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NATURE VERSUS DENTURE

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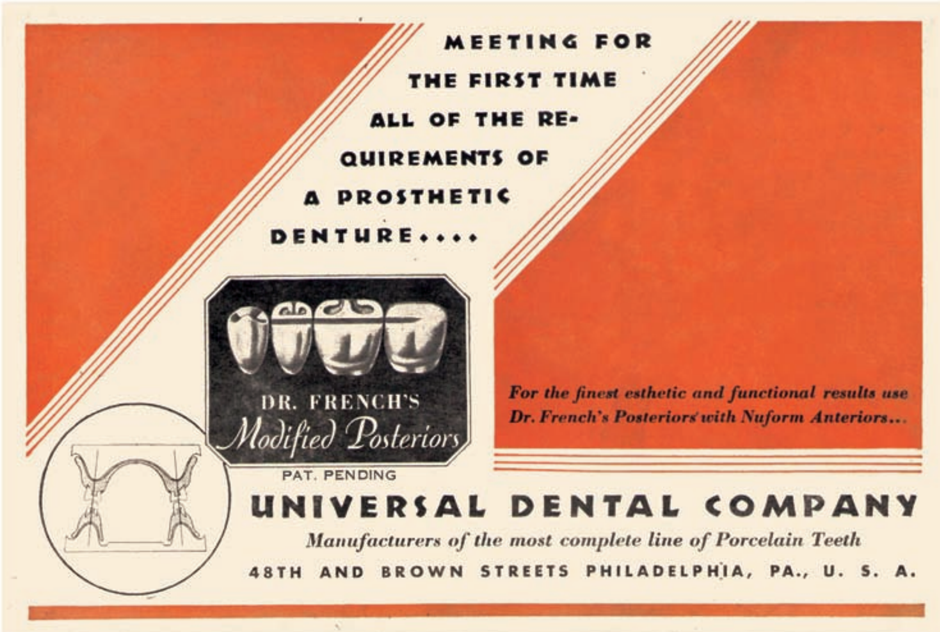

PROSTHESIS: ANATOMIC VS. NONANATOMIC

The term "prosthesis" is commonly used to describe artificial devices used to replace or restore missing or defective body parts or functions.[1] A dental prosthesis is an intraoral prosthesis used to recover or reconstruct missing teeth, soft or hard structures of the jaw, and the palate, and its primary function is to rehabilitate mastication or chewing. Mastication is considered a highly complex oral motor behavior, relying not only on the form of but also the relationship between the teeth, joints, muscles, tongue, and nerves. Despite this, dental prostheses have generally been based on "natural principles" and their forms have remained *anatomic*. Anatomic dentures, while identical in appearance to natural teeth, do not have roots and typically sit or float on top of mucosa, resulting in a disproportionate distribution of forces during mastication. In other words, anatomic dental surrogates do not perform as efficiently in a biological machine intended to function with teeth integrated into the jaw.

This problem formed the basis for *nonanatomic* dental prostheses that renounced natural imitations in favor of "mechanical principles."[2] Among the earliest deliberate attempts was Ash's tooth of 1858, which carried inverted cusps. However, an incomplete understanding of biomechanical principles along with a lack of technical knowledge resulted in a general dismissal of such nonanatomic dentures. Until the turn of the century, designs introduced by manufacturers such as the Dentists' Supply Company's "Twentieth-Century Anatomical Bicuspids and Molars" (1909) or "Trubyte" (1914) continued to focus on a "true-to-nature" approach.[3] But this trend shifted in the 1920s, in part due to technical developments and a professional acceptance of nonanatomic forms. Despite their uncanny appearance, for many dentists and designers like Victor H. Sears, nonanatomic forms were the optimum solution. In his view, if their design "had been first undertaken by engineers from the mechanical standpoint instead of by dentists from the anatomic standpoint, nonanatomic occlusal forms would from

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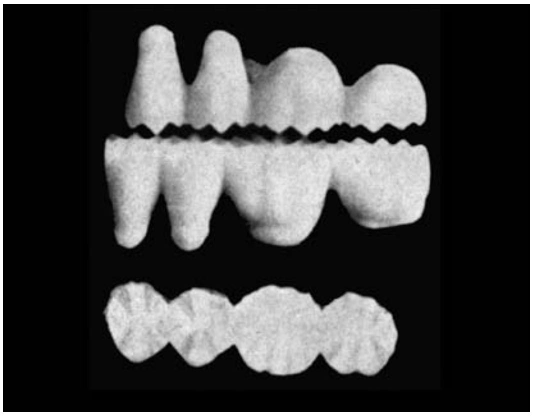
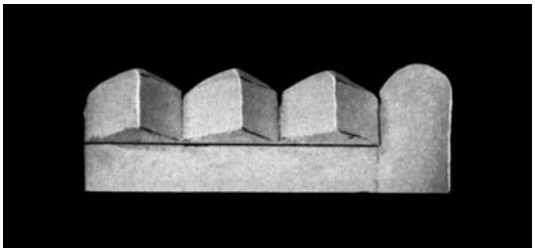
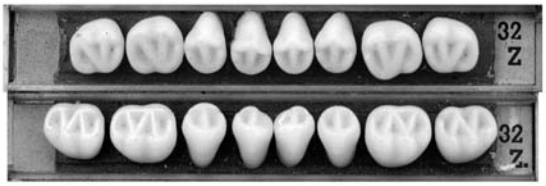
Above: Box lid for Felix A. French's Modified Posteriors. Introduced in 1935, they were a standout design of the prewar period. French, who believed that anatomically formed dentures were not meeting expectations, had spent eight years developing his design. The teeth came in both porcelain and acrylic varieties, and were manufactured and sold by the Universal Dental Company in Philadelphia, which continued to produce them until the end of the twentieth century. Courtesy the Dr. Samuel D. Harris National Museum of Dentistry, Baltimore.



