The Sophistication of The Human Eye

Compiled By Glen W. Chapman June 2003

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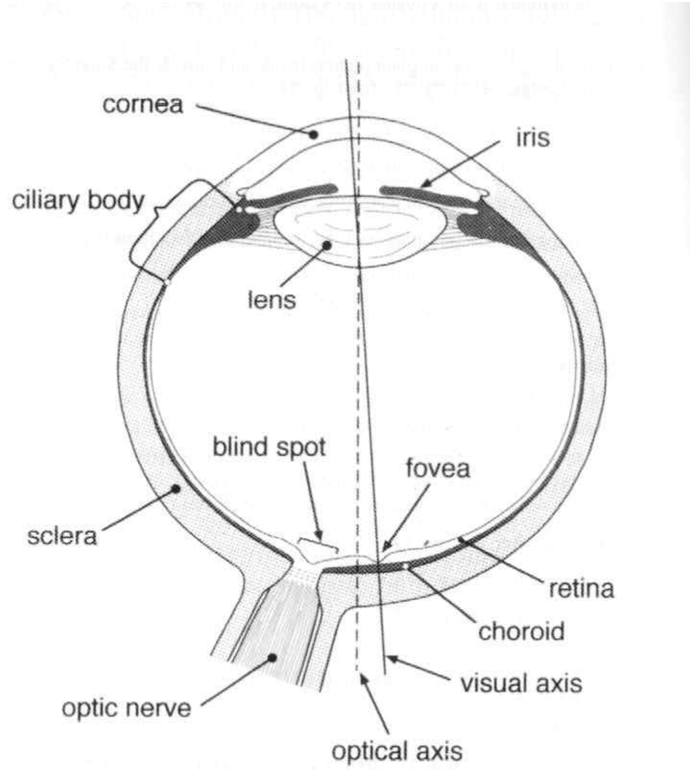
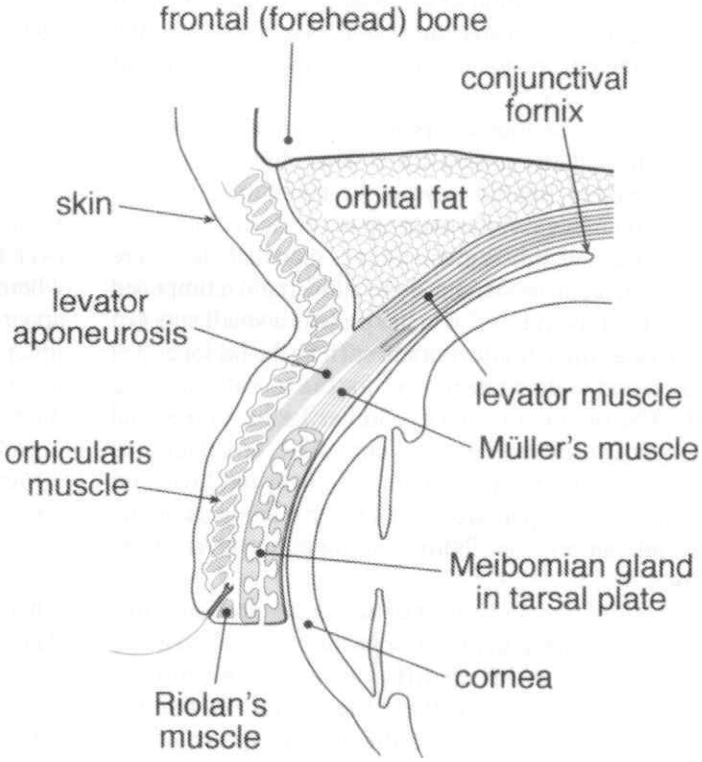
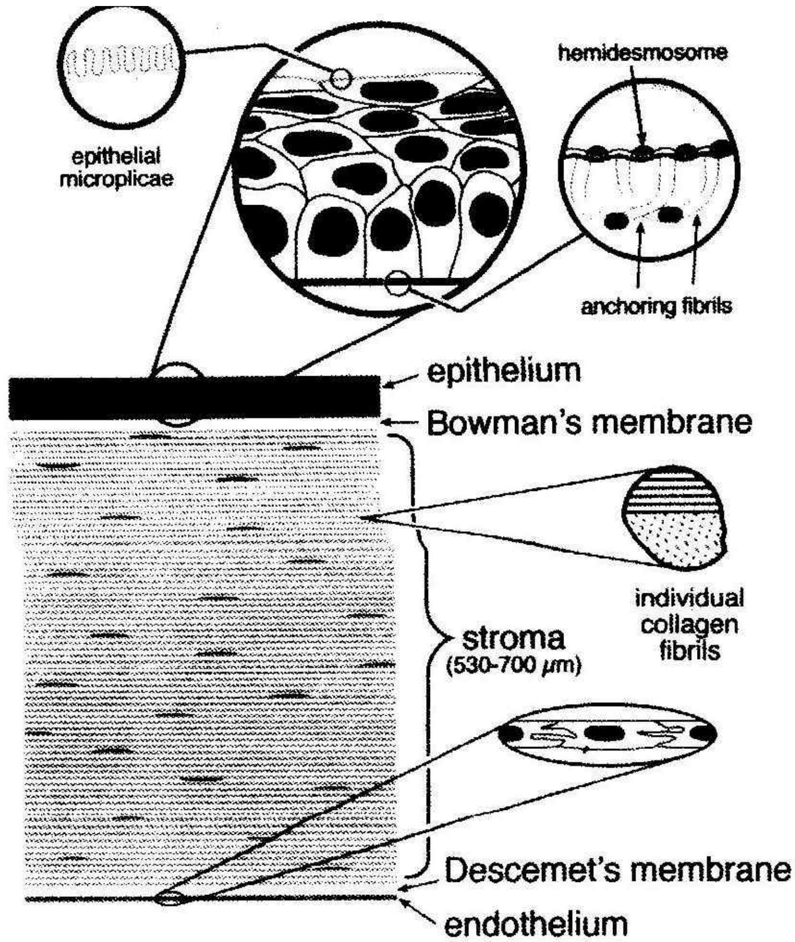


