The design of tears: an example of irreducible complexity

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The many critical functions of tears in the body are discussed from an intelligent design worldview. As more research is carried out, often what once were felt to be 'simple structures' in biology turn out to be extremely complex. Research has now shown that tears are a complex fluid that is required for long-term vision. Furthermore, although all animals that live in the atmosphere and possess eyes produce tears, only humans can shed emotional tears—a response that has been found to have several health benefits. This fact is indicative of one more difference between humans and animals.

Scientists have found evidence of intelligent design even in the seemingly simplest and most minute parts of the body, such as in tears. Once thought to be composed of simple water, tears now are known to be of such high level complexity that whole books have been written on them. Biochemist William Frey spent 15 years as head of a research team studying tears.[1] His team found that, although certain tear-production organs once were thought to be vestigial, all of their secretions now are known to be important and actually serve numerous critical functions in the body. A Johns Hopkins research team concluded:

> 'Tears aren't simple. They're complex creations of water, mucins, oils, and electrolytes; they also possess some protective bacteria-fighting substances that help reduce our risk of getting eye infections. Their functions are many and essential. For the cornea, they provide a smoother optical surface, so that our vision remains clear; they also help keep the cornea properly moisturized and rich in oxygen. For the eye in general, tears also act as "wiper fluid", allowing the eyelids to wash the eye free of debris with every blink.'[2]

The many functions of tears

Tears are secreted by the *lacrimal glands*, tiny sponge-like glands that rest above the eye against the eye socket. One of the most obvious functions of tears is to lubricate the eyeball and eyelid, but they also prevent dehydration of the various eye mucous membranes—and anyone with a 'dry eye' problem knows how painful a lack of tears can be. Keeping the corneal epithelium moist insures that the surface epithelial cells can survive, because all living cells require a watery (aqueous) environment. The average person blinks every two-to-ten seconds, and with every blink the eyelid carries this miracle fluid over the eye's entire front surface.

Tears form a complex tri-layered (or tri-phased) film consisting of an inner mucin dominated layer, an aqueous layer, and outer lipid (oil) layer.[3,4] The total thickness varies from the top to the bottom of the cornea, from before and after blinking, and the output of the tear glands. The thickness is estimated to be an average of 3 mm.[5,6,44] The secretions in each layer are tightly regulated.[3,7,8] The thin layer (usually around 0.2 mm thick) of oil on top of the aqueous layer reduces tear evaporation, keeping eye tissue moist and soft.[9] Much of the lipid part of the layer is near the eye surface and is produced in the tarsal gland (often called the Meibomian glands) located in both the upper and lower eyelids, and some by the glands of Zeis and Moll.[10] Even with normal tear production, lack of this lipid oil would soon result in dry and painful eyes due to evaporation.

A severe lack of tear lubrication produces a condition called the *keratoconjunctivitis sicca* requiring medication and sometimes surgery (tarsoraphy) to save the victim's eyesight. The innermost tear layer (about 0.5 mm) contains primarily mucins, which are sticky carbohydrates that allow tears to adhere to the eye surface and produce a thin, even coat.[2] The mucin also serves as a wetting agent by coating and wetting the microvilli of the corneal epithelium. Mucin is secreted by a specialized cell type called conjunctival goblet cells.[11]

Tears called 'basal' or 'continuous' tears normally flow constantly in both humans and animals, and routinely drain into the *lacrimal punctua* located at the nasal aspect of the upper and lower lid margins at the nasal border of the eye. A tear flow is visible on the cheeks when the tear production is *greater* than the drainage system can handle, and the overflow runs down the cheek (a condition called epiphora). Tears constantly bathe each cornea, not only preventing the eyes from drying out, but also helping to wash out foreign bodies (like dust) that are an omnipresent part of air.[12]

Extra tears called 'reflex' or 'irritant' tears are commonly elicited by mechanical irritation of the eye, infections, or even illness. The lacrimal glands automatically provide the proper level of tears for lubrication and protection when needed. The system works so well that Freese concluded reflex or irritation weeping appears to be designed as an emergency protection mechanism.[13] Onions trigger tears because the chemical they release turns into sulfuric acid on contact with the eye surface—a chemical that could damage the eye if it were not for the tear reflex that renders the sulfuric acid largely harmless.

