Peter S. Ungar

TEETH

A Very Short Introduction

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Chapter 1
Teeth matter

'Whoa, look at those teeth, they're so cool!' I enjoy walking through the exhibits at natural history museums when I visit for research. This time it was the Smithsonian. The little girl, six or seven, dragged her younger brother by the arm across a crowded hall to see the skull of *Dimetrodon*, a mammal-like reptile that lived nearly 300 million years ago. Its teeth *are* cool—but so are yours. Think about it. Your teeth are the product of half a billion years of evolution. They provide fuel for the body by breaking apart other living things; and they do it again and again over a lifetime without themselves being broken in the process. It's like a perpetual death match in the mouth, with plants and animals developing tough or hard tissues for protection, and teeth evolving ways to sharpen or strengthen themselves to overcome those defences.

Why are we drawn to teeth in the halls of natural history museums and in picture books of fossil species? There's something visceral about them. Perhaps it's because our early ancestors spent so much time running away from teeth. Or maybe it's because they define us. As George Cuvier, the great 19th-century naturalist is often quoted to have said, 'Show me your teeth, I will tell you who you are.' We know intuitively something about an animal by looking at its mouth. Think of *Tyrannosaurus rex*, with its long, sharp teeth for killing prey and ripping flesh. A little closer to home, a recent survey of nearly 5,500 American singles by the online dating service Match.com found teeth to be the #1 attribute both men and women use to judge potential partners. Yes, teeth matter.

I have spent my entire adult life studying teeth, but what I *really* care about is how Nature works, how life came to be as it is today, and where we humans fit into the picture. Teeth matter to me because they are great tools for working these things out.

The ecological angle

Teeth can help us understand ecology, the study of how living things interact with one another and with their physical environment. What could be more fundamental to those interactions than feeding? An organism eats its neighbour for the fuel and raw materials needed to grow, sustain itself, and reproduce. Teeth matter because they are right in the middle of it, mediating between eater and eaten. They are the front line in Nature's 'struggle for existence', as Darwin called it.

Conventional wisdom suggests that teeth gave early vertebrates an edge in the 'arms race' between predator and prey. The filter feeding, jawless fishes that dominated the seas for hundreds of millions of years had no chance once jaws and teeth evolved. As the renowned 20th-century paleontologist Edwin Colbert wrote, 'A vertebrate without jaws was efficient after a fashion, but unless it became adapted to certain very specialized habits it was not well enough equipped for survival in a world where a pair of upper and lower jaws had evolved as a food-gathering mechanism.' In reality, though, jawless fishes did just fine for nearly 100 million years, much of it alongside their jawed and ultimately toothed cousins.

But teeth must have given those that had them an advantage for capturing and immobilizing prey. They could be used to scrape, pry, grasp, and nip all manner of living thing. And better access to nutrients meant more offspring, and more evolutionary success. Teeth spread quickly through the oceans of the early Palaeozoic Earth, whether toothed fishes sidelined their toothless cousins or not. As 20th-century paleontologist James Marvin Weller wrote, 'Although teeth rarely excite the attention that their importance warrants, their evolution among the early vertebrates without a doubt played an unrivaled role in the successful adaptation of these animals and their achievement of rapid and effective dominance in the organic world.'

The next major milestone for teeth was the ability to occlude, wherein opposing surfaces come together in a precise way for chewing. This evolved in some amphibians and reptiles, but today mammals own occlusion and chewing. They use these mechanisms to rupture plant cell walls and insect exoskeletons for access to nutrients that would otherwise pass through the gut undigested. Chewing also leads to smaller particles for swallowing, and more exposed surface area for digestive enzymes to act on. In other words, it means the extraction of more fuel and raw materials from a mouthful of food.

This is especially important for mammals because they are endotherms—they heat their bodies from within. It takes fuel, and lots of it, to be endothermic and keep the home furnace burning. Chewing gives mammals the energy needed to be active not only during the day but also the cool night, and to live in colder climates or places with more fluctuating temperatures. It allows them to sustain higher levels of activity and travel speeds to cover larger distances, avoid predators, capture prey, and make and care for offspring. Mammals are able to live in an incredible variety of habitats, from Arctic tundra to Antarctic pack ice, deep open waters to high-altitude mountaintops, and rainforests to deserts, in no small measure because of their teeth.

The paleontological angle

Teeth matter a lot to paleontologists. First, they are the most common vertebrate fossils we find, and many species are known only from their teeth. Second, we can use them to infer the diets of past animals because tooth size, shape, structure, wear, and chemistry all relate to what an animal eats. Because diet is such an important key to ecology, connecting tooth to food can help us reconstruct paleoecology, the relationships between past organisms and their environments. We can trace changes in these relationships over time if we have a reasonable fossil record. And if we combine this with models of past climates, we might even figure out how environmental change triggered evolution. We can begin to understand how animals in the past differed from or were similar to those alive today, and how present-day animals, including us, came to be the way we are.

