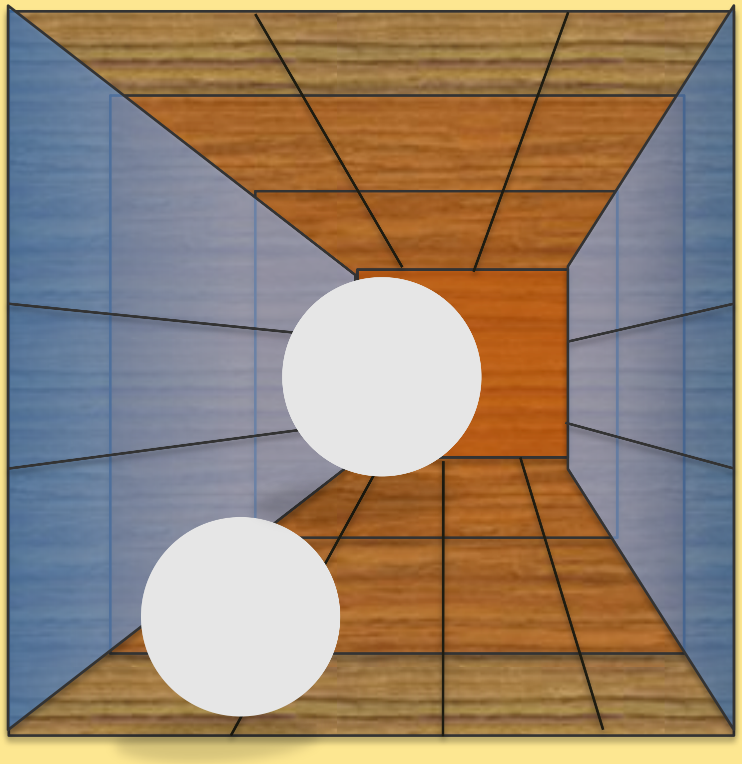
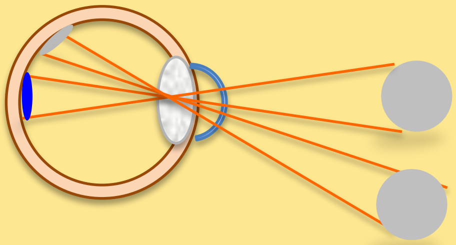
Why we see what we do

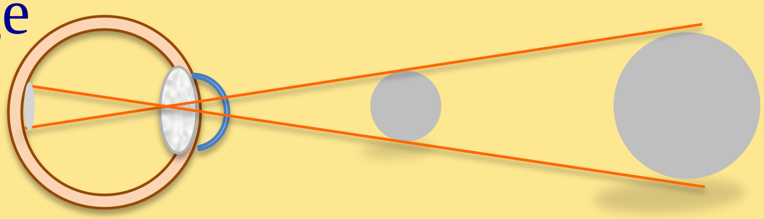


Professor Will Ayliffe

Gresham College

February 2011





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Eye and Brain; Seeing through illusions

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Steven Dakin London University

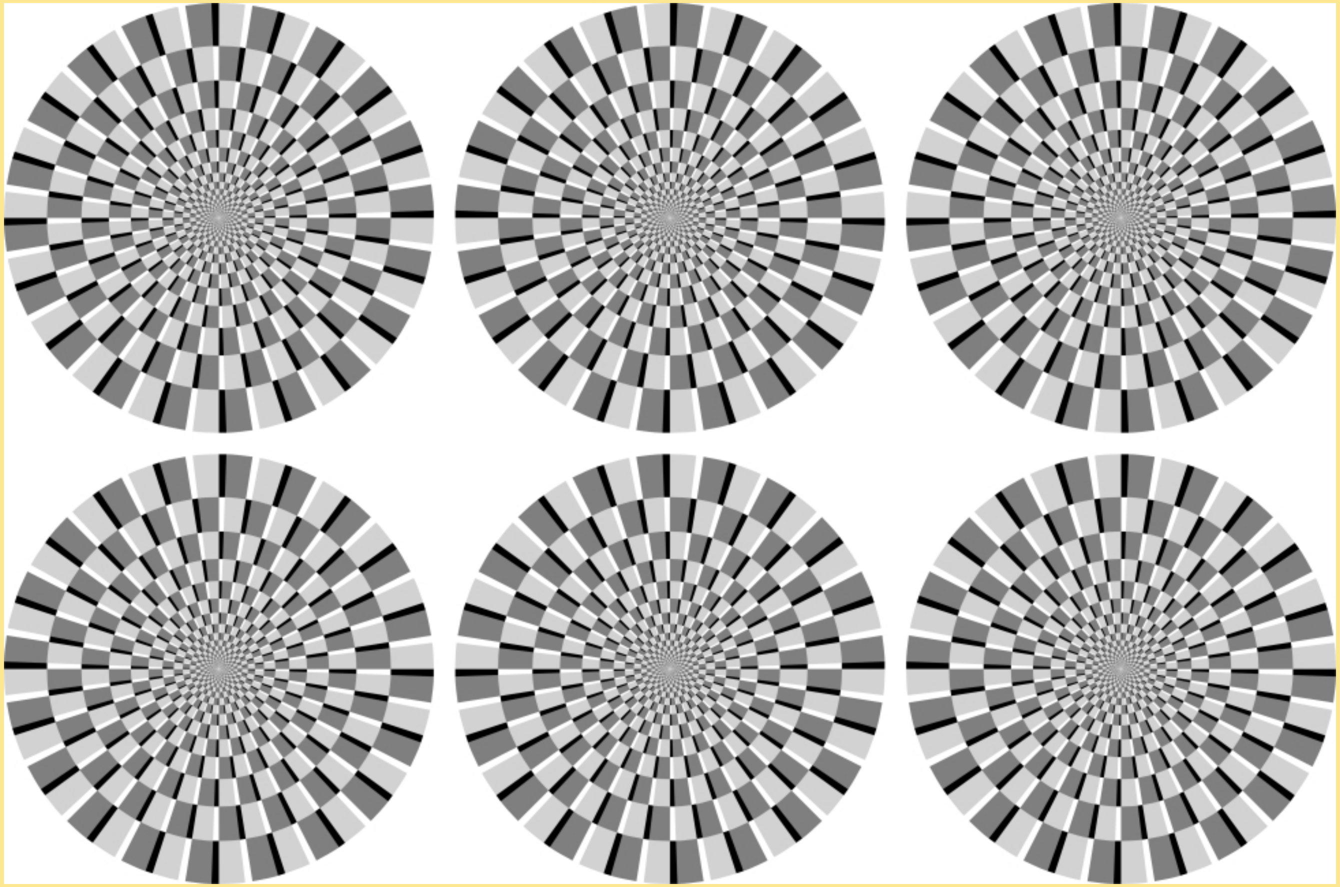
Akiyoshi Kitaoka: Kyoto

Nicholas Wade:

Staff (Judith Johnson)

Freddie and Maxim

Barbara Frank Dawn and colleagues at Gresham



"Seeing is deceiving."
Matthew Luckiesh

"Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our own mind." -- **William James** 1842-1910

A particular object has a size and a direction. The shape of the image of a particular object is not constant, depends on angle of view. The shape and size of an object changes as we move but it still appears the same, people don't become dwarves as they move away. The world doesn't move if you tilt your head. Shutting an eye doesn't cause immediate loss of depth perception, colours don't change as the light dims.

Son of eccentric Swedenborgian,
brother of Henry and Alice.
Ralph Waldo Emerson, Godfather.

Vision: An ambiguity-solving system.

The human visual system, evolved from primitive predator “shark” detectors.

The brain is programmed for interpreting moving 3-D objects, has to interpret an environment where objects are distorted by perspective.

The retinal image (from 3D or 2D objects) is flat and uncoloured, but perception is 3D, coloured textured, moving and vivid; set in depth in cluttered scene.

Even data from 2-D images on flat surfaces, also transformed into 3-D percepts.

The retinal image is ambiguous it could represent an infinite variety of possible objects. The brain has to choose. It does so with a astonishingly “correct” (useful) interpretations.

Perceptions are influenced by previous experience of what the image is likely to be in its particular context. They may be influenced by what our ancestors saw.

Unsolved mystery of the mind
“how we see”

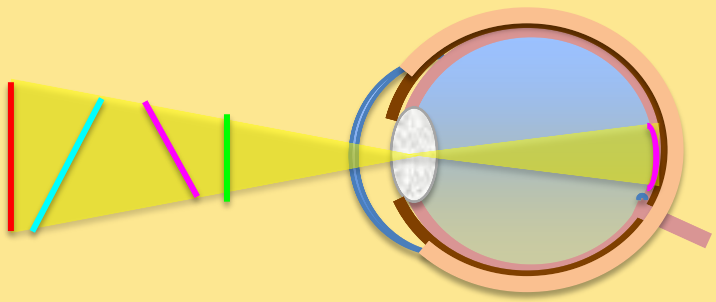
Vision appears effortless and instantaneous. We take it for granted;

Seeing begins with an image but ends with a perception

Perception is not a copy of the Retinal image

Actually constructed in the brain from incomplete and conflicting data.

The problem involves massive computing power and half the cells in the brain receive visual input.



Seeing is a complex mental process: but is subconscious.

Information from the retinal image is processed by the brain to generate a percept that doesn’t necessarily match the physical properties of its stimulus.

So perception and ‘*reality’* are going to be two different things.

Images and perception

Camera image is designed to be looked at by the human eye, to form another image, the retinal image.

Retinal image is not transmitted to the brain per se. Would need an internal eye to look at it; so on ad infinitum

Image is a set of brightness numbers

It is processed by the retina using specialised analogue computers (centre surround receptive fields)

Enhance light and dark borders

Extract relative luminosity values.

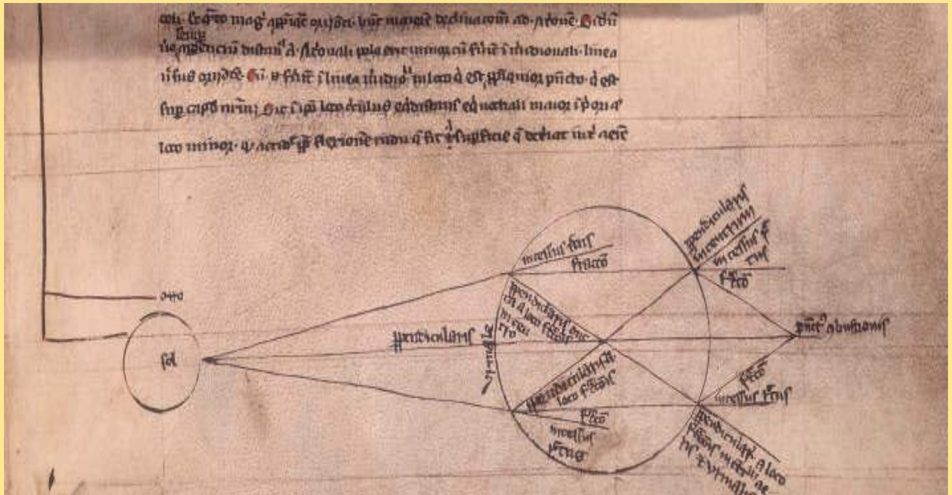
Beezer, drawn by Malcolm Judge.
The Man (ie “the reader”) is dependent on the decisions of the **numskulls**. He has the freedom only to reflect on what has occurred, all his thoughts and actions are instigated by Brainy and sent from Brainy's 'suggestion box’ seeming therefore to ” Man" to be his own. He doesn’t know of the existence of the numskulls. What he thinks is actually a consequence of the Numskulls action , not his own free will. Where does vision come from and why do people see what they do?

Image formation

Johannes Kepler (1571-1630): Assistant to astronomer **Tycho Brahe**, whom he succeeded as Imperial Mathematician. **Ad Vitellionem paralipomena** (a supplement to Witelo)

Showed how cones of rays from each point in the visual field are focused into a point-to-point correspondence on the retina. Image not caught by lens but focused and painted on the retina. Like the pinhole camera the image was inverted and reversed.

How perceived "I leave to the natural philosophers to argue about". in the hollows of the brain" due to the "activity of the Soul."



A diagram which shows light being refracted by a spherical glass container full of water. Opus Majus;Bacon, Roger poss Grosseteste, England; 13th century

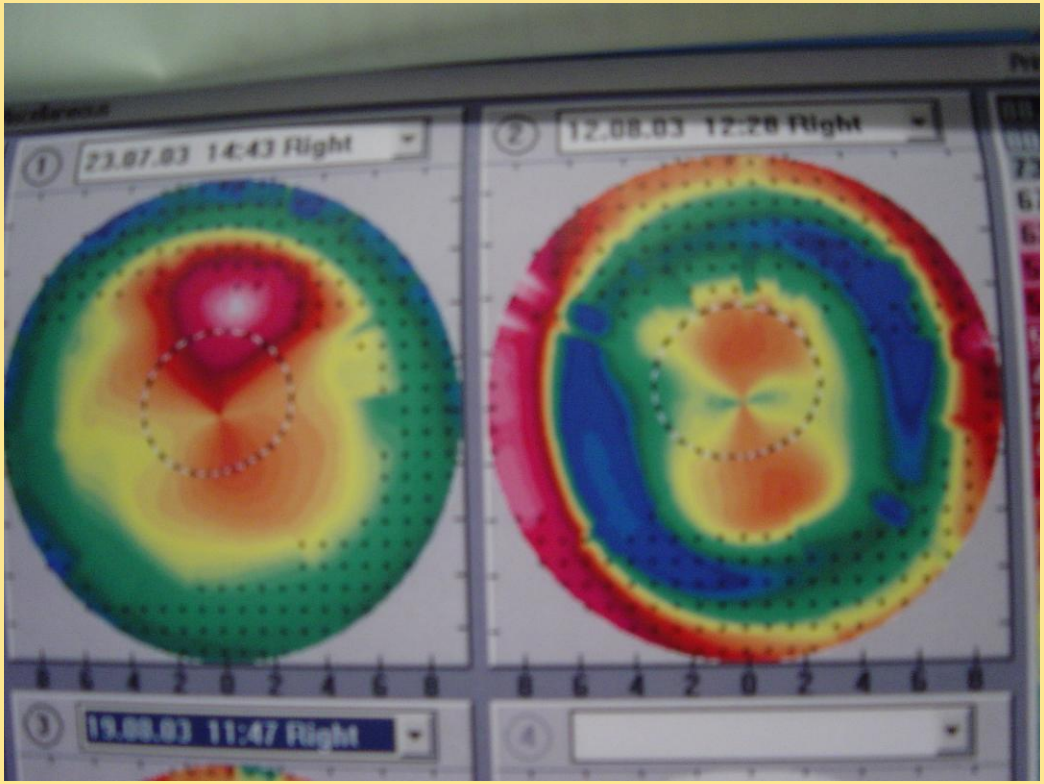
Optical blur

Image formation by optical devices is imperfect.

Spherical aberration

Chromatic aberration

Optical aberration



Retinal Image is blurred

Imperfect image may compensate for chromatic blur. Controversial.

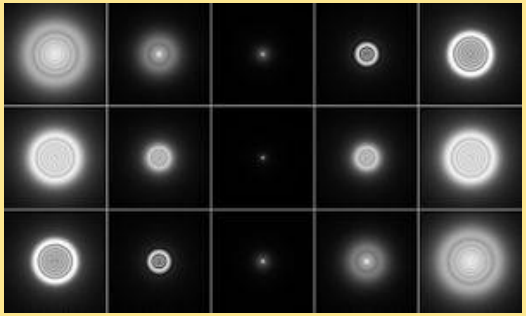
When eye is focused for mid spectrum the blue light is blurred and cannot contribute causing blur. (Yellow pigment in macula, less blue cones.

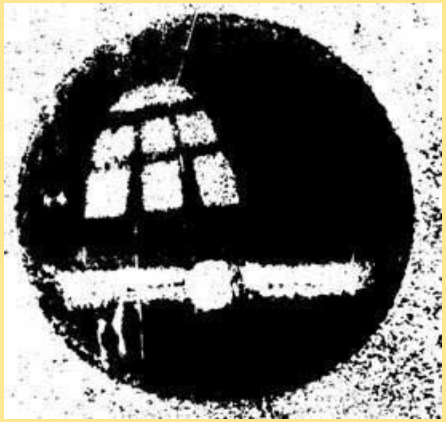
However monochromatic blur much larger.

Heinrich Müller: 1851 found a reddish pigment in the retinas of frogs.

Franz Boll: 1876 located this in rods, noted it bleached away post-mortem unless the eyes were kept in the dark. 20 secs yellow, 60 secs gone.

Willy Kühne: Fixed the eye of a freshly sacrificed rabbit produced an image of the window it faced in life “optogram”. Also claimed to have obtained an image from the retina of executed criminal 1880.





Receptive fields

1950: Stephen Kuffler (Wilmer, John Hopkins) electrodes inserted through eyeball into cat retina: Ganglion cell recording

In dark steady irregular firing 2-20/sec!

Diffuse light: No change

Small spots:

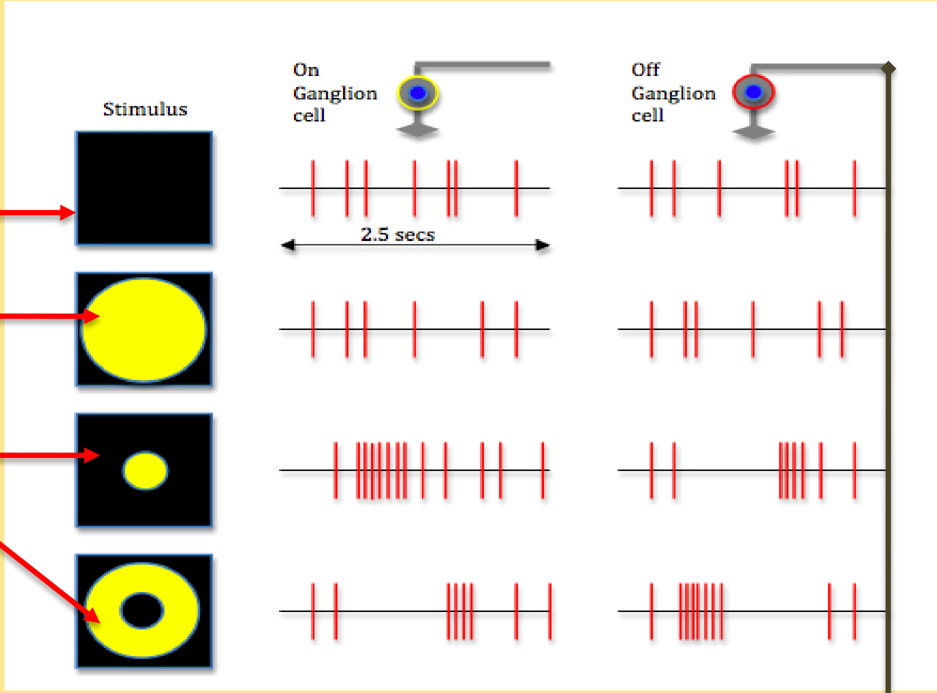
Some areas increased rate: on-center cell

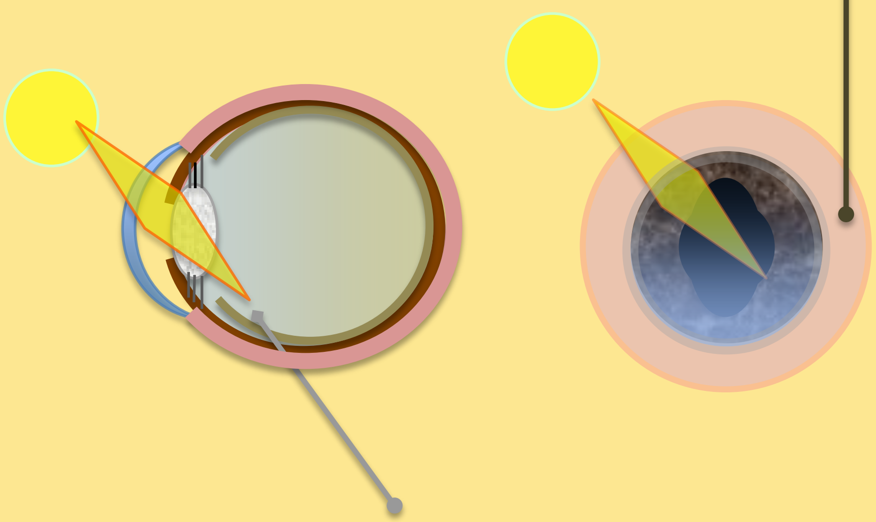
others that decreased rate: *off-center* cell