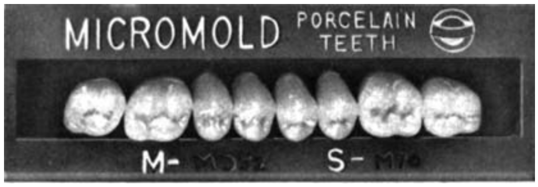
Posterior tooth blocks designed by LeRoy E. Kurth in 1945 for improved shredding. All images on this page courtesy *Journal of Prosthodontics* and Dr. Robert Engelmeier.

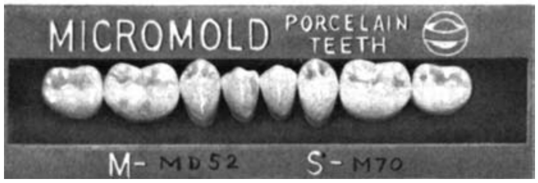


Designed by Rudolph Klicka in 1949, these "chewers" were intended to keep one's jaw slightly protruded while masticating. No record has been found that they were ever manufactured.



Denta Pearl Zeros, sold by H. D. Justi and Son beginning in 1941. They were made from acrylic resin, which had more cushioning than porcelain and allowed for quieter chewing.





Semi-anatomic teeth, designed by H. F. McGrane. The curved cusps of this design, manufactured in 1939, were engineered to decrease the force applied to the ridges around the edges of each tooth when chewing.

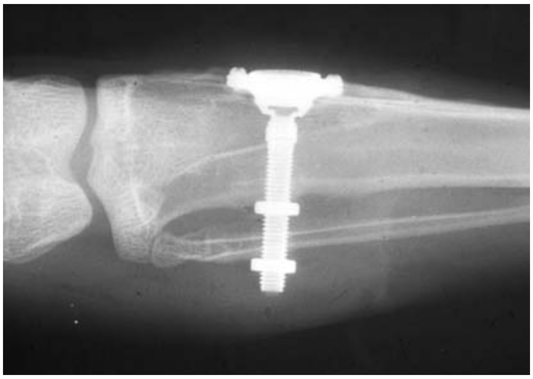
the start have been standard."[4] While they never fully replaced the anatomic forms as a standard, by 1950 all major manufacturers were offering nonanatomic dentures, on which the modern movement had left its mark: form finally followed function.

From "Scissor Bite" and "Chopping Block Teeth" to "Masticators" with pyramids, the design of nonanatomic dentures varied significantly but they all aspired for better mastication efficiency, stability, comfort, and durability.[5] In doing so, these prostheses went beyond simply restoring basic functions and toward extending them. Far from being a disadvantage, nonanatomic prostheses were seen by many as an advantage over natural forms or materials—they could chew more efficiently, their teeth did not decay or discolor, and they never caused any pain or discomfort. In that sense, these objects went from being a prosthesis to what I call a "transthesis"—an artificial device that adds to, extends, or transcends basic biological functions.[6]

MATERIAL: BIOMECHANICAL VS. BIOCHEMICAL

The human body rejects almost any foreign material. This reality had served as a major drawback for the development of dental implants (permanently fixed prostheses inserted into the jawbone). But in 1952, having inserted a titanium optic chamber in a rabbit's bone to study blood microcirculation within it, Swedish physician Per-Ingvar Brånemark fortuitously discovered that the bone and the metal had bonded so well that they could not be separated.[7] Through this accidental discovery, titanium became the first nonbiological material that not only the body does not reject, but rather accepts and embraces fully. Brånemark later named the phenomenon "osseointegration."

The discovery of the suitability of titanium for tissue-integrated prostheses became a turning point in dental implantology, and in 1965, Brånemark's patient Gösta Larsson became the first recipient of titanium



Radiograph of Per-Ingvar Brånemark's subject rabbit, showing the titanium optic chamber fixed to the animal's tibia and fibula. Courtesy European Association for Osseointegration.

dental implants. While early implants were cylindrical screws tapped into the mandible, other designs such as vented cylinders and expansive screws have since been introduced. The use of titanium allowed the development of dental prostheses to shift away from the exploration of forms and more toward that of materials—or, away from biomechanical principles and toward biochemical properties and biocompatibility. The shift from dentures to implants also transformed the nature of dental prostheses from removable intersomatic devices into permanent, biologically integrated intrasomatic artificial organs.

While this shift offers one explanation for the diminishing interest in nonanatomic dentures, it does not justify full abandonment of nonanatomic forms. Today, the functionalist dictum, "form follows function," is understood in restorative dentistry as addressing "the dependent relationship between the original biomechanical behavior" and "the nature of the materials used."[8] This reformulation of "form"—not simply to mean shape, but also the biomechanical and biochemical attributes that contribute to the maintenance of function—ultimately aspires to "closely resemble natural tooth anatomy and esthetics."[9] Form, here, no longer follows function, as it did earlier, but once again follows anatomy. While our bony conical tooth roots are now transformed into vented cylinders or expansive screws made of titanium, they are still crowned with a prosthesis that merely imitates natural tooth anatomy. Why did we abandon the nonanatomic forms altogether to go back to anatomic replicas?

