1 Dental Anatomy

Anatomy underpins all of dental anthropology. Before anything else can be done, the teeth being studied not only have to be identified to species, but each has also to be matched into the correct place in a series of 13 different positions in the upper or lower jaw, left or right. In all, there are 52 different possibilities for assigning a single tooth and it has to be done correctly. Even something so apparently minor as left or right side is important. For example if, amongst a group of isolated teeth, there are two lower left deciduous second incisors, this provides clear proof that at least two individuals are represented, even if no other element of the burial is duplicated in this way. Upper and lower, left and right must also be correct simultaneously because, if one is wrong, the other will also be. At the same time, these identifications must be made correctly even when parts of the tooth have been removed by wear, breakage or dental decay. They must also take into account a wide range of normal variations in size, shape and features. This chapter, therefore, provides detailed illustrated descriptions of the different teeth in living humans and a range of fossil and living primates. It outlines the way in which wear changes the shape and introduces a range of possible shape variations. In addition, it explores several well-known identification problems and suggests approaches for solving them. Before all that, however, the language of dental anatomy must be explained – the labelling of different tooth parts, the different sides or aspects of the tooth, and the systems for distinguishing different teeth in the series. Surprisingly, this is one of the most complex and confusing parts.

This chapter supports both undergraduate- and postgraduate-level laboratory classes in tooth identification and is designed also to act as a reference for researchers working on human remains in museum collections, in the field or in forensic cases. As an aid to identification and orientation of a tooth, the illustrations show both left and right, upper and lower teeth, twice life size so that the specimen can be held above them for comparison.

1.1 Definitions For Dental Anatomy

For this chapter, terms need to be used consistently and they are defined in this section. There is a good deal of variability in usage of names, and the choice of naming scheme used in this book is explained.

1.1.1 Taxa Included

We and our closest relatives are usually included in the family of primates known as *Hominidae* (commonly referred to as hominids). There is ongoing debate, but at the time of writing the family usually includes chimpanzees, bonobos, gorillas and orangutans, alongside humans. Hominidae are often divided further into two sub-families. Ponginae includes orangutans and anatomically similar fossil species. Homininae (hominines) includes living humans, chimpanzees, bonobos and gorillas, with the extinct fossil genera *Ardipithecus*, *Australopithecus* and *Paranthropus*. Some divide the Homininae further into three tribes (Table 1.1). *Ardipithecus*, *Australopithecus*, *Paranthropus*, living humans and extinct species of the genus *Homo* are included in the tribe Hominini (hominins). It is therefore very important to understand which of the various 'hom-' divisions is being used by noting the endings of the word: hominid, hominine or hominin. Similarly, there is considerable debate around the correct way to classify the extinct members of the genus *Homo*. This includes stratigraphic position, dating evidence, anatomical form and genetic evidence. It is not helped by the patchy nature of the primate fossil record and arguments often centre on a very small group of specimens, or even a single specimen. Such arguments are beyond the scope of this book, but Table 1.1 adopts the classifications and chronology of Wood and Boyle (2016) and Groves (2018).

This chapter, therefore, includes humans (genus *Homo*), with representatives of two extinct hominid genera *Australopithecus* and *Paranthropus* and three other living hominid genera: *Pan* (chimpanzee and bonobo), *Gorilla* and *Pongo* (orangutan). Smaller primates are a major component of some hominid fossil sites, so there are also two living Old World monkey (family Cercopithecidae) genera for comparison: *Macaca* (macaques) and *Papio* (baboons). It is not possible to describe in a short space all of the differences, but this small group makes it possible to explain how hominid genera are distinguished. It also provides a grammar of common anatomical features which can be used elsewhere in the book.