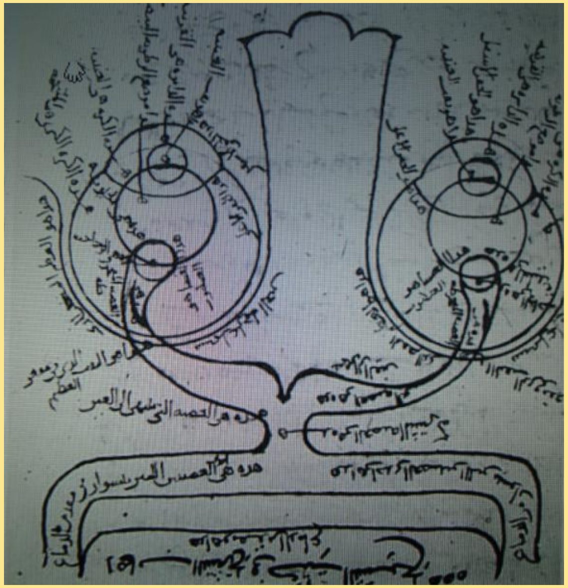
Moving away from on centre the firing inhibited. **Centre surround**

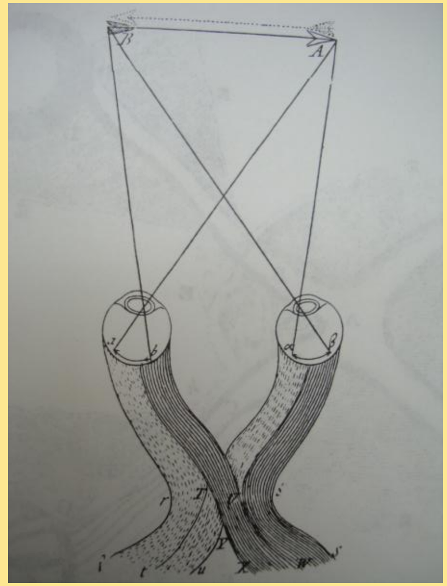
Analogue computer

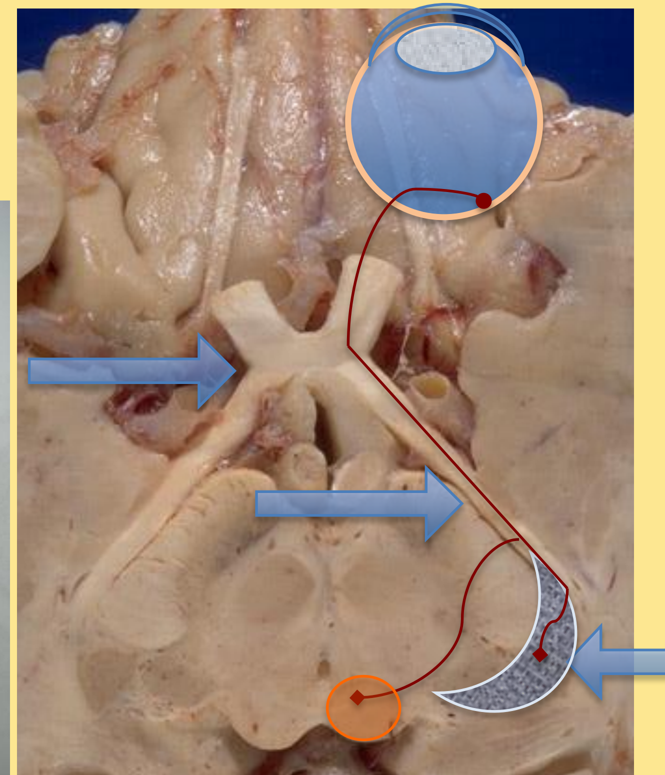
comparing (subtracting) light falling on + area with that on - area











Seeing begins with retinal image

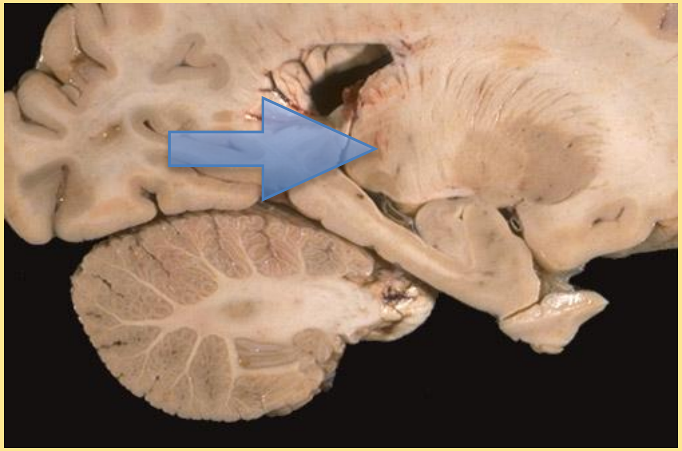
Image processing in retina

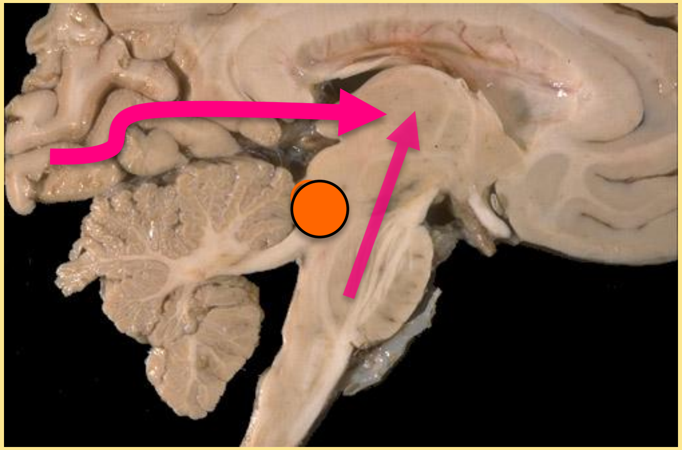
Output is comparison of relative brightness. Not a light meter. Absolute brightness is of no interest to the retina and is not helpful for survival.

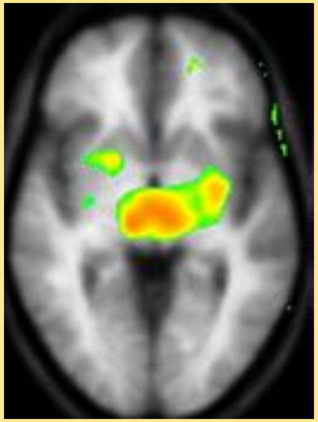
Digital output from retina (on/off) Relay and processing in Thalamus.

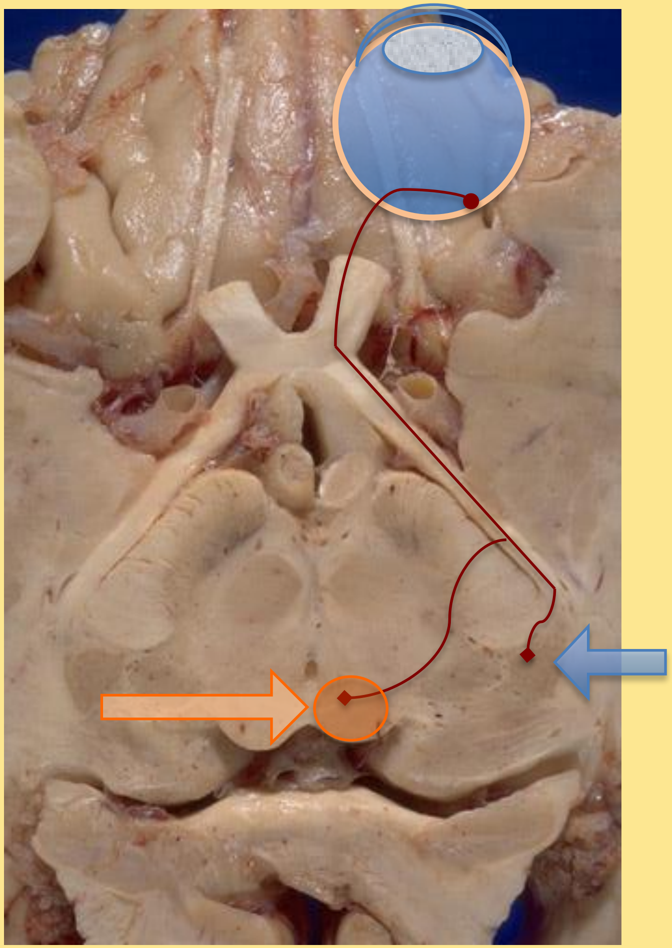
Gospel according to Matthew, Eadfrith. "Christi autem generation sic erat" or "The birth of Christ took place thus." Lindesfarne.

The thalamic relay of visual information: Lateral Geniculate Nucleus









Thalamus a paired structure size and shape of walnut, the switchboard of the brain.
All Sensory input relays in the thalamus
Vision uses the **LGN** whose major input is **not** from the eyes.
85% of input is from
i) reticular formation in pons (arousal, attention, awareness, motor function and sleep)
ii) Primary visual cortex
Remainder is from eye.
6 cell layers, 3 for each eye hemifield
Superior colliculus: Little hill: Moves eye and eyes towards objects

Mapping the scene

Point to point relationship

Parvo-cells: small slow conducting mostly from fovea

What information

Magno-cellular: Large fast conducting.

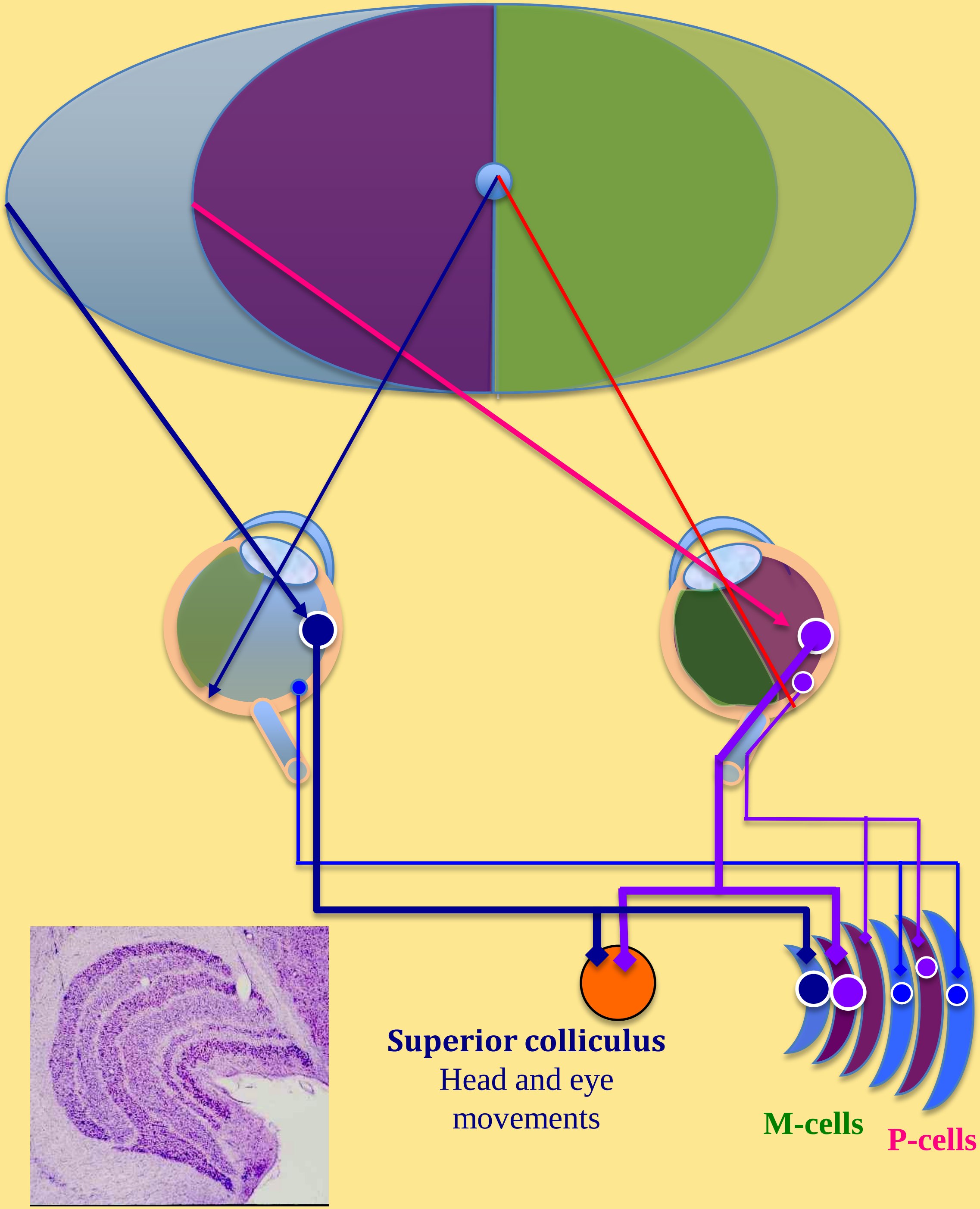
Where information

In the LGN information from the two eyes is kept separate.

6 cell layers, 3 for each eye hemifield.
Duplication of P-layers

All cells in the LGN have circular opponent concentric receptive fields, just like the ganglion cells.

Used for extracting edge/border information.



Purpose of retinal image

To compare number of photons absorbed by different photoreceptors.

The larger and better quality, the smaller the movement of an object needs to be to be detected. Birds have large eyes, collect more light.

The image is converted into map

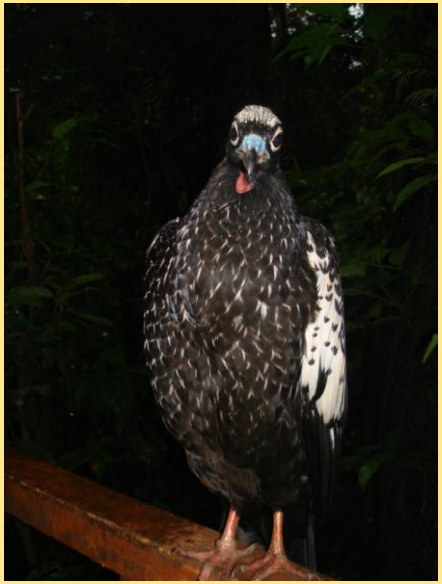
Second map underlies the first map

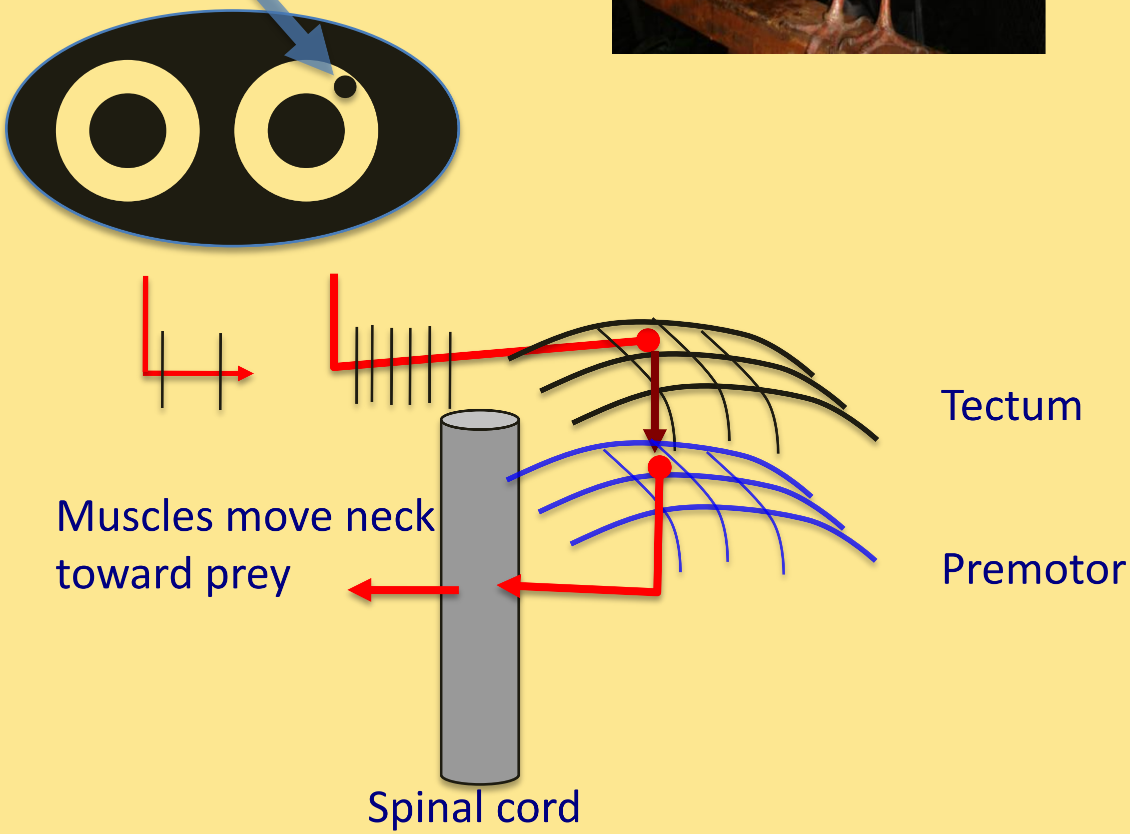
Unconcious automatic

Jaques Vaucansion’s duck

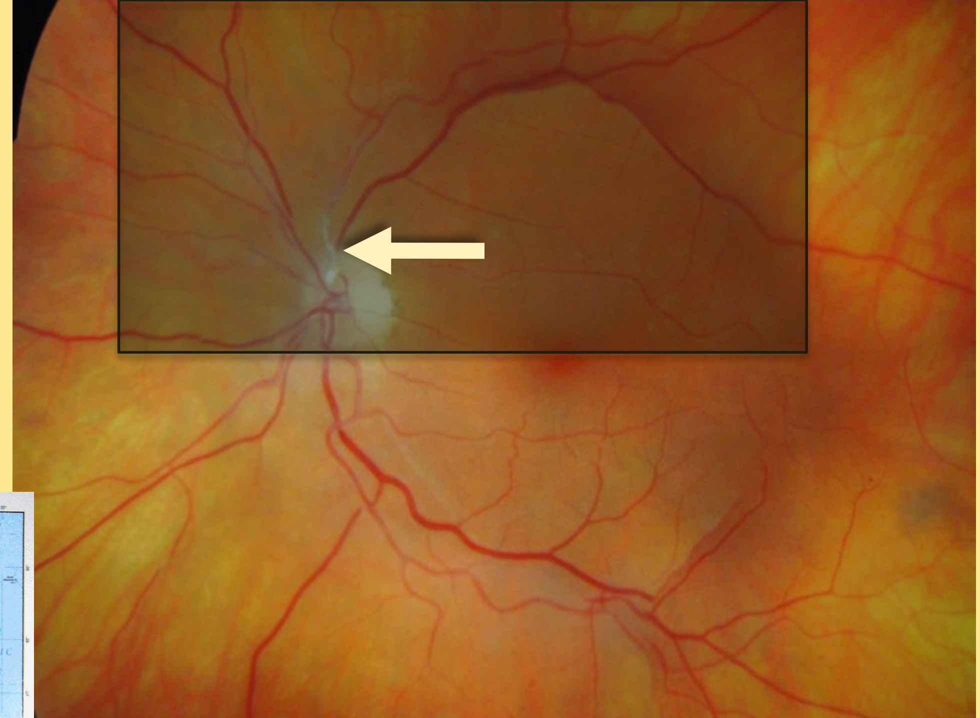
Decarte’s.

