semifluorinated block copolymers. This rearrangement is critical to the formation of the extremely hydrophobic surfaces produced by these polymers.

Gerhard Wegner has pioneered many approaches to investigating shape persistence. As he has said, "Supramolecular structures derived from shape-persistent ("stiff") macromolecules may be used as examples to demonstrate the correlation between chemical structure, order phenomena and performance in applications concerning advanced or developing technologies" (*8*). Starting with his groundbreaking studies of the topotactic polymerization of diacetylenes (*9*), he was one of the first to realize that shape persistence or chain stiffness offers a method of controlling the spatial arrangements of a polymer chain. In subsequent studies at the University of Freiburg and later as one of the two founding directors of the MPIP, he probed many other aspects of shape persistence in polymer science, including studies of conducting polymers, hairy rod polymers, and ultrathin films. His insightful work has influenced many scientists around the world and has led to his being honored with many scientific awards and visiting professorships. All who attended the meeting look forward to his further contributions to the science of polymers.

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PERSPECTIVES: LANGUAGE

Movement Patterns in Spoken Language

John L. Locke

If language is a product of the human mind, it is also, as Studdert-Kennedy once wrote, "a mode of action" (*1*). Words are put into play by movements of the human body. To fully appreciate the nature of spoken language, it is therefore necessary to ask whether, and in what ways, linguistic structure reflects the physical activity that yields fluently articulate vocalization. This is what MacNeilage and Davis (*2*) have done in their report on page 527 of this issue. By analyzing the babbling sounds and first words of infants in an English-speaking environment (and subsequently in environments where other languages are spoken), they found four (possibly universal) sound patterns that suggest how the spoken forms of words originate.

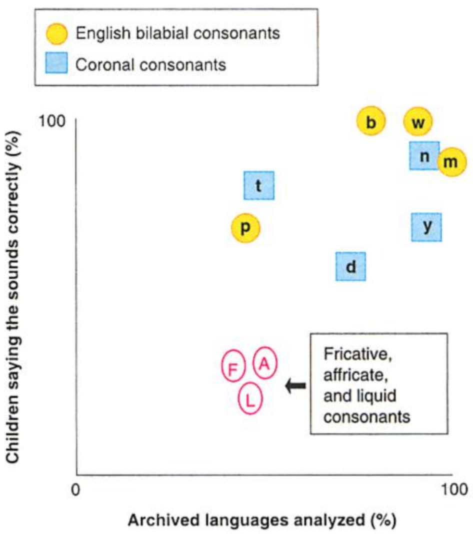
Dictionaries are considered prescriptive, but they also record the verbal habits of the educated and powerful. At one time, prominent Americans produced an aspirate /hw/ when they said the initial consonant in "wheel" and "which," but subsequent generations said /w/, causing lexicographers to revise earlier transcriptions.

Whether aware of it or not, people have always had control of the phonetic reins of language. Speakers who wish to charge "five bucks" sometimes request "fibe bucks"; others who are "supposed to," say they are "sposta." These smoothing operations make speech easier and more fluent. If repeated enough times, they can alter the structure of individual words as well as the sound system of established languages.

Phoneticians have offered various physiological and other explanations for the precise form assumed by speech sounds and syllables, as well as differences in the frequency of vowels and consonants within and across languages (*3*). In the 1970s and 1980s, several teams of linguists conducted systematic searches for phonological universals—patterns that appear in all or most of the languages that have been analyzed. They found that all languages include stop consonants such as /t/ and /d/, but not all have fricatives such as /s/ and /z/; and that all languages have single consonants, but some do not contain clusters such as /pr/ and /gl/. A particularly interesting finding was that every one of the archived languages had consonant-vowel syllables, although many lacked syllables with the reverse order (*4, 5*).

The new study continues in this vein (*2*). Peering inside particular languages, MacNeilage and Davis find that physical, or phonetic, effects may be more pervasive—and languages less arbitrary in structure—than linguists have previously supposed. But their studies begin not with languages in search of an explanation but with individuals in search of a language: preverbal infants who spontaneously emit speech-like sounds but know few words.

Infants usually begin to alternately lower and raise the jaw while vocalizing at about 7 to 10 months of age. With passive bunching of the tongue tip, this activity yields syllable sequences such as "yaya" or, if the tongue is flat, "wawa." If constrictions are



Infant babble, child speech and languages. Sounds that are babbled frequently are produced more accurately by English-learning 2-year-olds, and appear more often in the languages of the world, than other sounds (*5*). The four bilabial (lip) consonants of English are shown in circles; coronal consonants (produced by the tongue at the front of the mouth) articulated in a similar manner appear in boxes. Together, these items constitute about 60 to 80% of all consonant-like sounds in the babbling of preverbal infants. Note the high frequency of the labials (except /p/, which requires momentary interruption of laryngeal vibration) in children's speech and established languages. The coronals are about as frequent in archived languages but take longer to acquire. Fricative (F), affricate (A), and liquid (L) consonants, shown in ovals, are rarely babbled and are found at a reduced frequency in both children's speech and the languages of the world.

