Avian Eye

I. General Shape and Structure

A. Introduction

Of all vertebrates, birds rely most heavily on vision (diurnal primates excluded)

Flight is very visually demanding but other behaviors important as well!

foraging

predator detection

mate choice

Highly visual animals – eyes large relative to head size

European Starling – 15% of head mass

Human – 1% of head mass

Why large eyes??

Large eyes provide - larger and sharper images

Birds have 3 eyelids

- upper
- lower
- nictitating membrane – has own lubricating duct, cleans and protects eye

B. Shape

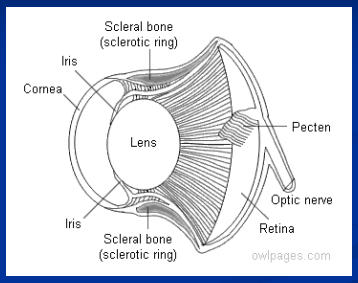
Avian eye has different shapes (unlike mammals)

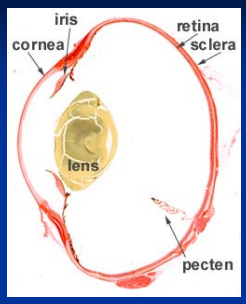
- Flat – majority of birds, similar to shape of lizards, horizontal axis shorter than vertical

- Globular – Falconiformes, many Passerines, axes are similar in length

- Tubular – owls, some eagles, horizontal axis is longer than the vertical

C. Internal Structure





- Aqueous humor – clear thin liquid in anterior chamber, lower osmotic pressure
- Vitrous humor – clear jelly-like substance that fills the posterior chamber of the eye, maintains shape of the eye
- Choriod coat – dark middle layer, richly supplied with blood vessels, absorbs radiant energy

- Cornea – transparent tissue covering the exposed area of the eye
- Iris – A thin sheet of striated muscle fibers and connective tissue that form a diaphragm in front of lens, controls the amount of light that enters posterior chamber
- Ciliary body – structure at the base of the iris containing muscle fibers that contract to alter the shape of the lens

- Sclera – a white layer composed of tough collagen fibers forming the white of the eyeball, supports shape of eye and attachment point for muscles, ossicles present in sclera
- Retina – inner surface of the eye, sensitive to light, contains photoreceptor cells and is continuous with optic nerve

II. Accomodation

Altering of refractory apparatus so image falls on retina.

A. Fish

Lens moved forward and backward (camera)

to change focal length

Cornea not involved (refractive index similar to water)

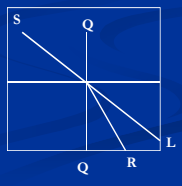
Refraction – the change of direction of a ray of light (ability of the eye to refract light so as to form image on retina)

SP – ray of light

SPL – original direction

SPR – refracted ray

QQ - perpendicular



B. Birds

2 lens system – cornea and lens (only lens in mammals)

1. Brucke's Muscle – operates through ciliary ligament

Contraction causes annular pad to press against lens (increases convexity)

insert picture

2. Crampton's Muscle – contraction increases curvature (thus corneas refractive power)

Most terrestrial (hawks and owls) muscle causes cornea to become more convex

a. Cornea provides coarse adjustment, lens provides fine adjustment

b. aquatic diving birds – cornea can't be used for focusing underwater (similarity of refractory index between cornea and water), muscle reduced.

c. some diving birds have muscular iris that presses against lens to further increase convexity (mergansers, cormorants)

C. Lens

Lens shape varies more among birds than any other vertebrates.

- flat anterior, convex posterior (Parrots)
- convex both anterior and posterior (ducks, owls, nighthawks)

benefits not understood

D. Iris

Color varies from deep brown (most common) to bright red (Red-eyed Vireo, American Coots), white, yellow (Brown Thrashers), green and blue.

May function in species recognition.

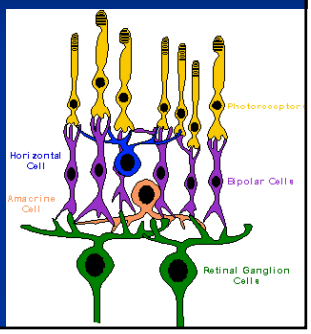
III. Retina

Retina is avascular (different from mammals) – prevents shadows and light scattering.