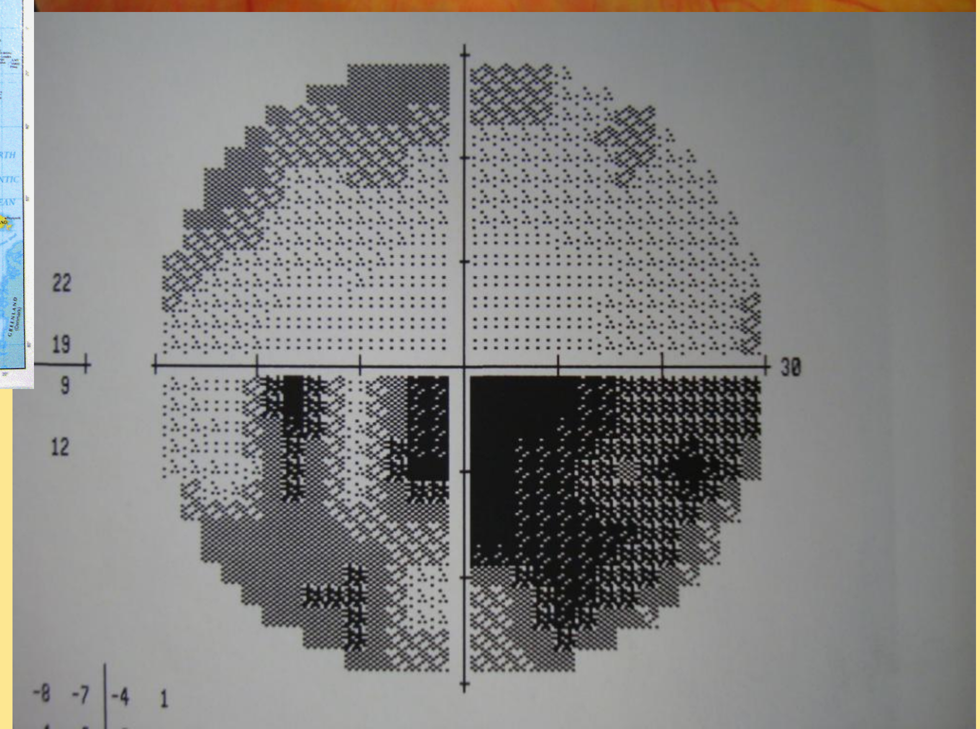
Image is inverted






Upside down
World Map
ANTARCTICA
SOUTHERN OCEAN
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
SOUTH PACIFIC OCEAN
AUSTRALIA
INDONESIA
BRAZIL
CHINA
INDIA
MONGOLIA
KAZAKHSTAN
IRAN
NORTH PACIFIC OCEAN
UNITED STATES OF AMERICA
CANADA
RUSSIAN FEDERATION
NORTH ATLANTIC OCEAN
ARCTIC OCEAN
GREENLAND




22
19
9
12
30
-8 -7 -4 1

Different parts of the brain do different jobs

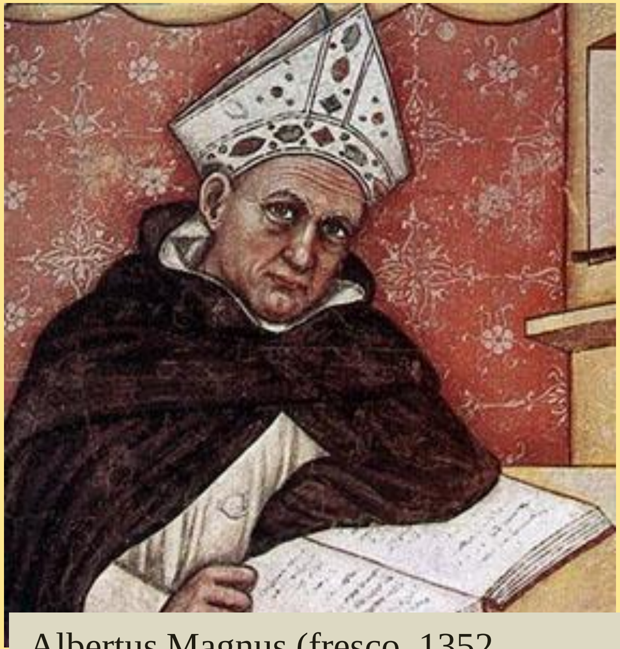
Albertus Magnus. Introduces the idea of localisation of different functions in different parts of the brain. Simplified by disciples for teaching less learned monks

After leaving the Thalamus, processed information passes to occipital lobe of brain

The scene is mapped yet again and further processing takes place

This edited information is transmitted across the surface of half of the brain, temporal and parietal lobes where specific tasks take place to extract information about object recognition, movement, colour etc

Higher centres?



Albertus Magnus (fresco, 1352, Treviso) Tommaso da Modena

Thomas Willis 1621-1675
Gresham connection

Importance of the cortex.

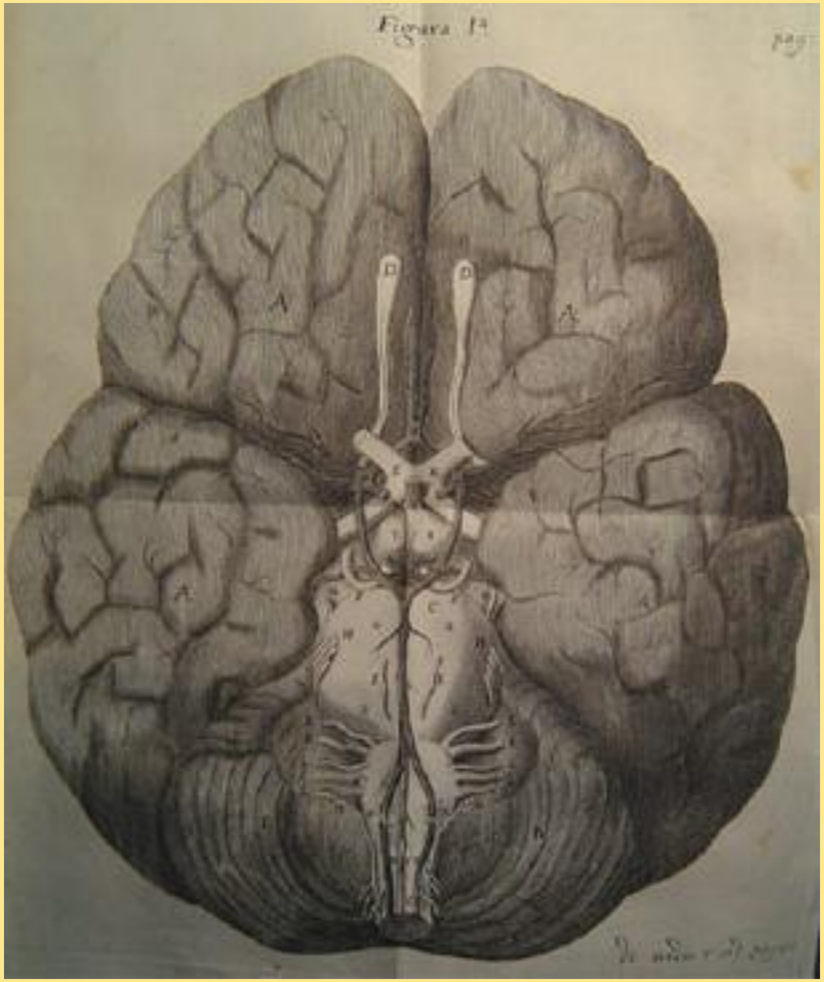
1664: **Cerebri Anatomie:** Opposed the concept of ventricular localization of brain function and proposed 3 areas in the brain:

corpus striatum received sensory input,

corpus callosum, converted to perception and imagination in the hard overlying tissue,

cerebral cortex where they were stored as memories.

Theory on brain function achieved widespread influence for more than a century.



Christopher Wren (1632–1723). familiar with anatomy, had performed many experiments, making models of muscles and eyes. injections India ink into the carotid arteries, used by Willis & Lower to determine circulation of the brain.

Alcohol allowed retention of well-preserved specimens of brains with anatomical details for the artist.

Cortex is not uniform structure

Francesco Gennari 1776, medical student student University of Parma, used ice to stabilise the brain and studied sections. No microscope, no staining.

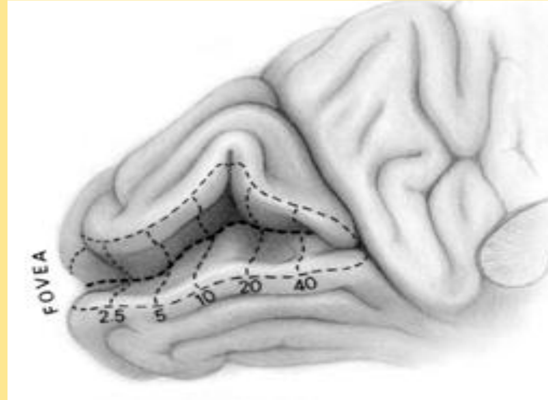
He found in these unstained frozen sections a white line in posterior (back)part of brain.

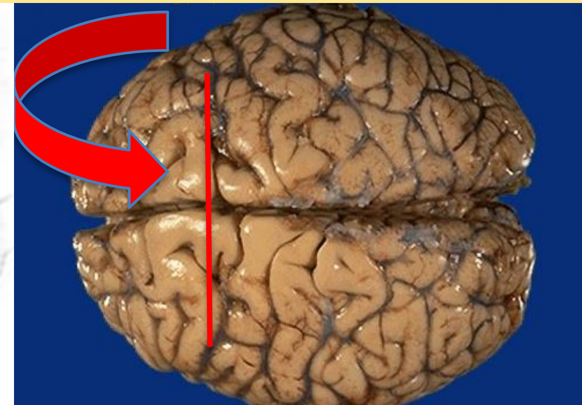
The cortex was not a simple rind

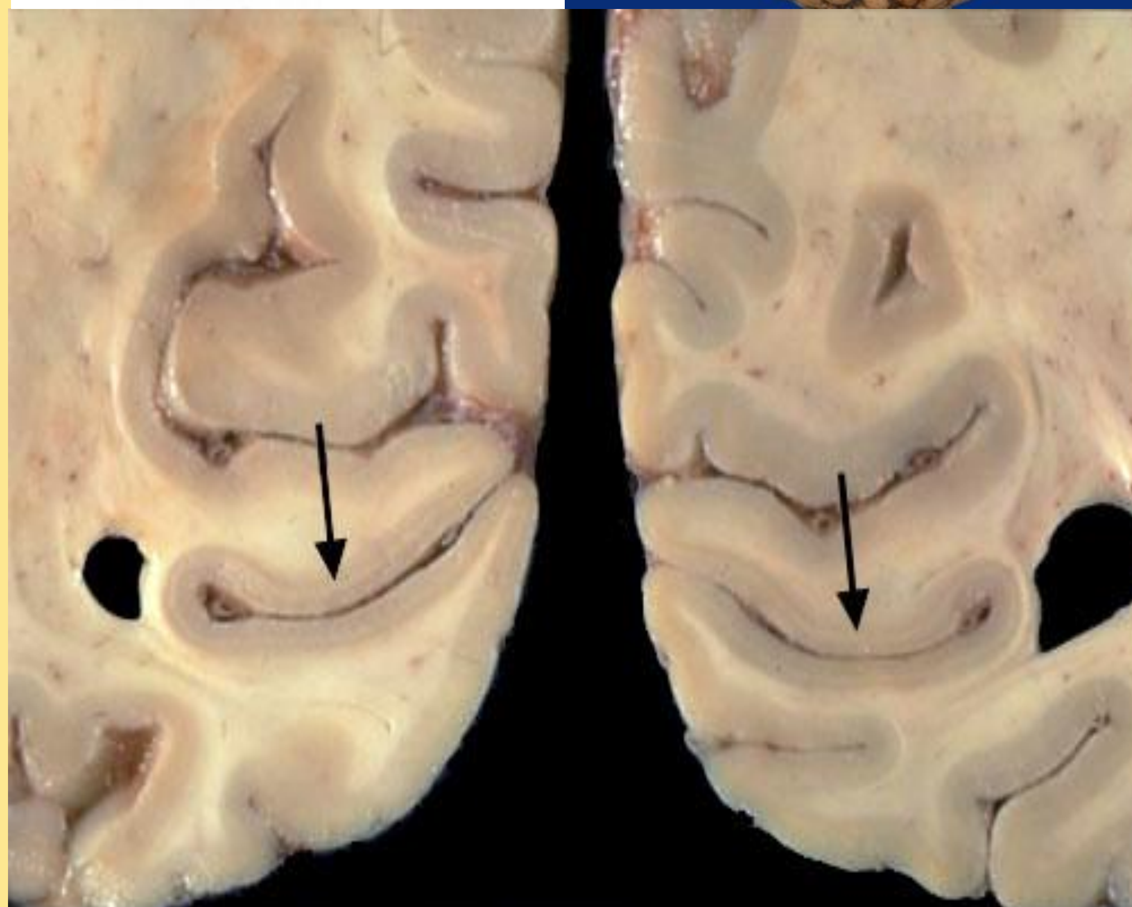
"**I** do not know the purpose for which this substance was created."

De Peculiari Structura Cerebri.

Said to be difficult and a compulsive gambler, briefly imprisoned and died poor.







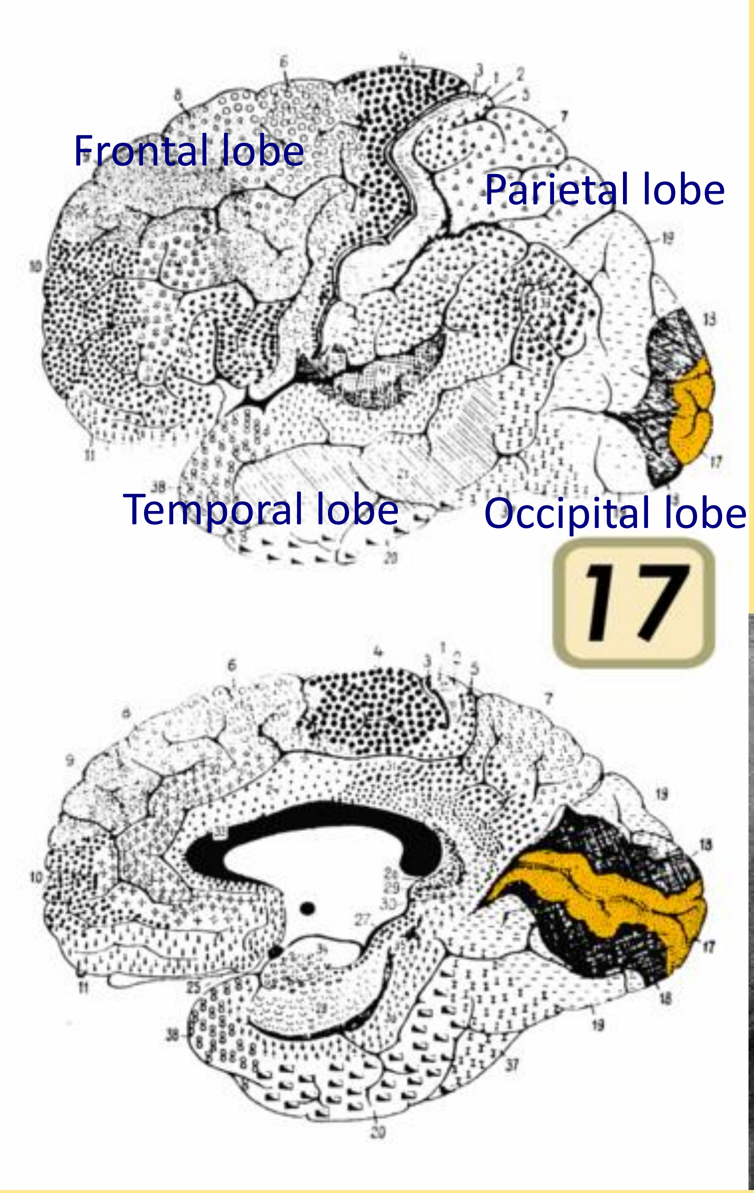
Arrangement of different types of neurones are distinct in separate areas of the cortex.

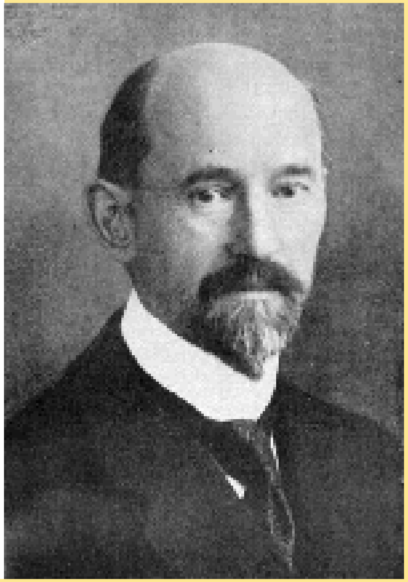
Korbinian Brodmann (1868 –1918) German neurologist studied organization of neurons he observed in the cortex using the Nissl stain.

Classified cortex into 52 distinct regions from these cytoarchitectonic features.

1909 published his original research on cortical cytoarchitectonics as

"Vergleichende Lokalisationslehre der Großhirnrinde in ihren Prinzipien dargestellt auf Grund des Zellenbaues" *(Comparative Localization Studies in the Brain Cortex, its Fundamentals Represented on the Basis of its Cellular Architecture)*





Vision is located in the occipital lobe

Franz Joseph Gall 1758-1828: Noted at school that boys with phenonemal memory also had "les yeux å fleur de téte" Bulls eyes. Proposed overdevelopment of the frontal lobes.

Studied medicine Strasbourg, completed his degree in Vienna.

Neuroanatomist, (first to dissect crossing pyramidal fibres) physiologist, and pioneer in the study of the localization of mental functions in the brain.

Different functions in different areas

White matter has conducting properties

Brain folded to save space.

Brain localization was revolutionary, contrary to religion

the mind, created by God, should have a physical seat in brain

Bartolomeo Panizza (1785 – 1867): Bologna and Pavia.

Follower of Gall

examined brains of pts blind after strokes; experiments on animal brains: **the occipital brain was crucial for vision.**

Discovery ignored: theory of the thalamus as the highest sensory centre and the cortex associated with intellectual function.

None of Gall's Phrenology areas for example, had sensory nor motor function.

It took a horrible wars to prove him correct.


Waterloo

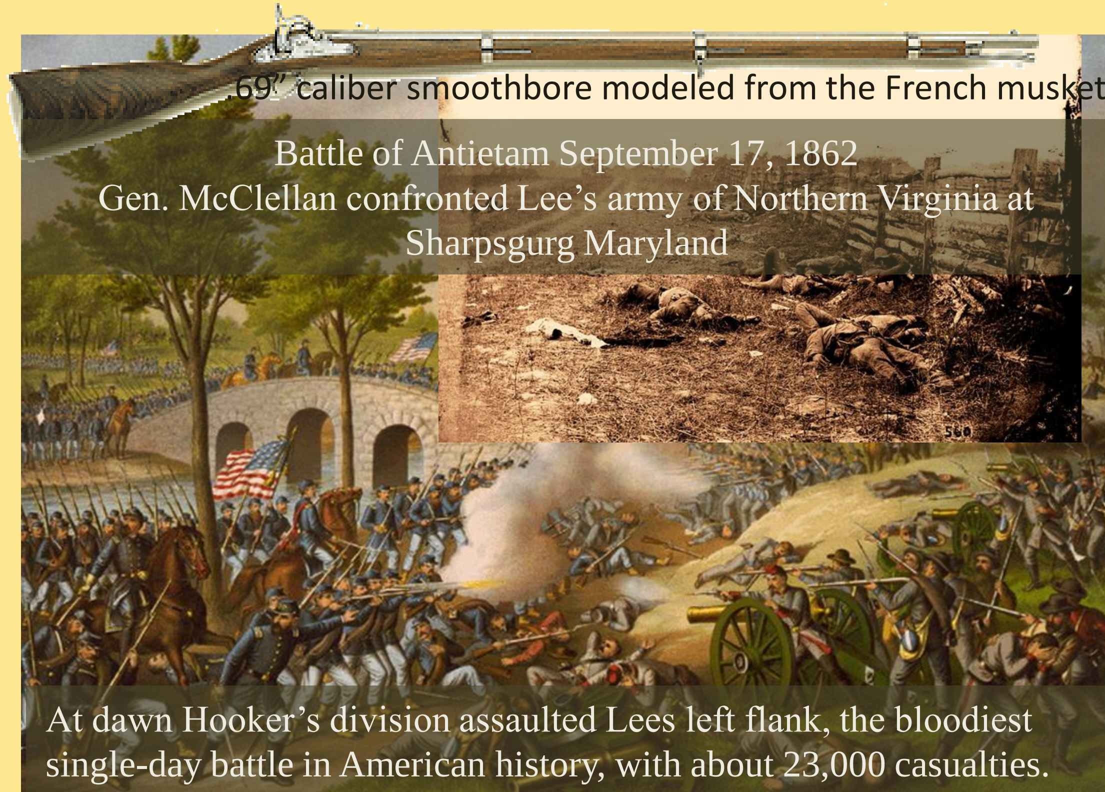
The visual map in the brain is centred on fixation

4th New York at the left front were the first to receive fire of the North Carolina regiments of Anderson’s Brigade. Private Patrick Hughes, Irish immigrant, shot in head with a musket.

8 yrs later: **Drs. Keen & Thomson;** complained that sight in his right eye was poor, however whiskey affected him as usual and his sexual prowess was undiminished!