1.1.2 Labels For Teeth

Each young primate has two dentitions. In living humans, the *deciduous (or milk) dentition* starts to form *in utero* 2–3 months after fertilisation, is about one-third completed by birth and erupts into the mouth during the next 2 years (Section 4.1). It is replaced gradually by the *permanent dentition*, for which the first tooth starts to form just before birth, and the last tooth is finally completed in the early twenties. The schedule is different in the other taxa described here. Each dentition is divided into four *quadrants*: upper left, upper right, lower

Table 1.1 Primate taxa referred to in this book

Taxa	Sites	Stratigraphic division	Date ranges
Family Hominidae, Subfamily Homininae, Tribe Hominini			
Ardipithecus ramidus	East Africa	Pliocene	4.5–4.3 Ma BP
Australopithecus anamensis	East Africa	Pliocene	4.2–3.9 Ma BP
Australopithecus afarensis	East Africa	Pliocene	3.7–3.0 Ma BP
Australopithecus africanus	South Africa	Pliocene	3.0–2.4 Ma BP
Australopithecus sediba	South Africa	Pliocene	2.0 Ma BP
Paranthropus robustus	South Africa	Lower Pleistocene	2.0–1.0 Ma BP
Paranthropus boisei	East Africa	Pliocene, Lower Pleistocene	2.3–1.3 Ma BP
Homo habilis sensu lato	Africa	Lower Pleistocene	2.4–1.7 Ma BP
Homo ergaster	Africa	Lower Pleistocene	1.7–1.4 Ma BP
Homo antecessor	Europe	Lower Pleistocene	1.0–0.9 Ma BP
Homo erectus	Africa and Asia	Middle Pleistocene	1.8 Ma to 27 ka BP
Homo heidelbergensis	Africa and Europe	Middle Pleistocene	700–100 ka BP
Homo neanderthalensis	Europe and West Asia	Upper Pleistocene	130–40 ka BP
Homo sapiens	Worldwide	Upper Pleistocene and Holocene	195 ka BP to present
Family Hominidae, Subfamily Homininae, Tribe Panini			
Pan troglodytes (chimpanzee)	Africa	Holocene*	Recent*
Pan paniscus (bonobo)	Africa	Holocene	Recent
Family Hominidae, Subfamily Homininae, Tribe Gorillini			
Gorilla gorilla (western gorilla)	Africa	Holocene*	Recent*
Gorilla beringei (eastern gorilla)	Africa	Holocene*	Recent*
Family Hominidae, Subfamily Ponginae, Tribe Pongini			
Pongo pygmaeus (Bornean orangutan)	Borneo	Holocene	Recent
Pongo abelii (Sumatran orangutan)	Sumatra	Holocene	Recent
Family Cercopithecidae, Subfamily Cercopithecinae			
Macaca (various living species of macaque)	Africa, Asia and Europe	Holocene	Recent
Papio (various living species of baboon)	Africa, Arabia	Holocene	Recent

BP, years before present; Ma, millions of years; ka, thousands of years; Holocene, 11.5 ka BP–present; Pleistocene, 1.81 Ma–11.5 ka BP; Pliocene, 5.33–1.81 Ma BP (Gradstein *et al.*, 2005). Dates rounded from Wood and Boyle (2016) conservative estimates. Living non-human hominid classification follows Groves (2018). *Pongo pygmaeus* and *P. abelii* do not differ enough dentally to divide them in the text and so they are together called orangutan. Similarly, *Gorilla gorilla* and *G. beringei* are combined as gorilla. *Macaca* and *Papio* taxonomy is complex and only genus-level anatomical features are included here for comparative purposes.
Key: * a few fossil Miocene (Pickford & Senut, 2004) and Pleistocene (McBrearty & Jablonski, 2005) tooth finds resemble gorilla and chimpanzee but there is very little fossil evidence for these genera.

