. 1-34).

Figure 1-10 The attached gingiva is demarcated in the coronal direction by the free gingival groove (GG) or, when such a groove is not present, by a horizontal plane placed at the level of the CEJ. In clinical examinations, it was observed that a free gingival groove is only present in about 30–40% of adults.

The free gingival groove is often most pronounced on the vestibular aspect of the teeth, occurring most frequently in the incisor and premolar regions of the mandible, and least frequently in the mandibular molar and maxillary premolar regions.

The attached gingiva extends in the apical direction to the mucogingival junction (arrows), where it becomes continuous with the alveolar (lining) mucosa (AM). It is of firm texture, coral pink in color, and often shows small depressions on the surface. The depressions, called "stippling", give the appearance of orange peel. The

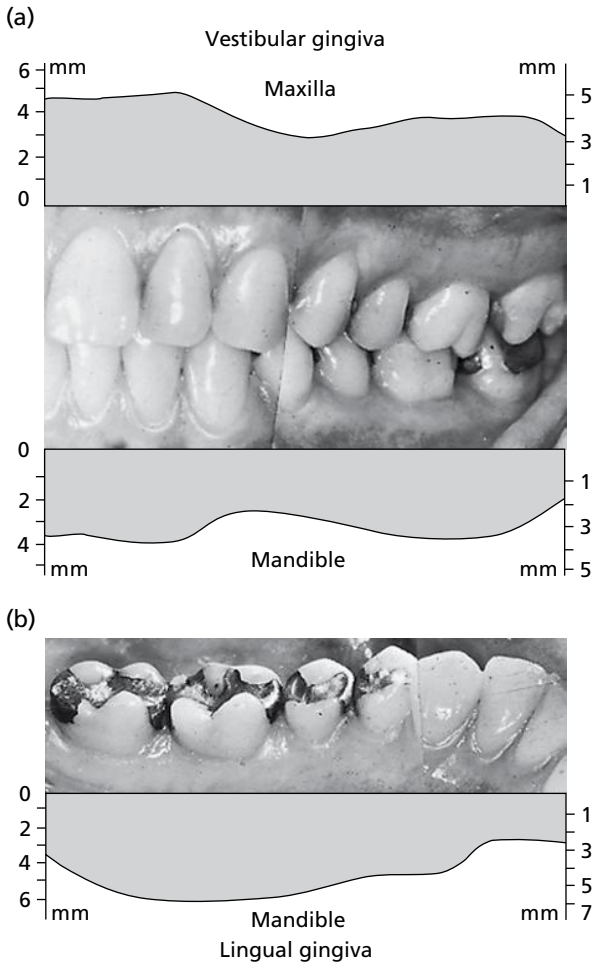


Fig. 1-11

gingiva is firmly attached to the underlying alveolar bone and cementum by connective tissue fibers, and is, therefore, comparatively immobile in relation to the underlying tissue. The darker red alveolar mucosa (AM) located apical to the mucogingival junction, on the other hand, is loosely bound to the underlying bone. Therefore, in contrast to the attached gingiva, the alveolar mucosa is mobile in relation to the underlying tissue.

Figure 1-11 shows how the width of the gingiva varies in different parts of the dentition. In the maxilla

(Fig. 1-11a), the vestibular gingiva is generally widest in the area of the incisors and narrowest adjacent to the premolars. In the mandible (Fig. 1-11b), the gingiva on the lingual aspect is particularly narrow in the area of the incisors and wide in the molar region. The range of variation is 1–9 mm.

Fig. 1-12

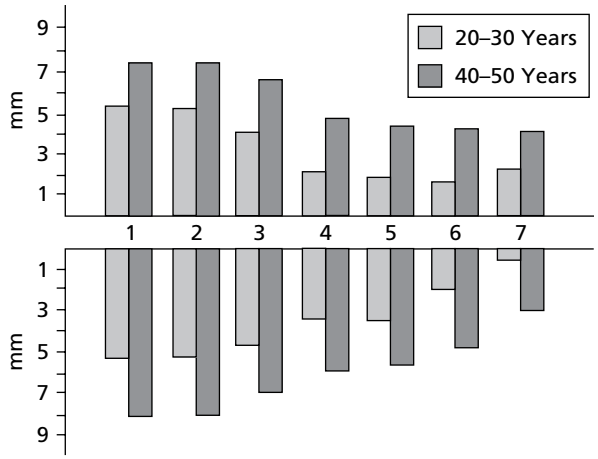


Fig. 1-13

Figure 1-12 illustrates an area in the mandibular premolar region where the gingiva is extremely narrow. The arrows indicate the location of the mucogingival junction. The mucosa has been stained with an iodine solution in order to distinguish more accurately between the gingiva and the alveolar mucosa.

