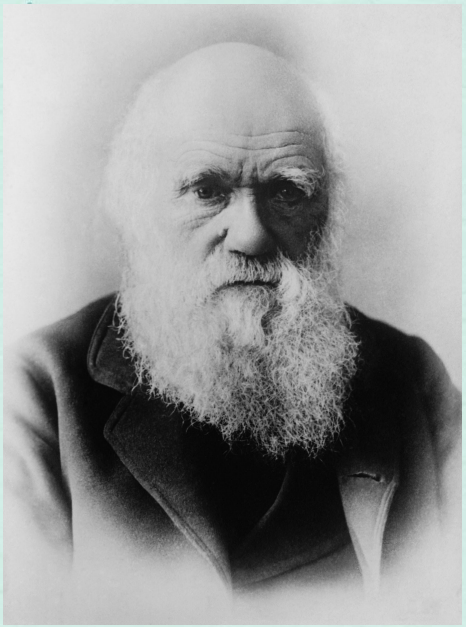
# Evolution Of The Eye

## Past - Present - Future

C-102319

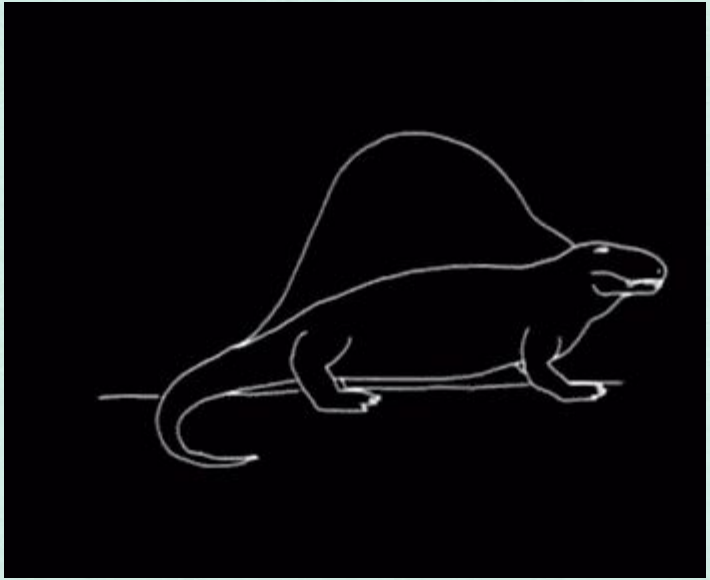
# What is evolution by natural selection?

1. Natural selection is a mechanism of evolution.
2. Organisms that are more adapted to their environment are more likely to survive and pass on the genes that aided their success.
3. This process causes species to change and diverge over time



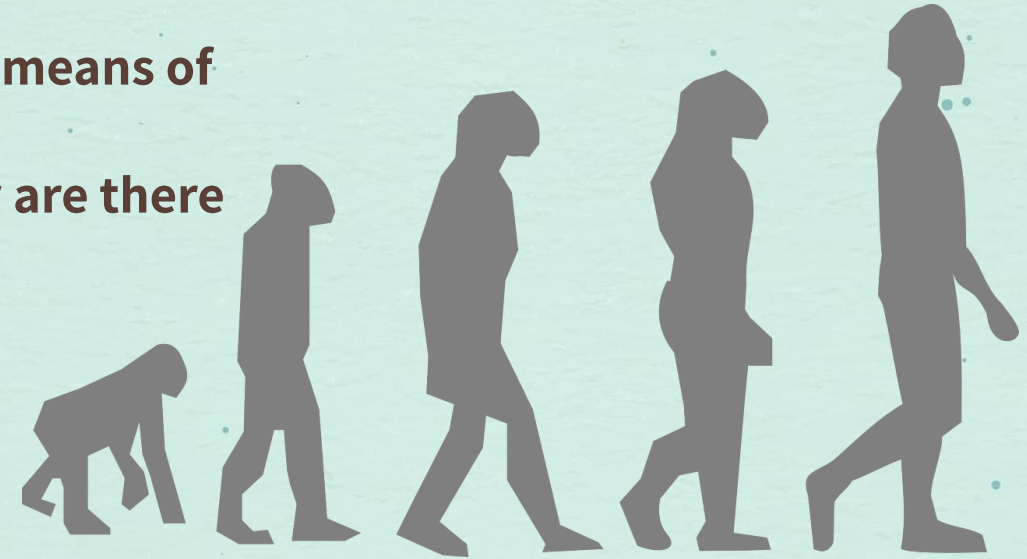
# What is evolution by natural selection?

