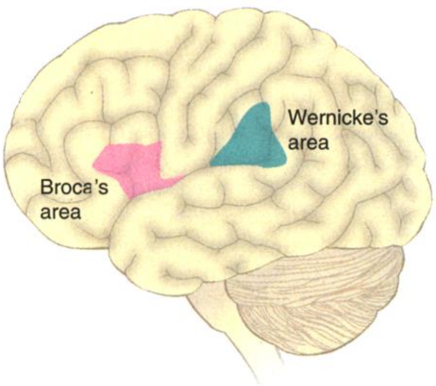
Stuttering: A Matter of Bad Timing

A RECENT NEUROLOGICAL INVESTIGATION OF stammering is briefly described in the Random Samples item "The stammering brain" (3 Aug., p. 795). The magnetic resonance imaging study, led by neurologist Anne Foundas at Tulane University, revealed some anatomical differences between stutterers and nonstutterers in the two brain regions associated with speech and language, Broca's area and Wernicke's area (see the figure) (*1*). In interpreting the results of such studies, it is important not to confuse cause and effect. That the observations of Foundas and colleagues are associated with the clinical problem of chronic involuntary blockage of speech is not disputed. That the observations can be interpreted as a cause of blockage is neurologically impossible.



Language centers. Broca's area (involved in speech planning) and Wernicke's area (involved in speech perception) are located on the left side of the brain and function at cognitive rates too slow to be considered a source of stammering.

Stuttering is an aberration of normal speech processing, which is a manifestation of synchronization of phonation (for speech power) with articulation (that shapes phonatory power into the sounds of speech) (*2*). Any cause of stuttering has to account for why it can be involuntary, and, more to the point, how high-speed speech sounds can be produced with low-speed cognitive and linguistic equipment.

Synchronization speed is revealed by the syllable rate (no sound can be produced outside the context of a syllable) multiplied by the number of sounds per syllable (*3*). Syllable and cognitive thinking rates are roughly the same, which is fortunate, otherwise we would be unable to speak at the same rate we think. George Miller decades ago demonstrated the cognitive rate to be 7 ± 2 thoughts per second (*4*). This is also the syllable rate, as I inadvertently discovered in 1964 when I found that voluntary fluency prevented stammering when each sound is under voluntary control. Unfortunately for treatment, each sound had to be a syllable unto itself, which resulted in a speech rate so slow that it droned (*5*).

The reason the Tulane study cannot have causal implications for stammering is that the enlarged linguistic areas of Broca and Wernicke (involved in speech planning and speech perception, respectively) are readily available to voluntary control and are intimately related to the slow cognitive function rates Miller described. Both areas function at rates too slow to have any role in the timing of high-speed phonatory and articulatory synchronization. It is when timing is awry that stammering occurs.

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References and Notes

1. A. L. Foundas *et al.*, *Neurology* **57**, 207 (2001).
2. In 1965, Stromsta defined stammering as a static involuntary articulatory posture that blocks fluent overlapping coarticulatory transitions [C. Stromsta, *Elements of Stuttering* (Atsmorts, Oshtemo, MI, 1986)].
3. Natural speech consists of syllables with up to six or more sounds per syllable. Thus, sounds in the word "sounds" are synchronized at about 25 to 45 per second (7 ± 2 syllables per second times 5 articulatory adjustments per 5-sound syllable).
4. G. Miller, *The Psychology of Communication* (Basic Books, New York, 1967).
5. W. H. Perkins, *Neural Mechanisms of Stammering* (Athens, Reno, NV), in press.

Managing Climate Risk

STABILIZATION OF ATMOSPHERIC GREENhouse gas (GHG) concentrations at a safe level is a paradigm that the scientific and policy communities have widely adopted for addressing the problem of climate change. However, aiming to stabilize concentrations at a single target level might not be a robust strategy, given that the environment is extremely uncertain. The static stabilization paradigm is based primarily on two assumptions: (i), that a safe level of GHG concentrations exists and can be sustained, and (ii) that such a level can be determined ex ante.

"Technologies that can rapidly remove GHGs from the atmosphere will play an important role..."

The United Nations Framework Convention on Climate Change (UNFCCC) calls for stabilization of GHGs at a safe level, and it also prescribes precautionary measures to anticipate, prevent, or minimize the causes of climate change and mitigate their adverse effects. Such measures should be cost-effective, and scientific uncertainty of threats of serious or irreversible damage should not be used as a reason for postponing them. In this sense, the UNFCCC can be understood as a responsive climate management scheme that calls for precautionary and anticipatory risk management where, in a continuous sense-respond mode, expected climate-related losses are balanced against adaptation and mitigation costs (*1*).

The availability of technological options for adaptation, preventive mitigation, and backstop risk measures will be critical for limiting the risks associated with climate change. Technologies that can rapidly remove GHGs from the atmosphere will play an important role, particularly if unforeseen catastrophic damages are expected to significantly decrease human welfare and natural capital. Terrestrial sinks are limited by land requirements and saturation, and concerns about permanence limit their attractiveness (*2*). However, biomass energy can be used both to produce carbon neutral energy carriers, e.g., electricity and hydrogen, and at the same time offer a permanent CO_2 sink by capturing carbon from the biomass at the conversion facility and permanently storing it in geological formations (*3*). To illustrate the long-term potential of energy-related biomass use in combination with carbon capture and sequestration, we performed an ex-post analysis based on a representative subset of the Intergovernmental Panel on Climate Change (IPCC) reference scenarios (*4, 5*) developed with the MESSAGE-MACRO modeling framework (*1, 6*). The cumulative carbon emissions reduction in the 21st century may exceed 500 gigatons of carbon, which represents more than 35% of the total emissions of the reference scenarios, and could lead, in cases of low shares of fossil fuel consumption, to net removal of carbon from the atmosphere (negative emissions) before the end of this century. The long-run potential of such a permanent sink technology is large enough to neutralize historical fossil fuel emissions and satisfy a significant part of global energy and raw material demand (*7, 8*).

In summary, we conclude that a system of climate risk management is practicable and necessary. Increasing deployment of sustainable bioenergy with carbon removal and sequestration, together with structural shift toward low carbon-intensive fuels, will turn out to be instrumental for such a risk-limiting regime and might offer ancillary benefits for sustainable development (*1*).

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Deciphering River Dolphin Evolution

IN "RIVER DOLPHINS ADD BRANCHES TO family tree" (News of the Week, 30 Mar., p. 2531), Dennis Normile discusses the molecular work of M. Nikaido and colleagues that indicates that river dolphins are old cetacean lineages that do not constitute a natural (that is, monophyletic) group (*1*). Nikaido *et al.* analyzed the insertion patterns for short interspersed elements (SINEs), which are transfer RNA–derived retroposons inserted throughout the genome, probably at random locations.

Although it was not mentioned by Normile, we published the same conclusions based on different molecular analyses more than 8 months earlier (*2*). Using phylogenetic analyses of nucleotide sequences from three mitochondrial and two nuclear genes (from 19 cetacean species, including all river dolphins), we demonstrated with statistical significance that extant river dolphins form a polyphyletic group. We suggested that they are relict species whose adaptation to riverine habitats incidentally ensured their survival against major environmental changes in the marine ecosystem or the emergence of Delphinidae (true dolphins). A few months later, Hamilton *et al.* (*3*) published an analysis of three fragments of the mitochondrial genome (from 29 cetacean species), confirming our results.

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