SPEECH: ARTICULATE VS. INARTICULATE

According to the book of Exodus, when God asked Moses to be his messenger and return to Egypt to liberate the slaves, Moses turned down the offer, responding reluctantly that he was *kvad peh*, "heavy of tongue" or tongue-tied, and begged God to send someone else instead.[10] Moses probably suffered from a lisp—a speech impediment in which a person cannot articulate sibilants. Sibilants are articulated by directing a stream of air with the tongue toward the sharp edges of the upper and lower incisors. Any error in the placement of the tongue or the shape of anterior teeth can result in inarticulate sibilants.[11]

Form, position, and even occlusion of teeth have a direct correlation with "articulate speech"—speech that is characterized by sharp enunciation. But this works both ways as dentists use articulate speech to determine the "correct" position or form of teeth. To establish this, first the edges of the maxillary incisors are positioned so that they make a definite seal against the lower lip when the patient pronounces *f* and *v* sounds. Once the position and length of maxillary incisors are established, the dentist moves on to adjust the mandibular incisors in relation to them. The key to this process is known as the "S" position, which is determined by setting the incisal edges of the mandibular teeth slightly lingual to the labial edges of the upper incisors when repetitive *s* sounds are enunciated.[12] The dentist typically asks the patient to say words such as "Mississippi" or count from sixty to seventy, continually making adjustments until "clarity of speech" is achieved.[13] Once the correct length and position for the maxillary and mandibular teeth are determined, the placement of the rest of the teeth is determined in relation to the mandibular movement during speech. Any deviation in this procedure would result in speaking with a slurring of words or *inarticulate* speech.

When and how exactly language was developed in human history is still an anthropological mystery.[14] But whatever evolutionary theory we subscribe to, it is reasonable to assume that the biological attributes of modern humans—our cognitive abilities, our dental morphology, our ability to control our muscles, tongue, and vocal cords—were instrumental in enabling us to enunciate certain sounds and ultimately develop language. What we are witnessing today, however, is quite the opposite: language, a techno-cultural invention, is designing our dental morphology. Our ancestors' age-old technique for communication is now the determining factor for our anatomy. It seems therefore easier for us to adjust our dentition to our language than to do the opposite. We may choose to have "Scissor Bite" dentures or permanently fixed implants with expansive titanium screws, but would still need to be able to enunciate *f* and *s* sounds exactly as our evolutionary ancestors once did.

PHYSIOGNOMY: NATURAL VS. ARTIFICIAL

As early as 500 BC, Pythagoras was accepting or rejecting students based on how gifted they looked, and Aristotle believed, for instance, that a large forehead is a sign that someone is "tardy," "large and erect ears are an evidence of foolish talking and loquacity," and eyes with large corners are "a sign of an evil disposition."[15] While physiognomy is considered an ancient pseudoscience, it is still applied to some modern sciences. An example of that is the *dentogenic concept*. Dentogenics (as in photogenic) is defined as "the art, practice and techniques used to achieve an esthetic goal in dentistry."[16] According to dentogenics, sex, personality, and age reveal themselves in our dentition. For instance, femininity is characterized by "compassion and tenderness, sweetness and mother love" and is expressed in dentition by "roundness," "softness," "smoothness"—in general by a "delicate type of tooth." Masculinity, meanwhile, is characterized by "aggressiveness, boldness, hardness, strength, action, and forcefulness," and is expressed by a sense of "harshness and angularity" in teeth.[17] Similarly, individuals are understood to occupy a position within a "personality spectrum" that classifies them into three general types: "vigorous," "medium," and "delicate."[18] Age is another factor, which reveals itself as the color, texture, and form of the teeth and gums lose their youthful quality and take a mature form.[19]

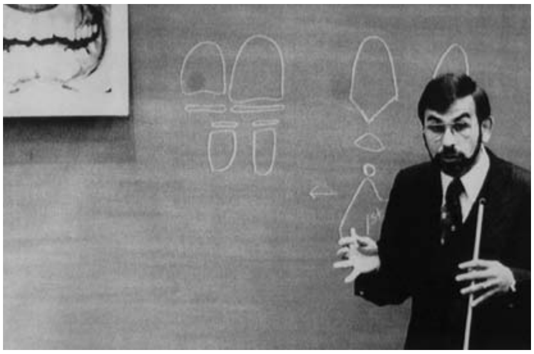
In dentogenics, the work of the prosthodontist is primarily concerned with aesthetics in order to represent a patient's (real or desired) age, sex, and personality. "Natural teeth" aesthetics are largely favored in response to the mechanical "denture look"—the artificial appearance of white, perfectly aligned dentures. To augment a "natural aesthetic" is to incorporate the wear and tear, the smoothness or hardness, and the anomalies unique to individuals. "Imperfection," as proclaimed in a scientific paper on dentogenics, "is an artistic requirement in creating the illusion of natural teeth." The dentist is endowed with "creative license" to interpret an individual's traits in designing his or her artificial teeth.[20] "A dentist must be an artist and a sculptor with highly developed perceptive qualities."[21]

What dentogenics reveals is the irony that the "natural" attributes in dental prostheses are just as artificial as the formal, material, and mechanical strategies used to produce them. But why should artificial teeth look natural? Our teeth now operate within a network of sociocultural codes and standards that assign meaning or value to them (i.e., rounder teeth to look more kind, or whiter teeth to look younger). All anatomic forms operate within a set of aesthetic codes—they speak in the same language. Nonanatomic prostheses, on the other hand, operate outside this protocol. When we choose anatomic prostheses (contact lenses, dentures, wigs, silicone breast implants, etc.) over nonanatomic ones, it is often not because they function better, are more comfortable, or even strike us as aesthetically superior, but because we do not want to fall below that threshold of normality and legibility. So until the norm shifts, and this sociocultural protocol is rewritten—as it was in the case of eyeglasses—we are likely going to hold on to our anatomic prostheses.[22]

IDENTITY: SUBJECTIVE INTERIORITY VS. OBJECTIVE EXTERIORITY

In June 1979, as American serial killer Ted Bundy stood trial in one of the first nationally televised judicial proceedings, Dr. Lowell J. Levine, a dental expert, showed how Bundy's crooked teeth matched a bite mark on a victim's left buttock. Bundy was found guilty, and with that, the larger public became aware of the little-known field of "forensic dentistry.[23] Since then, expert testimonies matching bite marks have continued to play a major role in many criminal cases, often putting defendants on death row.[24] After all, who has the audacity to dispute scientific evidence?