Cross section of the human eyeball.



frontal (forehead) bone
conjunctival fornix
orbital fat
skin
levator aponeurosis
levator muscle
Müller's muscle
orbicularis muscle
Meibomian gland in tarsal plate
cornea
Riolan's muscle



. *Cross section of the cornea.*

The cornea

The internal natural lens of the eye is a device for fine tuning the refraction of the eye's optical system, i.e. to vary its focal length according to the distance of the object being viewed. Now, it is true that the human eye can usefully function up to a point without its lens, particularly in those who are very shortsighted (myopic),[15] for whom removal of the lens can be beneficial [16] But this is only because of the presence of I another more powerful lens of fixed focus, namely the 'cornea' Approximately two thirds of the refraction of light rays entering the eye occurs at the 'interface between air and the thin film of tears covering the front surface of the cornea [17] Thus because of the cornea the eye can still form an image on the retina, albeit a blurred one, in the absence of the natural lens.[18] The refraction that normally occurs at the air/tear interface explains why, when the human eye is open underwater, the optical imagery is extremely blurred; the index of refraction of water is quite similar to that of the cornea and most of the optical power of the anterior corneal surface is lost.[19] If the cornea with its covering of tears is to act as an optical lens it has to be transparent to light. As a transparent object the cornea is remarkable for its efficiency in this respect in that normally it transmits more than 90% of incident light.[20] The cornea is part of the eyeball's tough fibrous outermost tunic of which it forms the anterior one sixth in section, the other five sixths being the white opaque sclera ('the white of the eye'). The predominant material of this tunic is the fibrous protein collagen which is found throughout the body and is the main constituent e.g. of tendons.

Several factors are together responsible for the cornea's high degree of transparency in contrast with the opaqueness of the sclera, and they reveal an extraordinary degree of organization and precision. It is obvious that the absence of blood vessels and pigment in the cornea and the paucity of cells in its stroma (see below) are prerequisites for its transparency. The external surface membrane, the *epithelium,* is about 50 μm thick and consists of 5—6 layers of cells which are constantly being replaced from the cornea's periphery. The epithelium is of homogeneous refractive index. When covered by a tear film it presents a perfectly smooth, almost spherical convex surface that does not scatter entering light. The corneal surface is the most specialized 123 mm^2 of the body's surface.[21] Disease processes affecting the epithelium may cause unevenness of its surface which scatters incident light; they may also disturb its transmission and refraction of light, all of which can markedly reduce vision. Besides its optical properties, the superficial cells of the epithelium have tight junctions between them so that the epithelium is semi-permeable; it functions as a barrier with a higher electrical resistance than that of the layers behind it. Important for the physiology of the deeper layers, it also controls the absorption of fluid from tears, medications etc, besides resisting invasion by microorganisms.

The basal cells of the epithelium are firmly adherent to their common basement membrane by means of hemi-desmosomes *(hemi* + Greek *desmos,* a band + Greek *soma,* body). The basement membrane in turn is anchored by fibrils[22] which reach into and, like Velcro, tangle with and grip the fibrils of' the underlying transparent membrane *(Bowman* 's—see below). The epithelium is constantly being replaced, the basal cells giving rise to the superficial cells; the basal cells also are constantly being produced by stem cells[23,24] located at the junctional zone between sclera and cornea, known as the *limbus.* The basal cells migrate over the cornea centripetally, marching in columns,[25] from the limbus; and the superficial cells are shed slightly below the cornea's central area. Animal experiments have revealed that when epithelium is lost with an injury, a coordinated response is triggered to close the defect: the normal movement of epithelium is accelerated with the cells flattening and the basal cells in the vicinity of the wound losing their hemidesmosomes within two hours.[26]

