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THE EVOLUTION OF BINOCULAR AND STEREOSCOPIC VISION IN MAN AND OTHER ANIMALS*

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Many years ago, on leaving the National Hospital in Queen Square, where I had been house-physician for two years, I began a series of experimental work in Sir Victor Horsley's laboratory in University College on various animals, birds, and reptiles to study the subject of binocular vision and the path of the pupil reflex fibres to light. My results after two years were given in a paper to a special meeting of the Neurological Society in December, 1899, where I showed my microscopical sections of the chiasma in the chameleon, toad, pigeon, owl, rabbit, and cat, demonstrating the Marchi degeneration in the chiasma and optic tracts of the pigeon and rabbit, and in the optic lobes of the pigeon and the pons of the cat, after enucleation of one eye under anaesthesia. In addition, the course of the pupil fibres was suggested by the partial posterior decussation of Meynert's fountain decussation, following wounds of the anterior corpus quadrigeminum. Later on, this work was published (Harris, 1904). I developed the view that the successive improvements in accuracy of vision by binocularity, and finally by stereoscopic vision, were correlated with the importance, indeed the necessity, for certain groups of animals and birds, which live by hunting and chasing other living creatures for food, to acquire good vision.

Thus the shrikes and swallows, the hawks, owls, and eagles required and developed the greatest acuity and accuracy of vision, largely binocular, and amongst mammals the Carnivora developed almost perfect frontal position of the eyes and commencing stereoscopic vision. In the highest group, primates and man improved greatly the scope and accuracy of focusing by stereoscopic vision, but no longer for the purpose of hunting food or escaping from enemies, but in association with the development of the hand—in the monkey and apes mainly for inspection of objects of food seized by the hand; and, finally, in man there was the much greater development of the thumb and the resulting use of the hand in association with good stereoscopic vision for every kind of manual and artistic work. Indeed, foveal acuity of vision has probably diminished in the most civilized races of mankind, though some—the Hottentots, some Indian natives, and the Tierra del Fuegians—are credited with far keener vision than the average white races. "Yet the cerebral development of macular vision in man, both in area of cortex and stereoscopic power of brain reception and perception, has without doubt greatly increased.

Stained sections of the chiasma in the chameleon, toad, owl, and pigeon demonstrated that there was total decussation of the optic nerves, while Marchi specimens of pigeon chiasma showed conclusively that the decussation of all the fibres was complete. Similar Marchi specimens of rabbit's chiasma showed that a very few fibres did turn back into the optic tract of the same side, but practically the decussation was total. Neither of the owls survived the operation of enucleation long enough to obtain the osmic acid staining for Marchi degeneration, but the appearance of the cut sections showed that there could be no doubt that the decussation in the owl was as complete as in the pigeon. There was good contraction of the pupils in the pigeon and owl to light shone directly on one eye, but no trace of consensual contraction in the other eye. Birds have voluntary power of contraction of the pupil, so a little care must be taken in testing their pupil's reaction to light, but after doing the test several times the bird gets accustomed to it.

I had a grey African parrot as a pet in those days, and its pupil was much easier to test, owing to the light coloured background. I remember trying to dilate its pupil with a drop of atropine, as I wanted to look at the retina and pecten, but the only result was that it stopped talking for a week. Birds' voluntary power of contracting the pupil is due to their having striated muscle in the iris which is unaffected by atropine. Marchi degeneration in the cat's chiasma showed much more semi-decussation than in the rabbit's, about one-third of the fibres turning back into the optic tract of the same side. In man the proportion of fibres decussating is said to be about seven to five. Consensual contraction of the pupil in the cat is well marked, but is absent in the rabbit owing to the almost total decussation.

Panoramic versus Binocular Vision

Vision in the rabbit and hare is completely panoramic, with no vision directly forwards, and they may even run forwards towards the gun when trying to escape. Several fish and reptiles and many varieties of birds have good binocular vision, though in all of them the decussation of the optic nerves in the chiasma is complete, and in none is there any consensual reaction of the pupil to light, even in the most frontally placed eyes of the owl, which may subtend an angle as wide as 150 degrees in the barn owl, compared with the human parallel optic axes, with the corneae in a horizontal line.