1. Cumulative changes that occur in a population over time
2. Produced at gene level as genes mutate/re-combine in different ways during re-production
3. Sometimes individuals inherit characteristics that give survival or reproduction advantages
4. Those then become more common as they are passed on



# Evolution Myths

1. Survival of the fittest
2. Natural selection is the only means of evolution
3. If we evolved from apes why are there still apes?
4. Species randomly form



# Taxonomy

Species - Homo Sapiens

Genus - Homo

Family - Hominadae

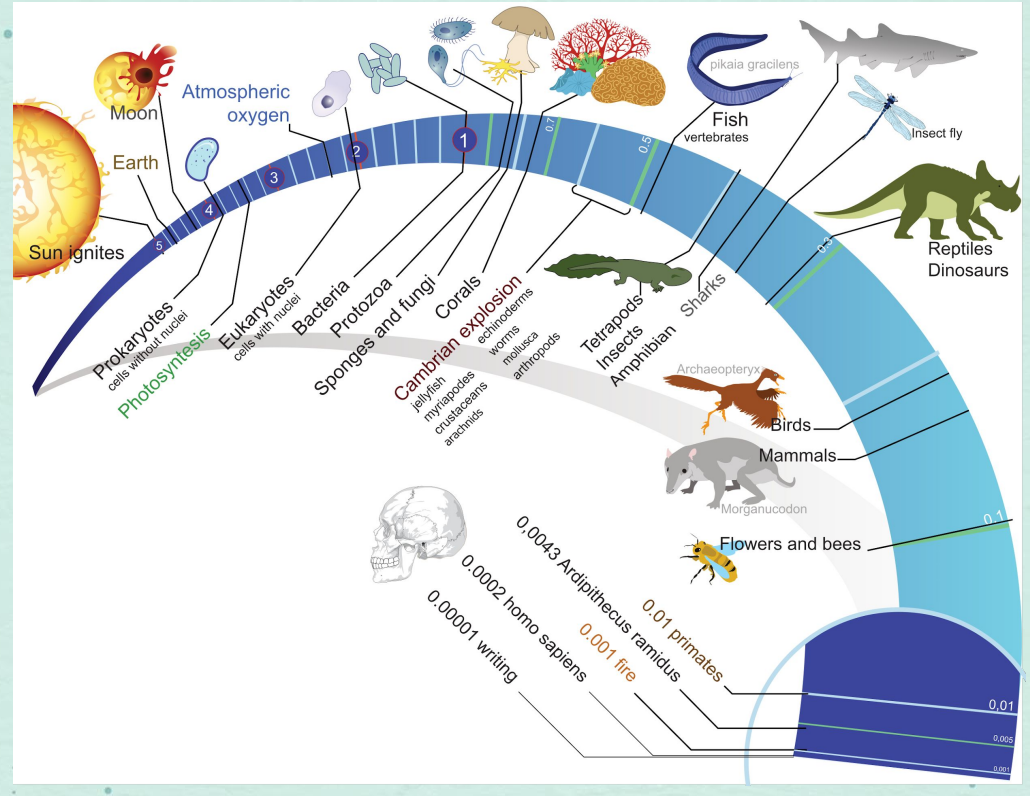
Order - Primates

Class - Mammalia

Also:

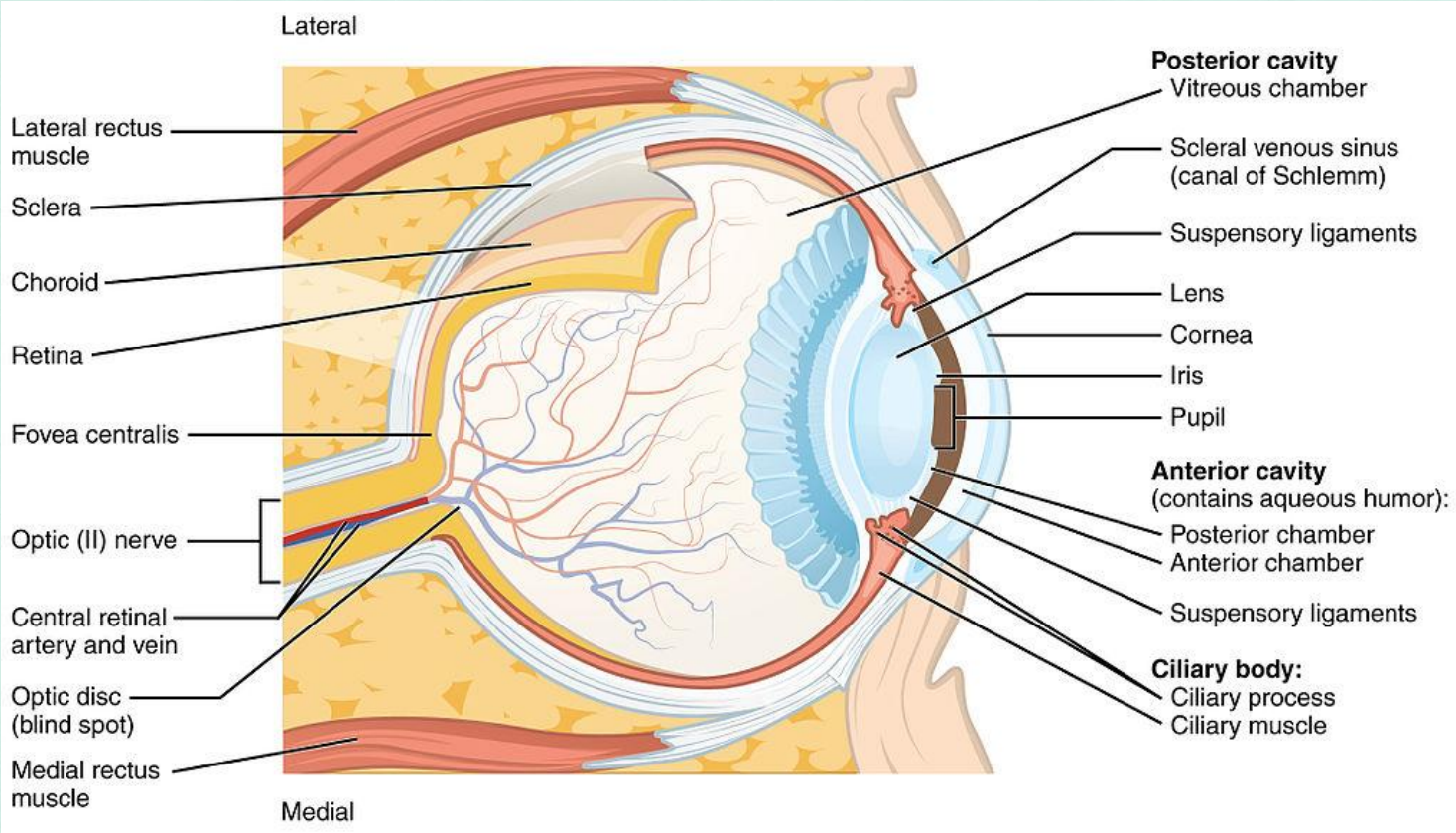
Homo antecessor
Homo erectus
Homo ergaster
Homo floresiensis
Homo habilis
Homo heidelbergensis
Homo longi
Homo luzonensis
Homo naledi
Homo neanderthalensis
Homo rhodesiensis? = Homo bodoensis
Homo rudolfensis