Bowman's membrane to which the epithelium is attached is about 12μm thick and apparently structure less with light microscopy, but electron microscopy shows that it consists of randomly oriented collagen fibrils. It is relatively resistant to invasion by pathogens and forms the anterior boundary of the *stroma* of the cornea,[19,27] a laminated cross-ply structure which makes up 90% of the thickness of the cornea (0.7mm peripherally and *0.53* mm centrally) It consists of more than 200 lamellae (layers or strips) of varying width and composed of collagen fibrils stacked one upon another and all running parallel to the corneal surface, each lamella being 1—2 μm thick. All fibrils within any given lamella are strictly parallel and are oriented at right angles to those in the lamella in front and in the lamella behind Moreover, the fibrils are of uniform diameter (about 35 nm) and each fibril is separated from all its immediate neighbors by a more or less constant interval (about *50* nm); the space between the fibrils is filled by a 'ground substance' which consists of proteoglycans, glycoproteins and salts.

A number of explanations for the cornea's transparency have been proposed over the past century and for a time it was attributed to the regular lattice-like arrangement of the collagen fibrils in human cornea. But the lack of this arrangement in other transparent tissues such as the dogfish cornea or the human lens points to another explanation. The cornea exhibits birefringence (the property of having more than one refractive index according to the direction of the transmitted light) and this supports the view that stromal collagen fibrils have a different refractive index from that of the stromal ground substance. The current understanding of corneal transparency[28] is based on diffraction theory. This shows that scattering of light passing through a medium does not occur when variations in its refractive index extend over distances less than half the wavelength of the light. This is consistent with the diameter of the collagen fibrils found in the cornea and the spacing between them, both of which together are well below half the shortest wavelength of light (380 nm). In contrast with the corneal collagen, sclera collagen fibrils vary considerably in diameter (25—480 nm) and are grouped in tightly packed interweaving bundles of varying dimensions; also, the intervening spaces between bundles are large relative to the wavelength of light, all of which render the sclera opaque.

The uniform and close *spacing* of the collagen fibrils and their small diameter are thus fundamental to corneal transparency. The spacing is maintained by tight regulation of the hydration of the ground substance (mainly its glycosaminoglycans), collagen making up 15% of the cornea's weight and water 78%. Dehydration or excessive hydration of the ground substance disturb the orderly arrangement of the fibrils and so impair the cornea's transparency. As discussed above, the highly ordered laminar lattice-like configuration of the human cornea is not essential for its transparency. Its purpose, rather, is to maintain the cornea's shape, curvature, and mechanical strength. It enables the cornea to withstand heavy impacts, though not always without damage to internal structures.

Because the degree of hydration of the stromal ground substance critically affects the spacing of the collagen fibrils and hence the optical properties of the corneal stroma, we should consider how this is regulated. In its normal transparent state the cornea is thin and relatively dehydrated, i.e. by about 20%, and its stroma is therefore hyperosmotic.[29,19] The reason for this rests with the epithelium and the endothelium, particularly the latter. Both are semi-permeable membranes acting as barriers to the diffusion of electrolytes and the flow of water across them. For the epithelium, the flow of water is from the tears, while for the endothelium from the aqueous fluid. The epithelium, having tight junctions *(zonulae occludens)* between its superficial cells, is more effective in this respect than the endothelium and prevents excessive absorption of water from the tears. The *endothelium* is a single layer of homogenous cells, about 5 mm thick, lining the internal surface of the cornea; damage to this layer is manifested by clouding of the cornea with an excess of fluid in the stroma. While being less of a barrier to the flow of water than the epithelium, the endothelium controls it by pumping excess water back into the aqueous fluid from where it came. Between the endothelium and stroma is another transparent membrane *(Descemet's)* which is 10 µm thick. It is regarded as the basement membrane of the endothelium.

The *endothelial metabolic pump* is a chemical engine which actively transports electrolytes and with them water from the stroma into the aqueous. The principal ion involved is bicarbonate[3°] This mechanism is temperature dependent and requires oxygen, glucose, carbohydrate metabolism, and adenosine triphosphatase; when deprived of any of these, corneal swelling occurs. Further evidence of the presence of this chemical engine comes from studies with metabolic inhibitors (poisons) such as ouabain.

Space does not permit a discussion of the structure, function and transparency of the natural *lens*. But it should be clear from this brief survey that both the cornea and the lens are marvels of precision in optical and biochemical engineering. Both are highly organized structures whose development and maintenance require a huge amount of information to be encoded in the genome. In particular, the function of the cornea as a lens in the case of man, is indispensable together with the neural pathway (retina to brain), for any vision more than bare perception of light.