It is generally accepted that no two individuals have the same dentition, in part due to variation in the arrangement, spacing, size, and shape of teeth. Teeth are also the most durable and commonly preserved body parts.[25] This enables forensic dentists to identify individuals, sometimes only through their remains, by comparing the dead person's dentition with dental



Dr. Lowell J. Levine, a New York forensic odontologist, testifying during Ted Bundy's 1979 hearing in Tallahassee, Florida, that the bite marks on Florida State University student Lisa Levy reflected characteristics of Bundy's teeth.

records of known individuals.[26] But unlike DNA or fingerprints, dentition—subject to disease, alteration, or restoration—is variable within an individual's life. Dental identity is always in flux.[27]

As a result, dentists are encouraged to document the "maximum amount of dental information for analysis."[28] Through medical examination, a dentist is now at once an examiner, an inspector, and a surveyor. This archival impulse functions as what Michel Foucault has called "a procedure of objectification and subjection"—a mechanism that has transformed the economy of visibility into the exercise of power in our society.[29] While scientists of earlier periods had already developed this obsession with classifying objects (e.g. plants, animals, and humans), these taxonomies entered the domain of knowledge as general *categories* or *species*.[30] But what has changed is that our modern archives classify us, not only as members of pre-existing categories (*Homo sapiens*, males or females, aggressive or submissive, etc.), but also in all our individual uniqueness and singularity.[31]

The problem raised by Foucault, therefore, relates not to a "subjective interiority," but to an "objective exteriority" in which human bodies, events, and archives interact. The assemblage of this external body of files, documents, and dossiers, as Manuel DeLanda points out, gives us "a real identity which is neither a subjective feeling nor an ideological experience."[32] In this new *panopticon*, it is no longer the walls of the prison cell or the gaze of the watchman that holds us in place, but it is the material body we are trapped in that marks us and makes us visible: the ridges on our fingertips, the DNA within our cells, or the teeth implanted—by nature or our dentist—inside our mouths.

WISDOM: HUMAN VS. PREHUMAN

Humans are diphyodont, meaning they have two successive sets of teeth in their lifetime.[33] We are born with a set of twenty deciduous or "milk" teeth. Although none are visible at birth, their calcification begins at about fourteen weeks *in utero*, and is completed by three years of age. Around the age of six, the first permanent or succedaneous teeth emerge by pushing out the primary teeth and taking their place. Our second dentition is expected to complete by twenty-five years of age; we replace twenty with thirty-two.[34]

The third molars, a.k.a. wisdom teeth, are the last and most distal teeth that appear in our mouth. They usually emerge between the ages of seventeen and twenty-five, when we are believed to be "wiser."[35] Ideally, by the time they erupt, the posterior jaw has managed sufficient growth to allow room for all of our thirty-two permanent teeth. For most of us, however, that is not the case. As a result, the third molars are often considered "vestigial" or "useless"—a relic of a distant past when our ancestors had bigger jaws.[36] But "useless" is a useless term in biological anthropology. Why do we have these teeth if they are useless?

A common postulation is that these teeth were used to help chew down our primeval diet of coarse and rough food (such as leaves, roots, nuts, and raw meat).[37] As our diet evolved, so did our jaws, but for most of us presumably less-evolved *Homo sapiens*, our wisdom teeth have not quite caught up yet. It seems as though we are caught in the middle of an evolutionary cycle that has not been fully completed. Aside from diet, many anthropologists view the shrinkage of our jaw as a result of the growth of our brain—one kind of wisdom at the expense of another.[38] Jean-Jacques Rousseau, one of the first to outline this cerebralist theory, saw the growth of the brain as the instigator of the chain of events that transformed us, so to speak, from prehuman to human.[39] Others, like André Leroi-Gourhan, have considered bipedal locomotion as the determining factor for our evolution.[40]

We know today that none of these changes was the prime cause but that these traits instead coevolved as part of an evolutionary cascade, where change in each resulted in changes in the others.[41] But whatever the evolutionary causes of the disproportion between the size of our jaws and the number of our teeth may be, the majority of us are faced with a simple architectural problem: lack of space. Our third molars often cause crowding, tooth displacement, and other serious oral complications, which is why most of us choose to remove them, often before they even cause us any real problems.[42] While we may prefer anatomic prostheses and restoring our teeth to their "natural" state, most of us make a conscious decision to permanently alter or *correct* that natural biological condition when it comes to our wisdom teeth. Instead of thirty-two, we opt for twenty-eight.

TECHNOLOGY: SOMATIC VS. EXTRASOMATIC

Leroi-Gourhan's "paleontology of the knife" has opened the possibility of viewing the evolution of technology in relation to our own. This paleontology illustrates ten tools and artifacts, from the primal pebble and hand axe to the modern knife. But his scheme for the subsequent evolution of the knife is rooted not only in tools but also in human gesture: the conversion of the rectilinear motion of a longitudinal blade into the circular motion of a rotary blade.[43] For Leroi-Gourhan, in the manual creation of a material culture, gesture is a kind of "material action" that, coupled with speech, is a form of expression of cognition and language. This is what he describes as the *chaîne opératoire*, or "operational sequence."[44]

Leroi-Gourhan's diachronic sequence illustrates how, throughout our evolutionary history, these gestures or operations have become externalized and taken material form. We have essentially delegated our operations to objects, tools, or utensils. And through this "delegation," to borrow from Bruno Latour, "we have drawn a scale where tiny efforts balance out mighty weights."[45] The role of the knife, and utensils in general, should therefore be viewed within this larger network of delegations: techniques of production, preparation, and processing of food, now performed by an army of artificial extrasomatic, transthetic surrogates (from mechanical cutting devices to cooking techniques) that have enabled us to transcend our primordial diet and our limited abilities to digest.