# Evolution Timeline




“How could something as perfect as the eye evolve out of nothing?!”

# How complex is the eye?



# Basic components...

What do we actually need?

1. Photoreceptor?
2. Lens?
3. Aperture?

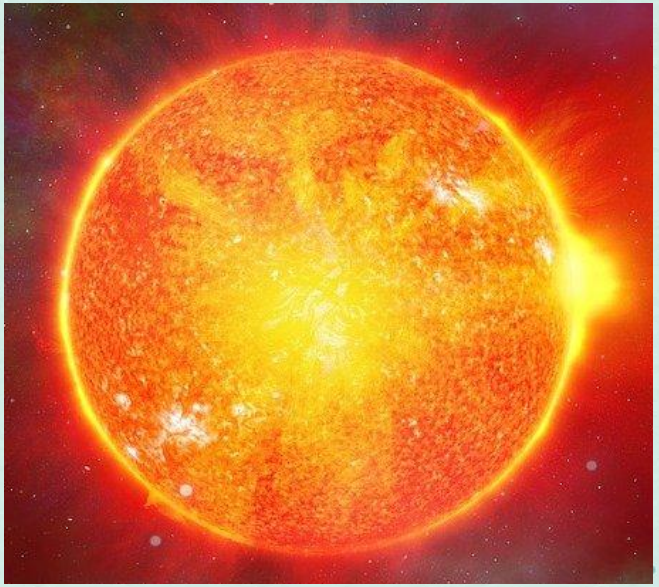
**1% Vision is better than 0%**

# Where did it all begin?

Photoreceptor

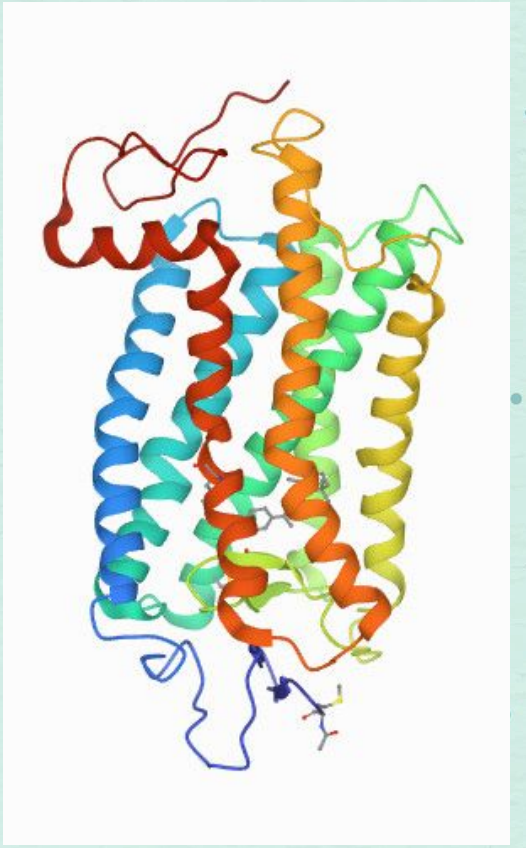
1. Advantageous
2. Sun provides energy
3. Also harmful

In all eyes, camera eyes like ours or insect eyes, it all starts from the same light detecting protein….