The cornea is nourished by nutrients in the aqueous fluid via the endothelium and in the blood via capillaries at the limbus. It receives oxygen principally via the epithelium; oxygen is dissolved in the pre-corneal tear film, directly from the ambient air when the eye is open, and from blood passing through capillaries of the conjunctiva lining the inner surface of each eyelid when the eye is closed. The tears are thus essential as a vehicle of oxygen for the cornea. If the cornea is allowed to dry its health and transparency will invariably quickly suffer, leading to vascularisation and even perforation. This is why loss of, or absence of an upper eyelid, e.g. at birth, is an ophthalmic emergency and a major threat to the cornea. The epithelium and the anterior two thirds of the stroma are richly innervated with pain receptors. The epithelium has adrenergic receptors which are believed to regulate the metabolic activity of the epithelium. Thus the cornea is one of the most sensitive parts of the body, 400—600 times more sensitive than the skin. It is exquisitely sensitive to touch and to drying of the tear film. In clinical experience, a denervated cornea is very vulnerable even without trauma; the epithelium is prone to break down and healing is delayed.

The eyelids

Eyelids[31] are beautifully designed devices which move, like the cover of a roll-top desk, and conform to the shape of the eyeball to close it. The upper lid is the more important, being larger than the lower and is essential for the health of the cornea. The lids serve two important functions: protection of the eyeball and maintenance of the precorneal tear film, besides signaling the state of wakefulness and attention of a subject! The movement of the upper eyelids spreads the tear film evenly over the surface of the cornea which thereby receives oxygen and salts.

Each eyelid has four layers in two groups of two: the skin and orbicularis muscle for closing the lid form the anterior lamella. Behind them is the tarsal plate with its lining of conjunctiva which make up the posterior lamella.[32] The skin of the eyelids is much thinner than that elsewhere on the face and concertinas easily to allow rapid unimpeded movements of the lids. The tarsal plate is a small sheet of fibrous tissue which reinforces and stiffens the lid for added protection and to give attachment for the muscles moving the lid. The margin of each eyelid has lashes to trap and repel foreign bodies, insects, etc. The tarsal glands *(Meibomian),* of which there are 20—30 in the lower lid and 30—40 in the upper, are embedded in each tarsal plate; they secrete an oil, contributing an important layer of the tear film.

The position and movement of the eyelids are controlled by a delicate balance between opposing muscles, namely the levator muscle which lifts the upper lid and the orbicularis which closes the lids. The *levator* is a thin flat muscle which extends back to the apex of the orbit and anteriorly it has two insertions:[33] a) to the upper border of the tarsal plate via a sheet of smooth muscle *(Muller 's)* and b), via its *aponeurosis* (Greek *apo, from* + *neuron,* sinew, i.e. a fibrous sheet acting as a tendon for the muscle), at the same level to the connective tissue of the orbicularis.[34] Its action is synchronized with the muscles moving the eyeball so that when the eye looks up the upper lid moves up also and vice versa when looking down; but for blinking it relaxes independently of the muscles moving the eye. The *orbicularis* is a thin sheet of muscle fibres which sweeps across each lid under the skin and parallel with the lid margins. Its fibers are thus concentrically arranged as arcs above and below the lid opening (the *palpebral fissure);* they are attached to bone (the orbital margin) and the lid ligaments at each end so that when they contract they act like a sphincter to close the lids. Normal gentle blinking involves the pretarsal muscle fibers, but with forceful blinking or spasm the fibers further away from the lid margins come into play.[35]

And so the eyelids clearly show abundant evidence of design in their structure. But, as with the visual pathway (retina to brain), their function is totally dependent at the same time on an intact coordinated nervous control system centered in the brain. An eye that will not open is blind and one that cannot close will rapidly fail from drying of the cornea. **All** has to be in working order for the eye to serve its purpose—another example of irreducible complexity, requiring a considerable input of genetic information.

Reflex (involuntary) blinking with a latent period of only about 50 milliseconds occurs in response to many kinds of stimulation as a protective mechanism for the eye. The stimuli range from unexpected flashes of bright light, to sudden movement in the periphery of the visual field, to irritants of the eye and face, or to abrupt loud sounds.

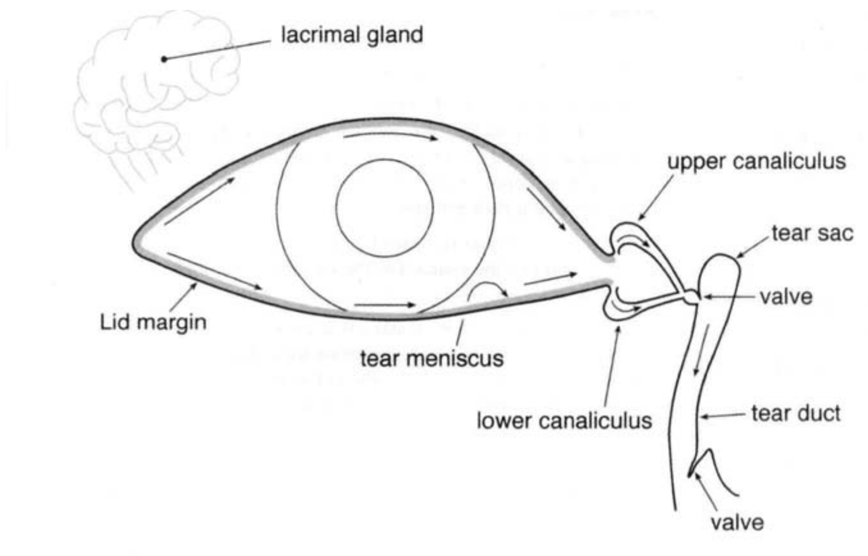


Diagram of the movement and drainage of tears.