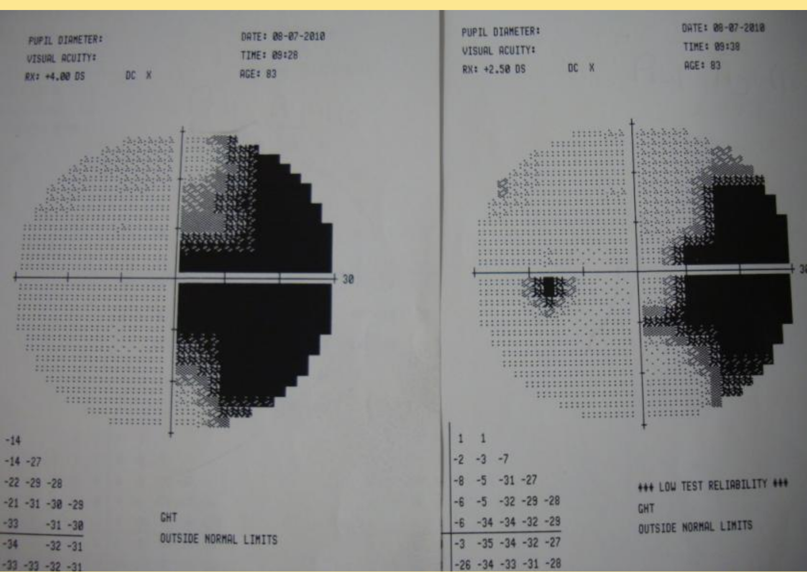
They carefully plotted the visual field and showed it was split down the middle of the foveal fixation.

The visual map in the brain is therefore centred on the fovea, with one half coming from the world located on the left side of fixation and one half coming from the right side.



Battle of Antietam September 17, 1862
Gen. McClellan confronted Lee’s army of Northern Virginia at Sharpsgurg Maryland

At dawn Hooker’s division assaulted Lees left flank, the bloodiest single-day battle in American history, with about 23,000 casualties.



rivate Patrick Hughes, Co. K, 4th New York Volunteers, was wounded at the battle f Antietam on September 17, 1862. He survived his head wound although a cone vould form from it when he sneezed. Painting by Edward Stauch.*The Medical and urgical History of the War of the Rebellion, 1870)*

Image is reassembled into maps

Image is a pattern of light and dark

Map is a device for transmitting information

Many types of information

Object connections: (Harry Beck 1931 tube map)

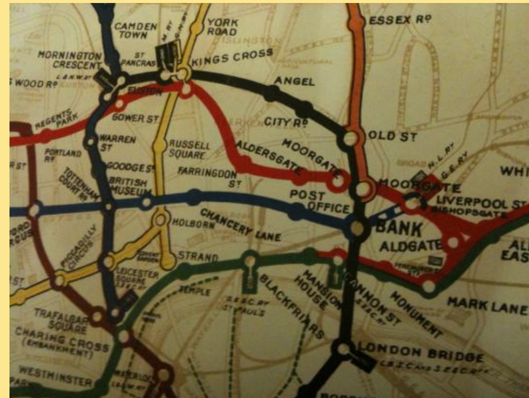
Spatial: Paris tube

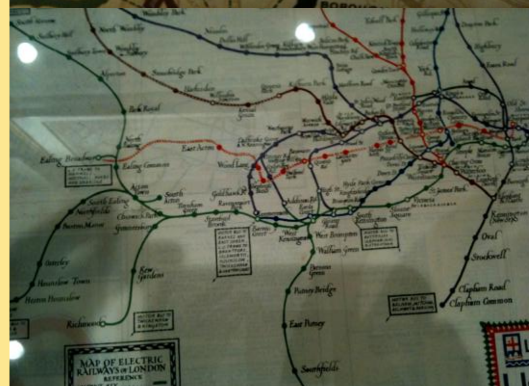
Non-spatial:

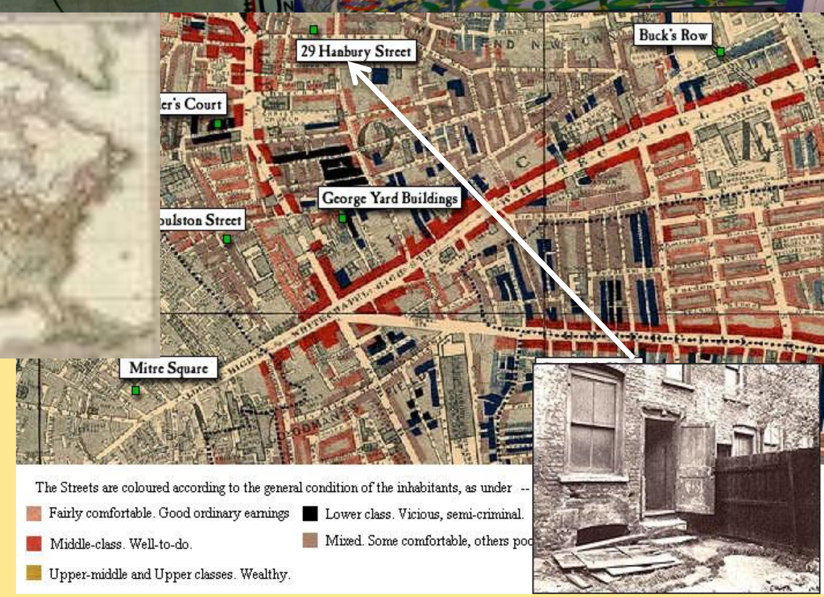
Wyld chart of civilizations 1815:

(Morgan). Colours countries according to civilisation level. From England V through Canada II (for containing cannibals and Frenchmen) either of whom elevated it above Australia (I)

Booth’s Poverty Map







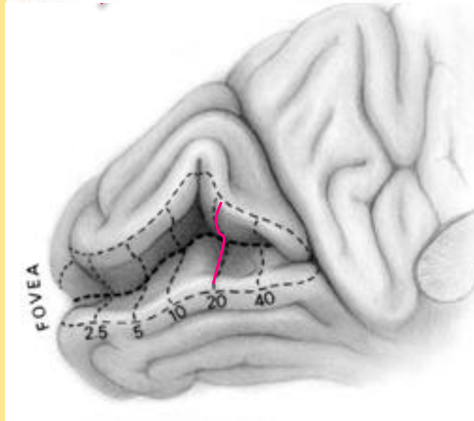
Tatsuji Inouye

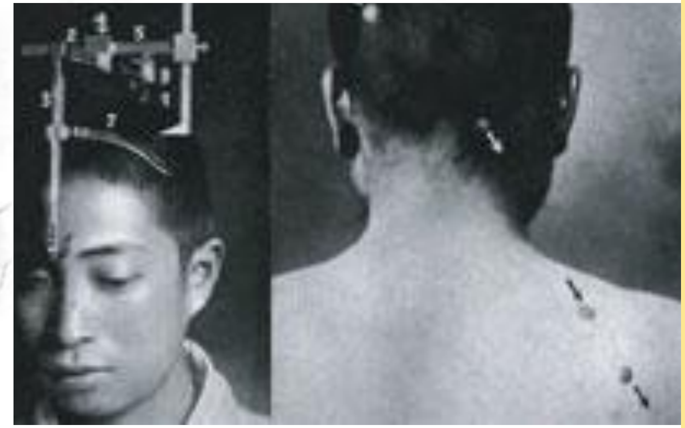
Russians equipped with new **Mosin-Nagant Model 91**. Small diameter 7.6mm, High velocity 620 m/s. Colonel Sergei Ivanovich Mosin designed the bolt and receiver, the Belgian Emile Nagant, designed the magazine system.

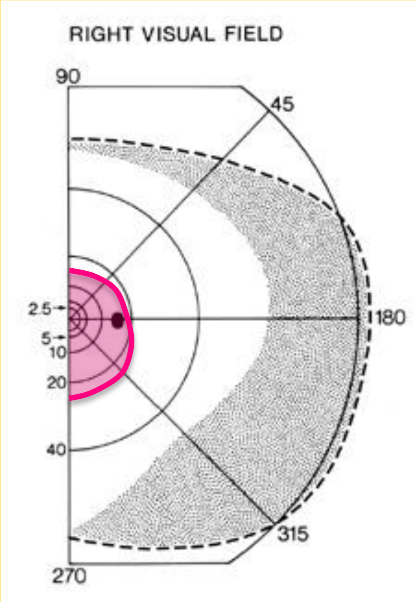
The young Japanese ophthalmologist, Dr. Inouye examined soldiers with visual defects for their pension board.

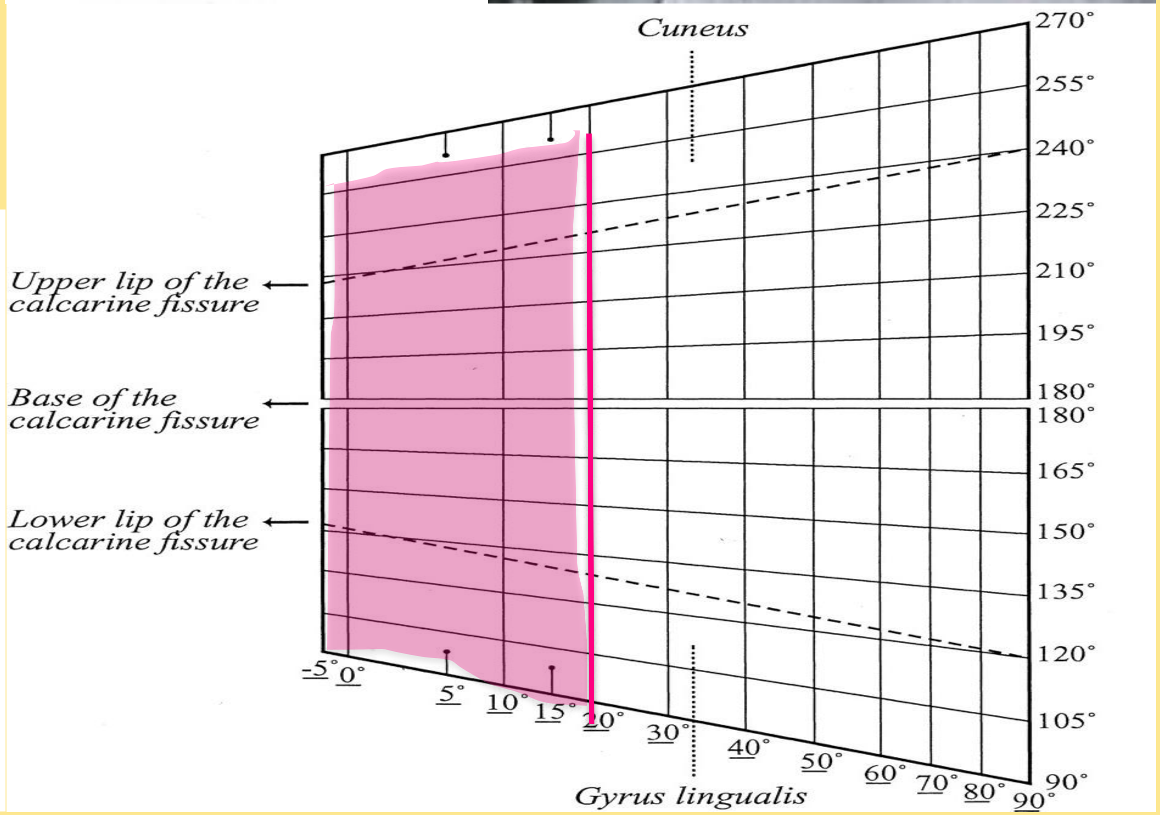
Inouye invented a device called the cranio-coordinometer.

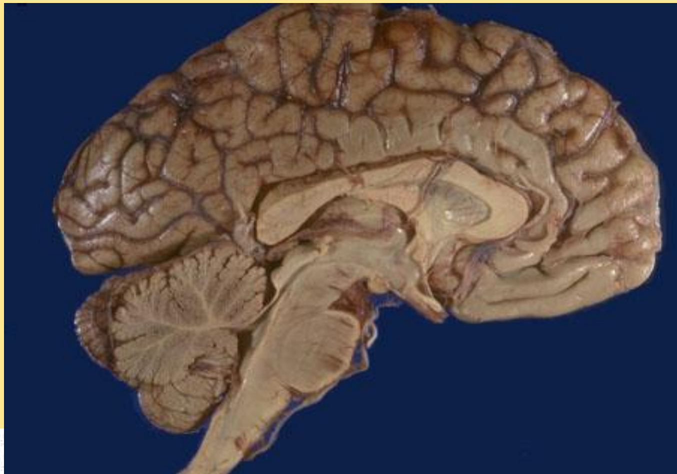
He discovered that vision was mapped in an orderly fashion along the base and walls of the calcarine fissure. Also noted the distortion: The central field is very magnified. Explains Ferrier's result.

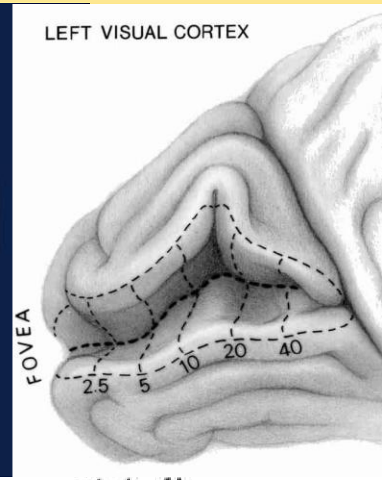


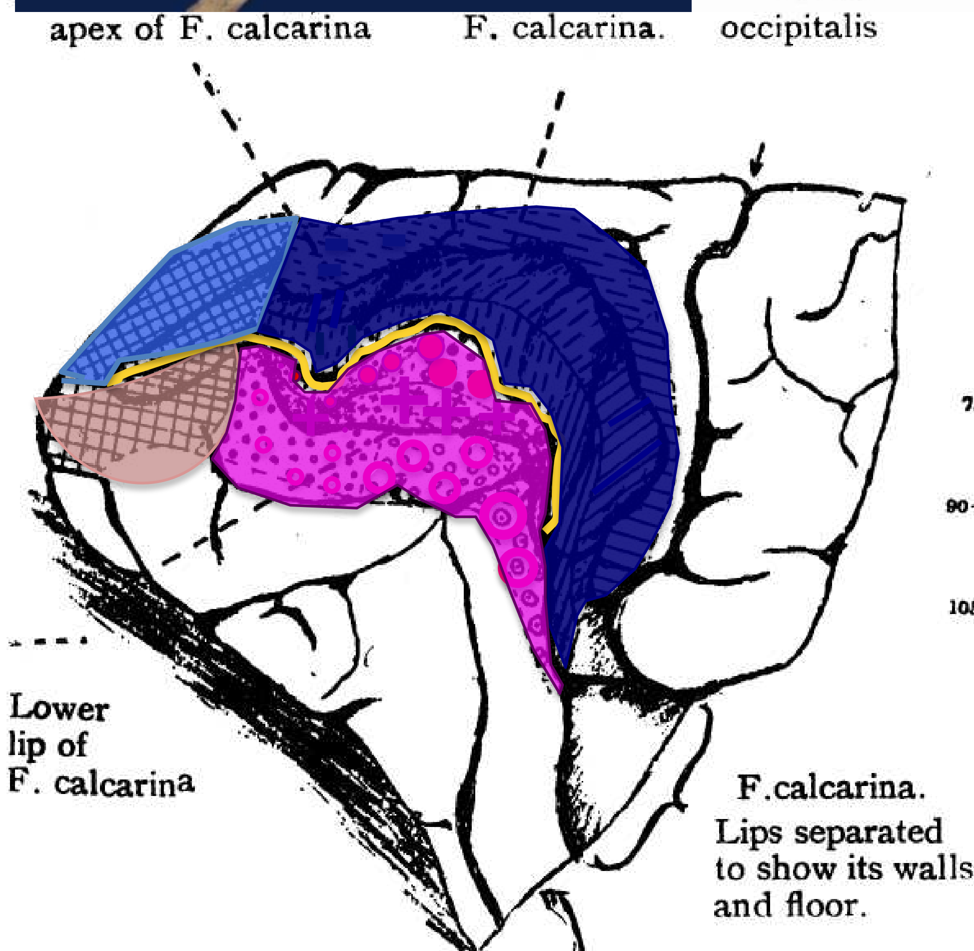


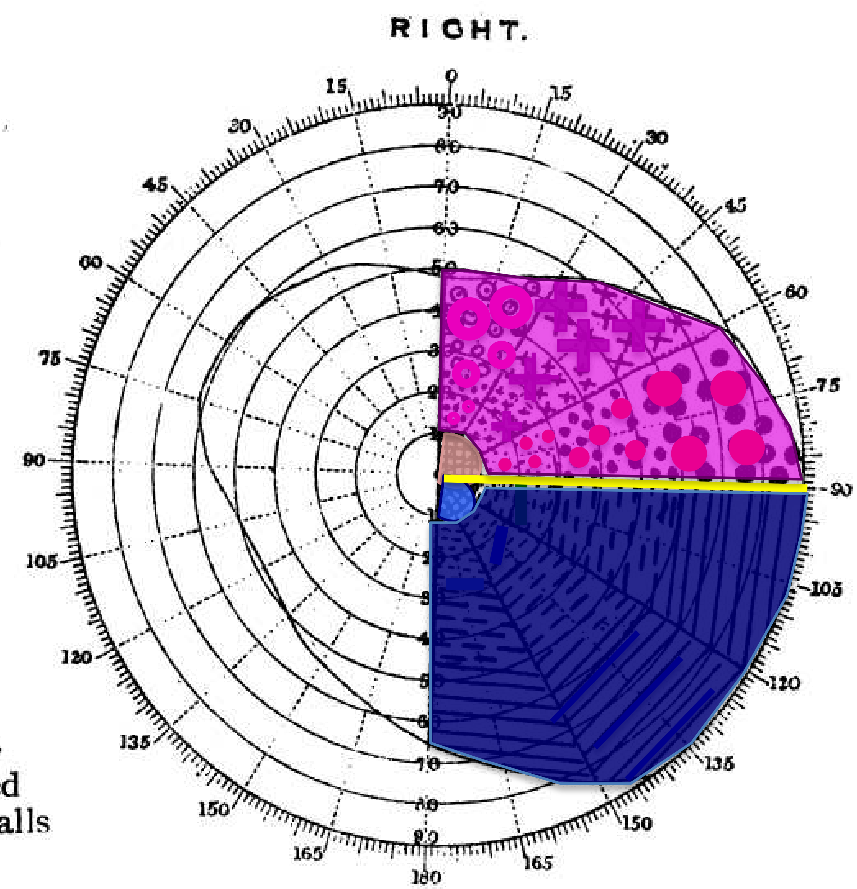







LEFT VISUAL CORTEX
FOVEA
2.5
5
10
20
40


apex of F. calcarina
F. calcarina.
occipitalis
Lower lip of F. calcarina
F.calcarina.
Lips separated to show its walls and floor.


RIGHT.