Prostheses, therefore, can no longer be seen only as somatic artificial attachments or appendages but also as extrasomatic artifacts that intervene on human subjectivity.[46] "Technology" in general, as Kathleen Woodward has argued, "serves fundamentally as a prosthesis of the human body, one that ultimately displaces the material body."[47] This prosthetic understanding of technology was ingrained in the modern movement. Writing in 1930, Sigmund Freud saw technologies of his time—the aircraft, the telescope, the camera, the telephone, etc.—as "auxiliary organs" that have turned man into a "prosthetic god." Freud went even further by describing architecture, or "the dwelling house," as a prosthetic extension of the body—not one's own, but a "substitute for the mother's womb, the first lodging, for which in all likelihood man still longs, and in which he was safe and felt at ease."[48] Modern architectural discourse too assumed architecture to be a prosthesis. Le Corbusier, for instance, had described not just our buildings but also "the mechanical system that surrounds us" as "an extension of our limbs; its elements, in fact, *artificial limbs*."[49] And as Mark Wigley has shown us, the modern movement displaced architecture from "artifice" into the "artificial": "a technological extension of the body that is neither natural nor cultural."[50]

Today, one could imagine a new paleontology where the lever, the doorknob, the light switch, the computer mouse, and the touchscreen, along with their own unique human gestures, are represented side by side, depicting the evolution of a particular species in our transthetic genus. With their evolution, our gestures have also evolved, become more complex, intricate, and sensitive, and yet also more effortless, seamless, and intuitive.[51] Today, our regular biological functions are detected, measured, and documented by a range of devices that transcribe them into digital data. Biology and technology are no longer as distinct and independent as we once imagined them to be, but are interdependent parts of the same ecology, the same *chaîne opératoire*, that constitutes our environment—be it somatic or extrasomatic.

CULTURE: GOD VS. MONSTER

While Freud celebrated technology as a prosthesis, he also acknowledged the difficulties associated with using such extensions of the self.[52] At the time, Freud was battling an intraoral cancer to which he finally succumbed. His mandible and palate had been removed in an operation and replaced by a prosthetic jaw, made of rubber. During the last sixteen years of his life, he was subjected to thirty operations and endured daily manipulations of his prosthesis.[53] The artificial jaw, designed to shut off the mouth from the nasal cavity, was described as a "horror" and was labeled by his friends "the monster."[54]

In a letter he wrote to Lou Andreas-Salomé a year after his jaw implant, Freud reflected on the cognitive dissonance between one's own body and such a prosthetic substitute, "which tries to be and yet cannot be the self."[55] In response, Andreas-Salomé articulated a view of prostheses that saw them not as a deviation but as the exemplar of the conditions of the body: "For that is after all the most quintessentially human thing in man, that he both is and is not his own body—that his body despite everything is a piece of external reality like any other."[56]

If the body is not the same as the self, it is, then, the original prosthesis with which we are all born.[57] It is therefore not about whether such prosthetics are anatomic or nonanatomic, biomechanical or biochemical, natural or artificial, but rather about the complex interplay within the network of delegations that allow us to retain and transcend our basic functions. Not only have we gone from somatic to extrasomatic, but we have also developed a system of interconnected operations that continually replace the actors and the procedures they operate within as the type and complexities of our actions grow and evolve. In this ever-changing cybernetic network, where the pace of cultural and technological mutations far exceeds our biological evolution, our bodies seem like outmoded prostheses struggling to maintain their functional and material value.[58] They are becoming more obsolete, more *useless*.

The perils of this uneven process of coevolution was regularly debated in the cybernetic circles of the postwar era with the emergence of more intelligent machines. Computer scientists like J. C. R. Licklider advocated going beyond the conventional prosthetic model toward the idea of the human body as the prosthesis of the machine before a final synthesis of the two. Such blurring of user and machine was achieved by the computer mouse, whose inventor, Douglas Engelbart, even believed that man would "hardly still be human" if he were to stop helping machines expand their intelligence.[59] Prostheses have therefore assumed the position of the body they once aimed to correct or complete. Their rapid technological evolution is now determining ours in more complex ways than our slow biological evolution determines theirs. In essence, we have become prosthetic humans in a more intelligent nonhuman network—we are no longer the magnificent god, but have become the outlier, the monster.

So why did the development of nonanatomic dental prostheses come to a halt? Perhaps we realized that our prosthetic or transthetic organs no longer need to be attached to our bodies. We learned that what it means to be *human* cannot be understood without the complex interplay between the organic body and its cultural and technological milieu. The concept of who we are—our identity, personality, language, culture, and technology—no longer rests within the bounds of our physical and material body but in the nonmaterial world we have created. And that the social, cultural and technological systems we have built outside of us have now as much influence over our biological and anatomical attributes as we did in shaping them.

1 The word derives from Greek: *pros*, "in addition" + *tithenai*, "to place."

2 Victor H. Sears, "Thirty Years of Nonanatomic Teeth," *Journal of Prosthetic Dentistry*, vol. 3, no. 5 (September 1953), p. 596.

3 Ibid., pp. 597–598.

4 Ibid., p. 596.

5 Nonanatomic dentures were specifically designed to address the problems associated with anatomic dentures by applying the occlusal load nearer to the center of the denture foundation. They offered "three types of special occlusal surfaces: (1) those that permit easy protrusive glide, (2) those that permit easy lateral glide, and (3) those that permit easy glide in all horizontal movements." As a result, nonanatomic dental prostheses were mainly concerned with the redesign of posterior teeth (premolars and molars) and rarely were new nonanatomic designs for anterior teeth (incisors and canines) proposed. The quotation is from Victor H. Sears, "Thirty Years of Nonanatomic Teeth," p. 599.