Tears are secreted mainly by the lacrimal gland which is under nervous control and is located in a smooth wide depression in the upper outer corner of the orbit anteriorly. From there they are swept and spread by eyelid movements over the cornea towards the inner angle of the eye from where they drain into the nasal cavity. The drainage apparatus consists of two canaliculi (each a fine tube at the inner end of each lid) which converge to open into the lacrimal sac; the sac drains below into the nasolacrimal duct which opens in the nasal cavity. Part of the orbicularis muscle is involved in tear drainage into the nasal cavity by a pumping action[36,37] which is lost when the muscle is paralyzed with consequent overflow of tears onto the cheek. This pump is effective even when the head is inverted and has two phases, active and passive. The active phase occurs when the eye is closed by contraction of the orbicularis. At the same time groups of orbicularis muscle fibers which lie alongside each canaliculus contract and compress both the canaliculus and the lacrimal sac. In this way tears are driven down the nasolacrimal duct which has mucosal valves to prevent reverse flow, e.g. when blowing one's nose. During the passive phase tears are drawn into each canaliculus by capillary attraction and by negative pressure generated by elasic recoil of the canaliculi and the sac.[38,39]

Tears

The tears[40,41] form a film that covers and adheres to the cornea and the conjunctiva (the surface layer over the sciera anteriorly and lining the inner surface of the eyelids). This film, principally as a carrier of oxygen, is vital for the health of the cornea and for the refraction of light entering the eye. The tears also lubricate the constant frictional movements between the eyelids and the eyeball, remove exfoliated epithelial cells and irritants, and carry antimicrobial proteins.

As mentioned above, tears are secreted mostly by the lacrimal gland,[42] i.e. their aqueous element and the importance of its nervous control has been underlined from clinical experience, in that operations to denervate the gland as a treatment for a watering eye resulted in a profound reduction of tear production.[43] Such operations were abandoned because patients were left with a dry eye, a far worse condition. 8—12 ductules convey tears from the main gland and open in the upper conjunctival *fornix* (Latin, arch or vault) laterally.

The tear film, about 7 μm thick, is a remarkably stable structure which remains intact for at least 30 seconds in young normal subjects before breaking up while staring. It thus fulfils the definition of a film, namely a thin fluid layer that resists gravitational flow when vertical. An important factor for the stability and adhesion of the film to the cornea and conjunctiva is the micro folding (microplicae) of the surface of the corneal and, to a lesser extent, the conjunctival epithelia. In histological section, the microplicae appear as microvilli (microscopic finger- like projections).[4°] When this surface folding is damaged, e.g. with chemical bums or viral infections, the film loses its stability and tends to break up easily. The film comprises three major components in two layers: an oily secretion, aqueous secretion and mucin. The oil forms a very thin outer layer (about 0.1 ~tm deep) and is secreted by the Meibomian glands embedded in the tarsal plate of each eyelid. Expulsion of oil from these glands is aided by the muscular action of blinking. This oily layer of the tear film retards evaporation of the aqueous element of tears. Normally, when tear production is not raised by emotional[44] or reflex stimulation, it acts a barrier to prevent the overflow of tears onto the cheek. The oil would not spread over the aqueous secretion without surfactants, mainly proteins. This contributes to the stability of the tear film.[45]

The inner layer (about 7 μm deep) forms the bulk of the tear film and current opinion[46] suggests it is a mucindominated gel, hydrated by aqueous fluid containing electrolytes, small organic compounds and many proteins. The mucin element (glycoproteins) is secreted by scattered specialized epithelial cells of the conjunctiva and possibly also the corneal epithelium. Human tears have a low surface tension compared with water, because of their surface-active agents, but have a high viscosity. Their mucin is thought to be responsible for their non-Newtonian viscosity characteristics, i.e. their viscosity falls in conditions of high shear; this would explain in part the stability of the tear film during steady fixation between blinks but its minimal drag with lid or eyeball movements.[45]