Modern mapping

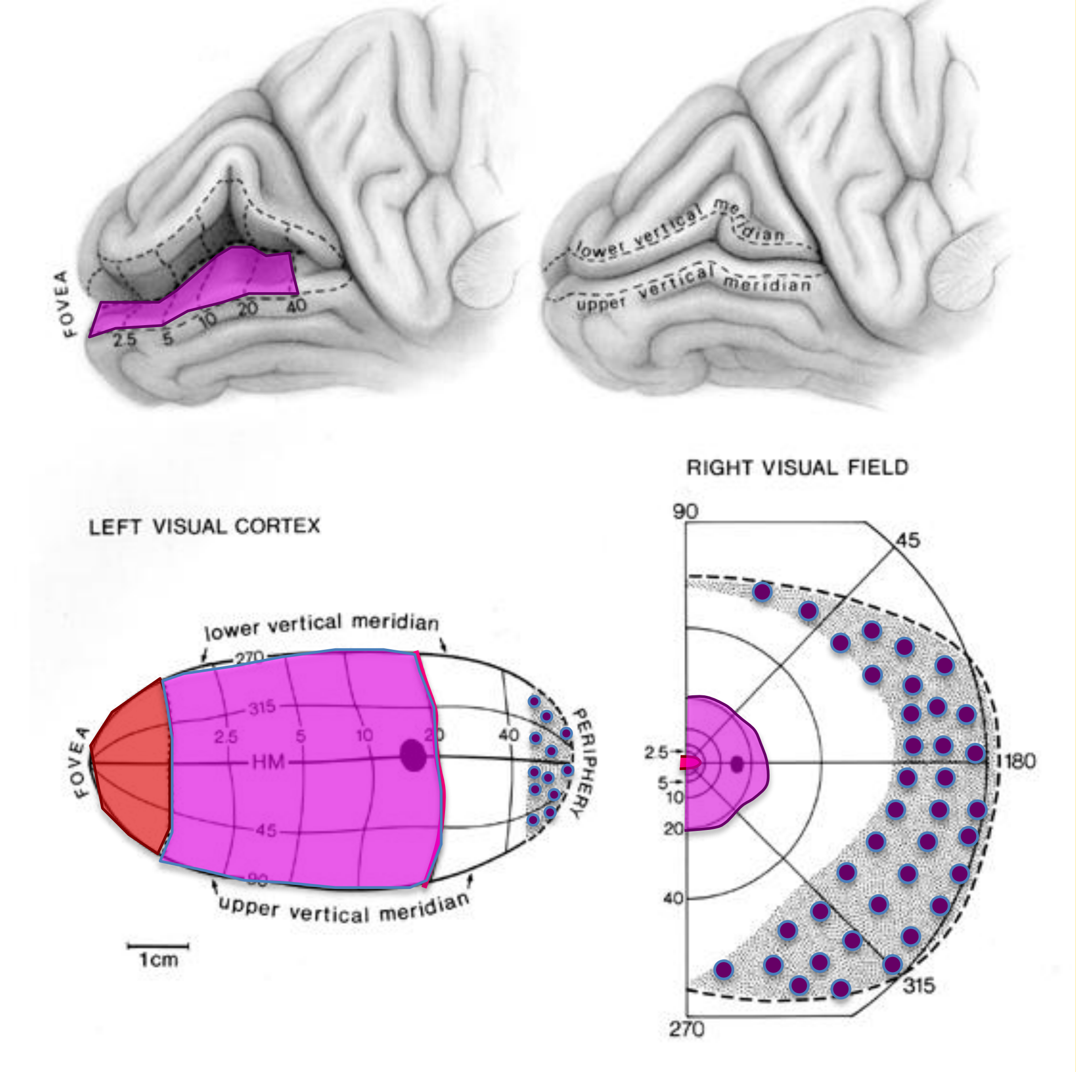
Horton & Hoyt, Arch Ophthal. 109:861, 1991

The representation of central vision is highly magnified compared with peripheral vision.

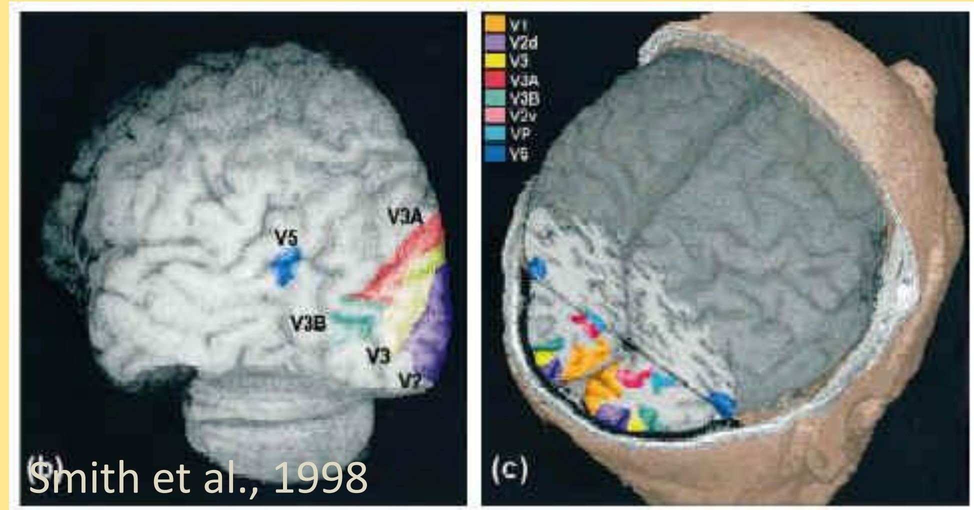
Brain area devoted to the central 1^{o} of visual field roughly equals the cortical area allotted to the entire monocular temporal crescent

Massive % of visual cortex field map devoted to central vision. (55% of the surface of visual cortex represents central 10^{o} of vision.

The cortical "magnification factor" (mm of cortex representing 1^{0} of visual field) 40:1 between the fovea and the periphery at 60^{o} eccentricity. The temporal crescent representation only 5% of surface area of primary visual cortex.



Visual cortex



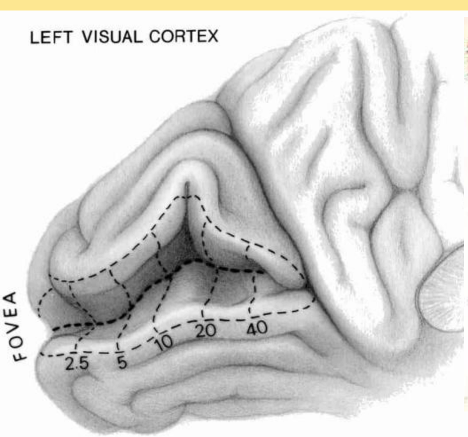
Striate cortex, V1, area 17. Thin sheet of grey matter on surface of brain overlying white matter, folded to maximise area, a plate of cells 2mm thick. 200×10^6 cells (LGN only 1.5×10^6)

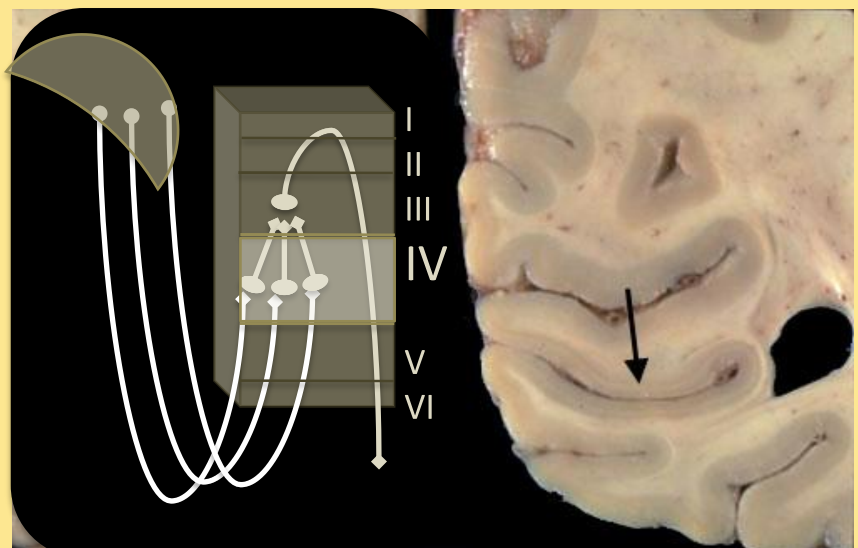
6 Layers

Thick layer 4 is the termination of LGN fibres. Forms a visible stripe (striate)

Tiled $2mm^2$ columns,

analogue super-computers





Columnar organisation

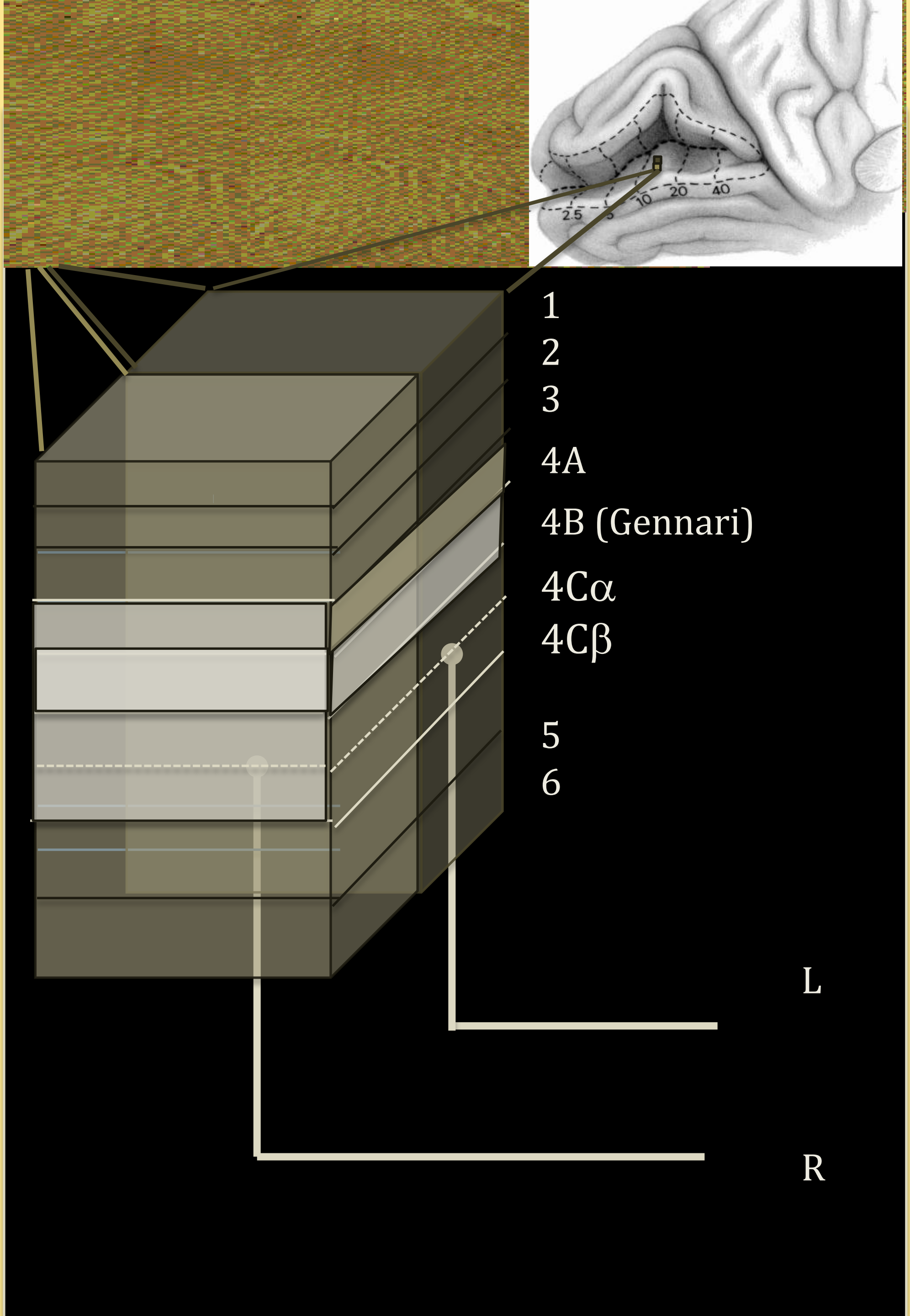
Monocular cells from LGN enter visual cortex in layer 4C. Not randomly distributed but clustered as columns.

Information from the right eye is in a separate column from information derived from the left eye.

This eye preference (dominance) is located in only middle layers.

After relay the information is passed onto cell collected as blobs, above and below layer IV which combine the information from the two eyes.

A useful model that is being updated and represents a simplistic view of reality.



Cells in Visual cortex do not respond to spots of light

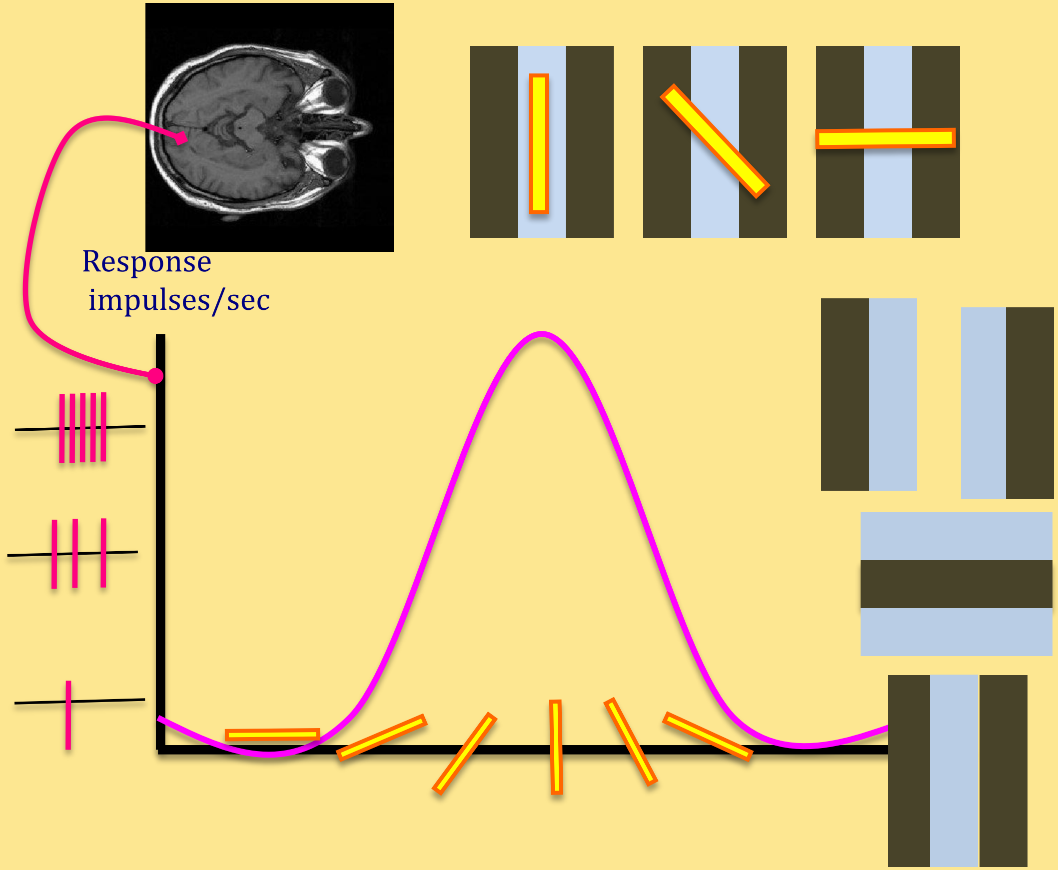
Cells respond best to a slit, dark bar on a light background or an edge boundary between dark and light.

Some cells strongly prefer one of these stimuli over the others; others respond about equally well to all three types of stimuli.

What is critical is the orientation of the line

Response, decays as orientation tilts

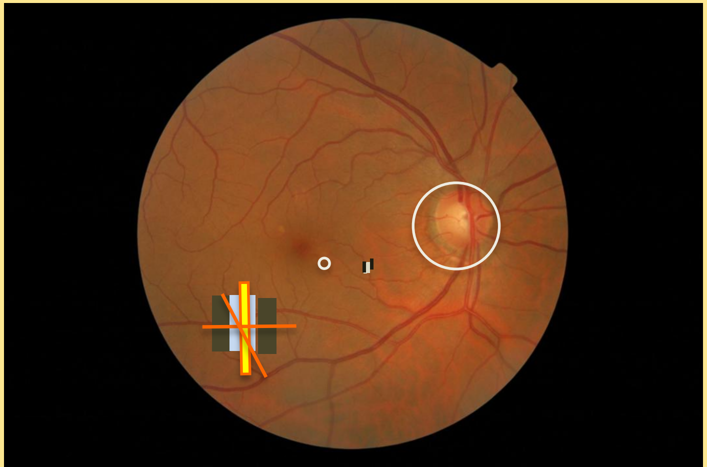
No response 90^0 degrees to the optimal.



Unlike cells at earlier stages in the visual path, these cells respond better to a moving than to a stationary line.

Size: near fovea 0.25^0. (moon 0.52^0 150µm)

In periphery 1^0 (288µm)



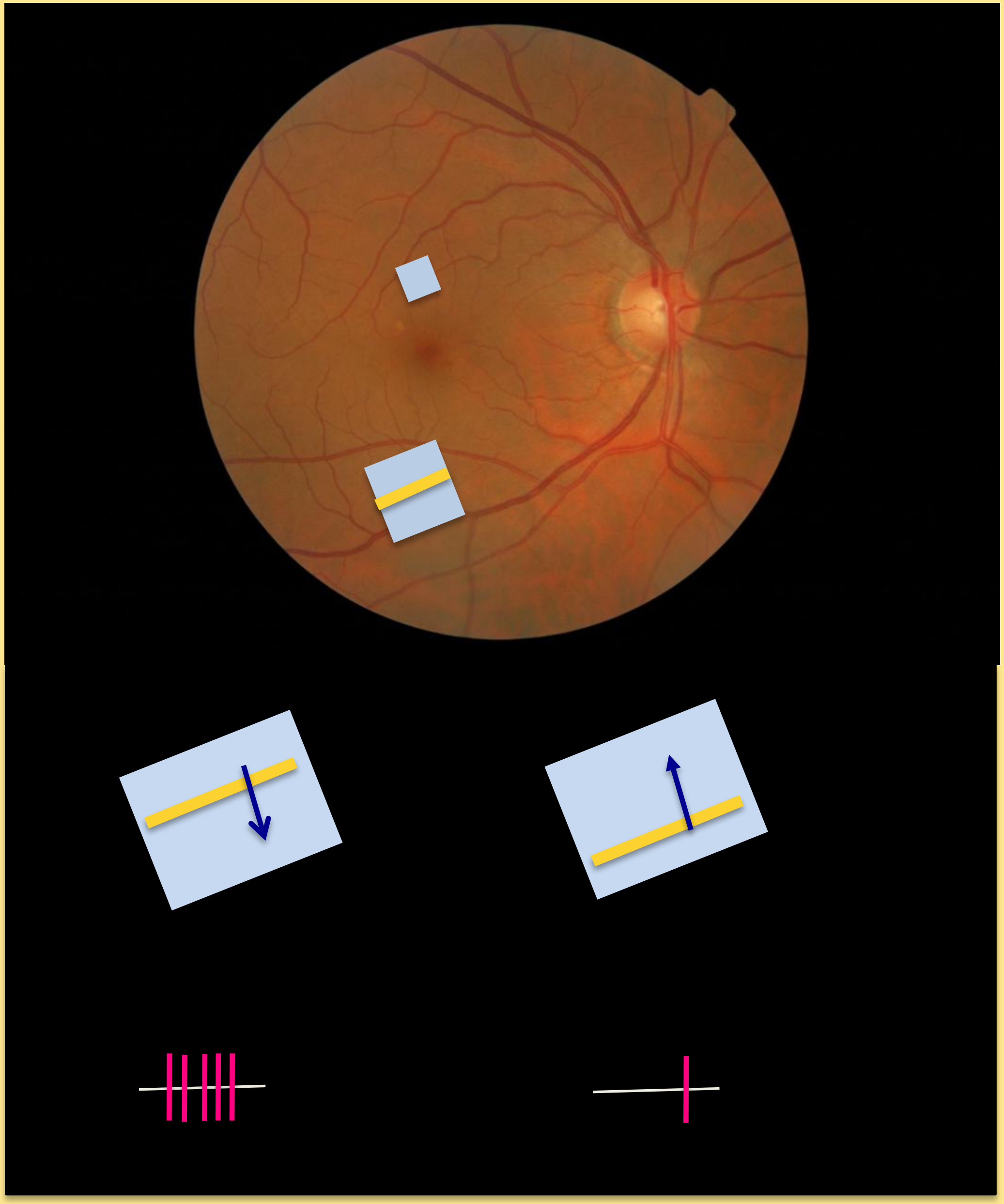
Complex cells in the visual cortex

Complex cells like simple cells respond only to specifically oriented lines.

Do not have inhibitory regions so no ON/OFF architecture. The complex cell therefore doesn't care where the stimulating bar of light is in the receptive field. (Simple cells switch off when the light touches the inhibitory edge)

In ~20% of cells, respond better to one direction of movement, the reverse may even elicit no firing of the cell.