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Although the chameleon has complete decussation of the optic nerves, yet it has the power of the most complete convergence of the eyes, with perfect binocular vision when seizing a fly or mealworm. Its eyes are stalked and covered with horny skin except for a small opening in front, at the bottom of which the small black pupil can be seen. When the animal is lively enough in the spring its eyes may be seen to move about quite independently in slow jerky motion, like searchlights; one eye may be pointed directly forwards and the other backwards at an angle of 180 degrees or 90 degrees vertically. If one eye catches sight of a fly or mealworm within range at a distance of a few inches, the eye remains fixed on it, while the other eye is brought round slowly until the two eyes are fixed on the morsel in perfect convergence. Then the mouth slowly opens and the sticky tongue appears; this is then flashed out, taking the grub unerringly, and withdrawn into the mouth. The tongue is not hinged at the front of the lower jaw as it is in the toad, which throws its tongue forward in an arc, as though on a hinge, and the fly or cockroach is gone in a flash, even quicker than in the chameleon's act.

In 1942 a remarkable book was published in America by G. L. Walls on the vertebrate eye, which by his permission I quote from freely in this paper. He states that associated with the perfect convergence of the chameleon's eyes is the highly developed retina, with a central fovea and yellow spot macula, the only animal besides the primates which has a macula; it has 756,000 cones per mm.² in its fovea, which is deeper and even more developed than the human. Walls devotes five pages to the evolution of binocular vision, and these are entirely given up to the question of the fusion of images and the perception of distance, though elsewhere he says, "The hunters tend towards frontality so as to have the best vision of the prey they are pursuing, while the hunted tend to retain laterality of eye position so as to be able to detect an enemy coming from any direction." He does not stress the idea that it is the carnivorous habits of certain reptiles, birds, and animals which have led to the evolution of binocular vision, or that stereoscopic vision has been perfected in the primates, and especially in man, in association with the development of dexterity of the hand for intricate work. In all other respects Walls's book is a mine of information, and my references to types of retinae and foveae are almost entirely quoted from it. I feel so sure, however, that the view of evolution of binocular and stereoscopic vision which I put forward nearly fifty years ago is correct, that I am venturing to discuss it once again.

Acuity of Vision

The marmots, or prairie dogs, have strongly lateral eyes like the rabbit, with little power of lateral movement and with panoramic vision, and for similar reasons, being vegetarian and requiring to avoid their enemies from both sides at the same time. Yet their acuity of vision compares in accuracy with human sight, for their retina, without foveae and containing only cones and no rods, compares in resolving power over its whole area with that of the human fovea. They have yellow lenses, which must mitigate the intensity of full daylight on the cones. On the whole, diurnal animals have a majority of cones in the retina, and pure cones only in the fovea or area centralis, while nocturnal animals have mostly rods; the owl's cones have become much more slender and rod-like in appearance, and the bird has no central fovea, only a temporal one. Many birds have two foveae, central and temporal. Diurnal birds, such as finches,

have mostly cones and comparatively few rods, and in hawks and eagles, and even in the common sparrow, cones are packed very closely in the fovea—400,000 per mm.² in the sparrow—while in the hawk, *Buteo*, no fewer than 1,000,000 cones per mm.² are found. This hawk's retina, with an eye as large as the human, has nearly twice the resolving power of the human fovea, while the visual acuity of some hawks and eagles is at least eight times that of man.

The sharp sight of vultures is well known, because of the great distances from which they can recognize a dying animal. Being carrion feeders on the ground, unlike hawks and eagles, which chase and capture their prey, often on the wing, vultures have no temporal fovea and do not require highly developed binocular vision. Even the shrike, or butcher bird, has much more acute vision than man. A falconer in the Middle Ages used to carry on his saddle a caged shrike which, after the hawk was loosed, would remain excited and fearful as long as the small bird could see the hawk, though long out of sight of the falconer.

A curious structure in the bird's eye is known as the pecten, a comb-like rugose outgrowth from the edge of the optic disk, very vascular and pigmented, but containing no nerve fibres. It is smaller in nocturnal birds, but its function is quite unknown.