Figure 1-13 depicts the result of a study in which the width of the attached gingiva was assessed and related to the age of the patients examined. It was found that the gingiva in 40–50-year olds was significantly wider than that in 20–30-year olds. This observation indicates that the width of the gingiva tends to increase with age. Since the mucogingival junction remains stable throughout life in relation to the lower border of the mandible, the increasing width of the gingiva may suggest that the teeth, as a result of occlusal wear, erupt slowly throughout life.

Microscopic anatomy

Oral epithelium

Figure 1-14a A schematic drawing of a histologic section (see Fig. 1-14b) describing the composition of the gingiva and the contact area between the gingiva and the enamel (E).

Figure 1-14b The free gingiva comprises all epithelial and connective tissue structures (CT) located coronal to a horizontal line placed at the level of the cementoenamel junction (CEJ). The epithelium covering the free gingiva may be differentiated as follows:

- *Oral epithelium* (OE), which faces the oral cavity
- *Oral sulcular epithelium* (OSE), which faces the tooth without being in contact with the tooth surface

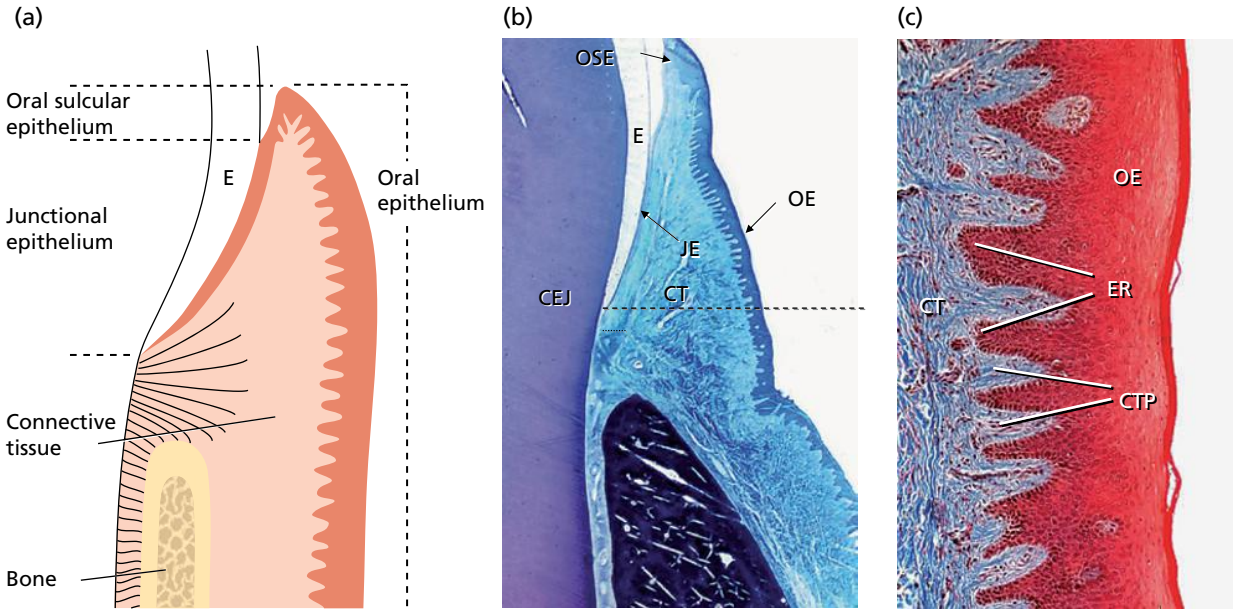


Fig. 1-14

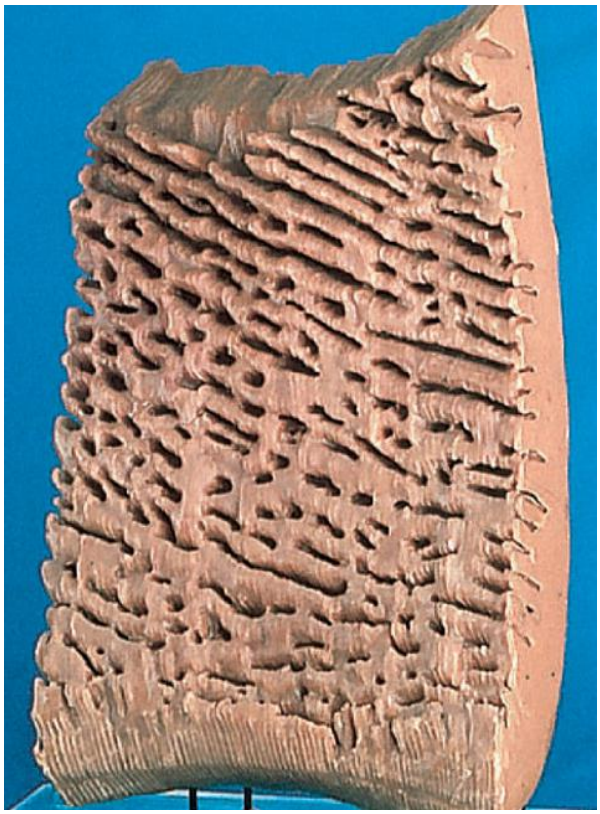


Fig. 1-15

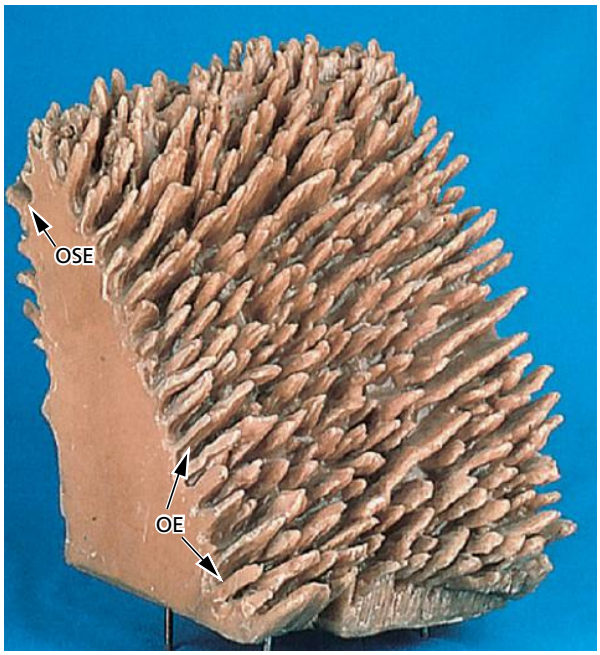


Fig. 1-16

- *Junctional epithelium* (JE), which provides the contact between the gingiva and the tooth.

Figure 1-14c The boundary between the oral epithelium (OE) and underlying connective tissue (CT) has a wavy course. The connective tissue portions which project into the epithelium are called *connective tissue papillae* (CTP) and are separated from each other by *epithelial ridges* – so-called *rete pegs* (ER). In normal, non-inflamed gingiva, rete pegs and connective tissue papillae are lacking at the boundary between the junctional epithelium and its underlying connective tissue (Fig. 1-14b). Thus, a characteristic morphologic feature of the oral epithelium and the oral sulcular epithelium is the presence of rete pegs: these structures are lacking in the junctional epithelium.

Figure 1-15 presents a model, constructed on the basis of magnified serial histologic sections, showing the subsurface of the oral epithelium of the gingiva after the connective tissue has been removed. The subsurface of the oral epithelium (i.e. the surface of the epithelium facing the connective tissue) exhibits several depressions corresponding to the connective tissue papillae (see Fig. 1-16) which project into the epithelium. It can be seen that the epithelial projections, which in histologic sections separate the connective tissue papillae, constitute a continuous system of epithelial ridges.