Larger receptive fields 0.5^0

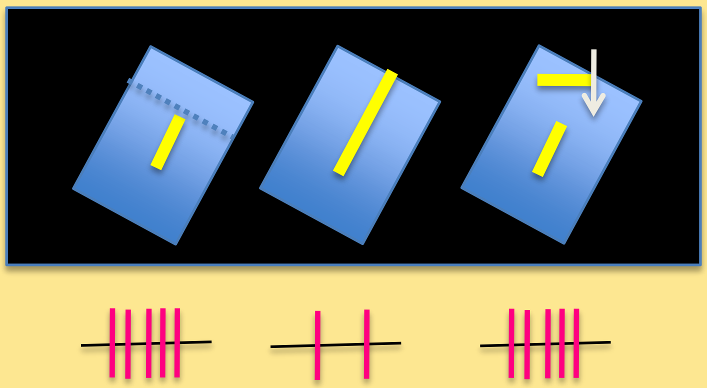


Hyper-Complex cells

End-stopped complex cells:

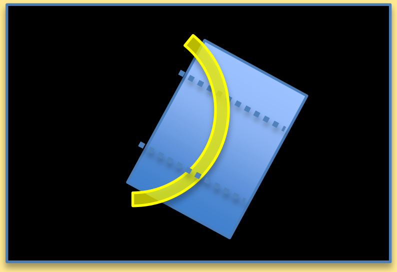
For an *end-stopped cell*, lengthening the line improves the response up to some limit, exceeding that limit results in a weaker response

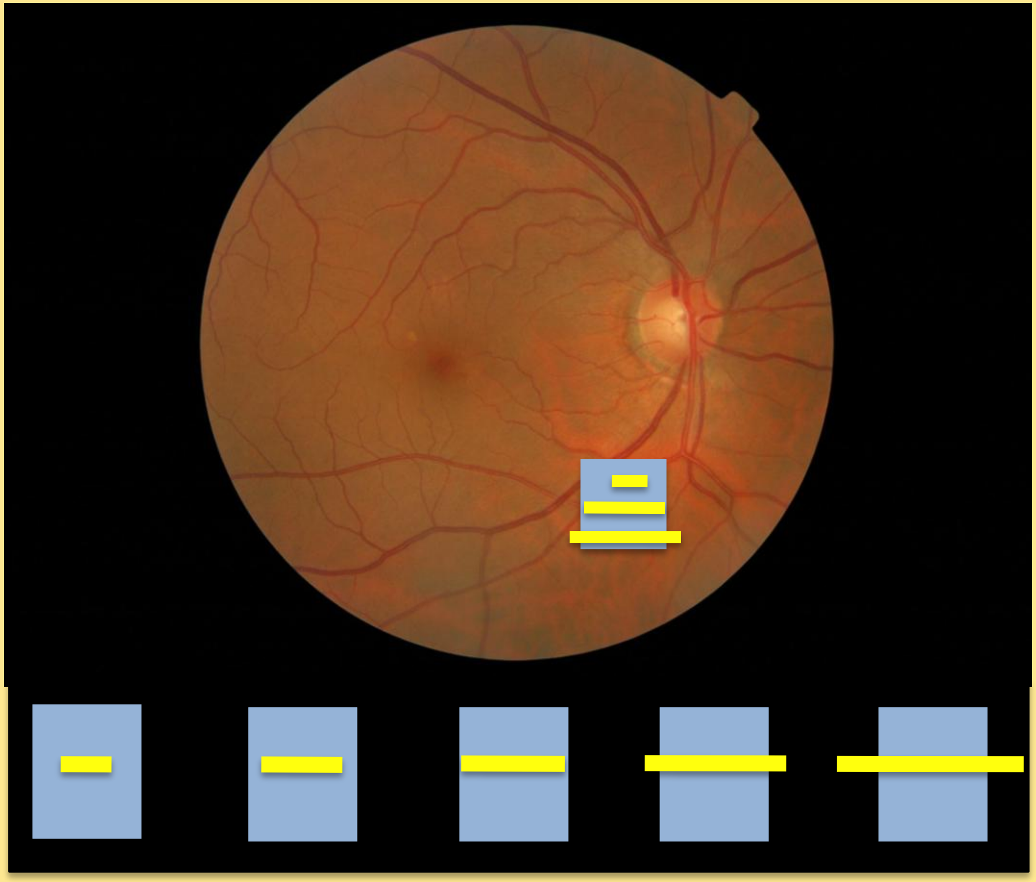
End stopped cells type 2

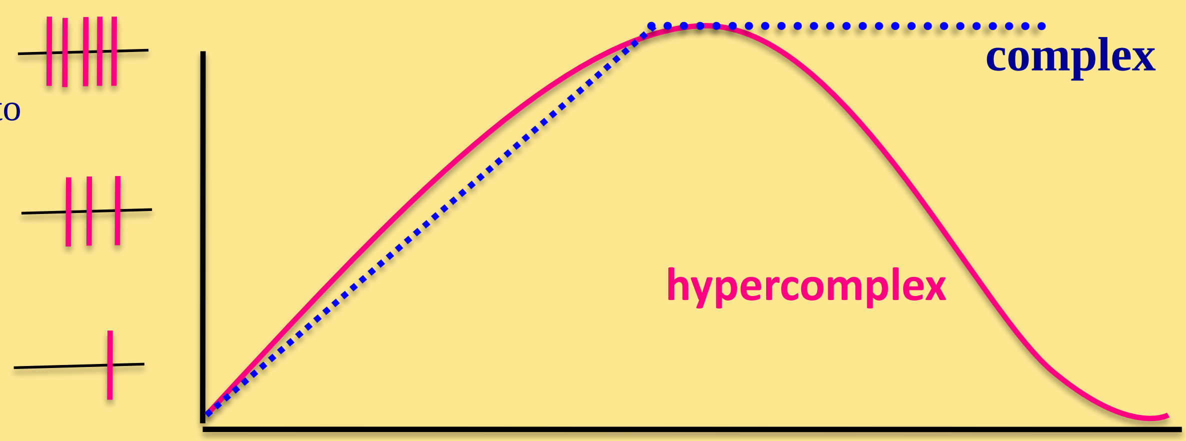


The inhibitory bit has same orientation as the excitatory line.

end-stopped cells are sensitive to corners, to curvature, or to sudden breaks in lines.

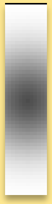


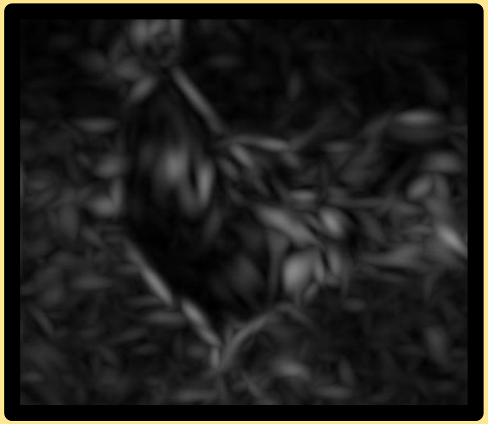




The map in the Visual brain is quite different from the retinal image

Composed of points which are complex analogue computers.



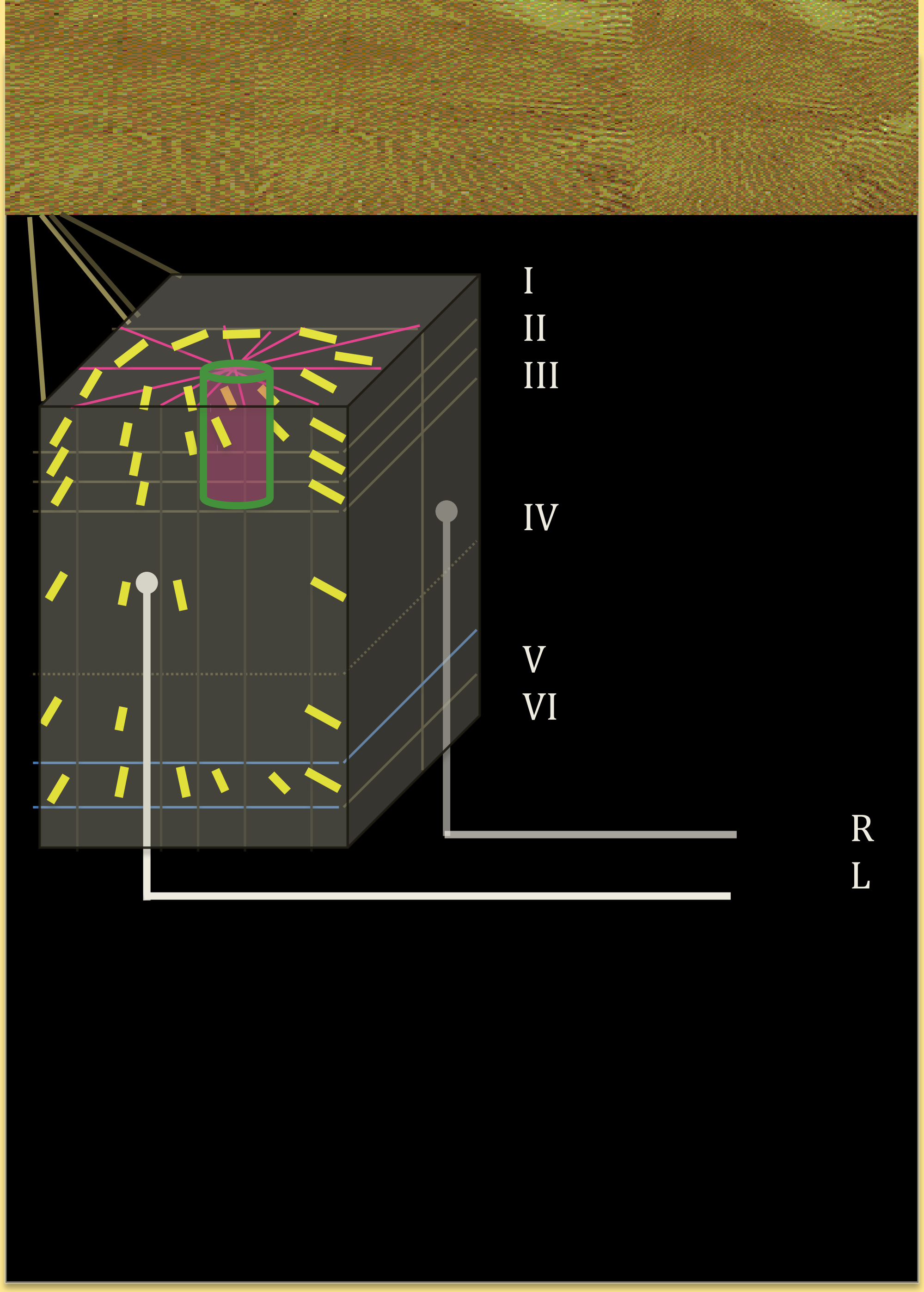


information extracted in the visual cortex

Stereopsis (depth perception)

Disparity between the two sets of information allows the brain to construct stereopsis, a realistic impression of depth.

Orientation of lines: radiating from the centre are vertical arrays of simple and complex cells with the same orientation sensitivity.

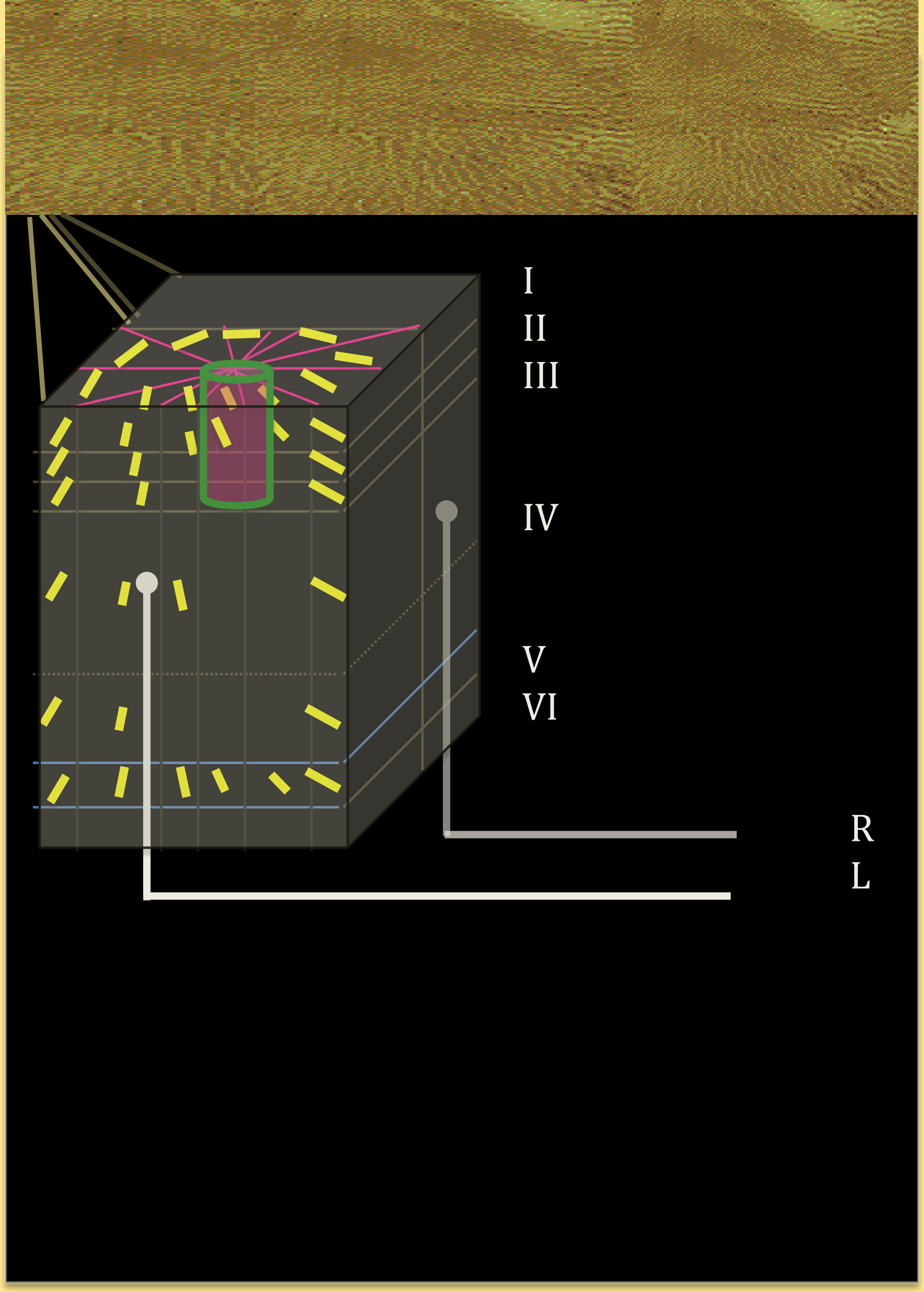


information extracted in the visual cortex

Blobs: cylindrical areas of the visual cortex where groups of neurons group. Maggie Wong-Riley 1979: cytochrome oxidase stain. They are located In the centre of the dominance columns

contain centre-surround opponent cells sensitive to colour,

Red-green cells respond to local color contrast (red next to green) compare the relative amounts of red-green in one part of a scene to the next-door part of the scene. color constancy (Edwin H. Land retinex theory).



Associated visual areas

David Ferrier 1843-1928: West Riding Lunatic Asylum, electrical stimulation animal brains: Correctly localised brain tumour in paralysed pt: Allowed **Mr. Macewen**, to remove it safely.

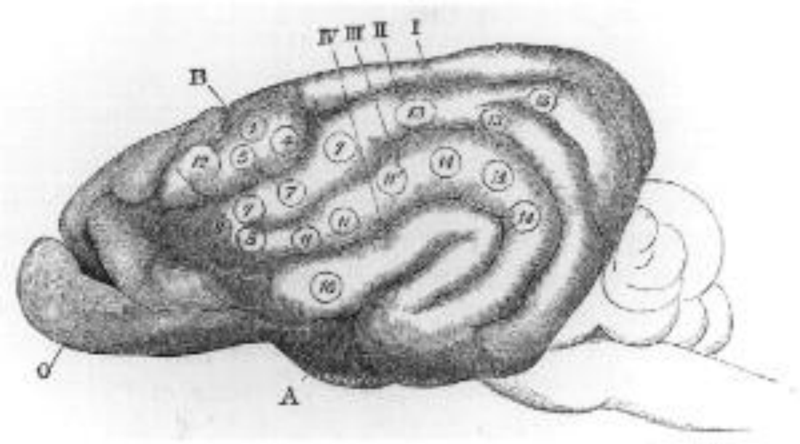
Experiments on vision more controversial. Removing the angular gyrus in a monkey made it unable to locate a cup of tea.

Herman Munk: Berlin Vetinary School, occipital lobe was where vision occurred. Removal of one lobe created blindness on the other side (hemianopia).

1881 physiological society. "I have not said anything about Ferrier's work because there is nothing good to say about it" "Mr. Ferrier has not made one correct guess, all his statements have turned out to be wrong".

Ferrier had not removed all of the occipital lobe. Only a small remaining bit will still allow peripheral vision. You have to remove a lot of the brain.

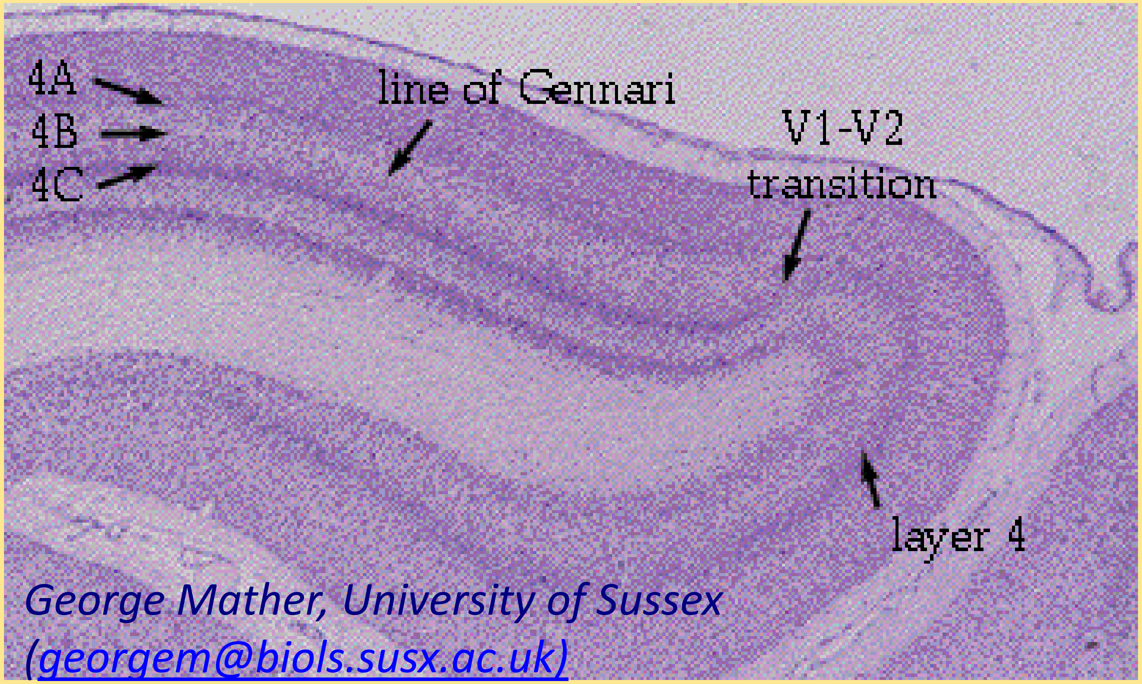
However demonstrated that other parts of the brain were concerned with vision.



Why does the brain contain so many cortical areas for vision?

Two schools of thought about how information is passed from the primary visual cortex (V1) to other visual areas of the brain.

1. the visual image is first processed in V1, and then passes intact through a series of higher cortical areas for further processing to extract perception.
2. images are broken down in V1 to components, colour, form and motion, these individual components are then pass on using their own private channels (parallel processing) to visual areas next to the striate cortex (extrastriate areas) specialized for their analysis. Livingstone and Hubel (1984, 1987).

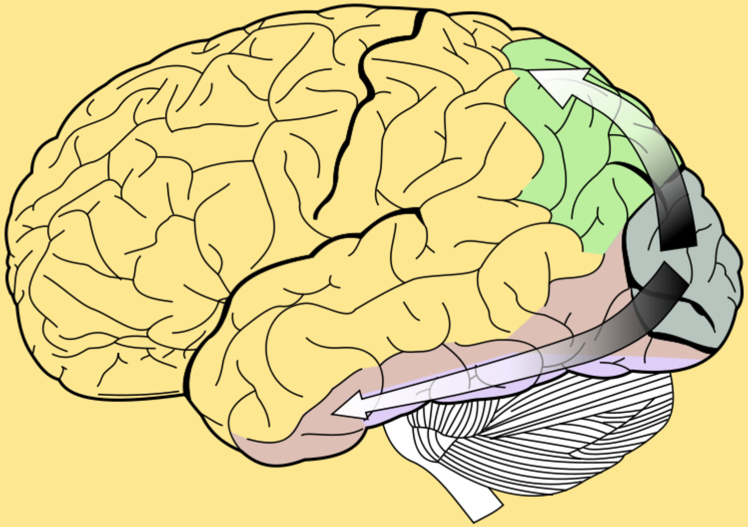


Visual area V2

First of the visual association areas.

Sends connections to **V3, V4**, and **V5**. It also returns feedback connections to **V1**.

