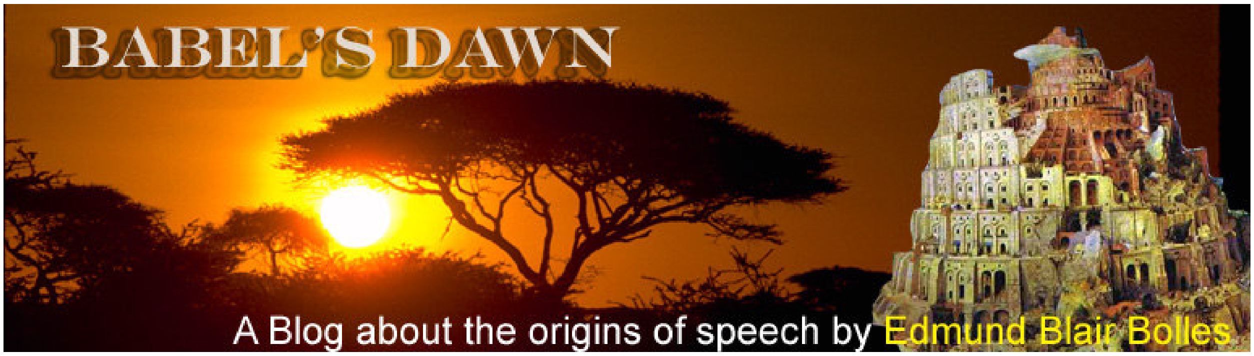
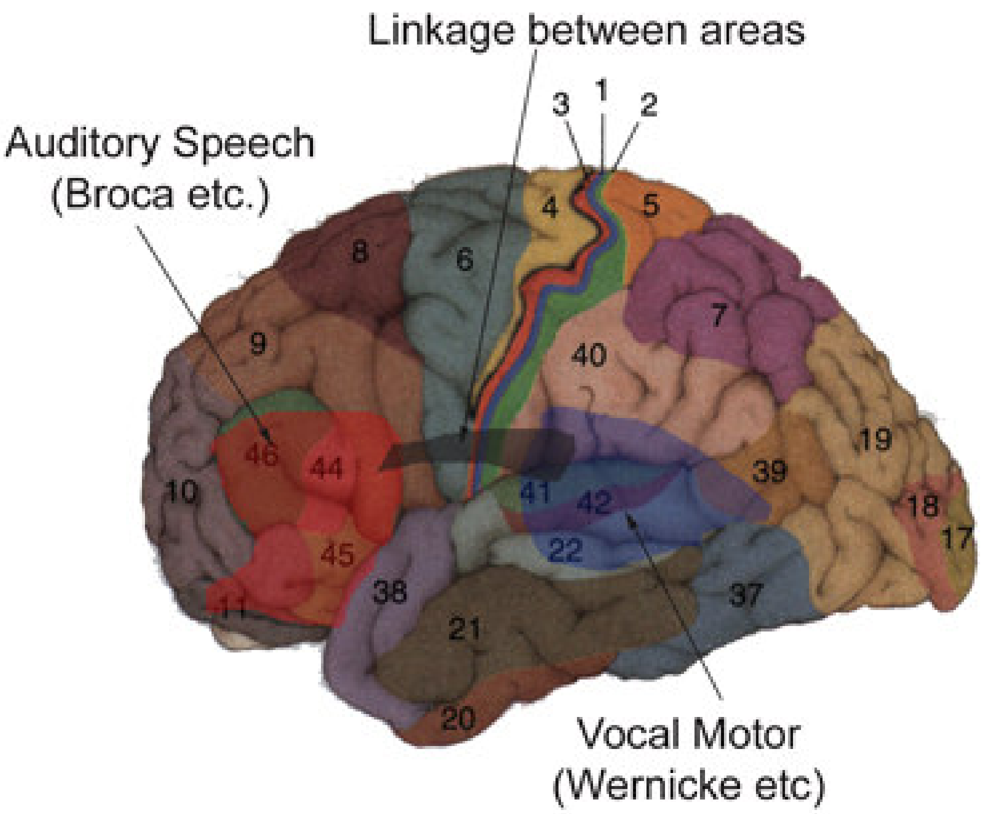
PDF version of post on http://www.BabelsDawn.com



Post of: July 5, 2009

Speech Circuitry



Sketch of proposed circuitry supporting phonological loop. The auditory region of the brain associated with speech (Broca's area and adjacent regions) shown under red shading is connected to the motor area controlling vocalization (Wernicke's area and neighboring regions). The connection is sketched under black shading. The numbers shown roughly identify the Broadmann regions.

One of the mysteries of language is the way, when it is viewed whole, there is nothing else like it in the biological world, but if the view focuses on a part—recognizing voices, making sounds, voluntary actions, voluntary attention, etc.—it seems quite like other phenomena in the animal world. The reaction of analytical thinkers to this mystery is to look about for the part that is not duplicated elsewhere in the animal kingdom—symbols, recursive syntax, displaced reference, etc. Each of these traits fails when put to a simple test: provide a sample of language that lacks the trait, and you still get something unknown to the rest of biology.