# Opsins

1. Protein
2. Binds to vitamin A
3. Springs form a coil, vitamin A sits inside
4. Vitamin A senses light and changes shape
5. Changes the shape of the opsin
6. Informs cell that light has been detected
7. First occurred approx 600,000,000 years ago
8. Related to oxidative stress
9. UV damages tissues so being able to avoid harmful UV is advantageous

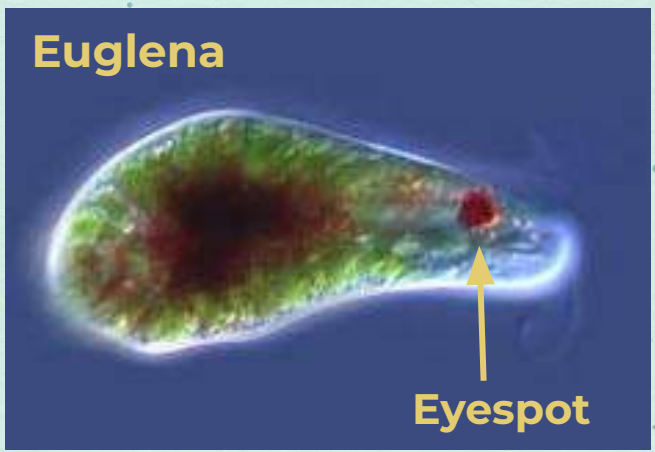


# What comes next?

**Step 1: Detecting light**

**Step 2: Where is light coming from?**

**Dark pigment cells shield photorector from one side enabling cells to determine which direction light is coming from**

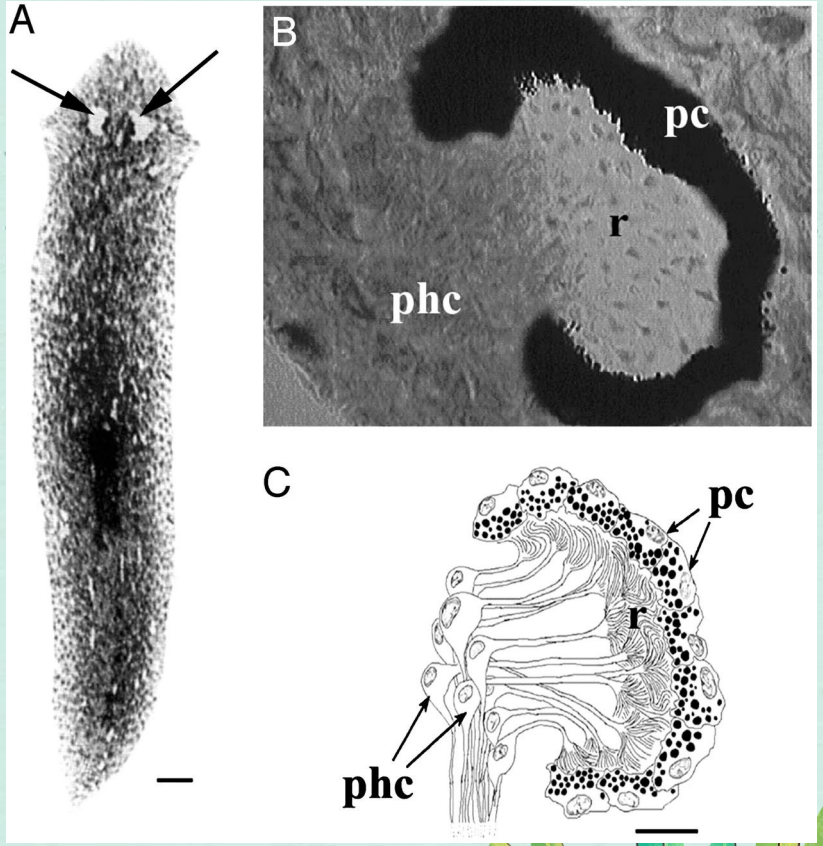


# Stage 3... The eye cup

1. To form a crude image a depression which contains a concentration of photoreceptors is required
2. First stage of low resolution vision
3. Each photoreceptor cell points in a different direction
4. Enables the animal to determine shapes position and structure