Vision may be defined as the reaction to light of certain cells known as visual cells in the retina, which is a cup-shaped structure pushed out from the optic lobe in the brain on each side, consisting of visual cells backing on to an external limiting membrane and a pigment layer, supported externally by a tough fibrous envelope known as the sclera. This is enormously thickened in the whales, so as to make the eye almost immovable. The visual cells consist of rods and cones, the latter being particularly useful in focusing, and are found especially in the area centralis or macula and the fovea, or central vision point in the retina. The fovea in all animals and birds possessing one is avascular, no capillaries intervening between the layer of optic nerve fibres in front and the visual cells at the back of the retina; otherwise the focused image on the fovea would be blurred.

Sphenodon, a New Zealand lizard with nocturnal habits, is the only terrestrial vertebrate with a pure rod retina. Such vision is called scotopic, and cone vision photopic. Rods are more sensitive to light than cones, are distributed especially in the external parts of the retina, and are more useful than cones in dim light. They are bathed on the outside in the visual purple, derived from the pigment layer, which is known as rhodopsin. The retina may be more or less bleached by exposure to strong light for several minutes, but the rhodopsin is gradually reaccumulated on the rods within about half an hour. Vitamin A is a valuable aid to such reaccumulation, and during the late war was made use of in readapting the vision of night-fighters by the administration of halibut oil.

Rays and Vision

The light which strikes the outer layer of visual cells through the inner transparent layers of the retina may be direct light vibrations from a source of light such as the sun, an electric lamp, or a candle. These vibrations of radiant energy are electro-magnetic in nature and have a speed *in vacuo* of about 186,000 miles per second whatever their source. Those vibrations which we call visible light are restricted to a band whose wavelengths vary from about 1/3,000 of an inch at the red end of the spectrum to 1/6,250 of an inch at the violet end. Those rays on the longer side of the red end are the infra-red or heat rays; and still further and with increasing wavelengths are the Hertzian waves of wireless telegraphy which are up to 10,000 metres, or about six miles, in length. Beyond the shorter violet rays are the still shorter ultra-violet rays, with chemical action, and further still come the shorter x rays, gamma rays from radium or from atomic explosions, and finally the cosmic rays, whose wavelengths may be as short as 1/6,000,000,000 of an inch. They have enormous penetrating power, and have been shown to pierce several feet of

lead. All these rays travel at the same speed, and astronomers and physicists assert that nothing can travel faster than light *in vacuo*.

Long wireless waves are constantly travelling all round the world, being reflected downwards by the Heavside layer in the upper atmosphere and passing perhaps through our bodies without our being conscious of them, but the shorter bands of heat and light rays are arrested by material objects, while the still shorter ultra-violet rays can in quantity damage us, and the still shorter x and gamma rays may be useful in destroying cancer cells but at the same time may be very dangerous. The shortest rays of all, the cosmic rays, we know little about, but it is believed that they reach our galaxy from the almost infinitely distant nebulae. In the upper atmosphere they ionize the air, producing ozone from the oxygen, which shields us from the destructive excess of ultra-violet rays in sunlight. Sir Spencer Jones, Astronomer Royal, in his foreword to a book recently published, *Across the Space Frontier*, comments on the risk from the destructive ultra-violet rays in the unfiltered sunlight that space travellers would encounter.

So it is just one small band, less than an octave, of medium short waves, which have the power of producing light when they strike a solid object and are then reflected into our eyes and retinæ, that enable us to see the world around us. These rays entering our eyes are focused by the cornea and especially by the lens to form an inverted image of the object upon the fovea, the central point of vision in the retina. Traversing the transparent layers of optic nerve fibres and ganglion cells and nuclear layers, the rays impinge on the cones in the fovea and on the rods and cones around the macula and the peripheral parts of the retina, and start electric currents. These pass inwards to the layer of nerve fibres and then along the optic nerves, decussating at the chiasma, so that rather less than half turn back into the optic tract on the same side, while the larger remainder cross over to the opposite side, the stimuli in each case reaching the two external geniculate bodies, where the impressions from both retinæ are laid over each other alternately, thus laying the foundation of stereoscopic vision. Thence the optic radiations carry the stimuli to the visual cortex in the two occipital lobes on the inner side around the calcarine fissure; lower retina to lower cortex, and upper retina to upper cortex. Thus the upper halves of our total visual field are perceived by the lower half of our visual cortex, and the lower visual field by the upper visual cortex. That this is so is proved by the fact that a lesion of the upper lip of the calcarine cortex and the cuneus above produces a blind area or scotoma in the lower visual field, and a lesion of the lower calcarine area and lingual lobe causes a scotoma in the upper half of the visual field.

