Psychology 1XX3 Notes – Vision II – Mar 1, 2010

- Brain: place where visual perception all comes together is the brain.

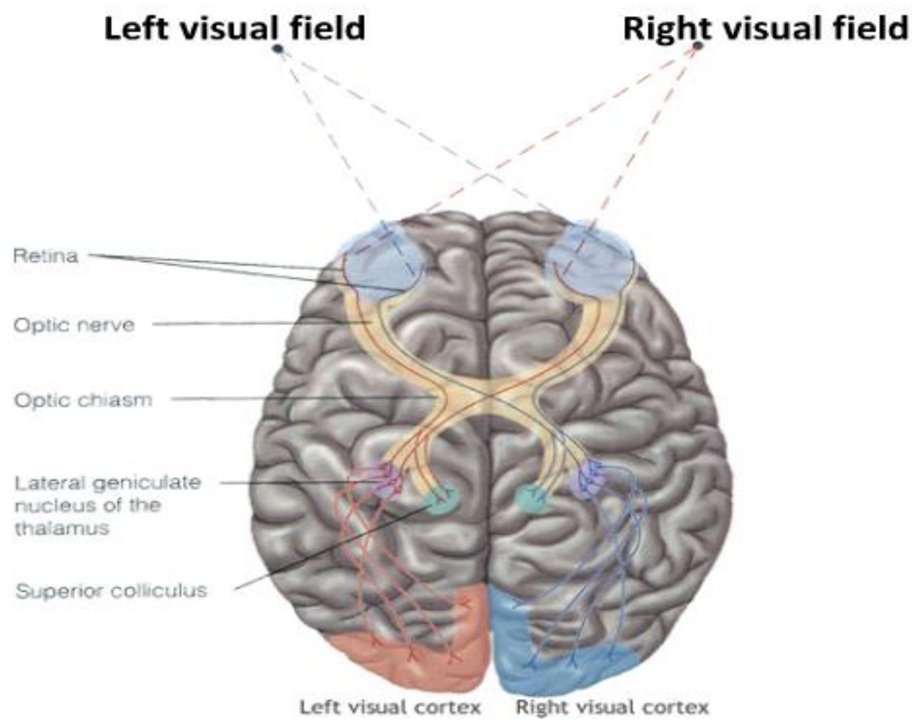
- Visual system: comprised of a set of assembly lines. Areas along the visual pathways process parts of the visual input before sending those partially-processed bits of information on to the next set of areas down the line for further processing.

Visual Fields and Hemispheres:

- Before reaching their respective hemispheres, the axons from the inner region of each retina, that is the region of the retina closest to the nose, have to cross over to the opposite hemisphere. The point at which the optic nerves from the inside of each eye crosses over to the opposite hemisphere is called the **optic chiasm**.

Two Visual Pathways:

- After the optic chiasm, the information from each visual field arrives in the opposite hemisphere, at which point the optic nerve fibres split and travel along two pathways.
- Most of the retinal or ganglion cell axons travel along the main pathway and synapse in the lateral geniculate nucleus (LGN), which is a part of the thalamus that receives visual information.
- After being processed here, the visual signals are sent to areas in the occipital lobe that make up the primary visual cortex.
- A smaller portion of the axons from the retinas takes a detour to an area in the midbrain called the superior colliculus, after which information is sent upwards to the thalamus and on to the occipital lobe or downward to structures in the brainstem.
- This smaller, secondary pathway seems to deal with coordinating visual input with information coming in from other senses, as well as localizing objects in space through head and eye movements. (See image below.)



Main Pathway: Two Subdivisions

- Within the main pathway are two subdivisions of specialization that are able to process their specific information in parallel. The **magnocellular pathway** is specialized to process movement information, while the **parvocellular pathway** deals specifically with colour and form information.

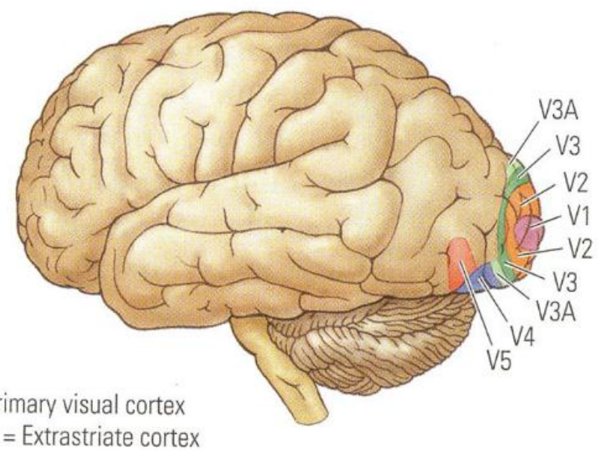
Main Pathway: Lateral Geniculate Nucleus