The aqueous fluid, secreted by the lacrimal gland, contains a host of antimicrobial proteins[46] which are the focus of continuing research. Similar proteins are also present in other mucosal secretions which are all products of the *common mucosal defense system,*[47] comprising the alimentary, respiratory and genitourinary tracts, the mammary glands and the eye. Surface immunization to pathogens is induced in sub-epithelial lymphoid tissue (e.g. that of Peyer's patches of the small intestine, the appendix, the tonsils and adenoids) which samples material within the lumen of the gut and respiratory tracts. This triggers the cloning of specialized lymphocytes producing specific antibodies, the lymphocytes traveling via lymphatics and the blood stream to seed e.g. the lacrimal and mammary glands. The variety of antibody produced by these particular lymphocytes is called *secretory immunoglobulin A* (IgA). Antibodies of this type are well suited to the mucosal environment because, unlike other classes of antibodies, they are resistant to various proteolytic enzymes. Besides secretory IgAs, the lacrimal glands secrete nonspecific antibacterial proteins such as lysozyme (a bacteriolytic enzyme), lactoferrin (an iron-binding protein impeding bacterial metabolism), cystatin (a bacterial proteinase inhibitor) and recently discovered in tears, lipocalin, another proteinase inhibitor. If injury or infection occurs, inflammatory cells from the blood are conveyed via the tear fluid.

Summary and conclusions

This brief review has perhaps given a glimpse of some of the human visual system's superlative optical, mechanical and coordinated biochemical engineering. We tend to take it for granted but its construction requires enormous amounts of information to be stored in the genome. This must raise the question, Where does this information come from? We have also considered, in relation to the human eye, a number of examples of irreducible complexity: the highly organized structure and the finely balanced biochemical mechanisms of the cornea; the dependence of the cornea on an adequate supply of the specialized fluid, the tears, and on the presence of the eyelids. In addition, both the lids and the secretion of tears require their respective nervous control system if the eye is to fulfill its purpose. The eye continues to be a thorn in the flesh of evolutionists and to reveal the emptiness of their sophistry.

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12. Spetner, Ref. 6, p. 160.

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14 When cataract (opacity of the lens) is so gross that all view of the retina is obscured, testing for light projection is an important preliminary before embarking on surgery. Defective light projection, in the absence of optic nerve or cerebral disorder, generally indicates severe retinal dysfunction and a poor prognosis for surgery.
15. Shortsightedness (myopia) means that parallel incident light rays come a focus in front of the retina, i.e. the eyeball is too long, resulting in poor distance vision.
16. Removal of an opaque lens (cataract) is normally followed nowadays in the same operation by implantation of an artificial one. Previously, simple removal of the lens was sufficient to restore adequate vision for many in the third world with the very basic lifestyle of a peasant and unable to afford spectacles.

17. Katz, M., The human eye as an optical system; in: Tasman, W. and Jaeger, E.A. (Eds), *Clinical Ophthalmology,* Lippincott-Raven, New York, vol. 1, ch. 33. 1998.

18. Regarding the human eye, let alone any other topic covered in *The Blind Watchmaker,* Dawkins makes several erroneous statements which have been left uncorrected in later editions. He says (p. 93) of the human optic nerve that it has three million nerve fibres whereas it actually has about one million; the same error appears on p. 17 (three million ganglion cells). The ganglion cells are said by Dawkins (p. 17) to 'constitute the "electronic interface" between the photocells and the brain' and to 'preprocess the information ... before relaying it to the brain'. In fact, however, processing of signals from the photoreceptors is much more (if not entirely) a function of cells in the retinal layers between the photoreceptors and the ganglion cells rather than the ganglion cells themselves. His diagram of the eye (p. 16) also has a number of errors. Yet another (p. 301) is where he says the retina has 125 million 'colour-coding photocells', whereas there are about *6.5* million of such *(cones)* while the rest of the photoreceptors are the 125 million or so *rods* for colour-free night vision. Dawkins is unrestrained in his castigation or ridicule of others' errors or wnat tie regazu~ a~ (e.g. p. 79); he would do well to attend to his own.

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23. The existence and importance of the limbal stem cells in their task of continually replacing corneal epithelial cells has only comparatively recently become apparent. Previously it had not been fully appreciated how specialised the corneal epithelium is and how essential it is for cornea! transparency. Depletion of the stem cell population from injury, e.g. chemicals or radiation, results in overgrowth of the cornea by conjunctiva with consequent impairment of vision and failure of corneal grafts. Limbal stem cell autografts have transformed the prospects for eyes so injured. See also Sarfati, J., 'Stem cells & Genesis', this issue, pp. 19—26.

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34. There are racial ariations of upper lid anatomy: the diagram shown in this article represents what is typical of the Caucasian variant. In the upper lid of Mongolians, the levator aponeurosis is inserted at a lower level, near the lid margin. so that the lid has a f'uller appearance with a lower skin crease. Jeong ci *of.,* The Asian upper eyelid: an anatomical study with comparison to the Caucasian eyelid, *Arch. Ophtho/inoL* 117:
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38. The tears form a meniscus along the margin of' each eyelid and flow trom the outer angle of the eye towards the inner angle where a small pool of tears (the ***focn.s' focriotofis)*** gathers. The pnoctoot (orifice) of each canaliculus clips into this 'lake'. During lid closure the two puncta 'kiss' attd prevent rcgurgttatiott of tears as the canaliculi are compressed. When the lids separate the puricta 'pop' apart and suck tears out of the lake.