Now comes the difficulty. We know from the optics of the eye that the image of any object seen is inverted on the retina. Why then do we see objects in their correct position, and not upside down? There is no known anatomical explanation of this, and so we must assume that there is some psychological reversal of the visual impression after it has reached the visual cortex. This reversal of the retinal inverted image is not a monopoly of the human brain, but must apply to all the lower animals, birds, reptiles, and mammals whose lenses focus on the retina in the same way as ours. It has been suggested that the baby gradually learns from experience, but a day-old foal will nuzzle his mother in the correct manner from the start without any teaching or experience, so it must see its mother the right way up.

A few instances have been reported of young children aged about 6 who, after an illness such as measles, or a head injury, or even after atropine has been put in the eye, may for several weeks see all test letters upside down and may draw objects such as houses and people in the inverted position. Mirror writing, which comes naturally to some children, is due to a somewhat similar process of psychological inversion.

Evolution of Retina

The most primitive light receptor is a spot of black pigment as is found in a unicellular microscopic animal, *Pouchetia cornuta*, or in the pigment in the surface epithelium of the earthworm, where light may cause chemical changes. The first approach to an actual eye is probably that of the limpet, *Patella*, in which a special layer of cells line the bottom of a depression in the skin. A further advance is the pin-hole camera type of eye in the nautilus; then, more elaborate and with focusing lens, the ocellus of the scorpion; then the snail, *Murex*, with a covering cuticle or cornea; and, lastly, the most highly organized of the pre-vertebrate eyes, that of the octopus and decapods, such as *Sepia* and *Loligo*, the cuttle fish, which have retina, vitreous, and spherical lens, with focusing power of moving the lens forwards or backward from the cornea, but very little, if any, binocular vision. These cuttle fish require highly organized and rapid variations of focus as they travel at speed over varying coloured backgrounds of sea-bed, so as to co-ordinate by their nervous reflexes the changing colours of the skin. Though these molluscs have such a highly developed eye, comparable to that of the higher mammals and human beings, the structure of their optic nerves and their central connexions show no evidence of binocular or stereoscopic vision, and there is no decussation of the optic nerves, which pass direct into the lobes of the supra-oesophageal ganglia, a primitive brain.

In passing, I might comment on the fact that the squid and the octopus have anticipated Sir Frank Whittle by many millions of years in their discovery of jet propulsion, with the difference that their method of movement is backwards, or retropulsion. At the same time they have the power of hiding from an enemy by ejecting from the ink sac into the jet a cloud of dark brown pigment, hence the name *Sepia*, or, as the fishermen call it, the pen-and-ink fish. They are, by the way, extremely good eating. It is remarkable that the order Mollusca includes one of the most primitive eyes in the limpet and one of the most highly developed in the cuttle fish.

Varieties of Retina

The vision of all vertebrates may be classed as either diurnal or nocturnal. The latter will have retinæ rich in rods, which are more sensitive to dim light than cones. Diurnal vision requires numerous cones, which give clarity of images with focusing in good light, so the foveae of diurnal vertebrates are pure cone. It is not only in relative numbers but also the relative amount of rod or cone substance that is important. This is brought about by an actual increase in size of the eyes, as in hawks, eagles, owls, the larger mammalia, primates, and man. Most birds, being active by day, have retinæ rich in cones, but many animals require retinæ of a mixed type and rich in rods—such as the Carnivora, wolves, lions, tigers, leopards, and foxes, as many a country farmer has reason to regret on finding his hen-roosts depleted in the morning. Large eyes in the Ungulata (horses and oxen), apes, and man allow of great numbers of rods to be interspersed among the cones without diminishing diurnal vision, while increasing their nocturnal powers in twilight and moonlight; thus man and the Carnivora especially are able to stay up and pursue their gangster business after the birds have gone to bed.