- The first stop for information that is sent from the retinal ganglion cells is the LGN.
- Just like retinal ganglion cells have receptive fields that are made up of many photoreceptors, LGN cells also have receptive fields that are made up of a combination of many ganglion cells.
- Information from many smaller bits are combined into one overall neural signal.
- The LGN is made up of six layers.
- Information from each eye projects to different layers of the LGN. Not only does each layer of the LGN receive input from a specific eye, but each layer of the LGN also receives input from a specific subpathway.
- Movement information that is processed along the magnocellular runs to 2 of the layers in the LGN, whereas information specific to the parvocellular pathway goes to the other 4 layers.

Main Pathway: The Occipital Lobe

- From the LGN, the visual information is sent to the occipital lobe for further processing.
- There are over 20 cortical areas that process visual information, but most of the research done on visual processing has concentrated on area V1 of the occipital lobe, otherwise known as the **primary visual cortex**.
- Collectively, the visual processing areas in the occipital lobe outside of the striate cortex are known as the extrastriate cortex. (See image below.)

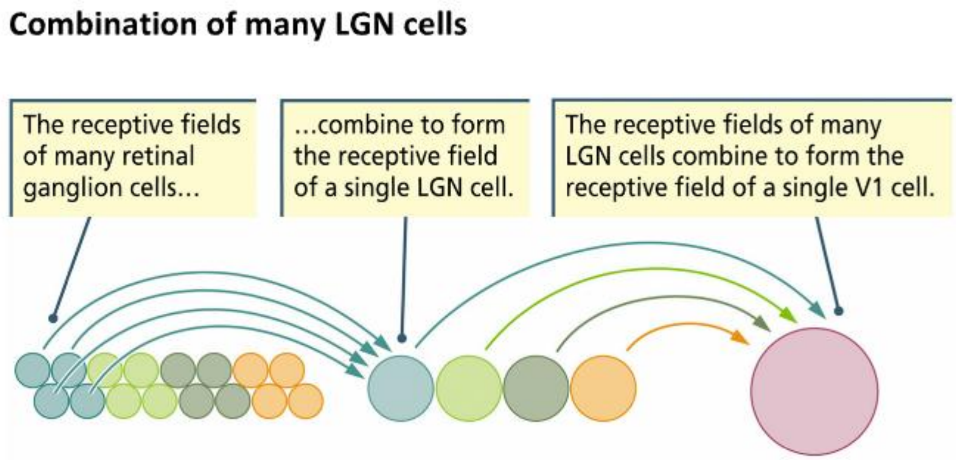
Primary visual and extrastriate cortex



V1 = Primary visual cortex
V2–V5 = Extrastriate cortex

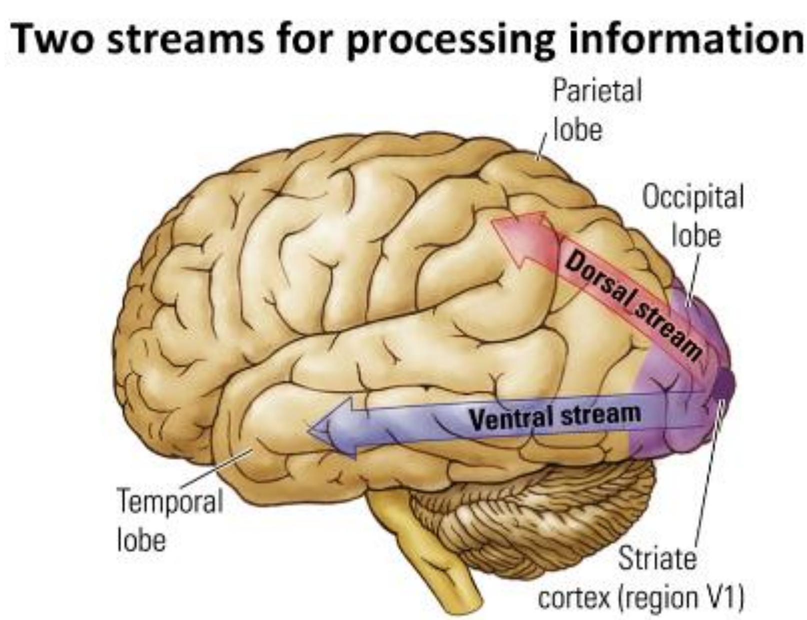
Primary Visual Cortex:

- Just as the receptive field of the LGN is made up of many ganglion cells, the receptive field of a single V1 cell is a combination of the receptive fields of many LGN cells.
- There is information from many sources being processed down into a single target.