Anatomically, V2 is split into a dorsal and ventral representation. Together providing a complete map of the visual world. V2 has many similarities with V1. Cells are sensitive to; orientation, spatial frequency, and color.



V2

V2 long common border with V1. Map is mirror-image of the V1 map.

Input is from V1 and Pulvinar largest thalamic nucleus

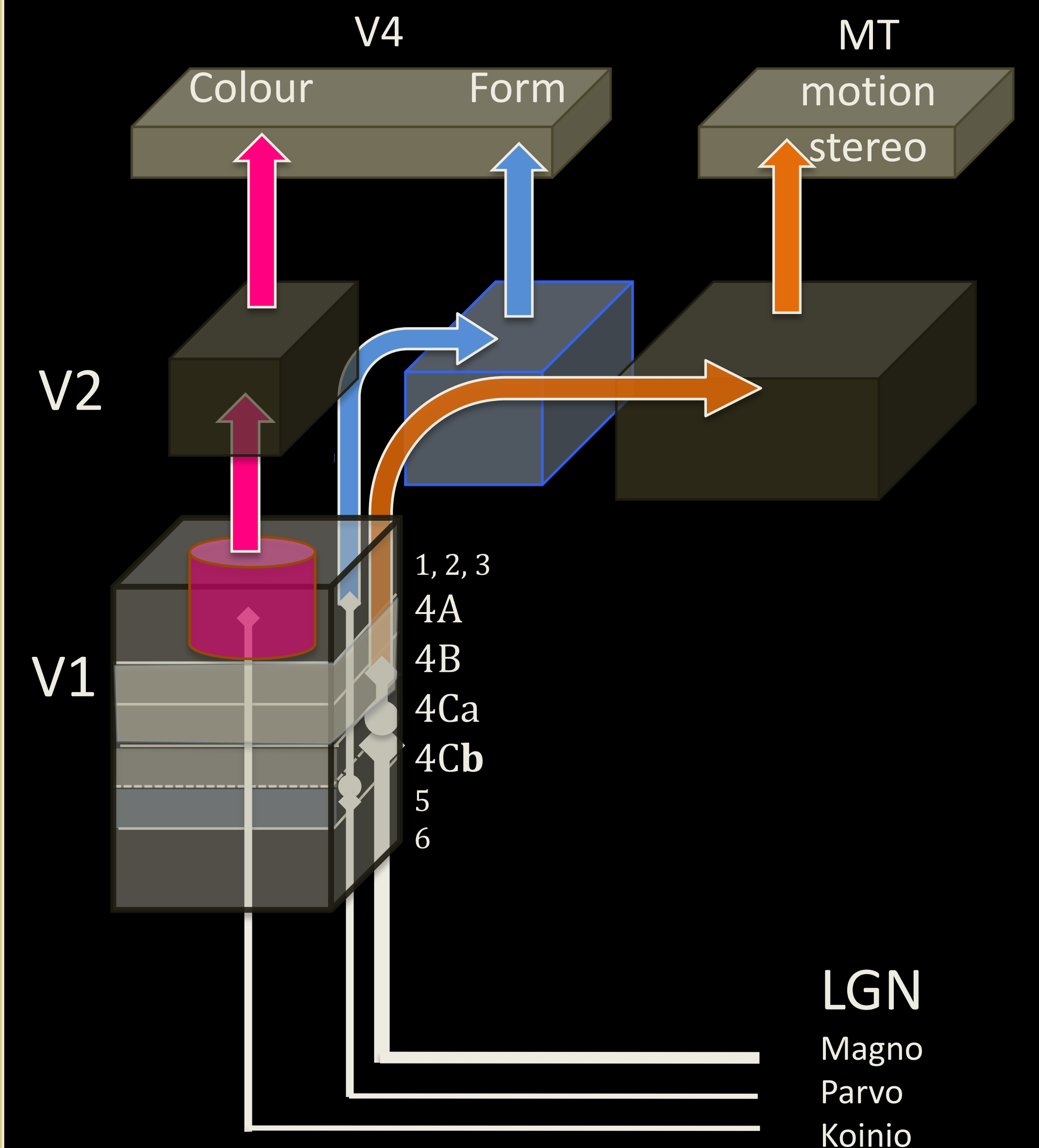
Thick stripes: magnocellular pathway. project to V3 and MT

Interstripes, receive input from the blobs and interblob regions of layers 2 & 3 of V1: project to V4, **parvocellular** pathway.

Thin stripes, input from the blobs of layers 2 & 3 of V1. project to V4: part of the parvocellular pathway.

M and P pathways not completely separate also a projection from V4 back to the thick stripes. There are also direct connections between MT and V4 and V3).

Sinich & Horton Neurology 2002



Compartmentalization of visual information from the lateral geniculate body to extrastriate cortex, according the scheme proposed by Livingstone and Hubel (Science 1988)

Orientation and depth

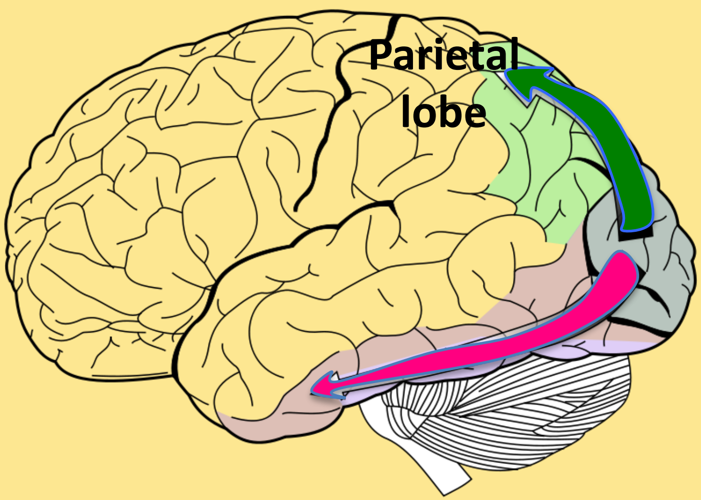
V3: Inputs from the **thick stripes** in V2, and from layer 4B in V1.

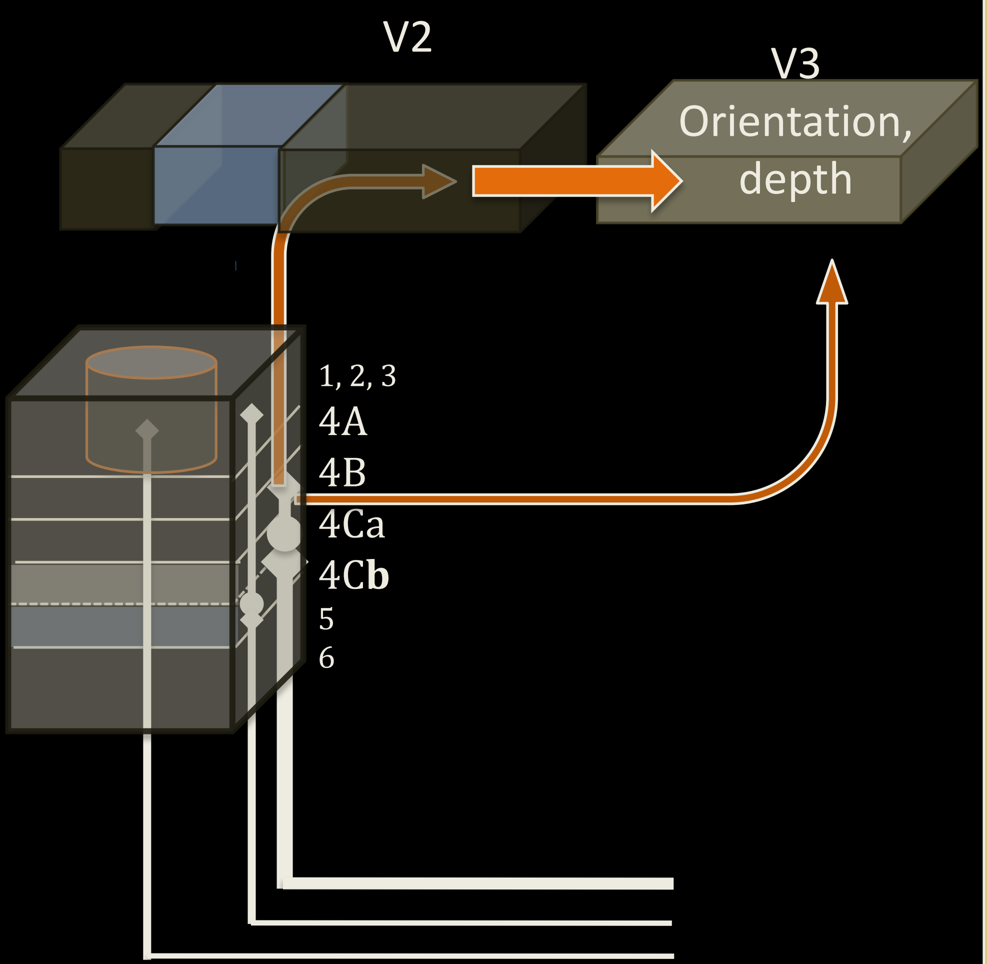
Only the lower part of the visual field is represented in V3

Cells sensitive to **orientation, or motion or depth.** Only few are colour sensitive.

Part of the dorsal stream. V3 is part of a larger area, named the **dorsomedial area (DM)**, has map of entire visual field. Neurons respond to **motion of large patterns** in the visual field.

ventrolateral posterior area (VLP). Map of upper field; weak connections from the V1, strong connections with temporal cortex.

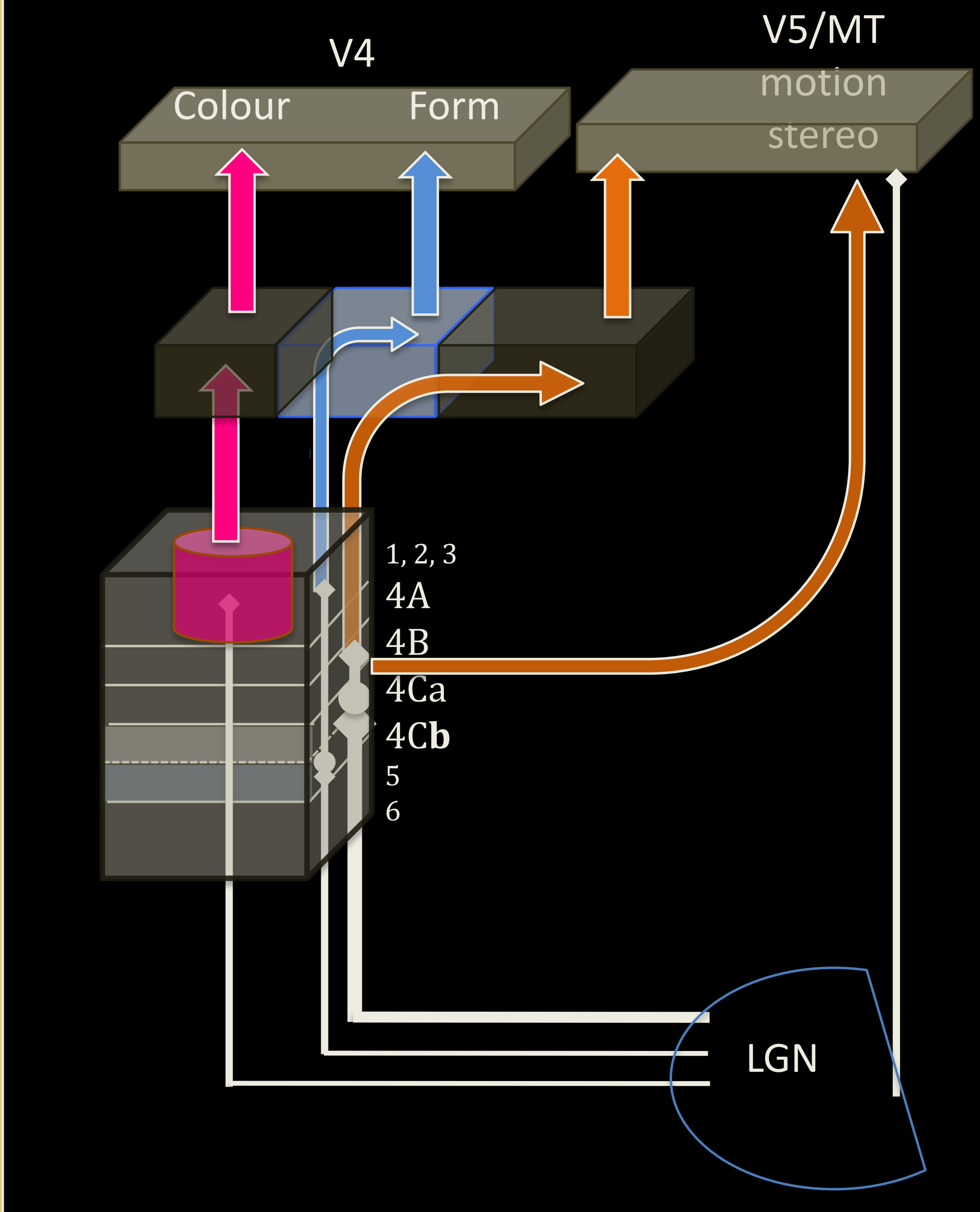




Analysis of Colour

V4: Discovered by Semir Zeki. It receives input mainly from the **thin** and **interstripe** regions of V2, but also has connections from V1 and V3. contains many cells that are colour selective, for **colour analysis**.

Also cells with complex spatial and orientation preference, suggesting that the area is also important for spatial vision.

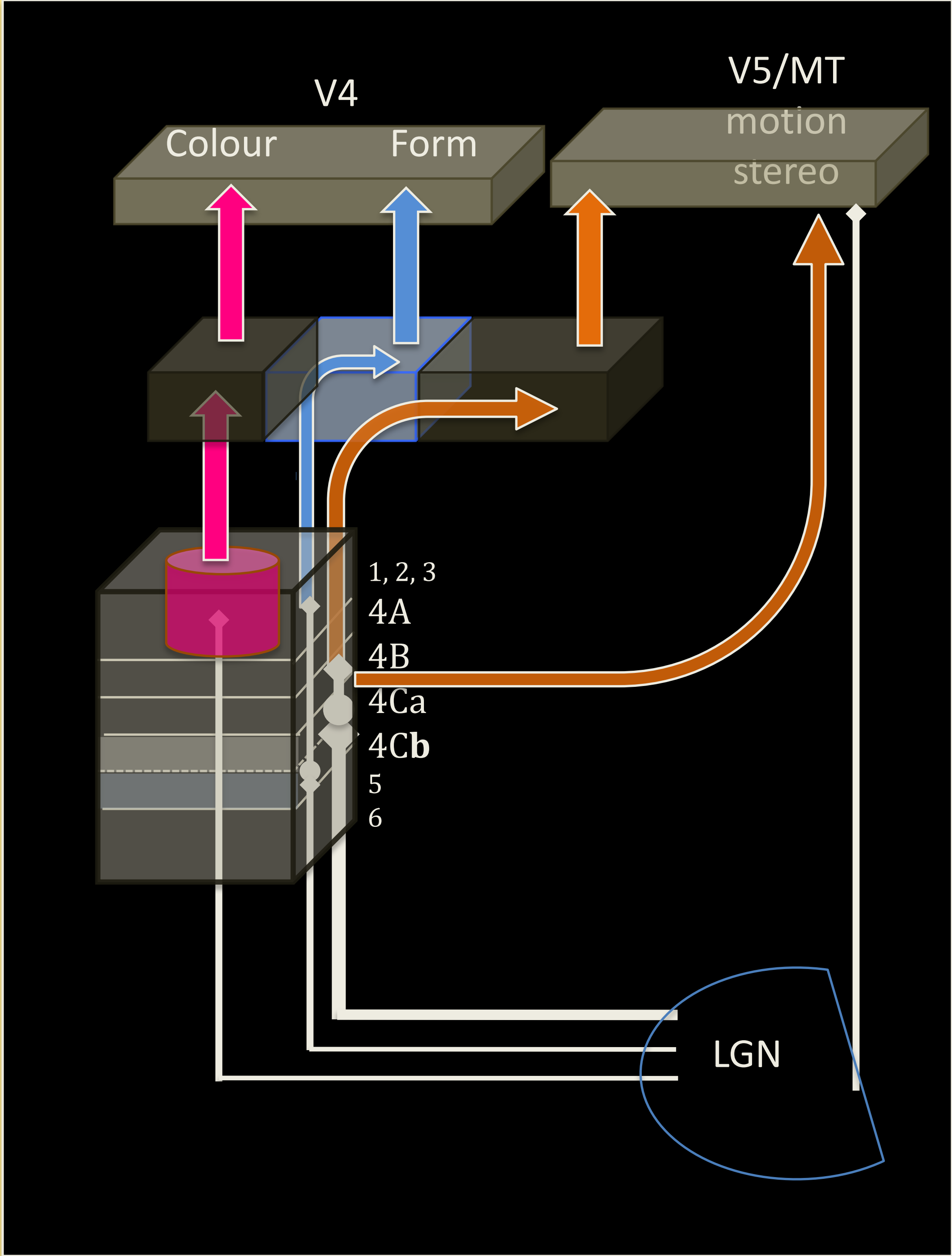


Analysis of Motion

V5. (aka MT) Middle temporal region. Connections from layers 4B and 6 in V1, and from thick stripes in V2. (Also direct pathway from the LGN). Most cells in MT are **sensitive to motion**, in direction and 'axis of motion' columns, for analysis of image motion. Why connections from V2 then, because few cells there are motion selective.

Hot spot for motion. M-cells in retina fire when part of an image moves across their receptive field.

Via LGN message is flashed to V1 where it is pooled and fed to cells sensitive to direction. They then feed onto a specialised map sensitive to motion in V5

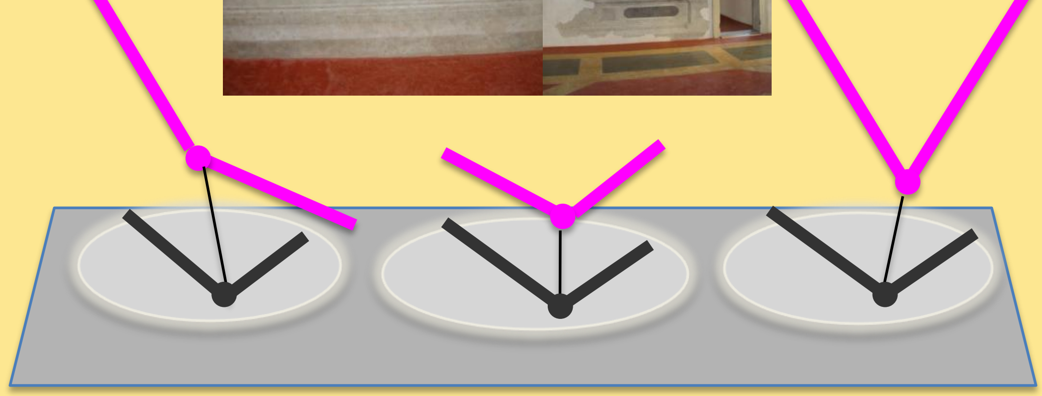


Analysis of depth
Analysis of distance

light rays do not tell us how far they have travelled; so how can we determine depth or distance from whence they came?

Images are flat but contain lots of information about depth.