Figure 1-16 presents a model of the connective tissue, corresponding to the model of the epithelium shown in Fig. 1-15. The epithelium has been removed, thereby making the vestibular aspect of the gingival connective tissue visible. Note the connective tissue papillae which project into the space that was occupied by the oral epithelium (OE) in Fig. 1-15 and by the oral sulcular epithelium (OSE) at the back of the model.

Figure 1-17a In most adults the attached gingiva shows a stippling on the surface. The photograph shows a case where this stippling is conspicuous (see also Fig. 1-10).

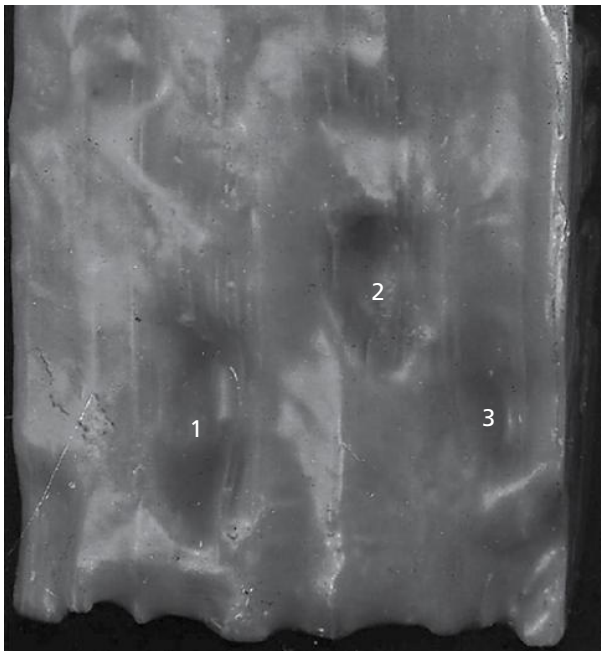
Figure 1-17b presents a magnified model of the outer surface of the oral epithelium of the attached gingiva. The surface exhibits the minute depressions (1–3) which give the gingiva its characteristic stippled appearance.

Figure 1-17c shows a photograph of the subsurface (i.e. the surface of the epithelium facing the connective tissue) of the model shown in Fig. 1-17b. The subsurface of the epithelium is characterized by the presence of epithelial ridges which merge at various locations (1–3). The depressions seen on the outer surface of the epithelium (1–3 in Fig. 1-17b) correspond to these fusion sites (1–3) between the epithelial ridges. Thus, the depressions on the surface of the gingiva occur in the areas of fusion between various epithelial ridges.

Figure 1-18 (a) A portion of the oral epithelium covering the free gingiva is illustrated in this photomicrograph. The oral epithelium is a *keratinized*, *stratified*,

(a)

(b)



(c)

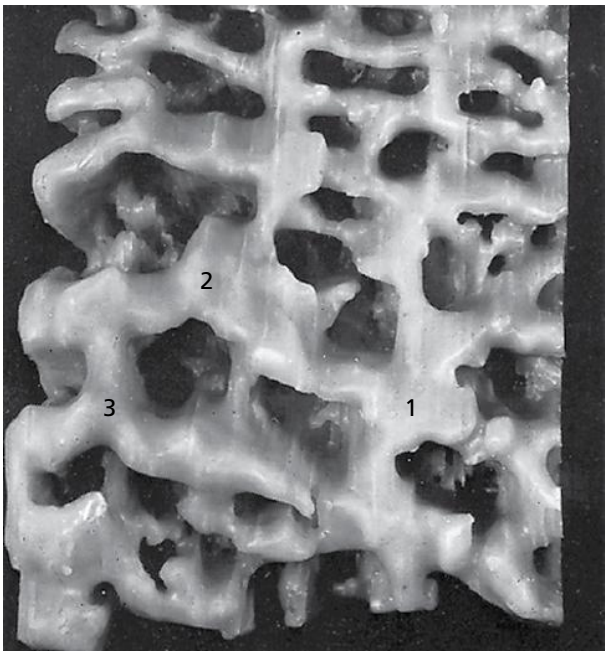
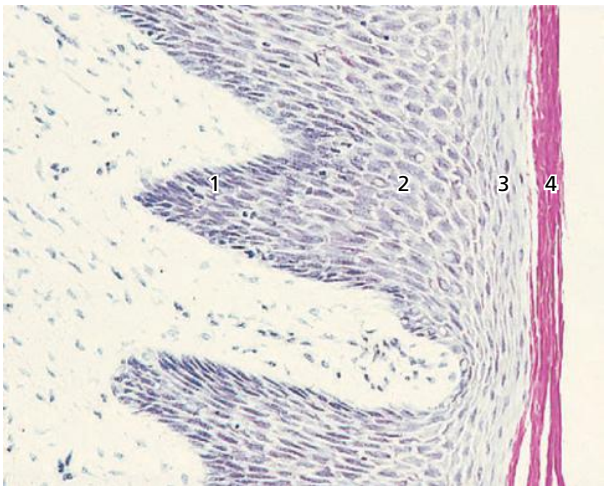