39. In passing we may note that, contrary to the assertions of evolutionists, the *pfico* ,sc'iniftotoi'/,s (Latm: *pfico.* a pleat or fold) is not a vestigial funetionless curiosity, a relic of the nictitating membrane found in animals. Its purpose is to enable unrestricted mobility for the eyeball svhen abducted (turned outwards). The conjunetiva is the surface membrane lining the eyelids and covering the anterior part of the selera; to allow the eyeball and lids to move independently **it** fbrms a continuous pouch or *soc* above, laterally' and below. But medially, because of the presence of the laerii'nal drainage apparatus, there is no conjunctival sac: instead there is the plica semilunaris which is a crescentic fold of conjunctiva. It arises in the upper fornix towards its medial end, extends downward, concentric with the limbns, to end in the medial third of the lower fornix. When the eye is abducted the plica partially unfolds as the cotiJunctiva stretches so that movement is unimpeded. When the eye is adducted (turned inwards) a fibrous extension from the sheath of the muscle contracting (the medial reetus) draws the plica posteriorly. partially unfolding **it** and deepening the lacus lacrimalis. See Records, R.E., The conjunctiva; in: Tasman and Jaeger, Ref. I 7, vol. 2, ch. 2.

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Peter Gurney qualified in medicine at the University of Bristol, England in 1960. He spent nearly six years as a medical missionary working amongst Muslims in Pakistan, Aden, Ethiopia and Eritrea before returning to the UK to specialise in ophthalmology and completed his training at Moorfields Eye Hospital, London. He is a fellow of the Royal Colleges of Surgeons and of Ophthalmologists, and has practised as a consultant ophthalmologist in the West Midlands since 1 980, retiring from full time service in 1998.

The Eye

By Dr. David N. Menton, Ph.D.

Darwin once said that the very thought of the complexity of the eye gave him the chills.

The eye is constructed exactly like a camera except that it is infinitely more complex and sophisticated. Like some modern cameras, it has auto-focus and automatic adjustment of the iris diaphragm. In the case of the eye, the lens actually changes it's shape or correction to focus at different distances. The lens is made of living cells that are marvelously transparent as is the cornea, the window like skin that covers the eye.

The most amazing component of the camera eye is it's "film" or retina. This light sensitive layer, which lines the back of the eye ball, is thinner than a sheet of Saran-Wrap and is vastly more sensitive to a wider range of light than any man made film. The best man-made film can handle a range of 1,000-to-one. By comparison, the human retina can handle a dynamic range of light of 10 billion-to-one and can sense as little as a single photon of light in the dark! In bright daylight, the retina bleaches out and turns it's "volume control" way down so as not to overload.

The light sensitive cells of the retina are like an extremely complex high gain amplifier. There are over 10 million such cells in the retina and they are packed together with a density of 200,000/mm{2} in the highly sensitive fovea. These photoreceptor cells have a very high rate of metabolism and must completely replace themselves about every 7 days! If you look at a very bright light such as the sun, they immediately burn out but are rapidly replaced in most cases. Because the retina is thinner than the wave length of visible light it is totally transparent. Each of these minute photoreceptor cells is vastly more complex than the most sophisticated man-made computer.

It has been estimated that 10 billion calculations occur every second in the retina before the light image even gets to the brain! It is sobering to compare this performance to the most powerful man-made computer. In an article published in the computer magazine _Byte_ (April 1985) Dr. John Stevens said:

"To simulate 10 milliseconds of the complete processing of even a single nerve cell from the retina would require the solution of about 500 simultaneous non-linear differential equations one hundred times and would take at least several minnutes of processing time on a Cray supercomputer. Keeping in mind that there are 10 million or more such cels interacting with each other in complex ways it would take a minimum of a hundred years of Cray time to simulate what takes place in your eye many times every second."

What makes this comparison even more incredible is the fact that nerve cells such as the photo cells of the retina conduct electrical signals approximately a million times slower than the circuit traces or "wires" in a man made supercomputer. Dr. Stevens said that if it were possible to build a single silicon chip that could simulate the retina using currently available technology it would have to weigh about 100 pounds where as the retina weighs less than a gram. The "super chip" would occupy 10,000 cubic inches of space whereas the retina occupies 0.0003 inches of space. The power consumption of the man-made superchip would be about 300 watts, whereas the retina consumes only 0.0001 watts of power!

Attempts to explain the evolution of the eye, like most other evolutionary "explanations," are merely untestable scenarios in the quise of science. Not only must one account for the eye itself but also an optically transparent "skin'" the cornea through the eye must look and a brain to process the optical information. The visual cortex of the brain, together with the eye, which is actually part of the brain, must translate optical information which begins as nothing more than differences in the amplitude and wave length of light rays into what is perceived as real time 3-dimensional color vision. There is undoubtedly a scientific explanation for all of this signal processing and we already know a great deal about it but we are no closer to a scientific explanation for how we came to have eyes in the first place. As radically different as invertebrates are from vertebrates in all of their organs, the invertebrate octopus has an eye strikingly similar to that of man! No wonder the Bible says "The hearing ear and the seeing eye the Lord hath made them all."