The cone is said to be the older of the two visual cells, and is of special value for focusing and sharp definition, though less sensitive in dim light than the rods. The human fovea is pure cone, but outside the macula rods outnumber the cones by 20 to 1. This greater sensitivity of the rods is demonstrable when looking at a faint star. If you look directly at it the star seems to disappear, but reappears on looking just to one side of it. The belt of Orion is a good test for this point. Or try the brightest star in the Pleiades, Alcyone, who with her six sisters, daughters of Atlas, were chased for five years by the hunter Orion and his dog Sirius, the brightest star in our sky, until Zeus saved them by translating them all to the heavens above.

Teleostean, or bony fishes, are peculiar in having very variable thicknesses of retinae, with twin cones as well as single ones. The eel has 3,000,000 rods per mm.² which is surprising, for its habitat in adult life in fresh-water lakes and canals would not seem to call for a very sensitive retina. The life story of this fish is altogether remarkable. When the adult after some years feels the urge to migrate its eyes grow enormously in size, the fish becomes silvery, makes its way down the streams to the sea, and thence across the ocean to the clear Sargasso Sea in the West Indies. Here they breed, and the adults then die, while the young elvers grow to a few inches in length and then slowly make their way back across the ocean to the estuaries and rivers whence their parents came, and ultimately grow to adult form in the ditches, lakes, and canals whence their parents migrated.

Vision in Deep-sea Fish

The more numerous the rods are in a retina the more sensitive is it to light, and the rods become greatly elongated and slimmer, so that greater numbers can be packed in the same space. This is found in the retinae of deep-sea fish, which dwell at the depth of a mile or more and live in Cimmerian darkness. They never see anything but the photophores or phosphorescent lamps carried by friends or enemies. This luminescence of deep-sea fish is produced by bacteria in tiny tubules in the skin, and this light the fish can conceal at will. About 96.5% of all deep-sea creatures are luminous. It has been claimed that some of them have as many as 25,000,000 rods per mm.² of retina. Some have tubular eyes, fixed in their sockets and immovable, as in the owl, but placed parallel for good binocular vision, others have the eyes fixed for upward vision.

Some freshwater fish have partial binocular vision, for a trout can take a fly quickly on the surface of the pool. It is, however, but an amateur at the job compared with the archer-fish, *Toxotes jaculator*, which can spit a thin stream of water from beneath the surface to hit and bring down a fly in the air several inches above the water. It has a narrow binocular field, but no fovea. As Walls remarks, "If his shooting depends on his sight of the fly in air when seen from under the surface, he must have a truly trigonometric range-finder in his brain to cope with the ever varying distortion of angles, size and distances." If the water is smooth a fish can see out of the water anything subtended by an angle of slightly greater than a right angle with his eye. A person on the bank would look like a tiny doll, which would enlarge the nearer it approached the surface.

Dryophis, the East Indian long-nosed snake, has good binocular vision, due to its having a temporal fovea. It is one of the only two genera that have a fovea, has the sharpest sight of all snakes, and is a most accurate judge of distance. Its pupil is shaped like a keyhole and is placed very laterally on the head, which slopes sharply forwards to its pointed nose, making its view quite unobstructed for good binocular vision.

Carnivorous Birds

Though many birds have two foveae, central and temporal, the owl has only a temporal fovea. The barn owl has the most frontally placed eyes of all birds, with a visual angle of about 150 degrees, compared with the human parallel eyes at 180 degrees. Its retina, being adapted for nocturnal vision, has comparatively few cones but mostly rods, except in its temporal foveae, with which its marked binocular vision enables it to focus and seize the little voles and field mice that are its usual prey. Owing to the owl's nocturnally adapted vision, if it is caught out in the open daylight it is partly blinded by the strong light and is apt to lose its way, and may get mobbed by small birds. Its eye is partly tubular in shape and is quite immovable in its socket, but to compensate for loss of ocular movement the owl has the extraordinary power of rotating its head on its neck to an angle of 270 degrees, or three-quarters of a circle.