Fig. 1-17

(a)



(b)

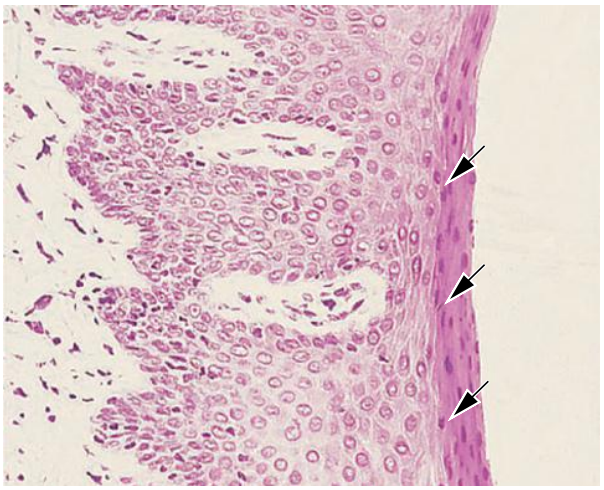


Fig. 1-18

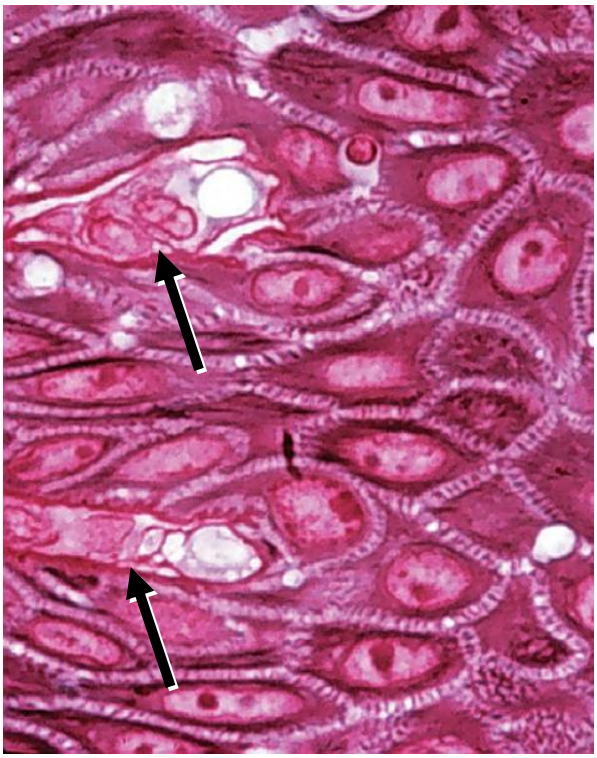


Fig. 1-19

squamous epithelium which, on the basis of the degree to which the keratin-producing cells are differentiated, can be divided into the following cell layers:

1. *Basal layer* (stratum basale or stratum germinativum)
2. *Prickle cell layer* (stratum spinosum)
3. *Granular cell layer* (stratum granulosum)
4. *Keratinized cell layer* (stratum corneum).

It should be observed that in this section, cell nuclei are lacking in the outer cell layers. Such an epithelium is denoted *orthokeratinized*. Often, however, the cells of the stratum corneum of the epithelium of human gingiva contain remnants of the nuclei as seen in Fig. 1-18b (arrows). In such a case, the epithelium is denoted *parakeratinized*.