Made possible by unique structure - Pecten

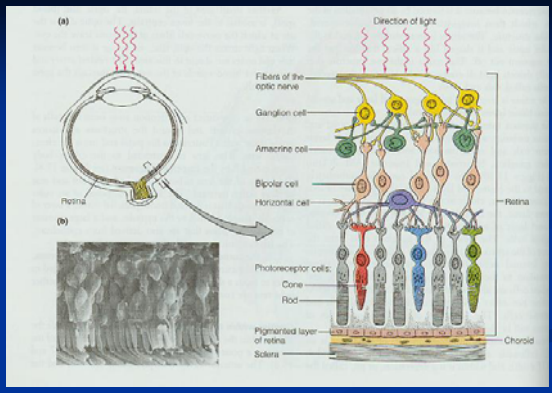
Retina has 3 types of photoreceptors

- rods – black and white vision
- cones – color vision
- double cones



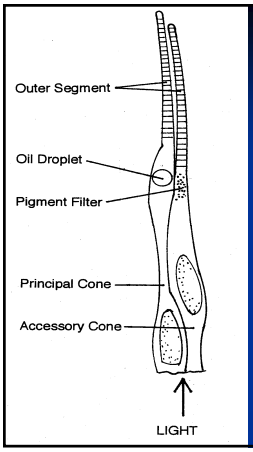
5 major classes of retinal neurons are recognized

- photoreceptors
- bipolar cells
- horizontal cells
- amacrine cells
- ganglion cells



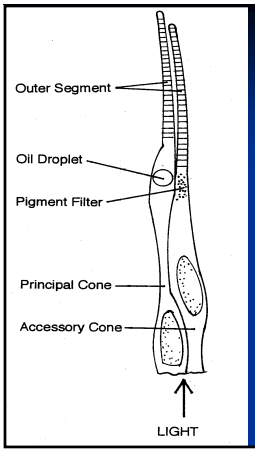
Nocturnal species have retinas made entirely of rod cells,

Diurnal species have duplex retinas.



Many of cone cells are "double cones"

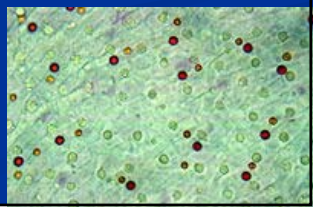
All vertebrates with exception of placental mammals have this cell type.



Consists of principle cone and accessory cone

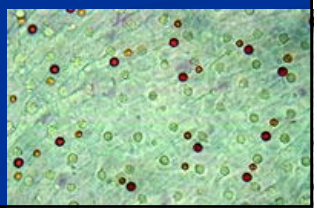
Single cones as well as one or both double cones may contain an oil droplet – common feature in vertebrate cones.

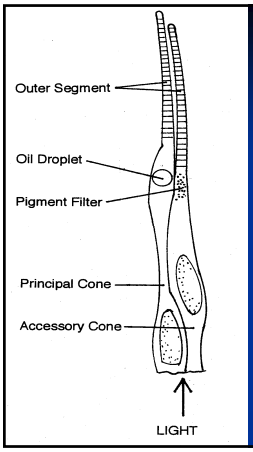
Consist of lipids in which carotenoid pigments are dissolved



Droplets can be transparent or clear, pale yellow, green, orange, or red.

Light must pass through droplet to reach visual pigments – acts as filter eliminating other wavelengths





Droplets positioned at distal end of inner cone segment.

Light must pass through before entering photosensitive outer segment

- Red oil droplets found in red sensitive cones
- Yellow droplets found in green sensitive cone cells and in part of the retina used in distant vision. Used as haze filter

- Blue and violet sensitive cones have clear oil droplets, common in aerial feeders that work against a blue sky
- UV vision found within birds, suggested that oil droplets screen out UV - so cones without oil sensitive to UV

House Finches have little UV perception and only 5% of cone cells lack oil droplets

Hummingbirds 15% of cone cells lack oil droplets

UV perception

- serves signaling function
- cue discriminating foods (plants, seeds, flowers etc.)
- may play role in navigation as adaptation to coloration of sky. Short-wavelength gradients would vary depending on sun's angle in sky.

Bennett et al. 1997

Do females use UV in mate selection?