The antibacterial function of tears

Another important function of tears is that they bathe the eyes in a very effective antibacterial and antiviral agent, an

enzyme called *lysozyme*. Lysozyme, from the word *lysos* (to split) and *enzyme* (because it is an enzyme that chemically splits certain chemical compounds), is a major source of the tear antigerm ability. Amazingly, lysozyme inactivates 90–95% of all bacteria in a mere 5 to 10 minutes.[14] Without it, severe eye infections would be common. Tears also contain immunoglobulin A and β-lysin (a bactericidal protein) to defend against bacteria.[11]

As Freese notes, 'The importance of tears can best be recognized by seeing what happens when someone does not have them'. As people age, the tear film often becomes thinner and can interfere with tear effectiveness. Victims of *Sjogren's syndrome* lack sufficient tears because of poorly functioning lacrimal glands, or the gland becomes nonfunctional as a result of an autoimmune disorder, a condition called dry-eye syndrome. The inability to secrete enough tears produces eye-burning sensations and redness. Light itself becomes very bothersome, and the eyes constantly itch and have a gritty feeling.

One sufferer described the condition as similar to having sand in the eyes. In time, if severe, it can cause blindness.[15-19] Ulcers eventually develop on the cornea, and loss of its transparency often occurs as well. The ideal solution is to treat the cause of the lack of tears, but use of artificial tears—such as methyl cellulose eye drops—can help patients cope with the problem. Another partial solution is to wear aviators goggles to keep out irritants and to help the eyes retain as much moisture as possible. In extreme cases punctal occulsions (surgery to block tear drainage) or tarsorraphy (other surgery) is required.

Emotional tears: unique to humans

One of the most amazing discoveries is that tear production actually may be a way of helping a person to deal with emotional problems. This finding lends some basis to the expression, 'crying it out will help you feel better'. Emotional tears are a response unique to humans, because only humans can weep. All animals that have eyes and live in the atmosphere produce tears to lubricate their eyes, but no creatures except humans possess the marvelous system that causes crying.[20,21] Interestingly, crocodiles secrete tears while eating their prey for reasons that are yet unknown. Scientific studies have found that *many* people feel better both physically and physiologically after crying; conversely, suppressing tears usually causes people to feel *worse*.[20,21] Persons who suffer from diseases that prevent them from crying tears—such as the rare, inherited disease called *familial dysautonomia*—tend to deal with stressful events very poorly. This finding also highlights one of the differences between humans and animals.

A study at the St. Paul Ramsey Medical Center in Minnesota compared tears caused by simple irritants to those brought on by emotion. Volunteers were caused to cry, first from watching sad movies, and then from freshly cut onions. The researchers found that the tears caused by the movie

Emotional tears, caused either by laughing or crying, are a response which only humans have, for only humans can weep.

(called emotional tears) contained far more toxic biological byproducts than irritant tears. Researcher William Frey found that *stress-induced* tears remove many kinds of toxic substances from the body, and thus concluded that weeping is an excretory process that removes such substances that can build up during times of emotional stress. The simple act of crying also reduces the body's manganese level (a mineral that affects mood and is found in up to 30 times greater concentration in tears than in blood serum). The researchers also found that emotional tears contain a 24% higher protein concentration than tears caused by eye irritants.[20,21]

Frey and his coworkers concluded that chemicals built up by the body during stress were removed by tears, thereby actually *lowering* stress. These chemicals include the endorphin called *leucine-enkephalin*, which helps to control pain, and *prolactin*, a hormone that regulates mammalian milk production. One of the more important compounds removed by tears is *adrenocorticotropic hormone* (ACTH), which is one of the best-known indicators of stress. Research indicates that suppressing tears increases stress levels and can contribute to those diseases that are aggravated by stress, such as high blood pressure, heart problems, and peptic ulcers. Although the exact role of these chemicals in lowering stress is not fully clear, clearly, a good cry can be a healthy response to stress.