Fish-eating Birds

The cormorant, *Phalacrocorax*, has the most powerful accommodation of all birds for compressing the lens by the ciliary muscle. Its lens, which is as soft as the turtle's, can be compressed into a pear shape giving an accommodation power of 40 to 50 dioptries, so essential in following his prey under the water. The gannet, *Sula bassana*, has only central foveae, and so cannot focus its distance when diving from a height into the sea after a fish. This has been proved by fastening a fish on a floating board, when the bird has been seen to transfix the board with its beak. The kingfisher has both central and temporal foveae. It generally dives into a stream from a perch above a pool, having focused a fish beneath the water with its central fovea, but the moment its head is beneath the water it must change its focus to its very external temporal fovea, using good binocular vision in this way as it spears the fish with its pointed bill. The swallow too requires the greatest accuracy in focusing power for catching flies and chafers at speed on the wing.

Many insects, especially the dragon-fly, and some Crustacea have round or oval protruding compound eyes, built up of conical-shaped lenses fixed with their bases against a smooth membrane or cornea, so that vision of objects behind the fly or lobster is possible. Anyone who has tried to stalk a fly from behind must often have noticed this point for himself.

Colour Vision

Colour vision has been demonstrated in fish, reptiles, and birds by training them to take food from different coloured containers. Coloured objects reflect only those coloured rays which we see, absorbing all the rest of the rays of the spectrum. Many street lamps, though excellent illuminants, are very poor in red rays, though rich in green and blue; consequently at night our hands and faces will appear corpse-like in hue, as there are no red rays in the light that illuminates them.

For many years the Young-Helmholtz trichromatic theory—red, yellow, and blue, or red, green, and violet—disputed pre-eminence with Hering's view of three colour substances in the retina, white-black, red-green, and yellow-blue. There are seven primary colours in the spectrum—red, orange, yellow, green, blue, ultramarine-indigo, and violet—and Granit has suggested that there are seven different receptors in the retina, one for each primary colour. This theory has been further developed by Hartridge as a polychromatic theory, which seems likely to oust the older theories, neither of which explains various forms of colour-blindness, which can be satisfactorily explained by the polychromatic theory.

Some brilliant effects of colour, such as the vivid green of some beetles' wings and the coloured eyes of peacocks' feathers and of butterflies' wings, are due to excrescences on the material of the wings acting like a diffraction grating, a piece of plate-glass engraved by a diamond with very close parallel lines, over 12,000 to the inch. These fine lines at their edges break up white light into its spectral colours, and it would be just as useless to try to extract coloured substances from the peacocks' feathers or butterflies' wings as it would be to do so from a rainbow.

Conclusions

Hitherto we have traced the development and value of binocular vision as an assistance to carnivorous fish, reptiles, amphibia, and birds in catching their prey. When we examine the vision of mammals the same and increasing value of binocular vision and frontal placing of the eyes is seen in the Carnivora as compared with the browsing and grass-eating animals, which have panoramic vision and almost total decussation of the optic nerves. The semi-decussation of the nerves in the

Felidae and other Carnivora now introduces an additional element of value—namely, stereoscopic vision, by which I mean that the images from both eyes are now beginning to be laid over one another alternately in the visual centres, first, in the external geniculate bodies, and thence via the optic radiations in the calcarine and neighbouring cortex. This factor doubtless increases the accuracy of fusion of images in depth.

