Visual Perception

part one: The Structure of the Visual System

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February 17th 2010.

Visual perception

ability to interpret information from visible light reaching the eye. This perception is called eyesight or vision

Nicolaus Steno: Danish anatomist and polymath; In *1665 gave a* lecture *Discours sur l'Anatomie du Cerveau [Discourse on Brain Anatomy] in Paris:*

Gentlemen, instead of promising to satisfy your curiosity about the anatomy of the brain, I intend here to make the sincere, public confession that this is a subject on which I know nothing at all

Our perception does not identify the outside world as it really is, but the way we are allowed to recognize it, is a consequence of transformations performed by our senses.

photons converted to images,

vibrations into sounds

chemical reactions into smell and taste.

Actually, the universe is silent, colourless, inodorous, and dark.

"The Eye has Dominion over all Things. The World was made for the Eye and the Eye for the World" (John Taylor address to Oxford Students)

In fact it is the outermost part of the brain, the grey-matter rind (**cortex**, which envelops the white matter core) that is the organ of perception.

This has only become known in the last 100 years.

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 do thoughts come from and why do people behave as they do?

The neurological basis for eyesight

Light from the environment is focused by crystalline lens to form image on retina.

Processing of this image begins in the retina where brightness and edges are enhanced.

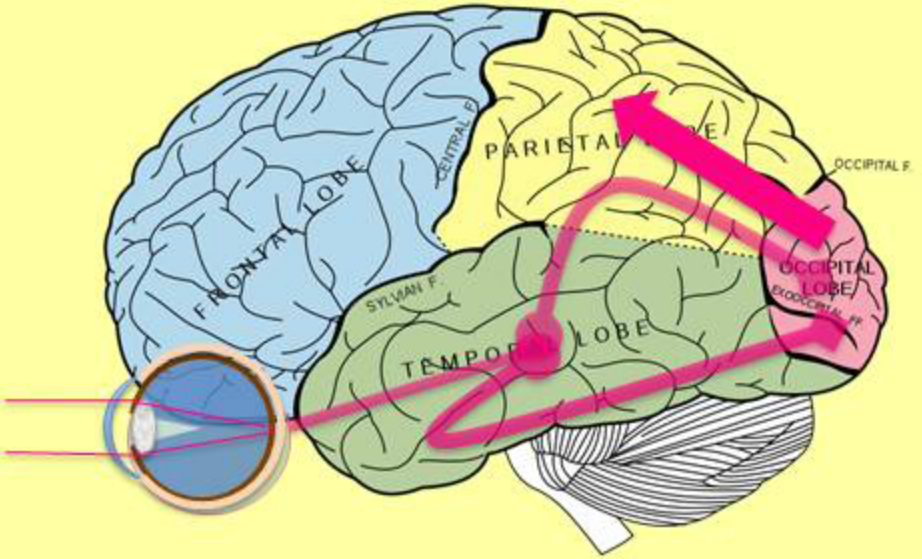
The information is then passed down the optic nerves, crossing at the chiasm, to a relay station in the thalamus, deep in the brain (lateral geniculate nucleus). Fibres then fan out to the visual cortex located in a deep fold (calcarine fissure) the occipital lobe of the brain.

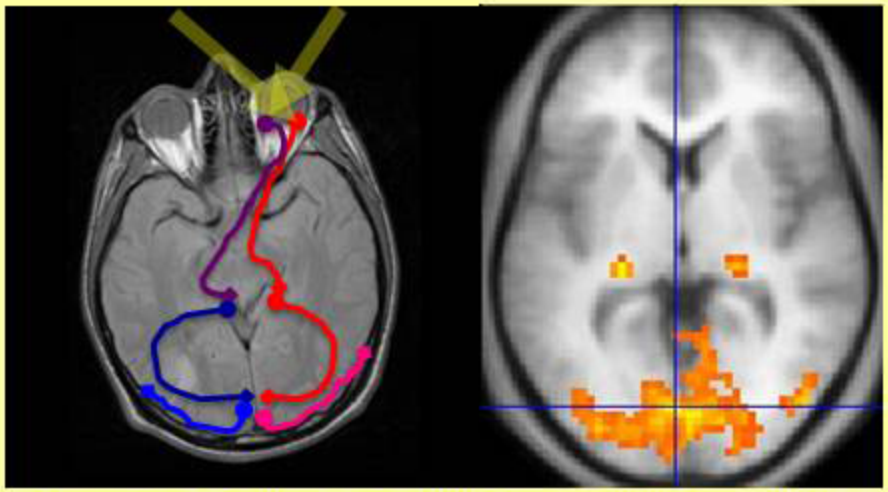
Following further processing visual information radiates on to further visual centres; in the parietal and temporal lobes.