Emotional and irritation tears are stimulated by different sympathetic and parasympathetic nerves. The fifth cranial nerve, for example, is involved in reflex tears. A topical anesthetic applied to the surface of the eye can inhibit both reflex and irritant tears (the type triggered due to an eye irritant), but not emotional tears. Emotional tears evidently are initiated in the limbic system of the brain, that part which is responsible for emotions—both sad and happy or painful and pleasant.

Tears as part of human communication

Tears are also an extremely effective method of communication, and usually can illicit sympathy far faster than any other means. Montagu concluded that weeping contributes not only to the individual's health, but also to the group's sense of community; 'it tends to deepen involvement in the welfare of others'.[22] Tears effectively convey that one is sincere, and anxious to deal with a problem.

Although it often is assumed that boys are less likely to weep (and thus to keep their emotions within themselves) because of social conditioning, Frey's research found that adult women have serum prolactin levels almost sixty *percent* above the average male. This difference may help to explain why women as a whole cry more frequently (Frey found they cry four times more often). Before puberty, the serum prolactin levels are the same in both sexes, and studies have found that the crying level of boys and girls is much more similar before puberty.[23]

Tears and creationism

Atheists commonly argue against creationism by concluding that 'design arguments from nature are untenable, by the simple fact that nature is not as beautifully designed nor as "perfect" as believers would have us think'.[24] The most common example of 'bad design' is the human eye—an example that has been conclusively refuted.[25–27]

The second claim made by Darwinists about the eye is that it is not irreducibly complex: 'It is not true that the human eye is irreducibly complex, so that the removal of any part results in blindness.'[28] As evidence Shermer and others note that 'lots of people are visually impaired … yet they are able to utilize their restricted visual capacity to some degree and would certainly prefer this to blindness'.[29–31]

The concept of irreducible complexity does not mean that *all* extant parts are necessary for the organ to function, but that *certain* parts are necessary for it to work at all. One can see without certain structures—even the lens, as Darwinists often stress—but many other parts are needed for *any* vision to result. The reason a person can still see without a lens is because 70% of the refraction or bending of light that enters the eye (focusing) is done by the cornea. Unlike the cornea, however, the intraocular lens is capable of changing its refraction (and thus its focus), allowing us to see clearly at different distances.

If the retina, the optic nerve, the cornea, or any one of many thousands of other parts are removed (including the tear-generation system), *total* blindness can result.[32–38] Most body structures can function without certain parts, but many are critical. For the eye, thousands of parts are critical, such as the retina, which is considered one of the most complex of all body parts. Without most of its basic parts—such as the optic nerve—the eye will not function properly, and one does not have merely poor vision, but no vision. Hundreds of papers could be written on the numerous other systems that are required for the eye to function, establishing that it definately is an irreducibly complex structure.

The eye is also 'over designed'—meaning it has redundancy of many parts and can sustain damage to certain of its parts and still function. For example, there are many diseases that ravage the eye, and yet it still can retain some function. For example, in the case of diabetic retinopathy several thousand pin-sized laser burns are put into the retina to reduce the neovascular stimulus (pan-retinal photocoagulation). As much as 20% or more of the retina can be destroyed, and the patient often doesn't even detect the missing zones. This is due in part to the fact that the brain is excellent at filling in holes in the image such as the famous blind spot.[39]

A computer literature search of over 16 million references by the author did not locate a single article that even speculated as to how the human tear system evolved. This conforms with Behe's finding that no clear evidence exists for the evolution of even a single biochemical structure or system in the human body.[40] Many articles were located that discussed medical issues (such as the evolution of lacrimal inflammatory lesions[41]) but none that discussed the biological evolution of the tear-system structure itself.