Development of the Hand and Thumb in Co-ordination with Stereoscopic Vision

In the higher mammalian group of primates and man the importance of catching living food has disappeared, as apes and monkeys are mostly fruit eating, and man also is largely fruit eating and agricultural. There is now a more important reason for the development of stereoscopic vision of the highest type, in the increasing importance of the hand in seizing objects for inspection, and for important manual work of all descriptions requiring accurate vision. No one could watch the monkeys in the outdoor cages at the Zoo without noticing how they use the hand and vision in co-ordination for receiving and inspecting the morsels offered to them. Though improvement in vision for hunting animal food is no longer necessary, the human hand is an immense improvement on that of the monkey, chimpanzee, or gorilla—in the development of the thumb and thenar muscles in proportionate strength and the power of opposition of the thumb to the other fingers. By this improvement the value of the hand as a working tool acquires much greater delicacy of movement and co-ordination with vision in its manifold uses of building and of manufacturing tools, objects of vertu, and works of art of every description, as exemplified by a Michelangelo or a Raphael in sculpture and painting, or a Cellini in gem making. In these arts the closest co-ordination of eye and hand is essential, but with musical instruments vision plays little part in the marvellous execution of a Paganini or an Abbé Liszt. Here the ear and memory, and the intensity of practice, take the place of vision.

The monkeys and apes have concentrated on developing all four limbs with four hands, as *Quadrupana*, and the South American monkeys have added even a fifth "hand" in their prehensile tail, thus making an ideal machine for tree-climbing and swinging from branch to branch, and enabling them to travel long distances along the upper regions of the primeval forests without danger from carnivorous enemies on the ground. The offshoot, man, has concentrated on his fore-limb only, and by hand and vision combined—with increasing brain development, the acquisition of speech, and the discovery of fire, of agriculture, firearms, steam power, electricity, the telephone, the internal combustion motor, and, lastly, the means of flying, in ever-hastening speed of invention—has gradually developed from his doubtful position as a cave man to his present supremacy in the living world.

We have yet to see whether the most recent and most powerful invention, atomic fission, will be harnessed for peaceful production of power for all the nations, when all the coal and oil have been used up, or whether it will lead to the greatest means of destruction of civilization in history.

REFERENCES

- Harris, W. (1904). *Brain*, 27, 107.
Walls, G. L. (1942). *The Vertebrate Eye and its Adaptive Radiation*. Michigan.

AUREOMYCIN, CHLORAMPHENICOL, AND TERRAMYCIN IN OPHTHALMOLOGY

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The place of the sulphonamides and of penicillin in ocular infections mainly due to Gram-positive organisms, and of streptomycin in infections mainly due to Gram-negative organisms, is now well established. None of these agents has, however, proved of much use in virus infections, except that the sulphonamides are valuable in the treatment of trachoma and in inclusion blennorrhoea, with penicillin almost as effective in the latter infection. The newer antibiotics with their alleged efficacy over a wider range of viruses offer the possibility of therapeutic agents in ocular infections which are due to viruses and are not readily controlled. Outstanding among these are dendritic ulcer, disciform keratitis, epidemic keratoconjunctivitis, and herpes ophthalmicus. Dendritic ulcer of the cornea, a not uncommon condition, shows varying severity and a tendency to frequent relapses. Disciform keratitis, with its dense interstitial infiltration, generally leads to much loss of vision from the resultant interstitial fibrosis. Ocular complications of herpes ophthalmicus, which include a variety of corneal reactions, iridocyclitis, both active and quiescent, and episcleritis, as well as destructive corneal ulceration, are serious considerations. Epidemic keratoconjunctivitis is the least significant from the point of view of resultant damage, but its prolonged course, marked symptoms, and occasional sequels of dendritic ulceration and disciform keratitis, as also the frequency with which it occurs during epidemic periods, present problems of some magnitude. Evidence for the virus origin of these affections is best in herpes ophthalmicus, and almost as definite in dendritic ulceration and in disciform keratitis; the virus origin of epidemic keratoconjunctivitis is less definitely established. Whilst there is little doubt that the first three of these affections are due to a virus of the herpes group, such little as is known of the morphology of the virus of epidemic keratoconjunctivitis suggests that it has some affinity to the virus of trachoma. The assumption that viruses are responsible for a variety of other nondescript corneal and iris reactions has as yet little support.

In the present study an attempt has been made to assess, experimentally and clinically, the value of the different modes of administration of aureomycin, chloramphenicol, and terramycin. The difficulties in establishing experimental virus lesions in animals on which these agents could be tested have precluded any experimental assessment of these drugs. We have had to rely instead on clinical observations.