A very brief introduction to the history of dental research

People have been thinking about teeth for a very long time. Aristotle discussed them in *De partibus animalium*, around 350 BC. His comparisons of tooth number, size, and shape among animals according to their diets served as the pinnacle of knowledge on teeth for nearly two millennia. And much of his work still stands the test of time. There are other bits and pieces on teeth that survive from antiquity, recorded in general works on anatomy and medicine by Hippocrates and Galen and their later compilations by Avicenna. But there is little else until Aristotle's corpus and other classical works began to spread through Europe as movable-type book printing took off in the late 15th and early 16th centuries. This prompted many studies on anatomy and zoology, several of which touched on teeth.

The first known book on teeth is *Artzney Buchlein* (1530), a short, anonymous collection of descriptions of dental pathologies and their treatments. Soon after, the great Flemish anatomist Andreas Vesalius devoted a chapter of *De humani corporis fabrica* (1542) to teeth. Another renowned anatomist of the time, Bartolomeo Eustacio, followed with *Libellus de dentibus* (1563), the first known book devoted in its entirety to dental structure and function. And Eustacio took a comparative approach, contrasting human teeth with those of other animals.

The invention of the microscope in the 17th century led to significant advances in understanding how teeth are put together. Antony van Leeuwenhoek and Marcello Malpighi documented the microscopic structure, or histology, of dental tissues in detail. And there were many more influential works in the 18th century, such as *Le chirugien dentiste* (1728) by Pierre Fauchard, and *The Natural History of the Human Teeth* (1771) by John Hunter.

But the golden era of odontography, the descriptive study of teeth, really came in the early 19th century. We owe much of our knowledge today to naturalists of the time, including Georges Cuvier, Richard Owen, and Christoph Giebel. And as the theory of natural selection began to take hold later in the century, comparative anatomists such as Thomas Henry Huxley, William Flower, and Richard Lydekker entered the mix. Work on dental histology also flourished. Some students might recognize Andres Retzius, Victor von Ebner, Samuel Salter, and John and Charles Tomes from the microscopic dental structures that bear their names. The transition from description to explanation, or odontography to odontology, also began late in the 19th century, with Edward Drinker Cope, Henry Fairfield Osborn, and others who developed models for the origin and evolution of teeth. These models are in large part still with us today.

Studies of teeth have continued to progress in the 20th century and into the 21st. Their results are the subject of this book. Works on growth and development have brought new insights, and we are beginning to discover the genetic controls over tooth size and shape. Recent advances in our understanding of how species relate to one another provide a framework for understanding how teeth evolve. Studies of tooth size, shape, structure, wear, and chemistry offer fresh insights into how teeth work, how animals use them today, and how they used them in the past. And new fossil finds are filling important gaps in the paleontological record, allowing us to document the major milestones in the evolution of teeth and chewing.

Chapter 2
Types and parts of teeth

Many different kinds of teeth are found in the animal kingdom. Not only do they vary between species, but also within a mouth, both by generation (baby teeth versus adult ones) and by type (front teeth versus back ones).

Variation within a mouth

Tooth generations. Most vertebrates shed and replace their teeth. Sharks, for example, can do it hundreds of times, with tens of thousands of teeth passing through the mouth in a lifetime. And replacements can differ in size, shape, and structure from their predecessors. Larger teeth often succeed smaller ones as the jaw grows throughout life in non-mammalian vertebrates. These replacements tend to come in an alternating pattern, every other or every third position to prevent large gaps in the tooth row.

Mammals do things differently because our jaws stop growing in adulthood. We don't need multiple generations of progressively larger teeth—two generations work just fine. Our baby teeth, also called milk or deciduous, are usually smaller, with thinner and whiter enamel; and their crowns and roots are shaped differently from those of their adult, or permanent, replacements. We replace our first twenty teeth, all but our molars, and add a dozen of those as space in the jaws is made available. The final molars erupt around the same time that jaw growth finishes. Most other mammalian species have a different pattern, though. Many are born with permanent teeth in place; their deciduous ones never completely form, or they erupt and are shed in the womb. And a few apparently keep their milk teeth and never replace them. Mice, for example, have adult teeth at birth, and toothed whales evidently never get them.

Tooth types. Many vertebrates are *homodont*; their teeth all look about the same. They are often cone- or needle-shaped, and function to acquire, capture, contain, or kill. Mammals and other animals that need to chew and break food into pieces are usually *heterodont*; their front and back teeth differ, with a dental division of labour for food acquisition and processing respectively. The sheepshead fish, for example, has front teeth that look like our incisors, used for scraping and grasping. Their back teeth are flat, pebble-like structures, used to crush sea urchins and other hard foods. Herbivorous lizards, like the iguana, also have dental differentiation, with cone-shaped front teeth for cropping vegetation, and more complex ones behind them for shredding. And mammals take this differentiation to an extreme, with four distinct types: incisors, canines, premolars, and molars (see Figure 1).

Incisors are the front teeth. These are usually flattened and shovel-shaped with one cusp and one root, but they may have more. Incisors serve a bevy of functions, from grasping or nipping to stripping, scraping, and other behaviours that bring food into the mouth in chunks small enough to chew or swallow. These teeth can be quite specialized, ranging from ever-growing chisels in rodents and rabbits used for gnawing, to comb-like structures in colugos with prongs for grooming, and tusks in elephants and narwhals used as tools for prying and digging, as weapons, or as special sensory organs.