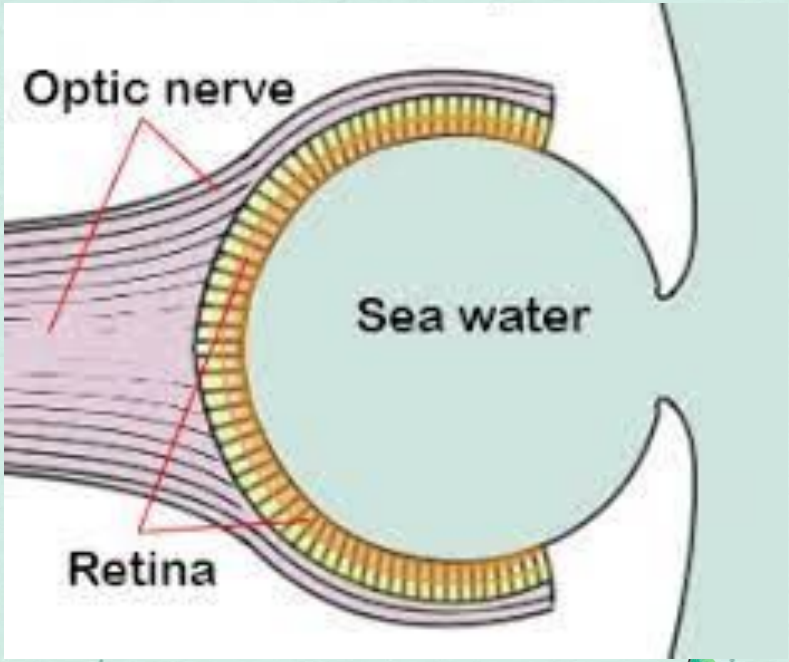
# Planarian Flatworm

Eye cups



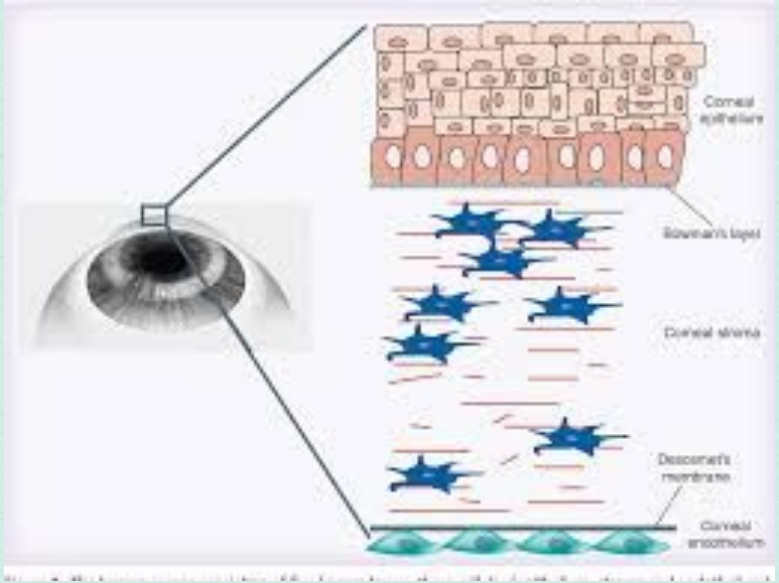
# Deeper Eyecups – Pinhole Camera

Nautilus



# Stage 4 – The Cornea

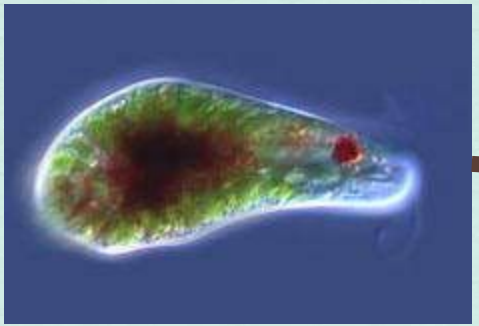
1. Pinhole opening allowed parasites and bacteria to enter the aperture
2. Protective layer then developed to protect inside of the eyecup
3. Shares a common ectodermal embryonic origin as skin
4. Allowed humour to form circulatory fluid for oxygen, waste and nutrients

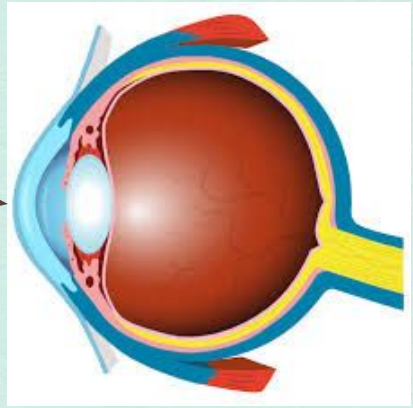


# The Game Changer – Crystalline Lens

1. Allows light to be focussed to a point on the retina
2. Adjust focus for different focal lengths
3. The bulk of the lens is formed from proteins belonging to two superfamilies, the α-crystallins and the βγ-crystallins
4. α-crystallins belong to the ubiquitous small heat shock proteins family that plays a protective role in cellular homeostasis
5. Heat shock proteins (HSP) are a family of proteins that are produced by cells in response to exposure to stressful conditions
6. Known to also be expressed during other stresses including exposure to cold, UV light, and during wound healing or tissue remodeling.

# How long did this process take?





**Eye spot** **Eye Cup** **Camera Eye**

**Approx 364,000 generations or roughly 500,000 years**

Nilsson DE, Pelger S . A pessimistic estimate of the time required for an eye to evolve. *Proc Biol Sci* 1994; 256: 53–58

# The Eye Is Only Half Of A Visual System... or is it?

1. Our visual system requires a nervous system
2. Electrical impulses triggered by photons of light stimulating the retina are interpreted by the brain
3. Provides visual information but also circadian information
4. Some animals have complex eyes…. But no brain….