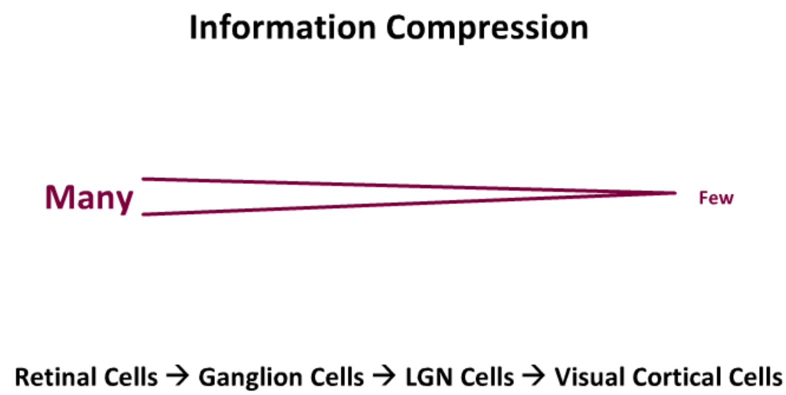


- Furthermore, the receptive fields from the retina are arranged in a topographical map in the primary visual cortex, such that neighbouring locations in the retina project to neighbouring locations in the visual cortex.
- The primary visual cortex is made up of six layers, and the LGN projects directly onto layer IV neurons from which information is carried to neurons in the other five layers.
- The 6 layers of the primary visual cortex are organized into cortical columns that are made up of about half mm squares of cortex that are perpendicular to the cortical surface.
- Although the vast majority of neurons in the visual cortex can respond to visual stimuli presented to either eye, most have a stronger response to one eye than the other. → information from each eye sent through the LGN projects more strongly to some cortical neurons and less strongly to others.
- The eye preference is maintained within the individual cortical column → all neurons within a given cortical column respond more strongly to input from the same eye.
- To some extent then, information from each eye is still being processed separately in the primary visual cortex, but the cortical neuron is also the first site of binocular processing.

Dorsal and Ventral Streams of Extrastriate Cortex:



- From the primary visual cortex, processed visual information, whether it is colour, form, or movement, is sent on to the extrastriate cortex and gets separated into the dorsal and ventral streams.
- The **dorsal stream** is referred to as the **“where pathway”** because it processes where objects are, including their depth and motion in the field.
- The dorsal stream progresses from the extrastriate cortex to the parietal lobe.
- In contrast, the **ventral stream** is referred to as the **"what pathway”** because it processes what the object is, including its colour and form.
- The ventral stream runs from the extrastriate cortex to the temporal lobe. We’ve learned how our brain processes visual input. (See image in previous page.)

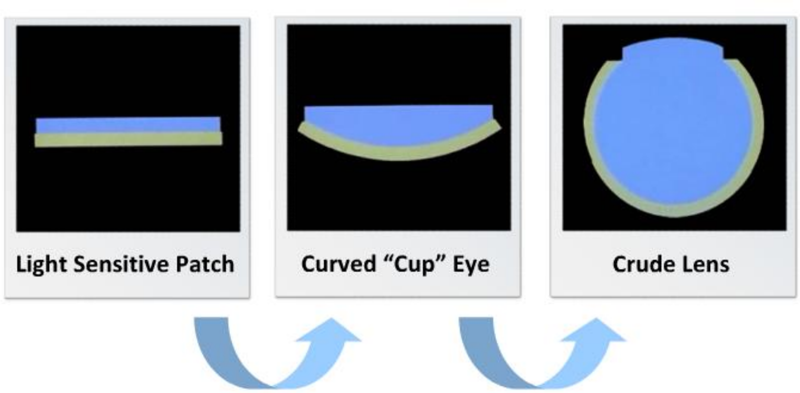


The Evolution of the Eye
Light Sensitive Patch:

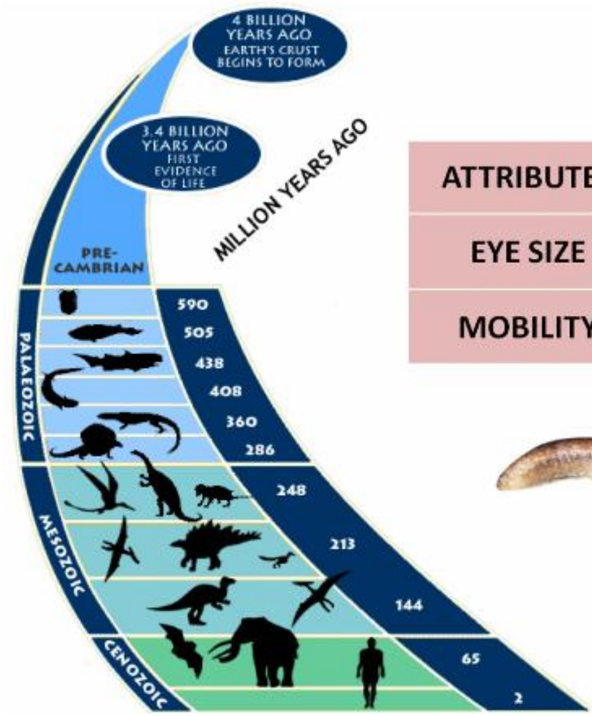
- Eyes could have started out as simple light- sensitive patches, like what jellyfish and worms have today.

Curved Cup Eye:

- At some point, some individuals may have developed a light-sensitive patch that was formed into a slight depression, which would have allowed the direction of light to be sensed, incurring a survival advantage. This is very much like the cup eyes that today’s clams have.
- Some individuals may later have adapted a crude lens, allowing them to process visual input at different distances. From here, the lens could have successively improved to allow better focusing and accommodation, such as a more transparent lens or one with better curvature.
- So the complex vertebrate eye evolved gradually, with new adaptations being layered on top of old adaptations. Eye evolution is an example of what is called **cumulative selection**, where small changes were made to the existing eye, and then new small changes were made to the modified eye, and so on, thus gradually increasing the sophistication of the eye. (See image below.)



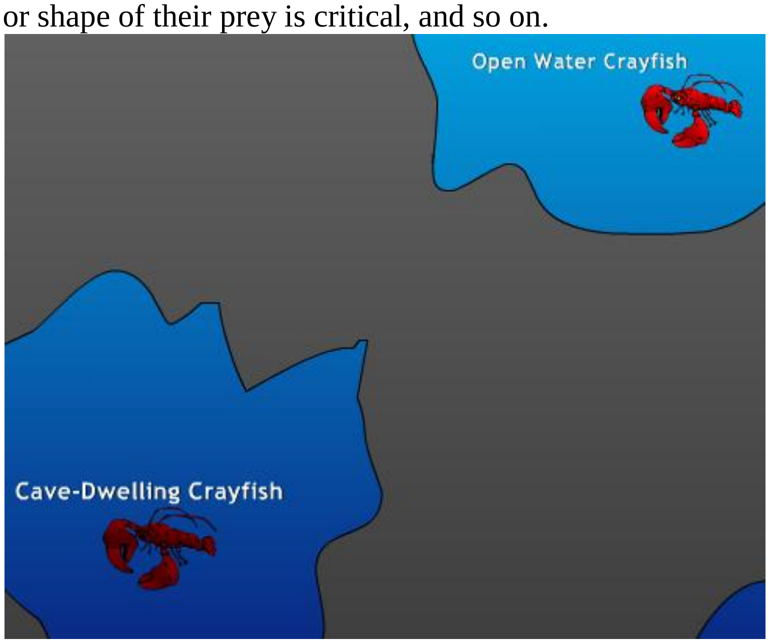
- Animals in the Precambrian period likely only had crude light- sensors, if any at all. Their tracks tended to be small and slow moving, like the motion of small slugs or worms. →b/c of poor mobility there was no need for detailed vision → if you see a predator you can't escape anyway (See image below)
- In contrast, the early Cambrian animals were larger and more mobile, and eyes would have been useful for both hunting prey and escaping predators. This would have led to an arms race between predators and prey to develop both vision and locomotion skills, leading to adaptive selection for better and better eyes.