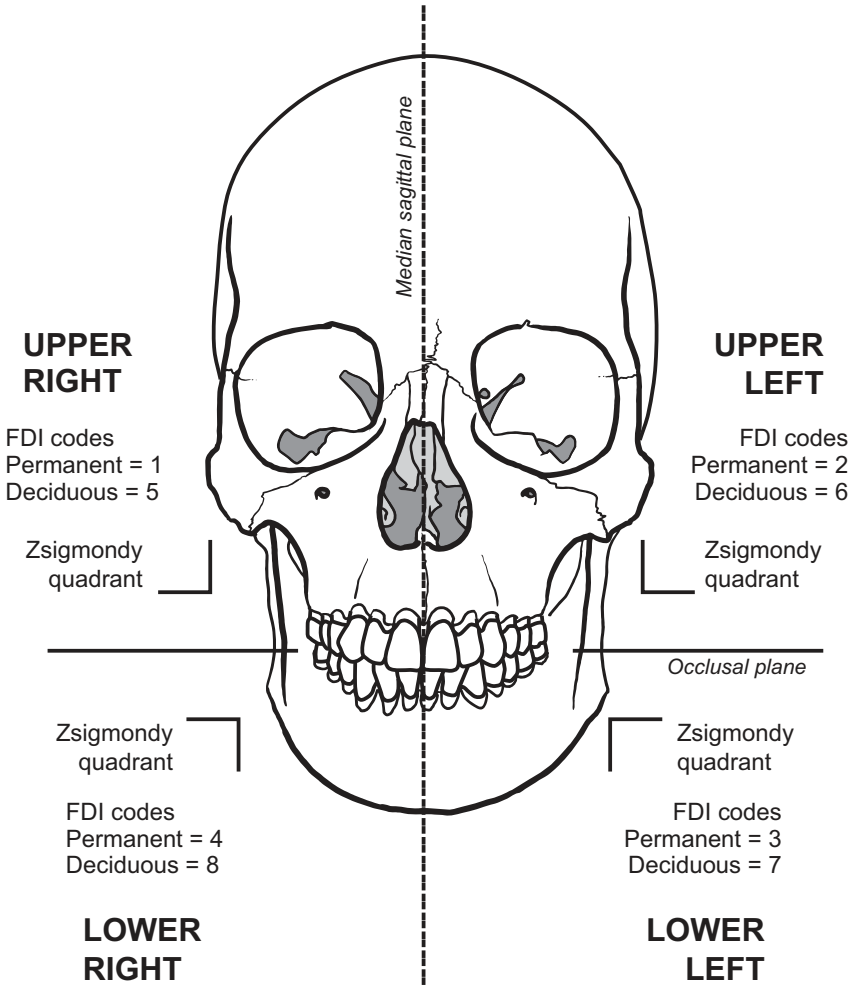

Figure 1.1 The quadrants of the dentition. FDI codes and Zsigmondy quadrant angles. See text and Table 1.3 for explanation.

left and lower right. Left and right quadrants are separated by the midline of the skull (the *median sagittal plane*) so that the upper left quadrant mirrors the upper right and the lower left mirrors the lower right (Figure 1.1). It is worth emphasising that left and right refer to the owner of the dentition's left and right, rather than the observer's. Some texts use maxillary instead of upper and mandibular for lower. Within each quadrant there are different classes of teeth – incisors (Latin *dentes incisivi*; cutting teeth), canines (Latin *dentes canini*; dog teeth), premolars (Latin *dentes premolares*) and molars (Latin *dentes molares*; grinding teeth). Incisors and canines are often described together as *anterior teeth*, while premolars and molars are called *cheek teeth*. In each quadrant of the hominid permanent dentition, there are normally two incisors, one canine, two premolars and three molars. Each quadrant of the deciduous dentition similarly comprises two incisors, one canine and two cheek teeth which are, properly speaking, deciduous premolars even though they are often called deciduous molars.

