Latent heliotropism

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Our past is always with us

The cover photographs and illuminating essays that accompany each new issue of the *BJO* remind us that ocular anatomy and physiology can only be fully understood as a function of evolution. I have become convinced that many evolutionary clues to human movement disorders lie buried within the ancient biology literature. For example, the torticollis that accompanies congenital homonymous hemianopia may attest to the primitive role of vision in establishing baseline muscle tone. Humans born with homonymous heminanopia maintain a curious head turn away from the side of the seeing visual field.[1 2] A patient with a congenital right homonymous hemianopia will tonically turn the head away from the seeing left visual field and towards the right shoulder, while the eyes are maintained in a leftward deviated position within the orbits.[1 2] Since visual fixation remains on the object of regard even when the head is turned, this torticollis does not seem to serve any obvious compensatory function for vision.[3] Patients with congenital homonymous hemianopia are generally unaware of their abnormal head posture and are unable to explain why they maintain it. In patients with acquired homonymous hemianopia, torticollis does not manifest unless the causative hemispheric injury occurs in infancy.[3 4]

Proposed explanations assume that the torticollis must serve a compensatory function for visual orientation or navigation. It has been suggested that the head turn may be an adaptive response to frontalise the visual environment relative to the body, that it may permit the patient to use saccades to increase the effective visual field during ambulation, or that it may serve to minimise a subclinical nystagmus that is damped in one lateral field of gaze.[1–4]

Torticollis is a manifest tonus imbalance of the neck muscles. Tonus describes the state of excitation of a living muscle during rest.[5] Recognising that the visual system exerts influence on tonus of the body musculature via the central nervous system, Meyer and Bullock proposed that the eyes function not merely as sensory organs but as components of a multimodally driven tonus pool that calibrates baseline muscle tone (that is, tonus inducing organs).[6] In many invertebrates, asymmetrical visual stimulation results in turning movements in the horizontal plane and in postural abnormalities. In this context, the tonus imbalance that accompanies human congenital hemianopia bears a striking resemblance to the heliotropic posturing of lower animals under conditions of asymmetrical illumination.[7]

> By redirecting our attention to the posture of our patients with congenital visual disorders, we can begin to deduce the role of vision in regulating human muscle tonus

In 1832, Augustine P Candolle introduced the term heliotropism to describe the turning movement (tropism) of plants towards or away from the sun (helio).[8] A bending towards the sun came to be designated as positive heliotropism while a bending away from the sun was designated as negative heliotropism.[9–11] Since heliotropic behaviour was also recognised in unicellular organisms as well as insects, fish, and other vertebrates, ethologists at the end of the 19th century, influenced heavily by Darwinian theory, became vigorously engaged in the study of animal heliotropism.[9–11] Controversy ensued when Jacques Loeb, the objectivist German biologist, promulgated the iconoclastic view that animal instinct could be reduced to the same elementary physicochemical laws which determine plant tropisms.[9] According to Loeb, animal heliotropism occurred when the exciting stimulus (light from one side) induced or accelerated chemical reactions in a portion of the retina.[9 10] The mass of photochemical reaction products formed in the retina passed directly through the central nervous system (which was conceptualised as a sort of protoplasmic bridge) to influence the tension or energy production in the locomotor appendages on both sides of the body, until a new plane of symmetry was re-established between the two eyes and the source of light.[9 10]

This radical theory challenged the anthropomorphic and teleological conception that animals sought or avoided light based on voluntary or instinctive reactions. By reducing instinctive behaviour to a series of tropisms and chained reflexes, Loeb postulated that the animal, which appears to move purposively and of its own will, is actually forced to go where it is carried by its legs and wings.[9 10] Although many elements of the automaticity of animal behaviour were subsequently disproved by Samuel O Mast and others,[11] the importance of both plant and animal heliotropism is indisputable. (Philosophers such as Joseph Campbell have even contended that plant heliotropism is a manifest form of consciousness to the surrounding environment![12]) As summarised by Duke-Elder " . . .the control of the movements of living organisms, both plants and animals, by light is a fundamental function of great phylogenetic age, preceding the acquirement of vision and, indeed, leading directly to its development. The association of the functions of equilibration and orientation with the visual system of higher animals is in every sense basic."[13]

Within certain limits, heliotropic responses in plants and animals are a function of the Bunsen-Roscoe law of photochemical reactions.[10 11] This law states that, in a light reaction, the effect is proportional to the simple product of the intensity of the stimulus and time. In the robber fly, for example, covering one eye induces a flexion of the limbs on the side of the animal with greater luminance and an extension of the limbs on the side with lesser luminance.[14] The alterations of tonus are directed in such a way as to assist in turning the body towards the light.[14] When a robber fly climbs a vertical cylinder, covering one eye or covering the homonymous half of the visual field of both eyes causes the animal to move in a spiral trajectory towards the light, with the number of circles per unit distance proportional to the intensity of the light.[14]

In 1944, Herbert S Wells argued that humans possess a latent positive heliotropism. In decerebrate animals, newborn infants, and functionally decerebrate or decorticate adult human subjects, rotation or tilting of the head to the side results in extension of the fore and hind limbs of that side and flexion of the limbs of the opposite side.[15] During levitation of the arms, turning or tilting the head to the right, turning the eyes strongly to the left, or shining a strong light into the eyes from the left increases abduction of the right arm and diminishes or abolishes tonus in the left arm.[15] A forerunner of this response can be seen in the classic fencing reflex of infants. Turning an infant's head to the left causes the right arm to flex and come over the head and the left arm to extend in a classic fencing posture.[16] The protective function of this reflex is obvious—when starting to fall to one side, it is advantageous to turn the head towards the side of the fall and to extend the arm on that side to block the fall. Since sunlight comes from the sky above, and animals in the earth's gravitational field fall to the ground below, a bright light from the left elicits the same reflex tonus imbalance as a fall to the right.

Another latent heliotropism may reactivate when congenital strabismus precludes binocular vision in humans. Many fish and insects exhibit a dorsal light reflex in which the eyes and body rotate in space to align with the direction of incident light.[17] In humans with congenital strabismus, covering one eye causes it to drift dorsally (towards the light). I have proposed that this dissociated vertical divergence and its associated head tilt (towards the side of the eye with greater visual input) arise from a primitive dorsal light reflex that functions in lower animals to equalise visual input to the two eyes.[17] Unlike congenital hemianopia, which corresponds to a telotactic response (a direct orientation towards or away from light without the necessity of bilateral balance),[7] dissociated vertical divergence corresponds to a tropotactic response (one that functions to re-establish binocular equilibrium rather than to orient the eyes directionally towards or away from incoming light).[7,17]

Latent heliotropism would explain many features of the impressive torticollis that accompanies congenital hemianopia in humans. Mechanistically, a heliotropism would circumvent any element of will or choice on the part of the individual; the head simply goes where the neck muscles pull it.[9] Many patients with congenital hemianopia have an associated hemiparesis, with increased flexor tonus on the side of the hemianopia (that is, opposite the side of the abnormal cerebral hemisphere).[18] Thus, one could even question whether the non-heliotropic tonus inducing effects of a head turn might be actively utilised in some patients to increase extensor tonus on the paretic side. By redirecting our attention to the limb and body posture of our patients with congenital visual disorders, we can begin to deduce the role of vision in regulating human muscle tonus.

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