	PERIOD	
ATTRIBUTES	PreCambrian	Cambrian
EYE SIZE	Small	Larger
MOBILITY	Poor	Better

Different Eye Designs for Different Environments:

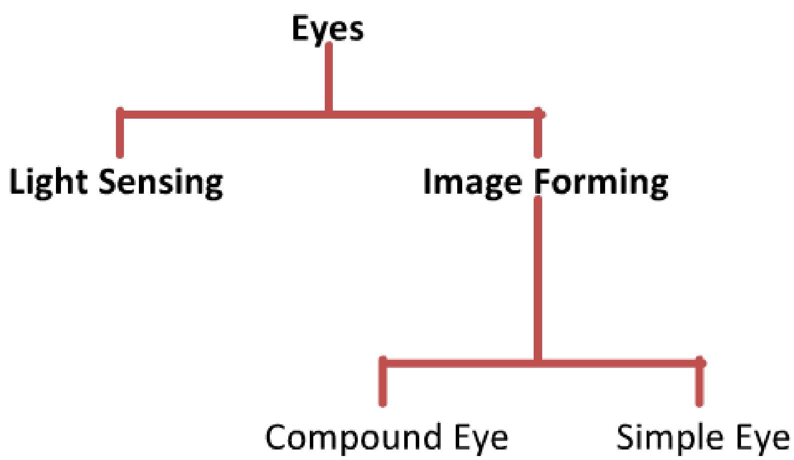
- Eyes can vary a lot across different species according to what the species needs to deal with in their daily lives: whether they live in an area with light or not, whether their food tends to come from above or below, whether the movement, colour, or shape of their prey is critical, and so on.



- The importance of the environment is clearly seen when comparing two closely related species with different ecological demands.
- See Image Above: These two species of crayfish are closely related genetically, but differ in their habitat either open-water of cave-dwelling.
- The cave-dwelling crayfish lives in an environment where no light exists and has no need to form an image. For them, the biological costs of building and maintaining eyes would far outweigh the benefits of having eyes, and so, they do not have eyes.
- On the other hand, the open water-dwelling crayfish would be expected to benefit from the ability to form an image and so, have developed functioning eyes.

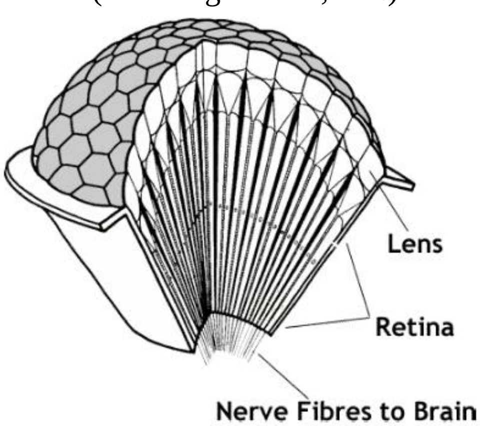
Different Kinds of Eyes:

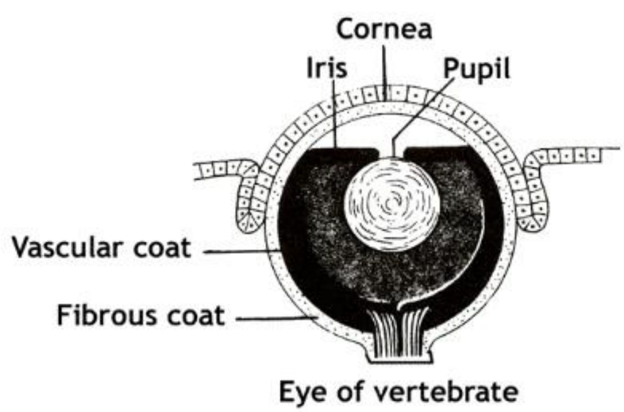
- Some animals don't have eyes at all, and others have eyes that can only detect the presence or absence of light but can't form images.
- These light instruments have evolved as solutions to the organism's needs.
- Image-forming eyes come in two quite different designs: **Compound eyes** and **simple eyes**. (See image below.)



Compound Eyes:

- Compound eyes are found in anthropods, such as insects and crabs. The eyes of these species are made up of an arrangement of individual tubular units called **ommatidia** that each point in a slightly different direction to gather the light that lays directly in front of it.
- These eyes manage to form a single image by putting together many separate signals from each ommatidium.
- Compound eyes are very good at detecting movement, but only at close distances. (See image below, left.)





- Simple eyes are found in vertebrates as well as molluscs, such as octopus and squid. (See image on previous page, right.)
- These are the types of eyes that we think of when we think of eyes; they have an eyeball, lens, and retina.
- The vertebrate eye can vary quite a bit in its design according to the environment that the species lives in. In fact, the environment has played a role in determining the shape and orientation of the pupil, the size of the eye, where the eyes are placed on the head, and where on the retina most of the photoreceptors are located.