1.1.2.1 Tooth Components and Surfaces

Each tooth is divided into a crown and a root (Figure 1.2). In primates, the *crown* is the part that projects into the mouth and the *root* is embedded in the jaws. There are three hard dental tissues. Dentine forms the core of the whole tooth and the crown is coated with enamel, whereas the *root* is coated with a thin layer of cement. The boundaries between these tissues are termed the *enamel–dentine junction* (EDJ or sometimes *amelodentinal junction*, ADJ), *cement–dentine junction* (CDJ) and *cement–enamel junction* (CEJ). The meeting point between the crown and the root is the *cervix* (Latin; neck), and *cervical* is used as an adjective for this part of the tooth. For some reason, this formal anatomical name is retained today while the formal names *corona* (Latin; crown) and *radix* (Latin; root) are rarely used, even though their adjective derivatives *coronal* and *radicular* are often employed. The base of the crown is called the *cervical margin* and, girdling the cervical one-third of the crown, there is often a broad bulge called the *cingulum* (Latin; girdle). The cervical margin may also be described as the CEJ, because in primates the cement layer on the root often overlaps the enamel at the base of the crown slightly. Inside the tooth is the *pulp chamber*, containing the soft tissue of the pulp, with small conical hollows (*pulp horns* or *diverticles*) in its roof and a floor which opens into a *root canal*, or canals. These openings are usually funnel like, narrowing down into the root, and are known as *canal orifices*. A tooth may have several roots, each with a root canal or canals, and the point at which roots are divided is known as the root fork, or *furcation*. The tip of each root is called the *apex* and just above it the root canal narrows to form the *apical constriction* or minor diameter. From that, the canal widens slightly to emerge as the *apical foramen* or major diameter (which is even so less than 0.5 mm across). This is rarely positioned exactly at the apex of the root, but slightly to one side. The whole blood supply to the tooth pulp must pass through the tiny apical constriction. In many teeth, additional *accessory canals* pass out from the sides of the main root canals (Vertucci, 2005). These do not carry a blood supply but do contain soft tissue. Most commonly, they pass between the floor of the pulp chamber and the furcation of multi-rooted teeth, where they are called *furcation canals*. Where they pass out to the side of the root, they are called *lateral canals*, and where they are found at the apex, in addition to the apical foramen, this arrangement is known as an *apical delta*. Another variation is the *isthmus*, in which two root canals within one root are joined together side by side with a ribbon-like connection. This can join the canals at any level within the root and could be present inside any tooth with a root containing two or more canals.

The aspect of the crown (Figure 1.3) that faces teeth in the opposing jaw when the mouth closes is known as the *occlusal* aspect (Latin *facies occlusalis*; closed up face). In human molars and premolars, there are broad crown surfaces that actually meet when the jaws shut and these can truly be called occlusal surfaces, but incisors and canines are tall and spatulate with high crowns that do not normally meet edge to edge and overlap instead (Section 3.1.1). In anterior teeth, it is therefore clearer to call the occlusal extremity of the crown the *incisal* edge (Latin *margo incisalis*). The complete opposite of occlusal is the aspect which contains the tips of the roots and, as the tip of each root is known as its apex, this is called the *apical* aspect.