The Human Eye

The human eye has the ability to transmit to the brain over one and a half million messages simultaneously. The retina at the back of the eye contains a dense area of rods and cones that gather and interpret information presented to the eye. The retina contains over one hundred and thirty-seven million nerve connections which the brain uses to evaluate data in its attempt to interpret the scene in front of your eyes. One hundred and thirty million of these special cells are rods that enable us to have black and white vision. However, about seven million eye cells are cone-shaped cells that allow us to see color. Each of these one hundred and thirty-seven million cells communicates directly with the brain, allowing us to interpret the visual image in front of us. Amazingly, scientists have discovered that while the image we receive in our eye is "upside-down" the cellular structure in our eye actually reverses the image to "right-side up" within the eye before sending it to the mind. The eye then transmits the corrected image at three hundred miles an hour to the brain where we "see" the image that is before us.

Creationists point to the extremely high resolution of the rods/cones in the eye, the servo iris system with great dynamic range in response; the focusing method being truly ingenious (organic lens deformation and servo automatic controlled muscle system); the detector sampling and signal processing; the storage and display system in the human brain (i.e., pattern recognition inside the brain). And, the whole complex system operates instantaneously without thought. The system is stereoscopic to produce depth of field images in the brain display system to produce an extra wide field of view. If man were to duplicate such a system he could not do it.' It would be impossible. Yet, all the complex replication plans are stored in an animal 's single cell. Scientists who believe in creation see this development as a model for creation .

The eye is engineered far more precisely than a modern, sophisticated camera. However1 recent research into its functions reveals that the human eye is vastly more complex and sophisticated than any camera ever made by man. In a manner similar to advanced cameras in the last decade, the human eye displays advanced auto-focus features with a remarkable ability to adjust the diaphragm of the iris automatically and at a phenomenal speed. The lens of your eye modifies its shape through tiny muscles that allow the eye to correctly focus on an object that is moving toward you or away from you. This act is not unlike the workings of a sophisticated, computer-controlled modern camera when it calculates distances and automatically adjusts to bring the object into focus. The lens of your eye is constructed of microscopic and transparent living cells. These cells allow light photons to enter through the cornea, pass through the fluid, and be analyzed by the phenomenal organ known as the retina.

To understand the complexity and sophistication of the engineering of the eye, we need to appreciate the retina. The retina lines the back of your eye and acts as a form of film which receives the actual image composed of light photons passing through the iris, cornea, and eye fluid. Your retina is thinner than paper yet its tiny surface (one inch square) contains 137 million light-sensitive cells. Approximately 95 percent of these cells are rods that can analyze black and white images, while the balance of approximately seven million cone cells are used to analyze color images. Each of these millions of cells are separately connected to the optic nerve that transmits the signal to your brain at approximately three hundred miles per hour. The millions of specialized cells in your eye can analyze more than one million messages a second.

The retina in your eye is the most light-sensitive object in the universe. It is so much more sophisticated in its design than even the most powerful electron microscope or spy camera. For example, the most advanced film available today can differentiate between a range of one thousand to one. However, recent experiments have confirmed that the retina of the human eye can easily differentiate and analyze a range of ten billion to one. Experiments have revealed that the retina can actually detect one single photon of light in a dark room, something beyond the range of engineering instruments. Recently, scientists have determined that the specialized cells in the retina actually partially analyze the image in the eye before it is ever transmitted through the optic nerve to the brain. These retina cells perform up to ten billion calculations per second in determining the nature of the image transmitted to the eye by light photons. No computers on earth are capable of matching these virtually instantaneous calculations.

In an article in *Byte* computer magazine in April *1985,* Dr. John Stevens made the following comparison:

> To simulate 10 milliseconds of the complete processing of even a single nerve cell from the retina would require the solution of about 500 simultaneous non-linear differential equations one hundred times and would take at least several minutes of processing time on a Cray super computer. Keeping in mind that there are 10 million or more such cells interacting with each other in complex ways it would take a minimum of a hundred years of Cray time to simulate what takes place in your eye many times every second.

In the article, Dr. Stevens wrote that if we were to attempt to duplicate the computing power of the human eye, we would have to build the world's most advanced computer with a single silicon chip (normally the size of a dime) that would cover 10,000 cubic inches and contain billions of transistors and hundreds of miles of circuit traces. The retina is so small that it fills only 0.0003 inches of space. If we could ever build the advanced device to mimic the human eye, the single computer chip would weigh at least 100 pounds, in comparison to the human retina that weighs less than a gram. The retina operates with less than 0.0001 watts of electrical charge. To duplicate the retina's abilities, the computer would need to consume **300** watts of power. In other words, the retina is 3,ooo,ooo times more efficient in its power consumption.