6 Although this transition was enabled by nonanatomic forms, the distinguishing characteristic shared by prostheses and transtheses is not necessarily related to form, but rather to their ability to transcend basic anatomical functions. In that sense, artificial materiality alone, for instance, may be viewed as transcending the undesired condition of decay or discoloration in biological materials, thus rendering even anatomic dentures transtheses. But most nonanatomic prostheses that we call transtheses here made a conscious attempt to go beyond basic biological functions, which their prosthetic predecessors only attempted to restore or substitute.

7 Per-Ingvar Brånemark, "Osseointegration and Its Experimental Background," *The Journal of Prosthetic Dentistry*, vol. 50, no. 3 (September 1983).

8 Stanley J. Nelson and Major M. Ash Jr., *Wheeler's Dental Anatomy, Physiology, and Occlusion*, 9th edition (St. Louis, MO: Saunders Elsevier, 2010), p. 81.

9 Ibid.

10 See Exodus 4:10.

11 Winston Churchill also had a lisp but in his case, maintaining this speech idiosyncrasy was crucial to his public persona and his dentures were specially designed to preserve it. They were sold in 2010 for £15,200. For more on Churchill's dentures, see Marvin Rintala, *Lloyd George* *and Churchill: How Friendship Changed Politics* (London: Madison Books, 1995), p. 64.

12 Earl Pound, “Utilizing Speech to Simplify a Personalized Denture Service,” *The Journal of Prosthetic Dentistry*, vol. 95, no. 1 (January 2006), p. 2.

13 Abdul-Aziz Abdullah Al Kheraif and Ravikumar Ramakrishnaiah, “Phonetics Related to Prosthodontics,” *Middle-East Journal of Scientific Research*, vol. 12, no. 1 (2012), p. 32.

14 While some anthropologists such as Richard Klein have suggested that human evolution may have been caused by a single physiological mutation that allowed fully modern speech, others, such as Robert Boyd and Joan B. Silk, have considered it more likely that cognitive innovations evolved gradually through the accumulation of small interrelated changes without a special macromutation. In other words, not every morphological change necessarily produces an alteration in behavior, and behavior is subject to the same evolutionary forces that shape morphology and physiology. See Boyd and Silk, *How Humans Evolved*, 7th edition (New York: W. W. Norton, 2015), p. 349.

15 Aristotle, *History of Animals*, trans. Richard Cresswell (London: George Bell & Sons, 1883), book 1, chapter 8, p. 12; chapter 9, p. 14; and chapter 8, p. 12, respectively.

16 John P. Frush and Roland D. Fisher, “Introduction to Dentogenic Restorations,” *The Journal of Prosthetic Dentistry*, vol. 5, no. 5 (September 1955), p. 586.

17 John P. Frush and Roland D. Fisher, “How Dentogenic Restorations Interpret the Sex Factor,” *The Journal of Prosthetic Dentistry*, vol. 6, no. 2 (March 1956), pp. 162, 165.

18 Ibid., p. 593. There is no doubt that dental morphology reflects phylogenetic relationships among species and reveals a lot about their social organization. This is also true for humans. In pair-bonded species, for instance, such as *Homo sapiens*, there is little sexual dimorphism (difference between the two sexes) in canine size while in species that are not pair-bonded, male canines are generally much larger than female canines. Male chimpanzee canines, for example, are 19 percent to 47 percent larger than female canines, while in modern humans, those differences between sexes are only 4 percent to 9 percent. (See, for instance, Robert Boyd and Joan B. Silk, *How Humans Evolved*, p. 244). But the ideas that personality is reflected in our dental morphology would be scientifically unacceptable today.

19 In young adults, for instance, the interdental gingivae (the gums) are finely stippled, pointed, and tight against the tooth. With aging, the attached gingivae lose their stippled appearance and gradually become smooth and edematous. The young tooth also has an unabraded blueish incisal edge of variable depth and hue. But as the individual ages, the sharp tip of the cuspid wears down to a more mature form, the adolescent quality of the tissues disappears, and the complete coronal portion of the tooth comes into view. The color and texture also change with age. In general, the wearing-down process of the teeth depends on the character of the occlusion, the muscular pattern, and, more importantly, the abrasiveness of the diet. For considerations of age in dentogenics, see John P. Frush and Roland D. Fisher, “The Age Factor in Dentogenics,” *The Journal of Prosthetic Dentistry*, vol. 7, no. 1 (January 1957).

20 Ibid., p. 10. The passage continues: “Seldom would one ever want to reproduce a condition suggesting neglect of the teeth, but as the artist painting a tree which has survived adversity for many years sees the majesty of resistance to the elements in the gnarled and twisted branches, and conveys this to his canvas, so must the dentist consider his patient as an artistic challenge, and predetermine the appropriate dignity due the age and personality of his subject, as well as the sex, and achieve a representative positioning of the teeth in the denture compatible with his interpretation.”

21 John P. Frush and Roland D. Fisher, “How Dentogenic Restorations Interpret the Sex Factor,” p. 162.

22 In fact, with the exception of eyeglasses, which not only have nonanatomic forms but are also extrasomatic, this strong tendency toward natural anatomic aesthetics is a common thread in nearly all human prostheses that have been developed to this day. For an overview of the influence of design on many prosthetic objects, including eyeglasses, see Graham Pullin, *Design Meets Disability* (Cambridge, MA: The MIT Press, 2011). In Pullin’s view, the transformation that turned eyeglasses “from a medical necessity into a fashion accessory” may be an early instance where a balance between clinical and engineering problem-solving, on the one hand, and more design-oriented explorations, on the other, opened up creative tensions and new directions within prosthetic design.