Figure 1-19 In addition to the keratin-producing cells, which comprise about 90% of the total cell population, the oral epithelium contains the following types of cell:

- *Melanocytes*
- *Langerhans cells*
- *Merkel's cells*
- *Inflammatory cells.*

These cell types are often stellate and have cytoplasmic extensions of various size and appearance. They are also called "clear cells" since in histologic sections, the zone around their nuclei appears lighter than that in the surrounding keratin-producing cells.

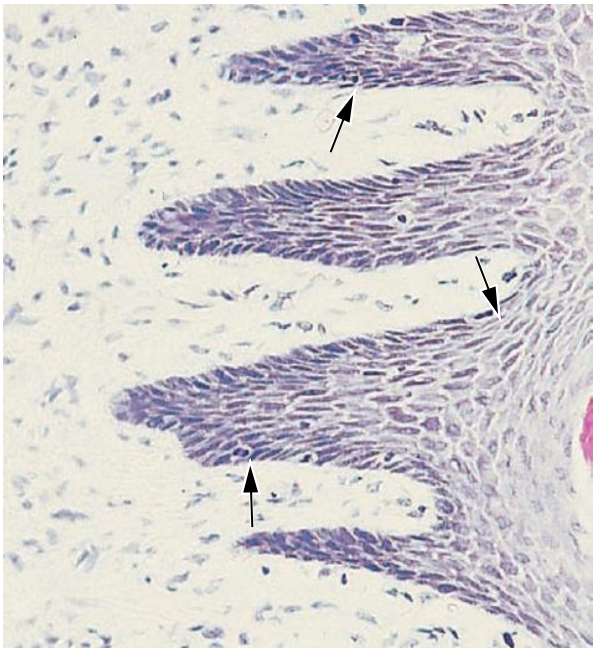


Fig. 1-20

The photomicrograph shows "clear cells" (arrows) located in or near the stratum basale of the oral epithelium. With the exception of the Merkel's cells, these "clear cells", which do not produce keratin, lack desmosomal attachment to adjacent cells. The melanocytes are pigment-synthesizing cells and are responsible for the melanin pigmentation occasionally seen on the gingiva. However, both lightly and darkly pigmented individuals have melanocytes in the epithelium.

The Langerhans cells are believed to play a role in the defense mechanism of the oral mucosa. It has been suggested that the Langerhans cells react with antigens which are in the process of penetrating the epithelium. An early immunologic response is thereby initiated, inhibiting or preventing further antigen penetration of the tissue. The Merkel's cells have been suggested to have a sensory function.

Figure 1-20 The cells in the basal layer are either cylindric or cuboid, and are in contact with the *basement membrane* that separates the epithelium and the connective tissue. The basal cells possess the ability to divide, that is undergo mitotic cell division. The cells marked with arrows in the photomicrograph are in the process of dividing. It is in the basal layer that the epithelium is renewed. Therefore, this layer is also termed *stratum germinativum*, and can be considered the *progenitor cell compartment* of the epithelium.

Figure 1-21 When two daughter cells (D) have been formed by cell division, an adjacent "older" basal cell (OB) is pushed into the spinous cell layer and starts, as a *keratinocyte*, to traverse the epithelium. It takes approximately 1 month for a keratinocyte to reach the outer epithelial surface, where it is shed from the stratum corneum. Within a given time, the