# Cladonema Radiatum

1. Type of Jellyfish
2. Has a complex camera eye, similar to ours
3. Has no brain
4. Signals from the retina transmit directly to the muscles
5. Bypassing the “middleman” of the brain

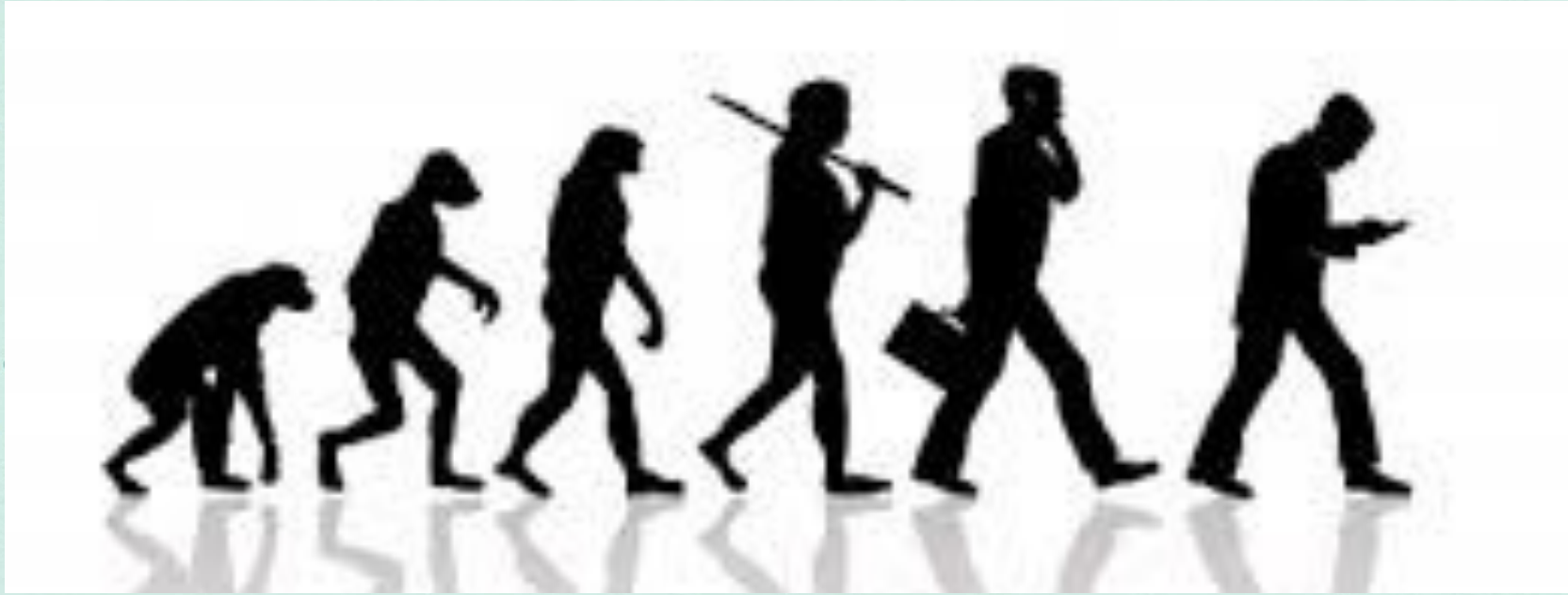
# The Master Genes

1. Work done by Basel University suggests that all animal eyes share a common origin
2. The details may be different but they're all under the control of closely related 'master genes' that themselves evolved from a common ancestor
3. Growing an eye is a complicated business and involves a huge alliance of different genes, switching on and off in a coordinated way
4. In humans and other animals, this alliance all comes under the control of a master gene called Pax-6

# Pax 6

1. Discovered in 1994 by Walter Gehring
2. Faulty copies can cause serious eye problems in animals as diverse as flies and rodents
3. Activating the gene in the wrong part of the body can produce eyes where they really shouldn’t exist, like the leg of a fly
4. You can take the version of Pax-6 from a mouse and shove it into a fly, and it will still be able to trigger the development of an eye

# Are eyes still evolving?



# The Present

## More than 350 hereditary eye conditions…

Abetalipoproteinemia

Ablepharon-Macrostomia Syndrome

Acrofacial Dysostosis, Cincinnati Type

Adenomatous Polyposis of the Colon

Adrenoleukodystrophy, Autosomal

Adrenoleukodystrophy, X-Linked

Aicardi Syndrome

Al Kaissi Syndrome

Alagille Syndrome

Aland Island Eye Disease

Albinism, Ocular Type 1

Albinism, Oculocutaneous, Type I

Albinism, Oculocutaneous, Type II

Albinism, Oculocutaneous, Type III

Albinism, Oculocutaneous, Type IV

Albinism, Oculocutaneous, Type V

Albinism, Oculocutaneous, Type VI

Albinism, Oculocutaneous, Type VII

Alkaptonuria

Alport Syndrome (Collagen IV-Related Nephropathies)