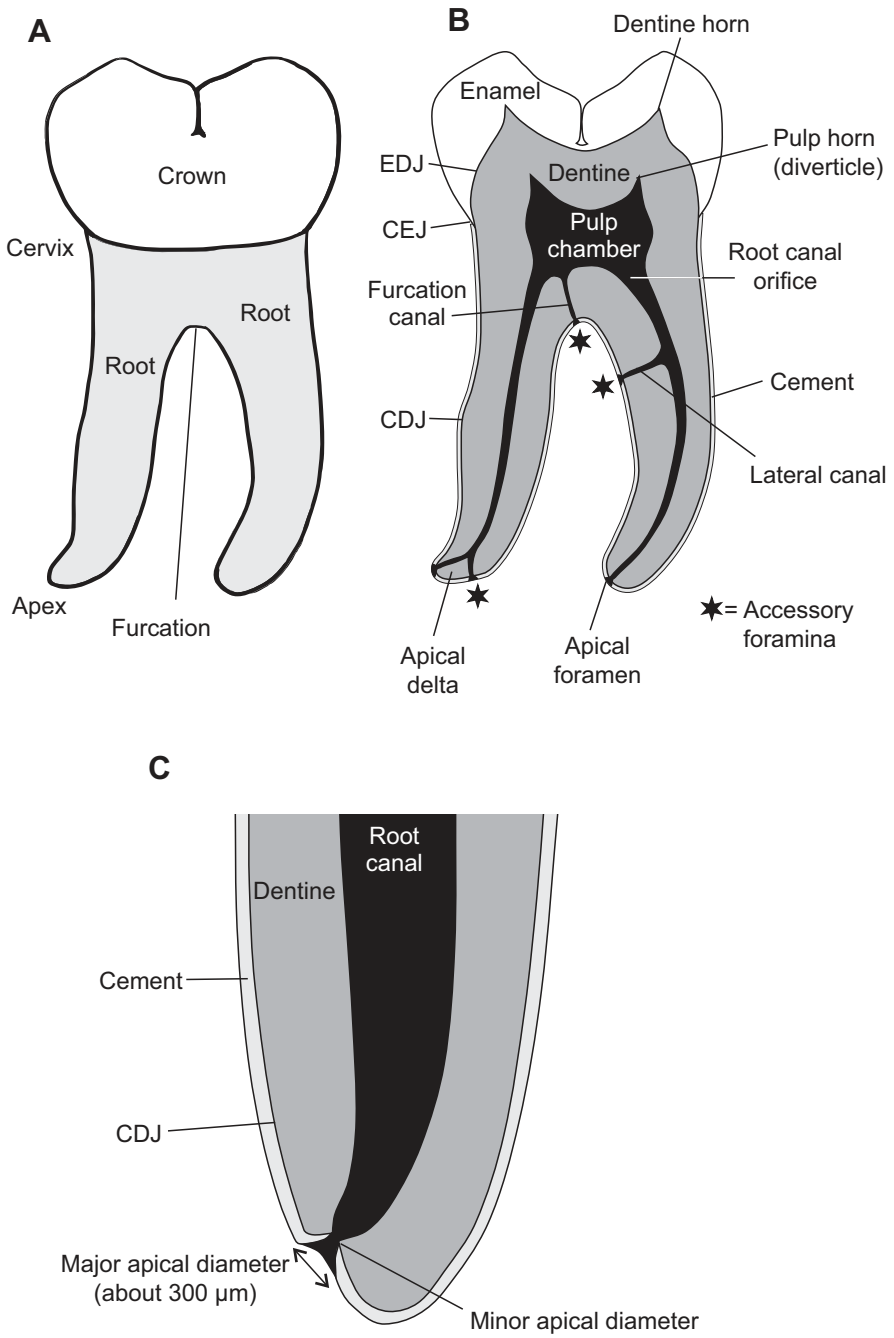

Figure 1.2 General anatomy of the tooth, pulp chamber, root canal and apical foramen. A, main components of a generalised human molar. B, section through molar showing the dental tissues, pulp chamber, root canals and foramina. C, details of the root apex and apical foramen. See text for details.