The Pupil:

- One aspect of the eye's architecture that varies greatly across species is the shape of the pupil: some shapes allow more variation in the size of the pupil than others.
- Primates have a circular pupil, which cannot vary all that much in size compared to other shapes. For eg. the pupil of a human can only increase the brightness of a retinal image by about 10 times, which doesn't allow a human to see across a very wide range of illumination conditions.
- Compare this to the pupil of a cat, called a slit pupil, which is shaped like a pointed oval. The cat's pupil can vary much more in size. In fact 10 times more than the range of a human. This allows the cat to capture more light in a dark environment and reduce the amount of light that enters in a very bright environment.
- The slit pupils also vary in orientation, with some species having slits that are vertical like the cat and climbing snakes, while other species have slits that are horizontal, like the horse, shark, and land-dwelling snakes.
- It turns out that the orientation of these slits tends to coincide with the animal's lifestyle: If their lives are dominated by what is happening on the horizon, then their slits tend to be horizontal, but if what is important to them is what is happening above or below them, then their slits tend to be vertical.

	PUPIL ORIENTATION	
ATTRIBUTES	Horizontal	Vertical
ENVIRONMENT	Horizon	Above & Below
SPECIES	Horse, Shark	Cat, Snake

The Size of Eyes

- If you break down and simplify the main functions of the eye, there are two of them, and these are **resolution (or acuity)** and **sensitivity (or ability to get enough light)**.
- Larger eyes tend to be better at both of these functions. So basically we see bigger eyes in species that need better eyesight; the benefit gained by having bigger eyes varies across species.
- For example, humans and hawks have big eyes in order to get good resolution, and we know this because their visual acuity is excellent whereas their night vision is not so great.

- In contrast, cats, horses, and owls have big eyes in order to improve sensitivity, and we know this because their ability to see details under very dim lighting conditions is excellent, whereas their visual acuity is much poorer than ours.
- Some species require both resolution and sensitivity, such as animals that hunt in the deep sea where lighting conditions are poor. (See image below.)

Visual Acuity and Night Vision for Different Species

Species	Acuity	Night Vision
Humans & Hawks	Excellent	Poor
Cats, Horses & Owls	Poor	Excellent

- The largest recorded eye is that of a deep- sea squid, with a diameter of about 40 cm, which is somewhere around the size of a small TV set.
- These animals have to be able to see the prey that they hunt in the depths of the ocean.
- Compare this to other species that don't need high acuity and function in bright daylight; they can have tiny little eyes that are less than a millimetre wide.

Example: How can hawks spot a tiny mouse many feet away with smaller eyes than us?

- For one, they have a wider daylight pupil, which allows more light to enter the eye and improve sensitivity.
- Hawks have narrower photoreceptors in the fovea, which means that they can have more densely packed receptors compared to us.
- Finally, their eyes have a built- in optical trick that functions as a crude telephoto system, magnifying the image they're looking at.
- Key Point: There is more to an eye's ability at resolution than can be judged by its size alone.

Eye Placement:

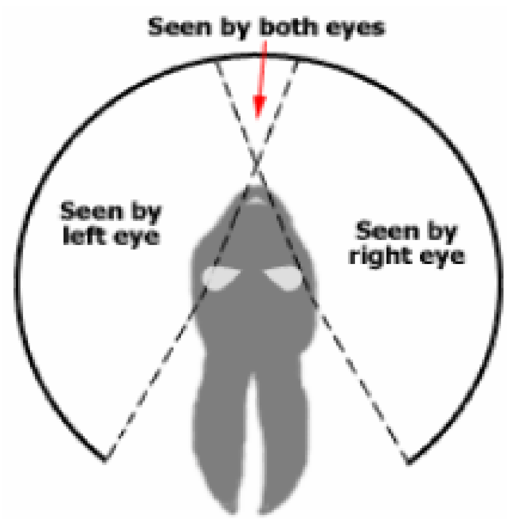
- Vertebrate eyes can vary in where they are placed on the animal's head.
- Eye placement on the head leads to a trade-off between **depth perception** vs. the **total view** of the environment the animal can see.