Each female allowed to assess 4 males either behind a UV filter or not.

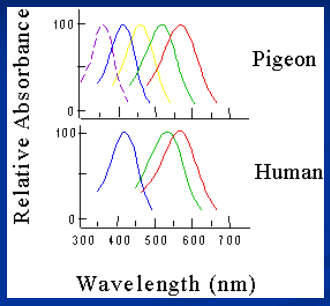
Measured how long female stood in front of each male.

"UV got great feathers baby!"

Under any lighting conditions females had repeatable tastes

- Without filter, females preferred males that had lowest UV reflectance
- With filter, used other characteristics

Consequently, birds have greater range of color vision



Some nocturnal species (owls, goatsuckers) have a layer at back of eye called "tapetum lucidum"

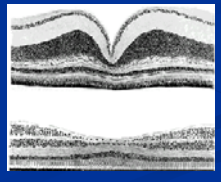
Acts as mirror & reflects light back through retina making it more likely light will strike sensory cells

Vision greatly enhanced under low light – produces the "eyeshine" of nocturnal animals

C. Areas and Foveas

Area – region of retina where cones are densely packed, and no rods – provides greater acuity

Fovea – is pit in retina and may be associated with area



Cone density in fovea

Humans = 38,000/mm2

Hawk = 65,000/mm2

Increased visual acuity is related to structure of the fovea

Visual acuity – ability to discriminate two points as separate entities from a distance.

Humans comparable to some birds

Passerines, raptors, vultures 2.5 – 3 x that of humans

American Kestrel

Recognizes insects (2mm long) from distance of 18 m!

afoveal – chicken, California Quail, Crested Guineafowl

monofoveal – most birds have single fovea positioned in center of retina

Owls single fovea temporally located

bifoveal – birds that require good distance estimation have both a central and temporal fovea.

Terns, swallows, swifts, hummingbirds

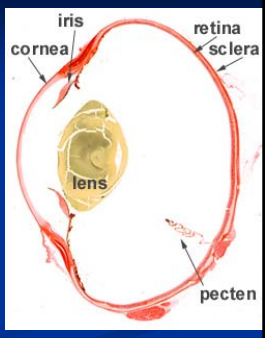
Provides good depth perception

IV. Pecten

A. Structure

Found in both birds and reptiles

located with base positioned over "blind spot"



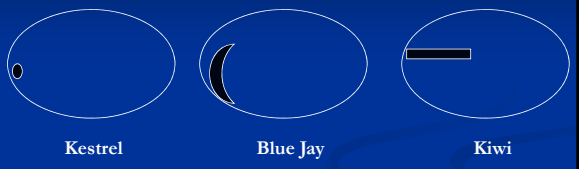
B. Function

Specific function has been elusive for ~ 200 years

Highly vascularized!

Provides blood supply for nutrients and O_2 exchange

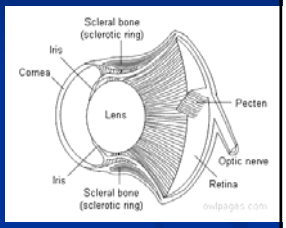
But shape is variable!



Kestrel **Blue Jay** **Kiwi**

Does it have other functions????

- shading of retina: eliminates light scattering so that bright images are in greater contrast
- detection of motion: images emerge between lamellated shadows (rapidly appears, disappears)
- orientation and navigation:



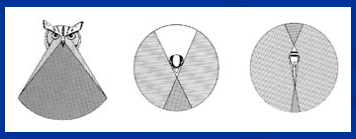
shadow cast by pecten from sun falls on either the central or temporal fovea

Using the position of sun could provide means to orient

V. Monocular vs. Binocular Vision

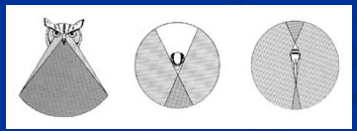
Eyes of most birds on side of head – accomodates images simultaneously (monocular vision)

Provides wide field of view (Rock Pigeons 300°, American Woodcock 360°)



Trade-off associated with monocular vision – difficult for depth perception

Binocular field of view occurs directly in front (and behind for Woodcocks)



Owls have eyes located in front giving much wider binocular field of vision

180° field of view overall – most binocular