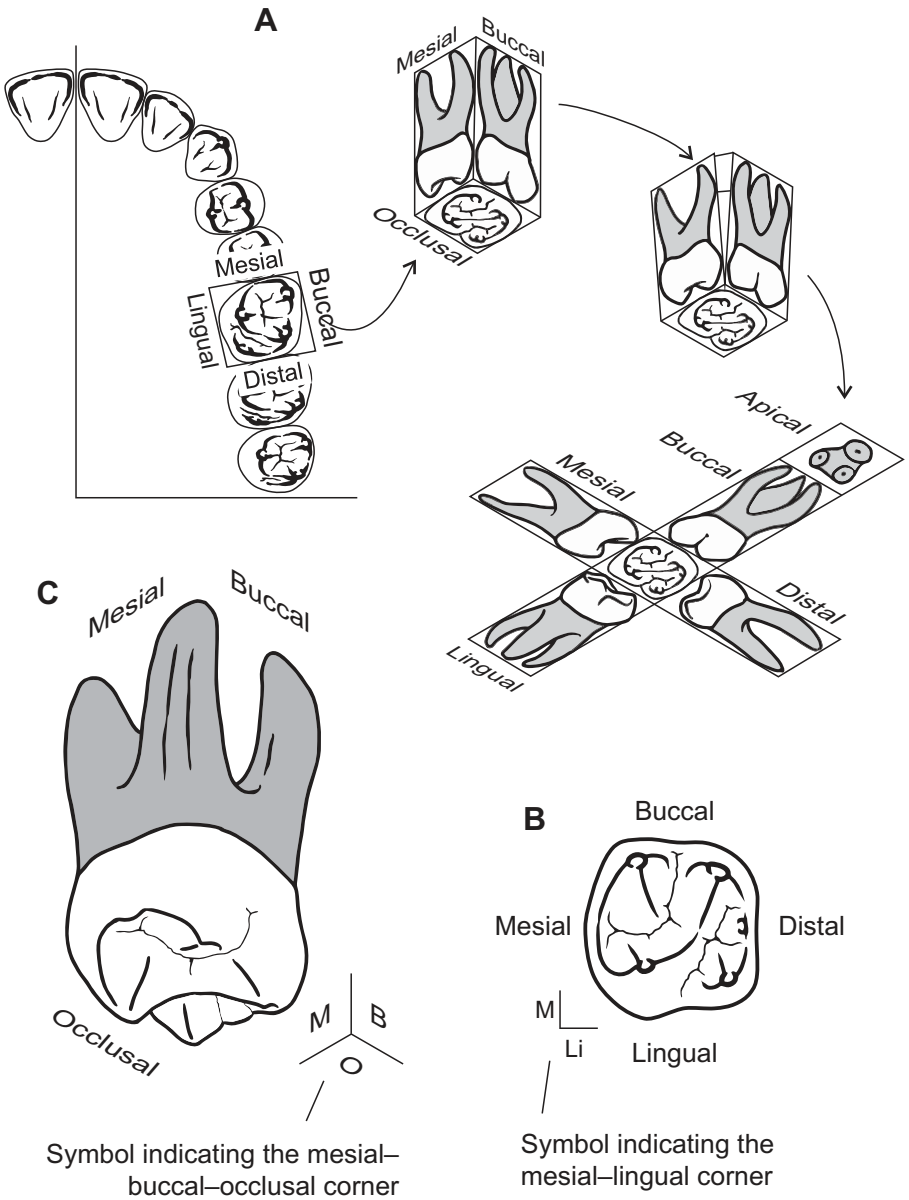

Figure 1.3 Labelling for surfaces and orientation of teeth. A, the six surfaces or aspects of a tooth, imagined as a box enclosing it (see Table 1.2). B, orthogonal projection of the occlusal surface with the mesial–lingual corner marked by the symbol used throughout Chapter 1. C, isometric projection of the tooth, seen from the mesial–buccal–occlusal corner, marked by the symbol used for this projection. See Table 1.2 for explanation of abbreviations.

Table 1.2 Names for surfaces of teeth

Mesial	M	The surface of all teeth that faces around the curve of the dental arcade towards the median sagittal plane.
Distal	D	The surface of all teeth that faces around the curve of the dental arcade away from the median sagittal plane.
Approximal or interproximal		The surfaces of a tooth crown that are in contact with another tooth in the same dental arcade.
Lingual	Li	The surface of all teeth that faces the tongue. This book uses the same term for both upper and lower teeth.
Palatal		The surface of upper teeth that faces the palate. This is the common usage in clinical dentistry books.
Labial	La	The surface of incisors facing the lips. Some texts use this term for the canines as well.
Buccal	B	The surface of canines, premolars and molars facing the cheeks.
Occlusal	O	The surface of all teeth that parallels the plane in which upper and lower dentitions meet. In particular, it is used to describe the broad surface of premolars and molars that meets in normal occlusion.
Incisal	I	The cutting edge of incisors and canines (equivalent to occlusal in the teeth that overlap during normal occlusion).
Apical		The surfaces of a tooth that face towards the apex of the roots.