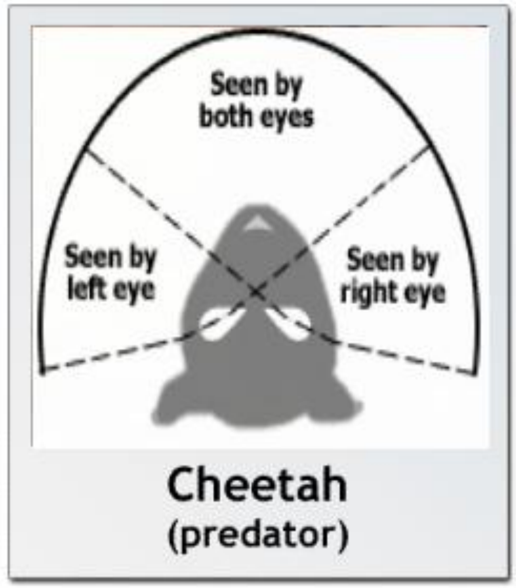
Prey:

- Animals with eyes located on either side of their head have two laterally directed eyes, like rabbits. This produces a large total view, with the animal being able to see almost all the way around their body without turning their head.
- However, these animals basically have 2 separate fields of view, with very little binocular overlap, and so depth perception is poor.
- Prey animals have adapted eyes with placement like this in order to continually scan their environment for predators. (See image on next page, left)

Predators:

- Another design for eye placement is to have both eyes directed toward the front, which is the typical for predators, including humans.
- This produces a very narrow field of view because both eyes are basically looking at the same scene. However, this means that there is a lot more binocular overlap which results in very good depth perception, a key asset for successful hunting. (See image on next page, right.)





Photoreceptor Density Ares on the Retina:

- A final example of the variations in vertebrate eye design has to do with the area of the retina that has the greatest density of photoreceptors.
- This region is called the **fovea** and for humans, is located sort of in the middle of our eye.
- However, the location of the area varies across species depending on their environmental demands.
- For example, fish that live in tiny crevices of a coral reef need to focus directly in front of them and so, the region of highest cell density corresponds to the part of the retina that processes what is happening directly in front of them.
- In species that need to pay attention to what is happening close to the horizontal plane, such as seabirds, grassland mammals like rabbits, and fish that live on the bottom of open waters, their region of greatest cell density forms a horizontal streak across their eye.
- In birds of prey like owls, their retina has the densest photoreceptors in the region that views the ground. In fact, an owl has to turn its head upside down to see something approaching from above!
- Finally, the pigeon, a lab animal that has been extensively studied, actually has 2 regions of concentrated cell density in the retina. → One region is for looking at food directly in front to help guide pecking behaviour, while the other is for more peripheral and for locating distant objects.

Prenatal Eye Development:

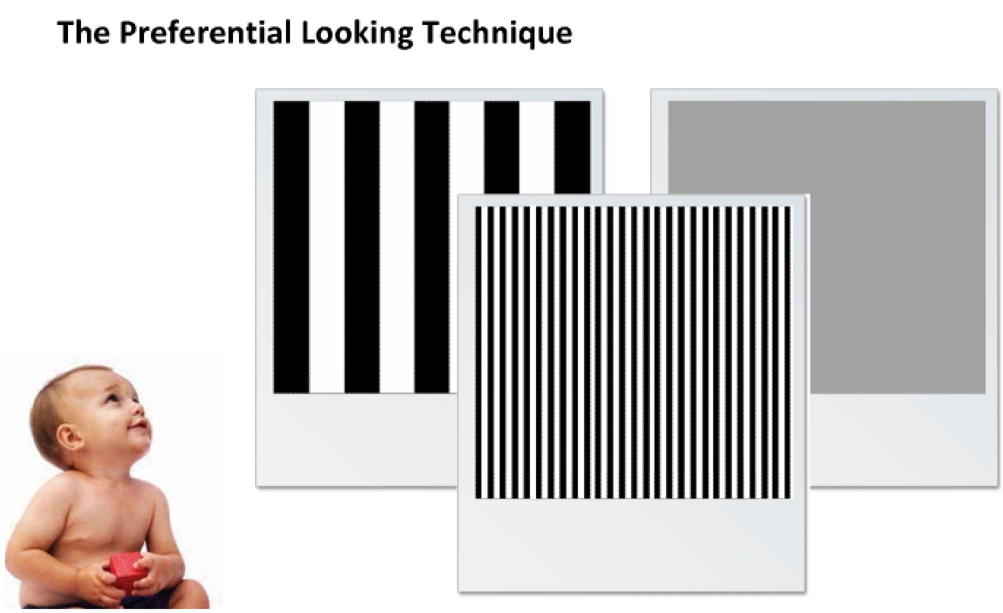
- Vision the least developed sense at birth, In fact, the eyes are formed during the second month of pregnancy, and are capable of reacting to light in the sixth month of pregnancy.
- Some random firing of retinal cells also occurs during the prenatal period that is critical for the organized wiring of the retinal cells, determining how neighbouring cells will be connected to each other.