Alström Syndrome

Angiopathy, Hereditary, with Nephropathy, Aneurysms, and Muscle Cramps

Aniridia 1

Aniridia 2

Aniridia 3

# The Present

Anterior Segment Dysgenesis 6

Anterior Segment Dysgenesis 8

Anterior Segment Mesenchymal Dysgenesis

Anterior Segment, Brain, and Facial Anomalies

Apert Syndrome

Aphakia, Congenital Primary

Arthrogryposis, Perthes Disease, and Upward Gaze Palsy

Asphyxiating Thoracic Dysplasia 1

Ataxia and Polyneuropathy, Adult-Onset

Ataxia with Oculomotor Apraxia 1

Ataxia with Oculomotor Apraxia 2

Ataxia with Oculomotor Apraxia 3

Ataxia with Oculomotor Apraxia 4

Ataxia-Telangiectasia

Autoinflammation with Arthritis and Dyskeratosis

Axenfeld-Rieger Anomaly, Plus

Axenfeld-Rieger Syndrome, Type 1

Axenfeld-Rieger Syndrome, Type 2

Axenfeld-Rieger Syndrome, Type 3

Axenfeld-Rieger Syndrome, Type 4

Ayme-Gripp Syndrome

# The Present

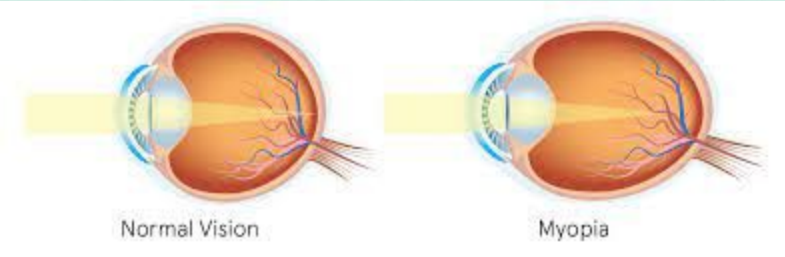
1. Internal and external factors contribute to which genes are “turned on or off”
2. Influences such as gender, environment, temperature and chemicals all play a part
3. Risk factors relating to ethnicity are largely due to geography
4. Evolution continues through the effects of “Genetic Drift”

# What is genetic drift?

“Genetic drift is the change in the frequency of an existing gene variant in a population due to random chance. Genetic drift may cause gene variants to disappear completely and thereby reduce genetic variation. It can also cause initially rare alleles to become much more frequent and even fixed”

# Case example: Myopia = Evolution?

**“Ultimately, genetic susceptibility and environmental changes have likely worked in combination to produce the greater prevalence of myopia observed today.”**