The remaining four aspects of each tooth (Figure 1.3 and Table 1.2) are labelled in relation to its position in the line of teeth, which curves around in an arch known as the *dental arcade*. One surface of each tooth faces along the arcade towards the median sagittal plane (Figure 1.1), so this surface is labelled *mesial* (Greek *meson*; middle). The opposite surface faces along the arcade away from the median sagittal plane and is called *distal* (a word made up from the 'dist-' part of *distant* to be the opposite of mesial). When pairs of neighbouring teeth in the same jaw are being considered, it is usual to talk about their adjoining sides (mesial facing distal) as *approximal* or *interproximal* surfaces. The surface that faces the tongue is known as *lingual* (Latin *facies lingualis*; tongue face), but in the upper jaw, where it faces the palate, the same surface is often termed *palatal*. Finally, the surface that faces outside the dental arcade, towards the cheeks and lips, is called variously *buccal* (Latin *facies buccalis*; cheek face), *labial* (Latin *facies labialis*; lip face) or *vestibular* (after the vestibule, which is the space formed between the teeth, lips and cheeks). The word 'labial' is usually reserved for incisors, although some authors use it for the canines as well (Jordan *et al.*, 1992). Similarly, 'buccal' is usually used to describe canines, premolars and molars, whereas 'vestibular' may be used for all teeth and is really a much more useful term. Usage is therefore variable, but the terms in this book (Table 1.2) are the most commonly employed in anthropology worldwide.

1.1.2.2 Dental Formulae and Tooth Names

Mammal dentitions are summarised by *dental formulae* which show counts of teeth in upper and lower quadrants on one side. The formulae for humans and the other primates included in this chapter are as follows.

Deciduous dentition

$$\frac{\text{di } 2}{\text{di } 2}\ \frac{\text{dc } 1}{\text{dc } 1}\ \frac{\text{dp } 2}{\text{dp } 2}$$

Permanent dentition

$$\frac{\text{i } 2}{\text{i } 2}\ \frac{\text{c } 1}{\text{c } 1}\ \frac{\text{p } 2}{\text{p } 2}\ \frac{\text{m } 3}{\text{m } 3}$$

where di is for deciduous incisors, dc deciduous canines and dp deciduous premolars, i is permanent incisors, c permanent canines, p permanent premolars and m permanent molars (Figures 1.4 and 1.5). Each formula summarises one side of the dentition with the top line representing the upper teeth and the lower line representing lower teeth. The more mesial of the two incisors in each quadrant is called the *first incisor* (some texts use central incisor) and the more distal is called the *second incisor* (lateral incisor in some texts). The more mesial of the two premolars is here called the *third premolar* and the more distal is called the *fourth premolar*. From mesial to distal, the molars are named first, second and third.

This book uses the name *deciduous third premolar* to mean what clinical dentistry texts call the deciduous first molar and *deciduous fourth premolar* to mean deciduous second molar. It also uses the name *permanent third premolar* to mean what dental texts call the first premolar and *permanent fourth premolar* to mean what dentists call the second premolar. This is because it is an anthropology book. Anthropology includes primates other than humans, many of which have more teeth per quadrant than humans do, as do the majority of mammals. For comprehensibility in a broader context of zoology the broader zoological terms are therefore used. The dental formula for the generalised mammal deciduous dentition is:

$$\frac{\text{di } 3}{\text{di } 3}\ \frac{\text{dc } 1}{\text{dc } 1}\ \frac{\text{dp } 4}{\text{dp } 4}$$

with deciduous first, second and third incisors, canines and first, second, third and fourth premolars. In the primates, as in most orders of mammals, there has been an evolutionary trend to reduction in the numbers of teeth in the dental formula. Evidence from fossils shows that incisors were reduced from the distal end of their row, to lose initially the deciduous third incisor. By contrast, premolars were reduced from the mesial end of their row, losing initially the deciduous first premolar. This is what has happened in New World monkeys, such as the howler:

$$\frac{\text{di } 2}{\text{di } 2}\ \frac{\text{dc } 1}{\text{dc } 1}\ \frac{\text{dp } 3}{\text{dp } 3}$$

where the three deciduous premolars are labelled second, third and fourth. In Old World monkeys, gibbons, orangutans, gorillas, chimpanzees, bonobos and humans, the deciduous second premolar has been lost through evolution as well and those that remain are therefore labelled deciduous third and fourth premolars.

