also affects its growth. For instance, γ-aminobutyric acid (GABA) inhibits the retinal neurons electrophysiologically, but Lipton has no evidence that GABA affects neurite outgrowth. Nevertheless, the Harvard researchers find that acetylcholine acts at nicotinic receptors as a tonic growth inhibitor for most retinal ganglion neurons.

Stanley Kater and Christopher Cohan, formerly of the University of Iowa in Iowa City, and John Connor of Bell Laboratories in Murray Hill, New Jersey, have just demonstrated that the level of intracellular calcium may be the determining factor in whether growth cones will elongate or stabilize. Last year Kater and his co-workers showed that two kinds of signals—action potentials and serotonin—inhibit the outgrowth of invertebrate neurons cultured from the buccal ganglion of *Heliosoma*. Using a calcium-sensitive dye to measure changes in the concentration of the ion in the growth cones of neuron 19, they now find that serotonin or action potentials raise calcium levels from 100 to 130 nanomolar to several hundred nanomolar, causing growth to cease.

It seems that even within the same animal, different neurotransmitters regulate the growth of different neurons. Bulloch and his colleagues find that glutamate regulates growth cone elongation in neuron 5 from *Heliosoma*, and Kater and his co-workers show that neuron 19 responds to serotonin. According to Cohan, "signals that inhibit growth cone motility also increase the calcium concentration inside the growth cones."

But Cohan also notes that, "after some time in culture, growth cones spontaneously stop elongating." To their surprise, the researchers find that calcium levels in spontaneously stable growth cones are low, at about 50 nanomolar, not high.

What does it all mean? "A neuron has a calcium set point," Kater proposes, which in *Heliosoma* seems to be about 100 nanomolar. "On either side of that set point is the realm of no growth. Other biochemical processes required for growth, such as the rearrangement of cytoskeletal proteins, also require strict calcium concentrations." So it is not surprising to Kater and his colleagues that a narrow range of calcium concentrations promotes growth.

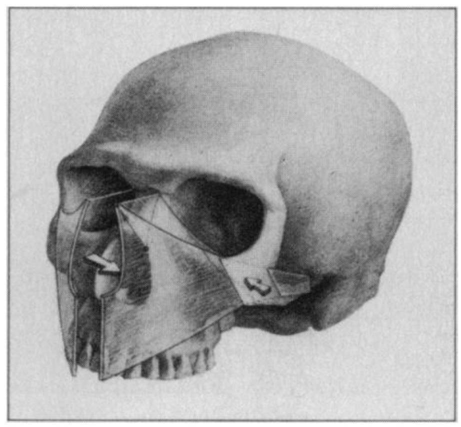
Kater also raises the question of whether neurons that are regarded as stable, such as those in the mature brain of a mammal, may be subject to some of the same tropic effects of neurotransmitters that developing or regenerating neurons are. Bulloch speculates along the same lines. "One of the reasons we are so excited about growth cones is that they may play a role in the synaptic changes that occur during learning." ■

DEBORAH M. BARNES

A New Look at an Old Fossil Face

Someone once said that if you were to take a Neanderthal individual, shave, wash and clothe him, he would be virtually indistinguishable from many of the denizens of the New York subway. That may be true, but Neanderthal anatomy is not as close to that of modern humans as this whimsy might imply. One major difference was the face: it was extraordinarily big. Why the face was so big has long been a matter of speculation among anthropologists, and in a recent publication Yoel Rak, of Tel Aviv University, adds his interpretation to the debate. The reason, he suggests, is mechanical: the face was built to counteract the considerable forces that Neanderthals developed between their upper and lower front teeth.

If you were to take hold of the nose of a plastic, western European face and tug mightily, you would finish up with a very Neanderthal-like face. Specifically, the middle of the face would protrude dramatically; and the nose would be very big. Viewed from the top, the head forms quite a steep triangle, with a wide base lining up from ear to ear, the two long sides running along the cheeks, and the apex being formed by the nose. By contrast, the modern human head would look like a truncated triangle: the face is relatively flat from top to bottom.



Making a Neanderthal face. *By swinging forward—like opening double doors—the sheets of bone beneath the eye regions of a modern human skull one forms the mid-facial projection and large nasal aperture of the Neanderthal (shown by the "transparent" overlay).*

This very peculiar facial architecture has therefore become something of a hallmark of the classic Neanderthals, who lived in western Europe between 100,000 and 35,000 years ago. One explanation for the anatomy, which was first developed during the 1950's, was that the enlarged nasal chamber formed what Rak describes as "an immense radiator that would warm and humidify dry cold air." Neanderthals, remember, lived through much of the last major glaciation in Europe, although some populations were in relatively temperate regions. In essence, this hypothesis argues that the nose led the way and the rest of the facial structure followed.

A second proposal, which was first put forward in the 1960's and is the one that Rak's latest contribution extends, invokes dental biomechanics as the selective agent of the protruding face. Neanderthals have very large front teeth (incisors and canines) relative to the back teeth (the premolars and molars). Moreover, Neanderthal individuals typically show very heavy wear on the front teeth, sometimes going down to the roots. Whether these people were processing tough food between their front teeth or manipulating hide or some other material, the forces developed there were clearly great.

Rak's contribution is to look in detail at the functional aspects of the facial architecture in a way that has not been done before. He shows how the sheets of bone beneath the eye region in modern humans are swung forward "as in the opening of double doors." The effect is to thrust the face forward and create a very large nasal opening. Mechanically, however, now that these sheets of bone are in much more of a forward plane, they can resist the forces created by heavy biting on the front teeth.

Specifically, biting on these teeth will tend to cause rotation of the front of the upper jaw. Sheets of bone that are deep vertically at the point of bite will be an effective counter to the rotation, bending, and torsion that is generated there. Other factors contribute to the shape of the face, of course, not least of which is the space required in the front of the face and beneath the nose for the roots of the unusually large front teeth. Nevertheless, in this hypothesis it is the face that led the way, and the nose was carried on before it.

The Neanderthal face, according to Rak, is quite distinct from that of modern humans. "The facial morphology of *Homo* specimens preceding the classic Neanderthal is more similar . . . to the morphology of those following it than either is to the Neanderthal," he notes. The clear implication is that the Neanderthals were not directly ancestral to modern European populations, the debate over which is becoming one of the hottest topics in human origins research. ■ ROGER LEWIN

ADDITIONAL READING

Y. Rak, "The Neanderthal: A new look at an old face," *J. Hum. Evol.* 15, 151 (1986).