23 Erik Eckholm, “Doubts about Bite-Mark Forensics Are at Center of a Death Row Case,” *The New York Times*, 16 September 2014.

24 While the lack of quantitative values and an insufficient database of dental records have limited the reliability of such testimony, bite-mark evidence is still admissible in US federal and state courts but used mostly as exculpatory material.

25 In fact, much of what we know about our evolutionary history and early primates also comes from their teeth. Teeth are more durable than other bones, and as a result, they are the most commonly preserved parts of the body. This is why for paleontologists teeth are the most exciting body part. There are a few reasons for this: first, the complex structures of teeth make them very useful for phylogenetic reconstruction; second, unlike bone, tooth enamel is not remodeled during an animal’s life and it carries an indelible record of an individual’s life history; third, teeth show a precise developmental sequence that allows paleontologists to make inferences about the growth and development of organisms; and finally, each of the major dietary specializations (frugivory, folivory, insectivory) is associated with characteristic dental features. So an individual’s teeth can also tell us a lot about their physiology, how fast they grew, what they ate, and even when and in what environmental and climatic conditions they lived. See Robert Boyd and Joan B. Silk, *How Humans Evolved*, p. 225.

26 As early as 1945, Adolf Hitler’s burned body was identified through the dental work in his lower jaw. See Xavier Riaud, “Dental Identifications of Adolf Hitler and Eva Braun,” *Journal of Dental Problems and Solutions*, vol. 1, no. 1 (27 October 2014).

27 Today, aside from matching bite marks and dental records, a variety of “dental chronological age estimations” as well as “dental DNA” is used by forensic scientists for positively identifying individuals. See Stanley J. Nelson and Major M. Ash Jr., *Wheeler’s Dental Anatomy*, p. 68.

28 Stanley J. Nelson and Major M. Ash Jr., *Wheeler’s Dental Anatomy*, p. 67.

29 Foucault described how for a long time, ordinary “everyday individuality” remained below the threshold of description. To be looked at, observed, or described in detail was a privilege. The disciplinary methods lowered the threshold of describable individuality and transformed this description to a method of control and domination. What is archived today is “no longer a monument for future memory, but a document for possible use,” where the child, the patient, or the prisoner is to become the object of individual descriptions and biographical accounts. In Foucault’s view, this turning of real lives into documents is no longer “a procedure of *heroization*,” but functions as “a procedure of objectification and subjection.” See Michel Foucault, *Discipline and Punish: The Birth of the Prison*, trans. Alan Sheridan (New York: Vintage Books, 1979), pp. 191–192.

30 André Leroi-Gourhan, *Gesture and Speech*, trans. Anna Bostock Berger (Cambridge, MA: The MIT Press, 1993), p. 66.

31 Michel Foucault, *Discipline and Punish*, p. 190.

32 Manuel DeLanda, “The Archive Before and After Foucault,” in *Information Is Alive*, ed. Joke Brouwer and Arjen Mulder (Rotterdam: NAI, 2003), pp. 10–11.

33 There are also *monophyodont* animals who only have one set of teeth, as well as *polyphyodonts*, whose teeth are constantly replaced. Polyphyodonts include most toothed fishes, many reptiles such as crocodiles, geckos, and most other vertebrates, mammals being the main exception. A few species of mammals, such as kangaroos and elephants, are polyphyodonts, but unfortunately we are not among them.

34 Stanley J. Nelson and Major M. Ash Jr., *Wheeler’s Dental Anatomy*, pp. 1–26.

35 Ibid., pp. 184–204.

36 James Speed Rogers, Theodore Huntington Hubbell, and

Charles Francis Byers, *Man and the Biological World* (New York: McGraw-Hill, 1942), p. 313.

37 All primates have the same kinds of teeth, but the number of each kind varies between species. The primitive mammalian combination of teeth types, expressed in a standard format called the *dental formula*, is written for each side of the upper and lower jaw as: 2, 1, 3, 3 for upper teeth (maxilla), and 2, 1, 3, 3 for lower teeth (mandible); which means, eight incisors, four canine, twelve premolars, and twelve molars (a total of thirty-six). Not all primates have retained that formula. For instance, while nearly all New World monkeys have retained their primitive dental formula, Old World monkeys, apes, and humans only have two premolars (thirty-two teeth in total). See Robert Boyd and Joan B. Silk, *How Humans Evolved*, p. 115.

38 A. J. MacGregor, The *Impacted Lower Wisdom Tooth* (New York: Oxford University Press, 1985), p. 3.

39 In the *Discourses on the Origin of Inequality*, Rousseau explained how by imitating animals and by reasoning, the "natural man," endowed with all the present human attributes but starting from scratch in terms of technical equipment, gradually invested everything within the technical and social order that would eventually lead him to the present-day world.

40 Leroi-Gourhan identifies five main "functional elements" that succeeded one another over the ages. The first element pertains to the constraints of locomotion, or "the mechanical organization of the vertebral column and the limbs"; the second element is the suspension of the skull; the third is dentition, and the role played by our teeth in defense and in capturing and processing food; the fourth is the hand, and its possible integration into the technical field; and finally, the fifth element is the brain, "whose role as coordinator is obviously a primordial one but which functionally appears as the tenant of the rest of the body." See André Leroi-Gourhan, *Gesture and Speech*, pp. 36–37.