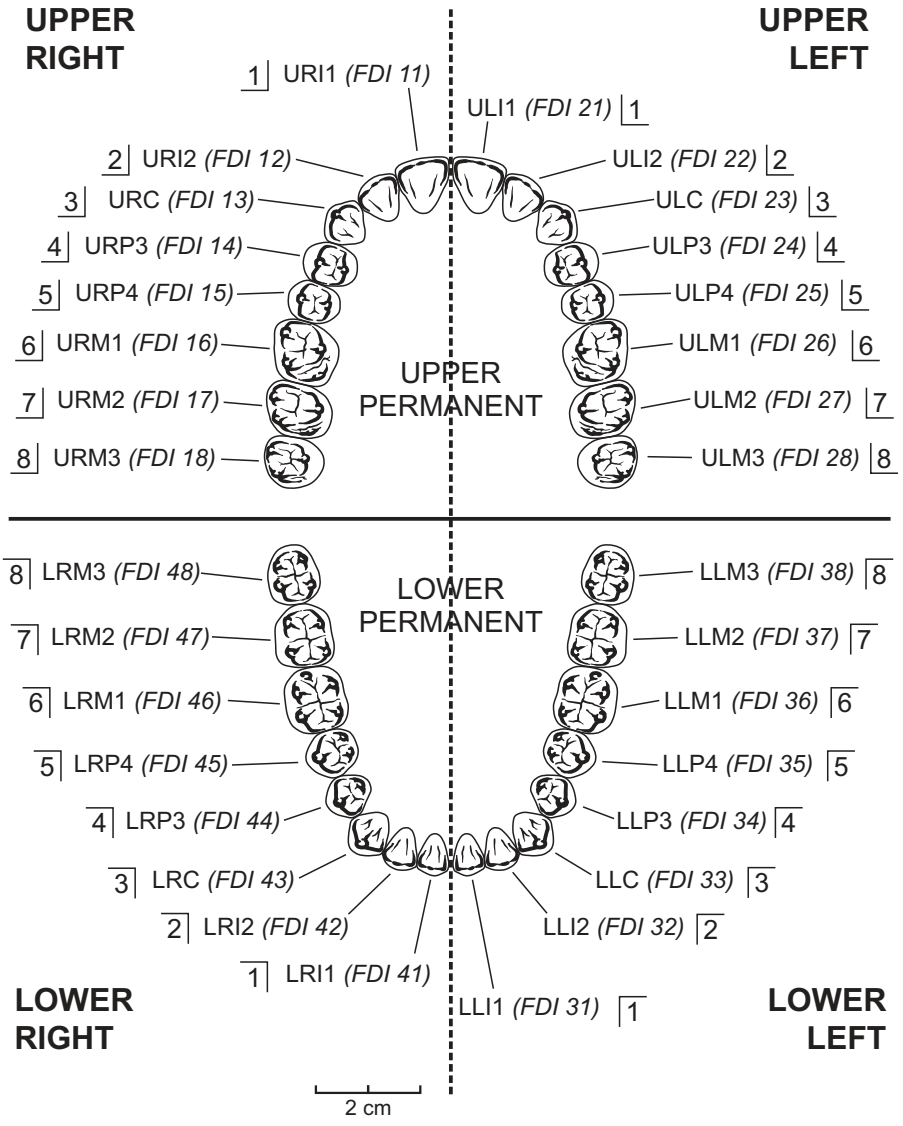

Figure 1.4 Human permanent dentition, seen in occlusal view and arranged in quadrants. Name abbreviations, FDI two-digit codes and Zsigmondy labelling are shown for each tooth. See Table 1.3 and the text for explanation.

The dental formula for the generalised mammal permanent dentition is:

$$\frac{\text{i}\,3}{\text{i}\,3}\ \frac{\text{c}\,1}{\text{c}\,1}\ \frac{\text{p}\,4}{\text{p}\,4}\ \frac{\text{m}\,3}{\text{m}\,3}$$