- Perspective: shape on the retina is ambiguous. Perspective can suggest 3D if we make assumptions
- Texture gradients: Cells in parietal lobe
- Shape from shading: Only works if we know where light source is. Assumption from above. Cells in V4 respond to shadow below. Rotate 90^0 no response
- Interruption of lines (occlusion). Tilted line detectors in V1
- Upward sloping ground
- Size constancy: Psychologically expand perception of the smaller image of a distant object.
- Atmospheric perspective



Identical 2D shadows can be generated by completely different 3D objects
We cannot reconstruct the original object on the basis of the image alone.
We could make a guess if we knew the angle of the lighting. More accurate prediction based on likelihood of which shape, acute or obtuse, in which context

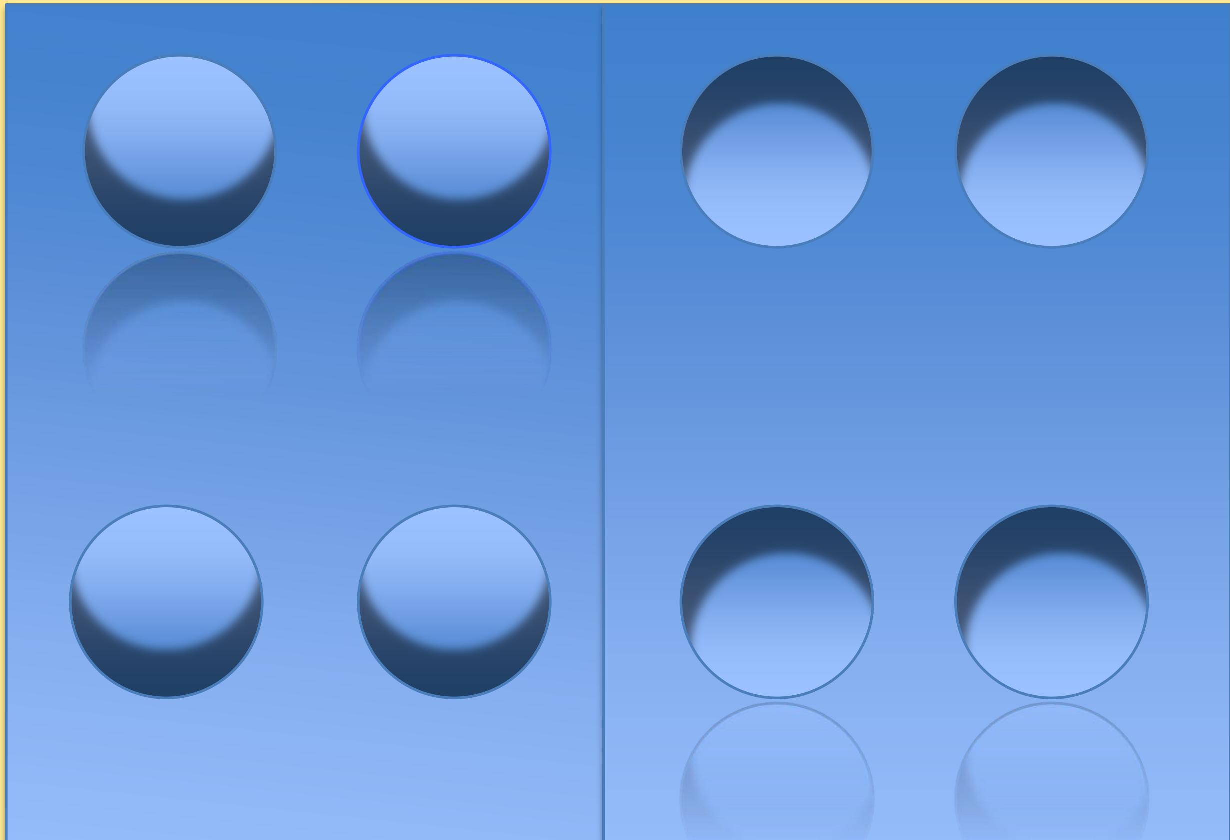
Shape from shading

1. To guide movements. Learns quickly (inverted prism experiment, learned to ride bike)

2. To interpret the shape of objects and the orientation with respect to gravity

   Learns slowly. Difficult to recognise upside down faces.

Two circuits in the brain. One wired to control of movement the other wired to recognition of shapes (and faces)



Our visual systems evolved with one major source of light and that came from the sky above.
Simple inversion of shaded images can dramatically change our perception of the object.
Buttons become dimples

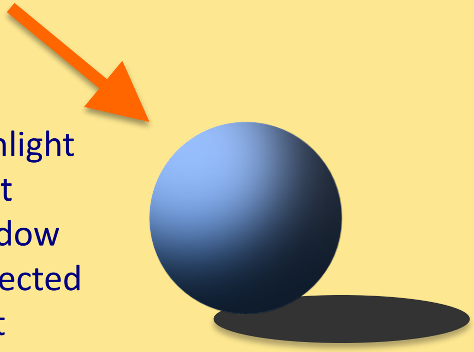
Thompson P (1980) Margaret Thatcher: a new illusion. Perception 9:483–484

Chiaroscuro
light and shade

Modeling of volume by depicting light and shade and their contrast.

Strengthens an illusion of depth on a 2 D surface. Important topic in Renaissance.

Highlight
Light
Shadow
Reflected light
Cast shadow



The Rest on the Flight into Egypt 1510 Gerard David

A Philosopher Giving that Lecture on the Orrery, (1766) by Joseph Wright of Derby
a public lecture about a model solar system, in The Orrery Lamp is put in place of the Sun, the partially illuminated faces may represent the phases of the moon, ranging from full (the children) to gibbous (man on the left) to new (man seen from behind

Analysis of distance

Motion parallax

Not always a good thing to bring attention to oneself

Brain has some purpose built analogue computers to judge range.

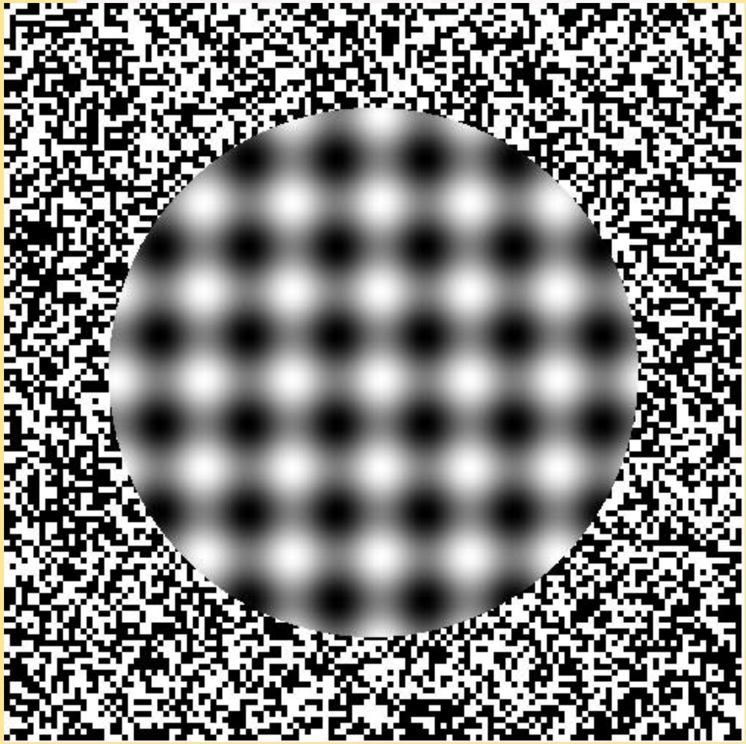
Binocular parallax

Compare the 2 images from each eye.

A shift of only a few 1,000ths of a mm changes light on a cone by ~5%. This causes it to fire. Upstream individual cells which have receptive fields in slightly different places can detect depth.

Random dot stereogram: Bela Julesz; Bell laboratories: Centre dots moved slightly in one eye’s image. How can they be found in the cluttered scene? Neighbouring points are same distance but now have no correlation in brightness This enables the parallax computers in the brain to find them. They have large receptive fields to make job easier, average light over large areas.

Useful to detect moths on bark



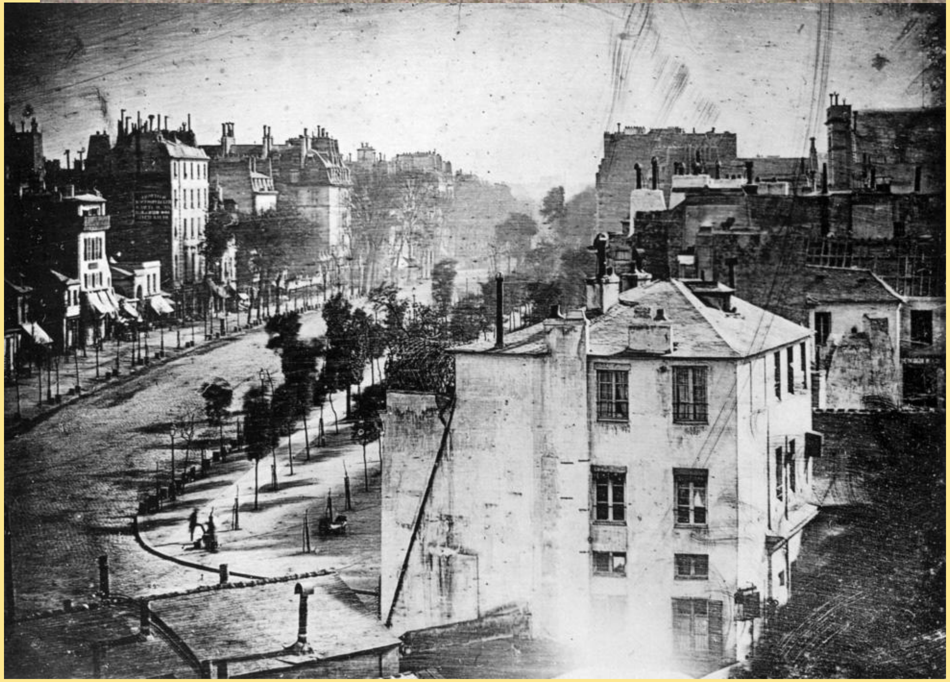
Analysis of motion

Photos and paintings cannot represent movement

We don’t see blur in moving objects. We also don’t see a series of frozen snapshots

The sense of movement is specific like smell.

Motion is computed directly from the retinal image



Motion detectors

Dynamism of a dog on a lead

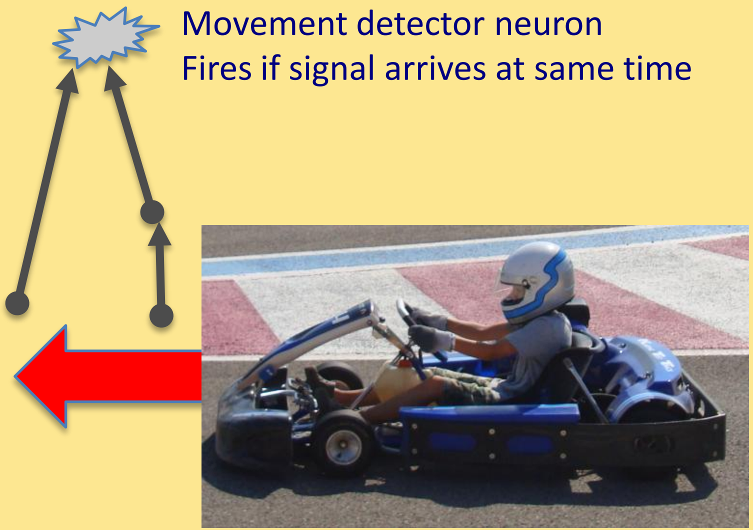
Giacomo Balla 1912

Movement detector:

Present in retina of rabbit

Brain of monkeys

Some of the parallax detectors also respond to differences of movement between the 2 eyes. Effect of object moving in third dimension. (pendulum)



Why so many maps?

Analogue computers good; but only at one thing

Brain has plenty of cells so not a problem

Many analogue computers, all working at the same time but only on their respective special task

Parallel processing

Object recognition

Face recognition

Colour

Movement

Probabalistic model of vision

We use experience to learn.

We adjust the weighting depending on the outcome.

A binary digital computer (all or none) is of no use in the real world where noise degrades the information.

Rosenblatt: Perceptron 1957

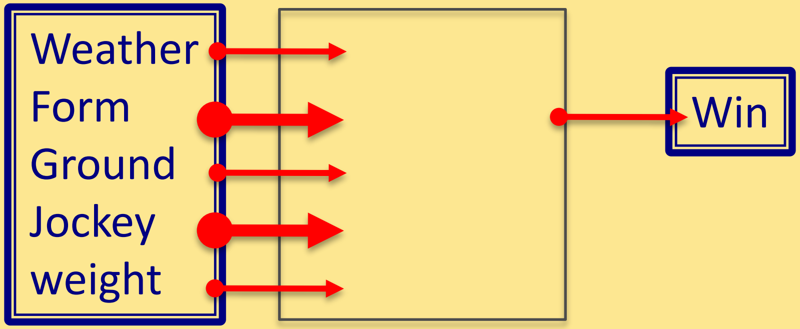
If horse wins nothing to adjust

If no information on weather, disconnect input.

Every time it wins strengthen inputs by select amount

proportional to flow at input x error signal

Machine moves over error landscape and learns.



Bayes: A model (prior). Collect some evidence then alter the model as needed (posterior)

Generative model

Sometimes wrong: Moon and Coal have similar reflectance.

Experience however tells us that something that reflects more light than its background is white.

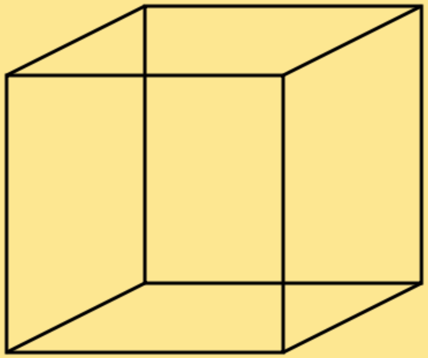
A probabilistic strategy based on past experience explains the remarkable difference between what we see and physical reality

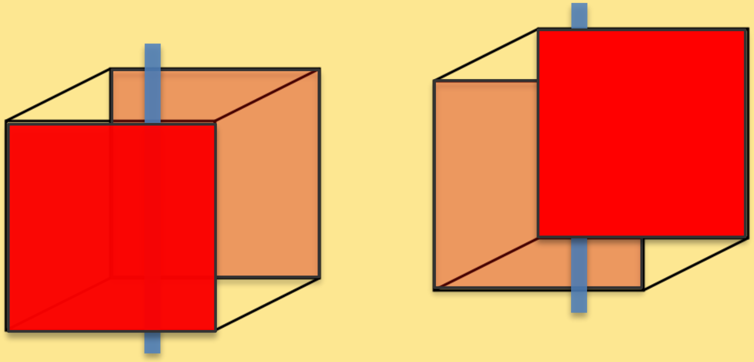
R. Beau Lotto, Dale Purves,

Perceptions are guesses. We select a pre-existing model and check against the data.

Sometimes 2 equally valid solutions

We then flip

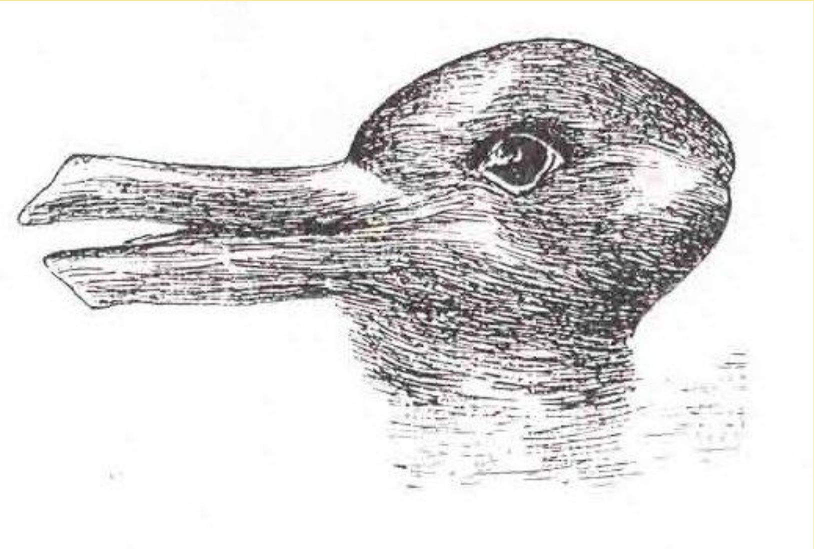




evidence drawn from the perception of brightness, color and geometry supports the idea that Berkeley's dilemma is resolved by generating visual percepts according to the probability distribution of the possible sources of the visual stimulus, whatever it may be.

observers see what a visual scene typically signified in the past, not what it actually is in the present.

We see what we do, therefore, because the statistics of past experience is the basis on which the visual system contends with the dilemma posed by the inherent ambiguity of visual stimuli.



Perception and hallucination

Perceptions can occur without retinal image:

Hunter Davis, Coleridge fell asleep after laudanum. He had just read a passage about the garden of Kublai Khan.

De Quincy: “If a man took opium whose talk was of oxen, he would dream about oxen”

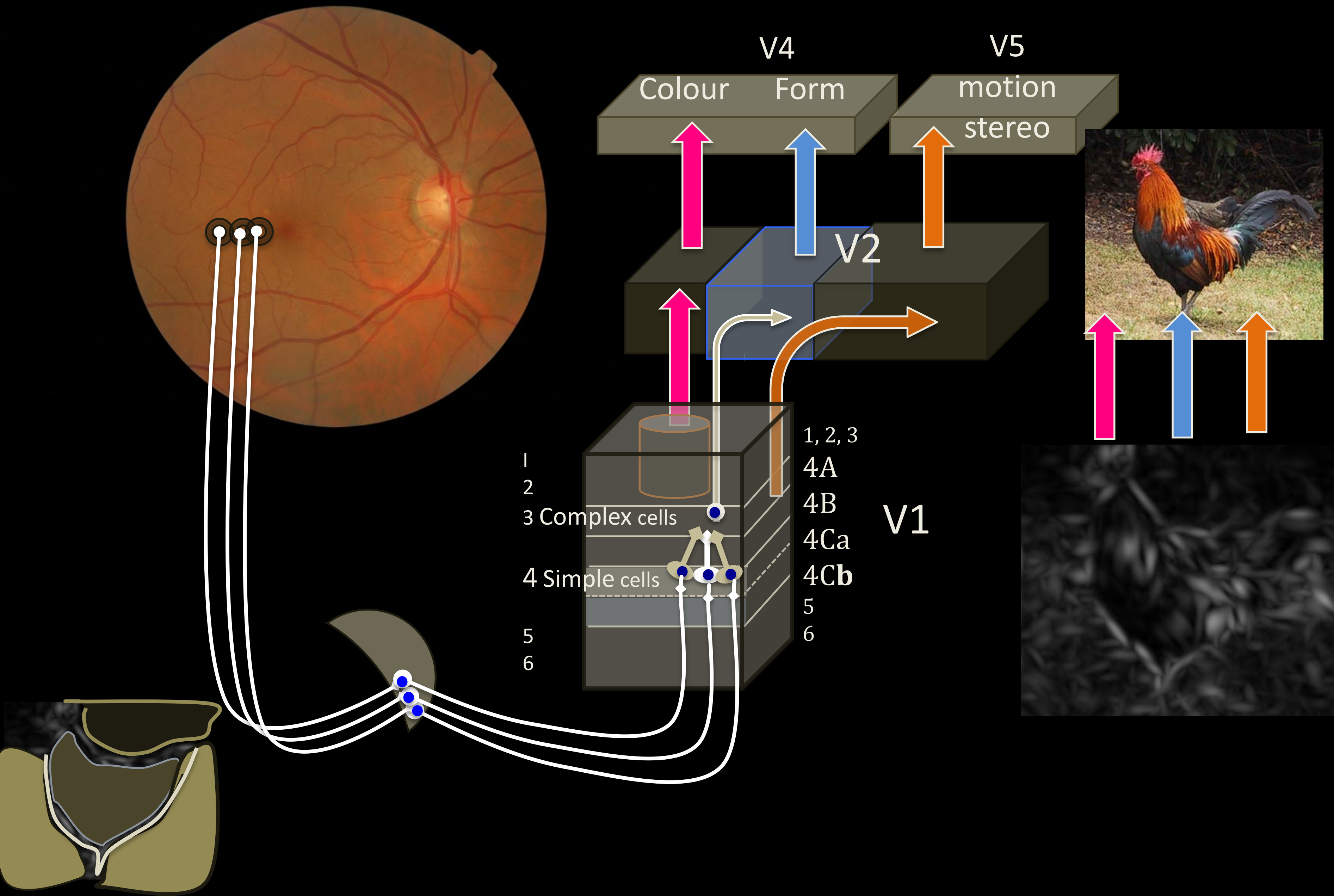
Johannes Peter Müller (1801–1858), Son of a Koblenz shoe-maker; physiologist, comparative anatomist, and ichthyologist:

1826, Ueber die phantastischen Gesichtserscheinungen *(On Fantasy Images)*, a study of visual hallucinations. When falling asleep, he saw imaginary images, experimented, showing vision to be an active process. Sleep-deprivation and caffeine led to mental breakdown.

In April 1827, he married a talented musician Nanny Zeiller,

Relapsed with breakdown immediately.

Constructing visual scene



"esse est percipi"

("to be is to be perceived")

George Berkeley 1709: "It is indeed an opinion strangely prevailing amongst men, that houses, mountains, rivers, and in a word all sensible objects have an existence natural or real, distinct from their being perceived by the understanding

There was a young man who said
"God Must find it exceedingly odd
To think that the tree
Should continue to be
When there's no one about in the quad."

"Dear Sir: Your astonishment's odd;
I am always about in the quad.
And that's why the tree
Will continue to be
Since observed by,
Yours faithfully, God."