The only relevant article on tear evolution that my search located indicated that we cannot explain how the tear producing structure could have evolved. The article discussed a putative nasal structure involving the tearing structure in Neandertals, which Schwartz and Tattersall claimed made them unique compared to modern humans.[42] Franciscus concluded that, among the serious problems with their analysis, was the fact that they relied on Neandertal specimens with damaged, incomplete, or even entirely absent relevant anatomy, and they failed to consider the normal ranges of the traits in both fossil and recent humans.

Conclusions

The research on tears has found that the seemingly simple, common process of producing tears is both enormously complex and an integral and necessary part of the miracle of life. In Calkins words: 'We are so used to taking for granted the enormous complexity of every component of the body, that we have become numb to the true miracle even the tear film is.'[43] Without tears, life would be drastically different for humans. In the short run, our eyes would become extremely uncomfortable, and in the long run eyesight, which is so important to the quality of everyday life, would be altogether impossible. The eye's tear mechanism is just one of many body systems which works so well that we take it for granted everyday.

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References

1. Frey, W., *Crying: The Mystery of Tears*, Winston Press, Houston, 1985.
2. Cassel, G., Billig, M. and Randall, H., *The Eye Book*, Johns Hopkins University Press, Baltimore, p. 233, 1998.
3. Tribout, B., Gras-Champel, V., Pannier, M. and Andrejak, M., Physiology and pharmacology of lacrymal and salivary secretions, *Revue Du Praticien* **51**(2):133–139, 2001.
4. Price-Schiavi, S.A., Meller, D., Jing, X., Merritt, J., Carvajal, M.E., Tseng, S.C. and Carraway, K.L., Sialomucin complex at the rat ocular surface: a new model for ocular surface protection, *Biochemical J.* **335**(Pt. 2):457–463, 1998.
5. King-Smith, P.E., Fink, B.A., Fogt, N., Nichols, K.K., Hill, R.M. and Wilson, G.S., The thickness of the human precorneal tear film: evidence from reflection spectra, *Investigative Ophthalmology and Visual Science* **41**(11):3348–3359, 2000.
6. King-Smith, P.E., Fink, B.A. and Fogt, N., Three interferometric methods for measuring the thickness of layers of the tear film, *Optometry and Vision Science* **76**(1):19–32, 1999.
7. Craig, J.P., Singh, I., Tomlinson, A., Morgan, P.B. and Efron, N., The role of tear physiology in ocular surface temperature, *Eye* **14**(Pt 4):635–641, 2000.
8. Yokoi, N., Mossa, F., Tiffany, J.M. and Bron, A.J., Assessment of meibomian gland function in dry eye using meibometry, *Archives of Ophthalmology* **117**(6):723–729, 1999.
9. Lozato, P.A., Pisella, P.J. and Baudouin, C., The lipid layer of the lacrimal tear film: physiology and pathology, *J. Francais D Ophtalmologie* **24**(6):643–658, 2001.
10. Hart, W., *Adler's Physiology of the Eye; Clinical Application*, Mosby, St Louis, 1992.
11. Snell, R. and Lemp, M., *Clinical Anatomy of the Eye*, 2nd Edition, Blackwell, Boston, p. 110, 1998.
12. Kennedy, C.C., Tears: medical research helps explain why you cry, *Mayo Clinic Health Letter*, p. 4–5, February 1992.
13. Freese, A., *The Miracle of Vision*, Harper and Rowe Publishers, New York, p. 19, 1977.
14. Montagu, A., The evolution of weeping, *Science Digest,* p. 32, November 1981.
