What Crosses Our Minds When Danger's Afoot

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One of the more mysterious and less-explored observations about human anatomy is also one of the oldest, going all the way back to the Father of Medicine.

"If the wound be situated on the left side [of the head], the convulsion attacks the right side of the body," Hippocrates noted in the 4th century B.C. The Greek physician recognized that trauma on one side of the head could cause a seizure limited to or, more likely, starting in the limbs on the opposite side of the body.

About A.D. 150, a physician named Aretaeus the Cappadocian extended this observation in a truly remarkable way.

He noticed that if the right side of the head was severely damaged, the left side of the body would be paralyzed. However, if the damage was in the right side of the spinal cord instead, the paralysis would be on the same side. He then came up with an explanation.

"The cause of this is the interchange in the origins of the nerves, for they do not pass along on the same side . . . until their terminations," he wrote, according to an account in the 1994 book "Origins of Neuroscience" by medical historian Stanley Finger. Each nerve "passes over to the other side from that of its origin, [separating from] each other in the form of the letter X."

This crossing over of the nerves that govern the muscles was debated through the Middle Ages. But by the early 1700s, its existence was certain, and even the site of the crossover was known. It is in the part of the brainstem known as the medullary pyramids.

Much later, research established that a similar "midline crossing" occurs with nerves carrying sensation, although at a different site. The sense of touch or pain in the left hand is perceived by the right side of the brain, and vice versa.

This arrangement is most highly developed in primates. At least 75 percent of the "motor" fibers that start on one side of the human brain end up on the opposite side of the spinal cord, where they stimulate the nerve cells that actually drive the muscles. In animals lower on the evolutionary tree, a smaller percentage of nerve fibers cross over.

Nevertheless, it is a general design feature -- and a tricky one to build into the animal.

Like cars on a crowded freeway, the tips of nerve fibers growing down from the brain as a fetus develops must be kept to one side of the spinal cord for a certain distance, at which point most are forced to cross the median strip and continue down the lanes on the opposite side of the cord.

The body accomplishes this by making a half-dozen or more substances that direct the growth of motor nerves down the cord. Some act as chemical guard rails, keeping the nerve tips away from the midline. Others function as molecular state troopers, diverting the mass of nerves across the midline at a designated spot.
All told, it is an amazing feat of evolution. The question is: Why does it exist?
The answer appears to be that this design is the natural result of two things: the physics of optical lenses and the emergence of limbs as a means of locomotion.
Earlier this year, Denis Jabaudon, a Swiss neuroscientist from Geneva University Hospital who is now at Harvard Medical School, explored this question in the journal Lancet Neurology. He extended and refined an explanation first offered 107 years ago by the Spanish anatomist Santiago Ramon y Cajal.

An artist who was persuaded by his father to become a physician, Cajal spent much of his career looking through a microscope at slides of brain and spinal cord tissue. His ink drawings of what he saw were as exquisite as they were scientifically informative. In 1906, he was awarded the Nobel Prize for Physiology or Medicine.

Trying to come up with an explanation for why one side of the brain controls the opposite side of the body, Cajal noted that when an optical lens forms an image of an object, it inverts and reverses it. Bottom becomes top, right becomes left. When the lens of the eye projects an image on the retina, it depicts a world 180-degrees reversed from reality. The brain must compensate if it wants to get an image of the world as it exists.

It could do that by "higher-order" processing -- something akin to mental software -- that unscrambles the message. But that is not the strategy evolution favored. Instead, it favored reconstructing something close to a literal version of the perceived world in the dark, solid, wet brain.

Objects that are next to each other in the physical world and in the image projected onto the retina are also next to each other in the brain cells that process the impulses from the retina and "see" the objects. To make this happen, information about the right side of the world is sent to the left side of the brain, and information about the left side of the world is sent to the right. This undoes the side-to-side reversal of the image created by the lens.

This crossover of visual information occurs in its purest form in animals that have eyes on opposite sides of their heads, the better to scan the world for danger. (Fish are a good example.) When one eye sees a threatening object, it sends an image of it across the midline of the brain to the side opposite where the threat is.

If the way to escape the danger is to move muscles on the side of the body where the "image" now resides, the impulses sent out by nerve cells controlling those movements do not have to cross the midline. This is the case with fish and other limbless vertebrates that move by bending the entire body.

However, if the means of escape involves moving limbs on the side of the body closest to the threat, things are not so simple. In that case, the motor nerve cells in the part of the brain where the "image" of the threat is held have to send fibers across the midline -- back toward the threat and to the muscles that will help escape it.

The existence of limbs that push away from threats -- combined with the immutable properties of optical lenses -- "is the engine that is driving the evolution of crossed motor pathways," Jabaudon said in an interview.

This sets the stage for the crossing of sensory impulses, as well.