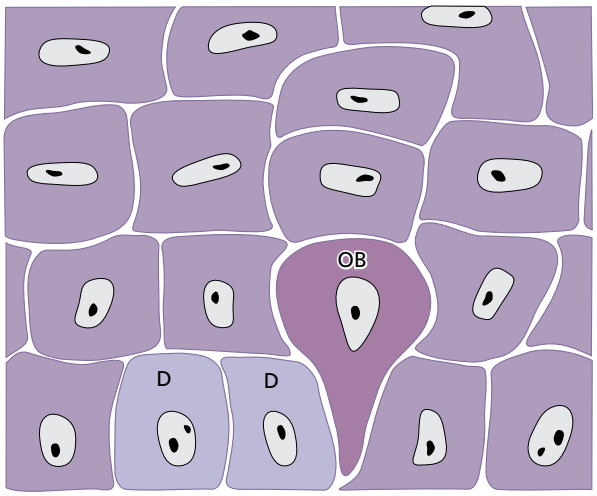


Fig. 1-21

Fig. 1-22

number of cells which divide in the basal layer equals the number of cells which are shed from the surface. Thus, under normal conditions there is equilibrium between cell renewal and cell loss so that the epithelium maintains a constant thickness. As the basal cell migrates through the epithelium, it becomes flattened with its long axis parallel to the epithelial surface.

Figure 1-22 The basal cells are found immediately adjacent to the connective tissue and are separated from this tissue by the basement membrane, probably produced by the basal cells. Under the light microscope this membrane appears as a structureless zone approximately 1–2 µm wide (arrows) and reacts positively to a periodic acid-Schiff (PAS) stain. This positive reaction demonstrates that the basement membrane contains carbohydrate (glycoproteins). The epithelial cells are surrounded by an extracellular substance which also contains protein–polysaccharide complexes. At the ultrastructural level, the basement membrane has a complex composition.

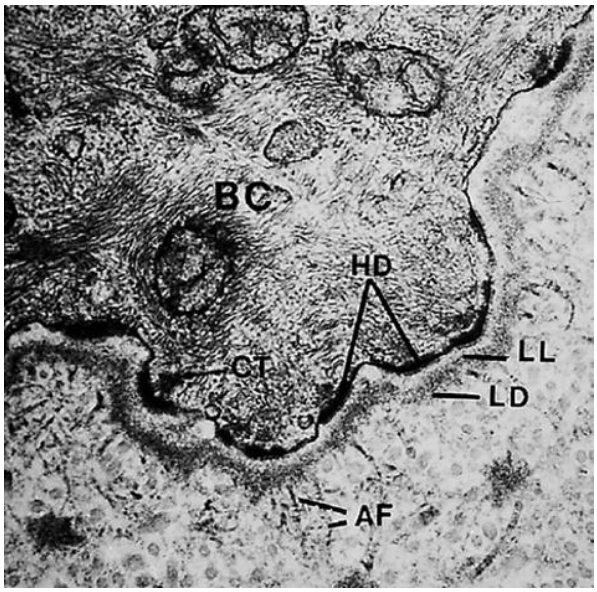


Fig. 1-23

Figure 1-23 is an electron micrograph (magnification × 70 000) of an area including part of a basal cell, the basement membrane, and part of the adjacent connective tissue. The basal cell (BC) occupies the upper portion of the micrograph. Immediately beneath the basal cell, an approximately 400-Å wide electron-lucent zone can be seen, which is called the *lamina lucida* (LL). Beneath the lamina lucida, an electron-dense zone of approximately the same thickness can be observed. This zone is called *lamina densa* (LD). From the lamina densa so-called *anchoring fibers* (AF) project in a fan-shaped fashion into the connective tissue. The anchoring fibers are approximately 1 µm in length and terminate freely in the connective tissue. The basement membrane, which under the light microscope appears as an entity, thus, in the electron micrograph, appears to comprise one lamina lucida and one lamina densa with adjacent connective tissue fibers (anchoring fibers). The cell membrane of the epithelial cells facing the lamina lucida harbors a number of electron-dense, thicker zones appearing at various intervals along the cell membrane. These structures are called *hemidesmosomes* (HD). The cytoplasmic *tonofilaments* (CT) in the cell converge towards the hemidesmosomes. The hemidesmosomes are involved in the attachment of the epithelium to the underlying basement membrane.

Figure 1-24 illustrates an area of stratum spinosum in the gingival oral epithelium. Stratum spinosum consists of 10–20 layers of relatively large, polyhedral cells, equipped with short cytoplasmic processes resembling spines. The cytoplasmic processes (arrows) occur at regular intervals and give the cells a prickly appearance. Together with intercellular protein–carbohydrate complexes, cohesion between the cells is provided by numerous "desmosomes" (pairs of hemidesmosomes) which are located between the cytoplasmic processes of adjacent cells.