15. McFadden, E.A., Woodson, B.T., Massaro, B.M. and Toohill, R.J., Orbital complications of sinusitis in the aspirin triad syndrome, *Laryngoscope* **196**(Pt 1):1103–1107, 1996.
16. Roberts, D.K., Keratoconjunctivitis sicca, *J. American Optometric Association* **62**(3):187–199, 1991.
17. Hornblass, A. and Berlin, A.J., Blindness following lacrimal gland surgery, *Plastic and Reconstructive Surgery* **73**(1):156, 1984.
18. Kaswan, R.L. and Salisbury, M.A., A new perspective on canine keratoconjunctivitis sicca. Treatment with ophthalmic cyclosporine, *Veterinary Clinics of North America, Small Animal Practice* **20**(3):583–613, 1990.
19. Thompson, H.S., Neuro-ophthalmology, *Archives of Ophthalmology* **86**(4):462–482, 1971.
20. Levoy, G., Tears that speak, *Psychology Today,* July–August, pp. 8, 10, 1988.
21. Frey, W.H. II, Desota-Johnson, D., Hoffman C. and McCall, J.T., The effect of stimulus on the chemical composition of human tears, *American J. Ophthalmology*, **92**(4):559–567, 1981.
22. Montagu, Ref. 14, p. 32.
23. O'Mara, P.F., Why Cry? *Mothering,* Spring, p. 70–71, 1990.
24. Shermer, M., *How We Believe*, W.H. Freeman, New York, 2000.
25. Bergman, J., Is the inverted human eye a poor design? *Perspectives on Science and Christian Faith* **52**(1):18–30, 2000.
26. Ayoub, G., On the design of the vertebrate retina, *Origins and Design* **17**(1):19–22, 1996.
27. Marshall, G., An eye for Creation, *Creation* **18**(4):19–21, 1996.
28. Shermer, Ref. 24, p. 110.
29. Frymire, P., *Impeaching Mere Creationism*, Writers Club Press, New York, p. 110, 2000.
30. Dawkins, R., *The Blind Watchmaker*, Norton, New York, p. 84, 1986.
31. Frymire, Ref. 29, pp. 36, 41.
32. Jihangir, S., Dry eye syndrome in Pakistani community, *J. Pakistan Medical Association* **40**(3):66–67, 1990.
33. Tsubota, K., Satake, Y., Ohyama, M., Toda, I., Takano, Y., Ono, M., Shinozaki, N. and Shimazaki, J., Surgical reconstruction of the ocular surface in advanced ocular cicatricial pemphigoid and Stevens-Johnson syndrome, *American J. Ophthalmology* **122**(1):38–52, 1996.
34. Tabbara, K.F., Ocular complications of vernal keratoconjunctivitis, *Canadian J. Ophthalmology* **34**(2):88–92, 1999.
35. Louie, T.D., Ocular cicatricial pemphigoid: case report, *J. American Optometric Association* **69**(3):153–160, 1998.
36. Leonard, J.N., Wright, P., Haffenden, G.P., Williams, D.M., Griffiths, C.E. and Fry, L., Skin diseases and the dry eye, *Transactions of the Ophthalmological Societies of the United Kingdom* **104**(Pt 4):467–476, 1985.
37. Khoo, C.Y., Corneal blindness in Singapore and its prevention, *Annals of the Academy of Medicine, Singapore* **18**(2):123–130, 1989.
38. Blodi, B.A., Byrne, K.A. and Tabbara, K.F., Goblet cell population among patients with inactive trachoma, *International Ophthalmology* **12**(1):41–45, 1988.
39. Calkins, J., private communication, 2001.
40. Behe, M., *Darwin's Black Box*, The Free Press, New York, 1996.
41. Jabs, D.A., Enger, C. and Prendergast, R.A., Murine models of Sjorgren's Syndrome evolution of the lacrimal gland inflammatory lesions, *Investigative Ophthalmology & Visual Science*, **32**(2):371–380, 1991.
42. Franciscus, R.G., Neandertal nasal structures and upper respiratory tract specialization, *Proc. Nat. Acad. Sci. USA* **96**(4):1805–1809, 1999.
43. Calkins, Ref. 39, p. 1.
44. Owens, H. and Phillips, J., Spreading of the tears after a blink: velocity and stabilization time in healthy eyes, *Cornea* **20**(5):484–487, 2001.

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