Linguistic richness has to be explained, both psychologically and physically. During the past week I read a paper suggesting the clarity might come by focusing on physical explanations.

The paper is by two Chilean investigators, Francisco Aboitiz and Ricardo Garcia, and was published in *Reviews in the Neurosciences*, "Merging of Phonological and Gestural Circuits in Early Language Evolution. (abstract here). The paper is very technical and a bit scattered, but I knew I had found this week's post when I read,

> phonology acquired an unprecedented richness by the progressive inclusion of the dorsal auditory pathway into the communication circuits. [p. 79]

"The dorsal auditory pathway," the authors propose, is "specialized in vocalization, processing, enhancing vocal repetition and short-term memory capacities that are crucial for linguistic development" [71]. In other words, the richness of language comes from the introduction of the capacity to speak voluntarily. Gesture may (or may not) have come first, but it was insufficient to bring us the rich instrument we enjoy today.

Immediately, I must include a to-be-sure paragraph to calm the enthusiasts of gesture. So, to be sure, sign language today is as rich as spoken languages. I say that with no *ifs*, *ands*, or qualms. But sign language today takes advantage of that dorsal auditory pathway the Chilean authors describe.

The original gestural language, however, was not as rich as modern language, and, of course, neither was the original spoken language. However—and here is the authors' point—gestural language, by itself, could not evolve into modern language, but speech could.

Apes can make voluntary gestures, but their vocalizations are automatic. This fact has been the biggest argument in favor of gesture as the first form of language. The problem is that at sometime, speech became the dominant form, so something must have happened to provide voluntary control over vocalization.

The theory of language's gestural origins uses mirror neurons. These are neurons that fire when they perform a action and when they see another animal perform that action.. This suggests a way for learning linguistic gestures. To oversimplify: if Jack sees Jill make a gesture, Jack's mirror neurons respond. Now Jack's brain knows how to make that gesture too. It's a simple tale that seems plausible enough, and maybe language began that way, but it offers no way to get from rudimentary learning to imitate gestures to the much richer behavior we see today.

The neurological pathway discussed by Aboitiz and Garcia matches a psychological structure that has been recognized for 35 years, working memory. The authors propose that the pathway supporting working memory evolved as a way to link auditory input with vocal output. The resulting structure made speech possible.

Working memory includes a functional operation known as the "phonological loop." In 1974, Alan Baddeley and Graham Hitch proposed that besides a short-term memory that works automatically, humans enjoy a "working memory" that requires deliberate attention. One part of this attentive memory is the phonological loop. The fleeting sound of speech is retained by rehearsing (repeating) the sound. The rehearsal does not have to be vocalized; imagining the sound is enough. The phonological loop appears to have no semantic or syntactic role, but it is important in keeping language in our thoughts long enough to organize and use speech. It appears to be crucial for the mechanical task of producing modern language, be it spoken, signed, or written.

Aboitiz and Garcia propose a physical expression of the phonological loop in the circuitry that links Broca's area and neighbors (auditory cortex) with Wernicke's area (motor cortex). This linkage makes voluntary vocalization possible, by providing a shortcut between "thinking about" sounds and moving muscles. (See illustration at top of post.)

Interest in linkages between these areas is hardly new and was discussed on this blog a year ago. (see: Building a New Brain from Old Parts) That post reported work on the evolution of the link, known as the arcurate fasciculus. The basic theme of that post was that the evolution of speech appears to rest on the integration of existing functions. It was the Chilean authors, however, who brought my attention to the importance of this system in making rich language possible. They propose:

> The accurate time-processing capacity and the short-term memory properties of this circuit enabled early humans to learn and repeat complex vocal utterances by imitation [p. 77].

"Time-processing capacity" is computer jargon for the ability to manage high-speed input. I suspect there are many benefits from the ability besides learning to make the sounds of the language around you. For example, I have often noticed that when I listen to a heavily accented speaker I have a great difficulty at first, but after a little time the trouble disappears. What's going on? At the start, I'm paying close attention, and trying to catch (translate) what's being said. After a bit, it begins to sound more like the language I'm familiar with and I can direct my attention to where the words point. It sounds to me like the sort of thing that can be quickly achieved, thanks to the phonological loop.

Another possible function comes in introductions. I'm terrible at remembering people's names, but when I do hear a name I work at learning it. I hear the name, and repeat it aloud. If I'm corrected, I try again, aloud. Then I repeat it a few times silently. And later, as I see the person again at the festivity, I repeat the name again in my head. Traditionally, we call this kind of action, association, but the circuitry reminds us of a second element: imitation. It is imitative association, something much more active than the kind of association that comes through operant conditioning.

Links:
Francisco Aboitiz: http://www.psiquiatriauc.cl/francisco_aboitiz
Abstract:
http://www.ncbi.nlm.nih.gov/pubmed/19526735?ordinalpos=2&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_DefaultReportPanel.Pubmed_RVDocSum
Aland Baddley: http://www.york.ac.uk/depts/psych/www/people/biogs/ab50.html
Graham Hitch: http://www.york.ac.uk/depts/psych/www/people/biogs/gjh3.html

Building a New Brain from Old Parts:
http://www.babelsdawn.com/babels_dawn/2008/06/spandrels-are-f.html