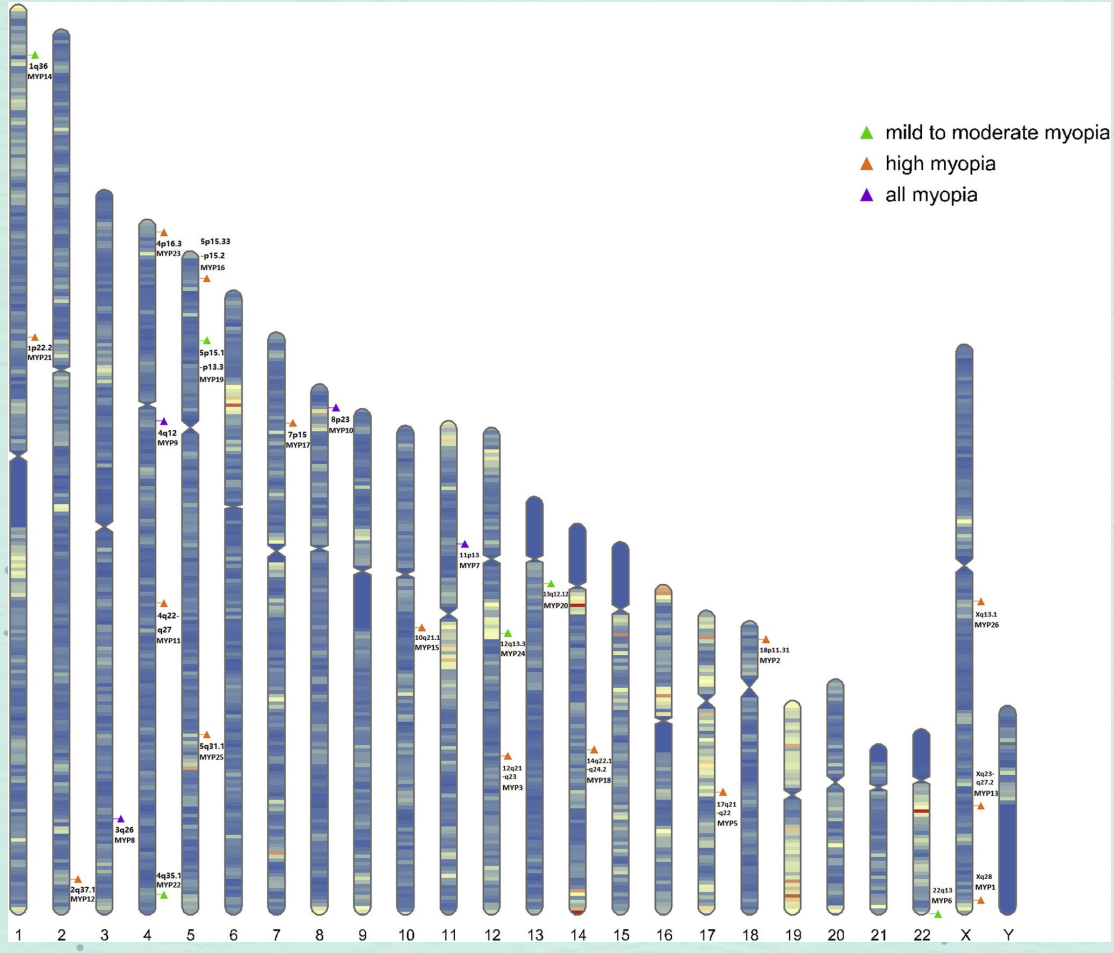

Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology. 2016;123(5):1036-42.

# Myopia – The Genetic Connection

1. 1 myopic parent increases risk of myopia by 3 times
2. 2 myopic parents increases risk of myopia by 6 times
3. Children with highly myopic parents are also found to progress faster, both spherically and axially
4. 25 myopia loci have been revealed and ethnic variations are observed

**“Myopia is etiologically heterogeneous because both environmental and genetic factors play important roles in myopia development” (Morgan et al., 2012).**

**“To date, more than 100 genes and over 20 chromosomal loci have been identified to be associated with myopia or the related quantitative traits via linkage analysis, candidate gene analysis, genome-wide association study (GWAS) and next-generation sequencing (NGS)” (Verhoeven et al., 2013a; Fan et al., 2012; Li and Zhang, 2017)**




# Location of 25 Myopia related loci

# Evolution is not constant improvement

1. Genetic drift
2. Environmental factors (phenotypic)
3. Natural selection not impacted as myopia is not a survival disadvantage
4. Historically socio-economic status shows higher prevalence of myopia in more affluent areas

# The Selfish Gene Theory

The fundamental argument that The Selfish Gene Theory makes is that the natural selection process in the evolution of living beings is not about making the species, community or group secure. It is about making the individual secure, and the individual is merely a vehicle for its genes

# The Selfish Gene

**“We are survival machines – robot vehicles blindly programmed to preserve the selfish molecules known as genes”**

**Richard Dawkins - The Selfish Gene**

# The Future... How will the eye evolve?

1. What will our environment look like?
2. How will genetic drift change?
3. More mixing between populations = greater genetic variety
4. Science & technology - now we can identify genes responsible for eye conditions - can we switch them on or off?

# Is the future already here?

1. Humans have trichromatic vision
2. We have 3 types of cone - determined by the Opsin protein
3. Each cone is attuned to a specific wavelength of light - short, medium, long or blue, green and red
4. Some mammals have 2 cone opsins so colour with less acuity
5. Certain species in the family of the mantis shrimp have at least sixteen opsins, fine-tuned to see red, blue, and green, as well as polarized light, ultraviolet, and a host of light unseen by us that we can only dream about.

# Is the future already here?

1. Colors are determined by the wavelength of the light we see
2. The gene for the shortwave opsin is on chromosome Y, whereas the Medium and Long are on the X.
3. This is why men are more prone to color blindness than women: A faulty opsin on one X can be compensated for by a woman's second; men have no such insurance.
4. The duplication of one opsin on the X to two at some point in our primate evolution allowed one of them to mutate freely without a loss of function, and thus we were free to acquire a new color sensitivity

# Is the future already here?

1. This happened tens of millions of years ago, long before humans, but something similar might be happening now in us
2. Some women might be tetrachromatic.
3. Through another random chance duplication, have acquired a fourth opsin on one of their X chromosomes.
4. Around one in eight women are estimated to have this extra gene variant, but whether that bestows tetrachromacy is not yet known.
5. Those who do see colors where we see monotones.
6. Will women evolve better vision than men?

# References...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1. Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology. 2016;123(5):1036-42.

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https://www.sciencedirect.com/science/article/pii/S0014483519303136

https://www.nationalgeographic.com/science/article/jellyfish-eye-genes-suggest-a-common-origin-for-animal-eyes

# Further Reading...

The Selfish Gene - RIchard Dawkins

The Blind Watchmaker - Richard Dawkins

A Brief History Of Everyone Who Ever Lived - Adam Rutherford

Sapiens - A Brief History Of Humankind - Yuval Noah Harari

Homo Deus - Yuval Noah Harari

The Ten Types Of Human - Dexter Dias