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tighter, one is likely to hear "baba" or the familiar "dada." Merely by leaving the nasal port open, "mama" or "nana" may be produced, or if the voice is alternately suppressed, "papa" and "tata." It is through such maneuvers that infants, guided by little or no ambient learning, are able to achieve a small repertoire of speech-like sounds.

The ontogenetic implications are clear. The earliest speech-like behaviors of infants are sufficiently like those of competent speakers to do linguistic service, especially when the linguistic community and (on their own initiative) the parents present infants with equivalent constructions such as, mama, papa, dada, bye-bye, pee-pee. With no more to learn than a few associations between sound and meaning, infants can move seamlessly from babble into speech, and this is exactly what they do (*6*).

The open-close movements of the mouth described by MacNeilage and Davis in babbling infants are tenacious. Premature birth, focal lesions in the brain, or mental impairment rarely suppress them or conspicuously distort their action. Significant delays in their onset, however, may point to previously undiagnosed deafness or other problems in the neural circuitry responsible for language and cognition (*7, 8*).

Following an earlier finding by Stoel-Gammon (*9*), MacNeilage and Davis observe that as infants make sounds, places of oral constriction tend to overflow their consonantal banks—that is, lingual (tongue) consonants such as /t/ and /k/ pull adjacent vowels to the front or back of the mouth, respectively; labial (lip) consonants such as /p/ leave vowels more neutrally positioned (see the figure). But the matter doesn't end there, for the investigators track these patterns directly into the structure of established languages, thereby reconstructing the phonetic behaviors of previous generations of speakers. One thus appreciates new dimensions to the sympathetic relationship that exists between phonology and physiology.

Some years ago, I pointed to an "anterior-to-posterior progression" in the utterances of children and the vocabularies of English and French (*5*). Lip-to-tongue words like "pat" and "mad" surpassed reverse-order items like "tap" and "dam." MacNeilage and Davis now report that this labial-coronal (lip-tongue front) effect occurs in several other languages for which relevant statistics have become available. They reasonably suggest a biomechanical cause, although more investigation is obviously needed.

There are several challenges ahead. In the past, evolutionary theorists have needed to explain the fact that all languages, save the signed systems of the deaf, are spoken. Now they must also explain the emergence of mandibular oscillations. But these problems may be connected. Elsewhere, I have suggested that the vocal modality of language may be linked to two factors that emerge from research on nonhuman primates: an association between status and volubility at the social level, and the open-close movements associated with tongue- and lip-smacking at the physical level (*10*).

Ontogeneticists have some new responsibilities, too, for any comprehensive account of the development of spoken language will have to explain the emergence of oscillatory activity and its specific connections to speech. Relevant evidence currently includes the fact that jaw openings and closings may be carried out silently (*11*) and that audible and repetitious movements of the hand, typically the right hand, frequently begin within a few weeks of the onset of babbling (*7, 12*).

If the substance of speech influences its form, as the new work indicates, additional phonostatistical analyses may provide more information about the motor bases of speech and the structure of established languages. In parallel with such research, a variety of behavioral studies could, in principle, tell us how the sequences of sound movements selected for linguistic use in earlier times benefit modern users of language, either in their social communication or in moments of private cognition.

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PERSPECTIVES: CIRCADIAN RHYTHMS

Marking Time for a Kingdom

Michael W. Young

Our sleep-wake cycles, and many other behavioral and physiological rhythms, are controlled by endogenous, 24-hour (circadian) clocks. Over the last 30 years genetic screens have been systematically applied to the dissection of circadian clocks in *Cyanobacteria*, the fungus *Neurospora*, and the fruit fly *Drosophila melanogaster*, but only recently has circadian genetics been applied to mammals (*1*). In a major breakthrough for time-conscious mammals, Takahashi, Lowrey, and their colleagues (*2*) describe the identification of a crucial circadian gene in hamsters on page 483 of this issue. The *tau* mutation, accidentally discovered in a shipment of Syrian hamsters, reduces the period length of the hamster's circadian rhythm from 24 to 20 hours. The investigators show that the *tau* locus, encoding casein kinase Iε, is a homolog of the *Drosophila* circadian gene, *double-time*. It is astonishing that genetic screens are identifying the same molecular determinants of time in creatures as different as mammals and fruit flies.

In *Drosophila*, seven genes appear to interact together in clock-like feedback loops in a bewildering array of cell types inside and outside the nervous system (*3*). The fly clockworks are approaching genetic saturation: New mutations tend to map to old genes, suggesting that the most important elements of the fly's circadian clock have already been identified. But what do these fly genes tell us about circadian rhythms in other organisms? Recently, molecular biology has hinted that there is a single toolbox of clock parts carried by the entire animal kingdom. Homologs of the fly clock genes *period*, *timeless*, *clock*, *cycle*, *double-time*, *vrille*, and *cryptochrome* have been isolated from fish, frogs, mice, and humans; for some of these genes, further testing in vertebrates supports their involvement in circadian rhythmicity. But, the acid test is genetic screening. For example, in the absence of preconceptions, what would independently surface in mammalian clockworks if we were to ask for a list of its most important parts?

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