Immaturities in the Eye:

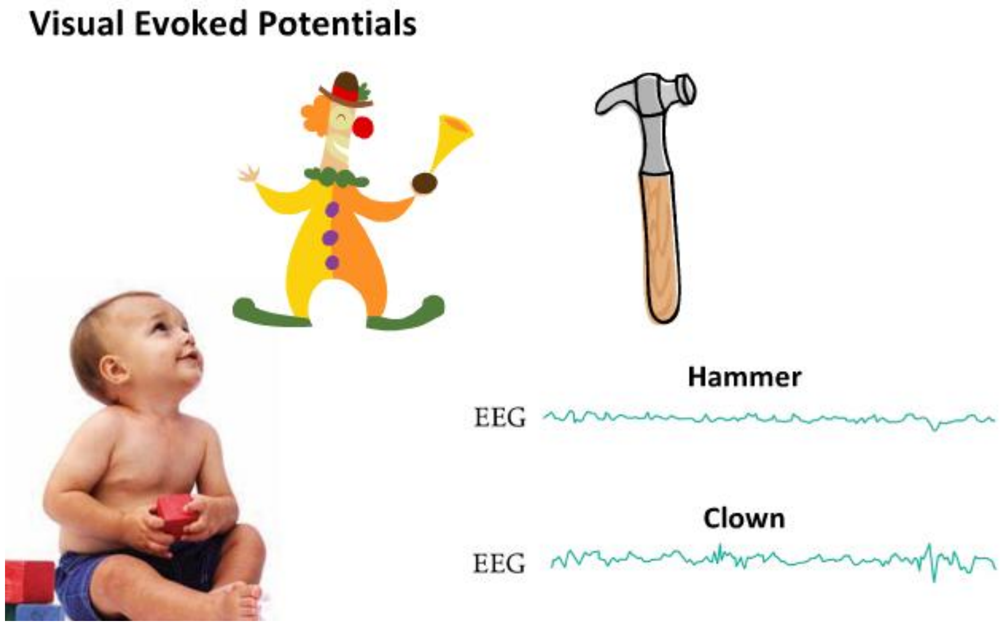
- The reason our visual system is the least developed sense at birth is because there is so much additional work that has to be done to make vision fully functional, and a lot of that work requires that the system be used, something that is not really possible before the baby is born and exposed to the light.
- Within the eye itself, the lens muscles are weak, which limits how well the newborn can focus.
- Because the pupil does not react properly to changes in light, the clarity of the image is blurred.
- With environment interactions and continued exposure to light, by around 3 months, the infant's able to focus has improved to a level that is almost adult-like.
- The newborn’s retina has a much lower density of cells than an adult retina would have, and even these cells are not yet fully developed. This is especially true for the fovea, where retinal cells don’t reach adult- like levels until after 4 years of age.
- The optic nerve and visual cortex also require several years to mature. By some estimates, the relevant brain development is not fully complete until around 11 years of age.

How to Measure Infant Visual Acuity:

- **The Preferential Looking Technique**: One such method is the preferential looking technique. This method is based on an infant's natural preference to look at a card that has sharp contrasts between light and dark, like a black and white striped card, compared to a uniformly grey card. If the stripes are made progressively smaller and closer together, the baby will no longer prefer the striped card, since their visual acuity isn't sharp enough to tell the difference between the small striped card and the grey card. So, if you measure the point at which the infant shows no preference for either card, you have a good estimate of the infant's visual acuity. (See image below.)



- **Visual Evoked Potentials**: Another way visual acuity is studied is by examining visual evoked potentials, or by looking for the characteristic pattern of electrical brain activity that accompanies a new visual stimulus. Discriminably different stimuli typically evoke discriminably different brain responses. Using these measures of brain activity, it is possible to tell when a baby can discriminate two visual images that differ in visual details. (See image on next page.)



Infant Visual Acuity:

- Both of these techniques show similar patterns of development for visual acuity.
- At birth, visual acuity is pretty dismal, with the details that a newborn can see at 20 feet being about the same as what an adult can see at 600 feet.
- By 6 months of age, the baby's visual acuity is already dramatically improved, as they are now able to see the detail of something at 20 feet that an adult can see at 100 feet.
- By one year of age, babies are close to adult-like levels for visual acuity, although they do not fully reach adult acuity until around 4 to 6 years of age. Babies have very poor visual acuity because the visual structures in the eye and, more importantly, in the brain, are not yet fully developed. In fact, human visual systems will not reach a mature state until quite late in childhood, around 11 years of age.
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