For example, an animal moving its left legs to escape a threat on its left side will want to tell the brain how the job is going. The brain needs to know: How hard are the feet pushing? Is there something painful underfoot? Furthermore, it makes sense to send the answers to the part of the brain where the threat was "seen" and the order to move the legs was given.

But that is on the opposite side of the body from the leg that is being told to move. Consequently, that foot-to-brain sensory information has to cross the midline, too.

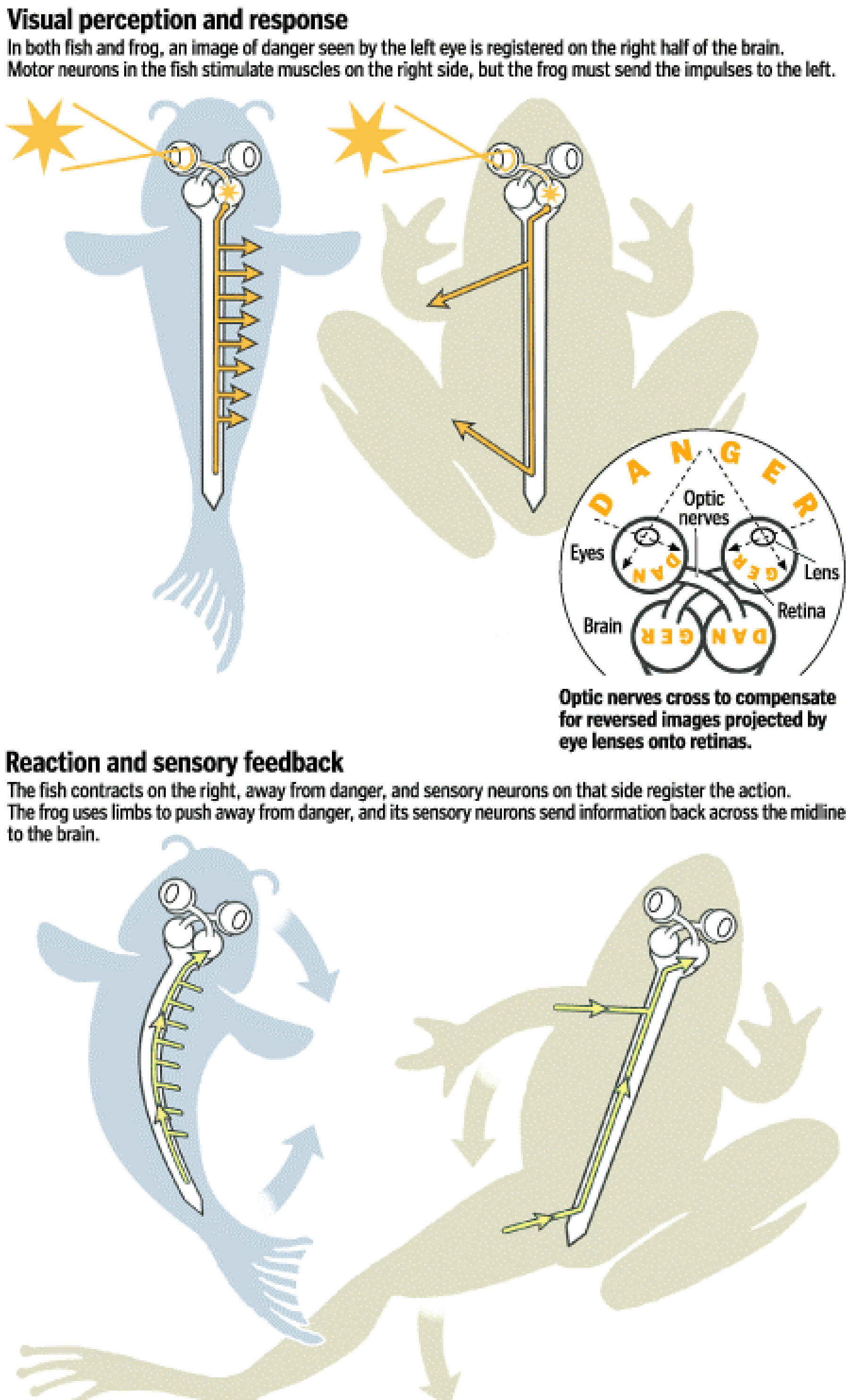
The pattern of crossed motor nerve tracts is found in nearly all limbed creatures. It even exists in some organisms with "pseudo-limbs," such as rays, whose wings function like arms.

Things get more complicated in animals with stereoscopic vision, where both eyes see an object. In that case, only half the nerve impulses from each eye are sent across the midline.

But the architecture of crossed motor and sensory pathways -- established much earlier by natural selection -- is maintained all the way up the evolutionary tree to human beings.

Graphic

Crossing Over to Compensate



Crossed nerve pathways: a result of the physics of lenses and the emergence of limbs.

SOURCE: The Lancet | BY PATTERSON CLARK - THE WASHINGTON POST