41 Around the time of the origin of our genus, *Homo*, there were several interrelated changes in our life history, including bipedalism and increased brain size, as well as reduced sexual dimorphism, extended lifespans and longer childhoods, increased reliance on meat and hunting, tool use, and the greater role played by cultural transmission. Bipedalism is one of the traits that evolved early on in our lineage. The earliest hominids, such as *Ardipithecus ramidus*, who lived between six to four million years ago, were bipedal even though they had a brain size similar to that of chimpanzees. And it was not until around four million years later that we find the first evidence for the use of tools, even though brain size had not changed much in the interim. This suggests that the increase in brain size was not the main evolutionary driver, as Rousseau had suggested. To assume that bipedalism alone could cause all other evolutionary changes, as Leroi-Gourhan did, is also too simplistic since it is difficult to assume a direct correlation between biological traits. See Robert Boyd and Joan B. Silk, *How Humans Evolved*.

42 Some of these complications include bone destruction, jaw expansion, damage to surrounding teeth, or even development of tumors that can cause the jaw to break. For more on wisdom teeth, see Rachele Cooper, "Why Do We Have Wisdom Teeth?," *Science Line* (5 February 2007). Available at <scienceline.org/2007/02/ask-cooper-wisdomteeth>.

43 André Leroi-Gourhan, *Gesture and Speech*, p. 336.

44 See the section titled "Memory and Rhythms" in André Leroi-Gourhan, *Gesture and Speech*, pp. 219–266.

45 See Bruno Latour, "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts," in *Shaping Technology/Building Society: Studies in Sociotechnical Change*, ed. Wiebe E. Bijker and John Law (Cambridge, MA: The MIT Press, 1992), p. 229. Latour also describes this delegation as "displacement," "translation," or "shifting," and argues that "this reversal of forces is what sociologists should look at in order to understand the social construction of techniques."

46 In fact, in most contemporary scholarly literature, especially those in Science and Technology Studies (STS) and cultural studies, the term *prosthesis* is used to describe any extrasomatic artificial object or machine (such as a car, a computer, or a sexual device) that mediates human relations. See, for instance, discussions of the cyborg, especially as introduced by STS scholars like Donna Haraway, as well as Celia Lury's *Prosthetic Culture: Photography, Memory and Identity* (London: Routledge, 1998), or Gabriel Brahm and Mark Driscoll's *Prosthetic Territories: Politics and Hypertechnologies* (Boulder, CO: Westview Press, 1995).

47 Kathleen Woodward, "From Virtual Cyborgs to Biological Time Bombs: Technocriticism and the Material Body," in *Culture on the Brink: Ideologies of Technology*, ed. Gretchen Bender and Timothy Druckrey (Seattle: Bay Press, 1994), p. 50.

48 Sigmund Freud, *Civilization and Its Discontents*, trans. James Strachey (New York: W. W. Norton, 1961), p. 42.

49 The passage reads: "*We all need means of supplementing our natural capabilities*, since nature is indifferent, inhuman (extrahuman), and inclement; we are born naked and with insufficient armor. ... The barrel of Diogenes, already a notable improvement on our natural protective organs (our skin and scalp), gave us the primordial cell of the house; filing cabinets and copy-letters make good the inadequacies of our memory; wardrobes and sideboards are the containers in which we put away the auxiliary limbs that guarantee us against cold or heat, hunger or thirst. ... Our concern is with the mechanical system that surrounds us, which is no more than an extension of our limbs; its elements, in fact, artificial limbs." Le Corbusier, *The Decorative Art of Today*, trans. James I. Dunnett (Cambridge, MA: The MIT Press, 1987), p. 72. Italics in original.

50 Mark Wigley, "Prosthetic Theory: The Disciplining of Architecture," *Assemblage*, no. 15 (August 1991), pp. 7–8.

51 A key part of this evolutionary process was the development of the computer mouse, which facilitated a seamless interface between man and machine. For more on the computer mouse, see Mark Wigley, "The Architecture of the Mouse," *Architectural Design*, vol. 80, no. 6 (November–December 2010).

52 Sigmund Freud, *Civilization and Its Discontents*, p. 42.

53 Sharon Romm, "The Oral Cancer of Sigmund Freud," in *An Anthology of Plastic Surgery*, ed. Harry Hayes Jr. (Rockville, MD: Aspen Publishers, 1986), p. 218.

54 Ernest Jones, *The Life and Work of Sigmund Freud* (New York: Basic Books, 1957), p. 96.

55 Sigmund Freud, "Letter of 11 August 1924," in *Sigmund Freud and Lou Andreas-Salomé: Letters*, ed. Ernest Pfeiffer (London: Hogarth Press, 1972), p. 137.

56 Lou Andreas-Salomé, "Letter of 3 September 1924," ibid., p. 138. For Freud's view of the body as "garment," see his essay "Metapsychological Supplement to the Theory of Dreams," in Sigmund Freud, *General Psychological Theory* (New York: Macmillan, 1963), p. 151.

57 This view is the basis of posthumanism. For more on posthuman theories, see N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: The University of Chicago Press, 1999).

58 In fact, most of the changes in human societies since the origin of agriculture about ten thousand years ago, and perhaps even before that, have been the result of cultural, and not genetic, evolution. Agriculture led to the emergence of sedentary villages, social inequality, large-scale societies, architecture, writing, and many other innovations that we can trace in the archaeological record. Today, cultural change is operating at a much faster pace than genetic change, and the evolution of human behavior and of human societies is not, for the most part, driven by natural selection and the other processes of organic evolution, but instead by learning and other psychological mechanisms that drive our cultural and technological evolution. See Robert Boyd and Joan B. Silk, *How Humans Evolved*, p. 349.

59 Douglas C. Engelbart, "Augmented Man, and a Search for Perspective," paper summary for Western Joint Computer Conference, 16 December 1960, quoted in Mark Wigley, "The Architecture of the Mouse," p. 54. The full sentence reads: "And when the day comes that intelligent machines begin to usurp his role, our individual would hardly still be human if he didn't want to continue developing his augmentation system to extend to the limit his ability to pursue comprehension in the wake of the more intelligent machines."