It is integrated with information from other senses and used as a basis for actions.

Today everyone knows that the brain has different functions located in different parts.

This was not always the case, the homogenous, folded soft tissue was once thought to have lowly role in the functioning of animals.





shows regions of activation including primary visual cortex (V1, BA17), extrastriate visual cortex and lateral geniculate body in a comparison between a task involving a complex moving visual stimulus and rest condition (viewing a black screen).

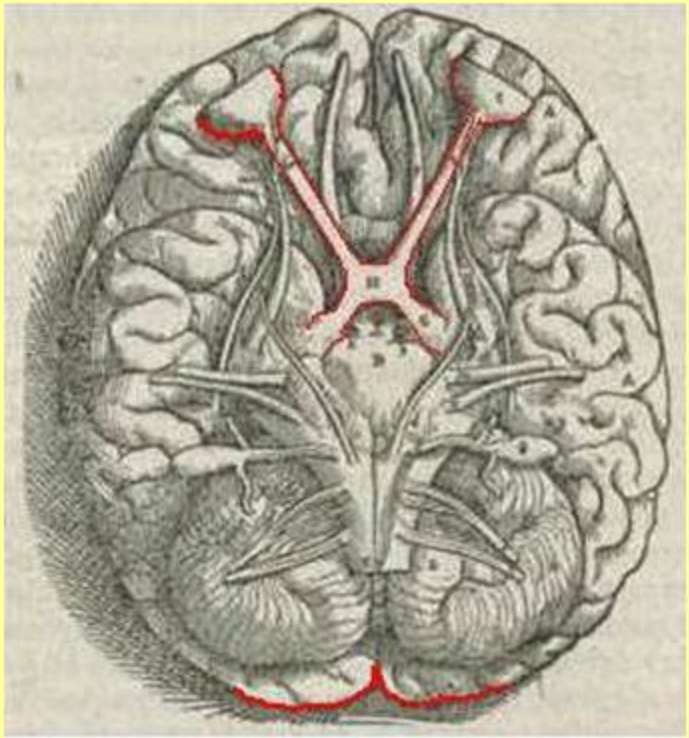
Chiasm

Galen: Optic nerves come together (but remain on their own side)

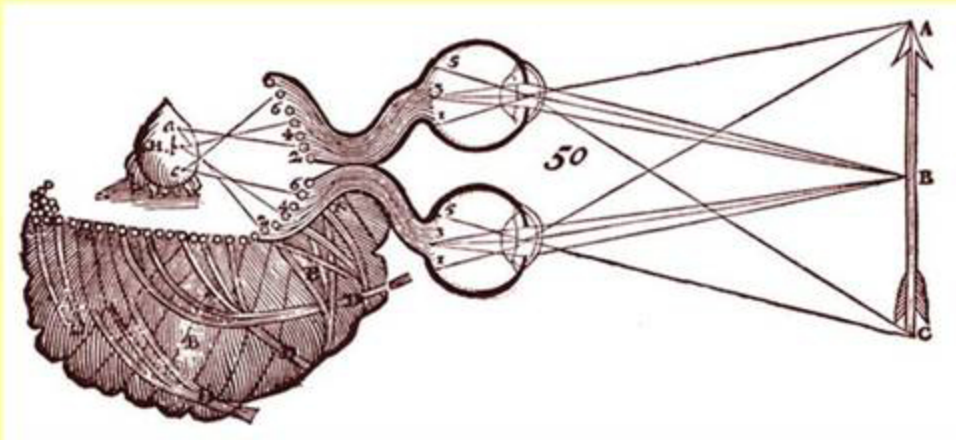
Vesalius: Concurred.

Descartes argued that because our lenses reverse the image falling on the retinas, there must be a partial fibre crossing in the brain so that the two reversed images, one from each eye, can be brought into register in the pineal.

Some surrogate 'person' in the brain must have a map if seeing was to be possible: Brainy in the numskulls?



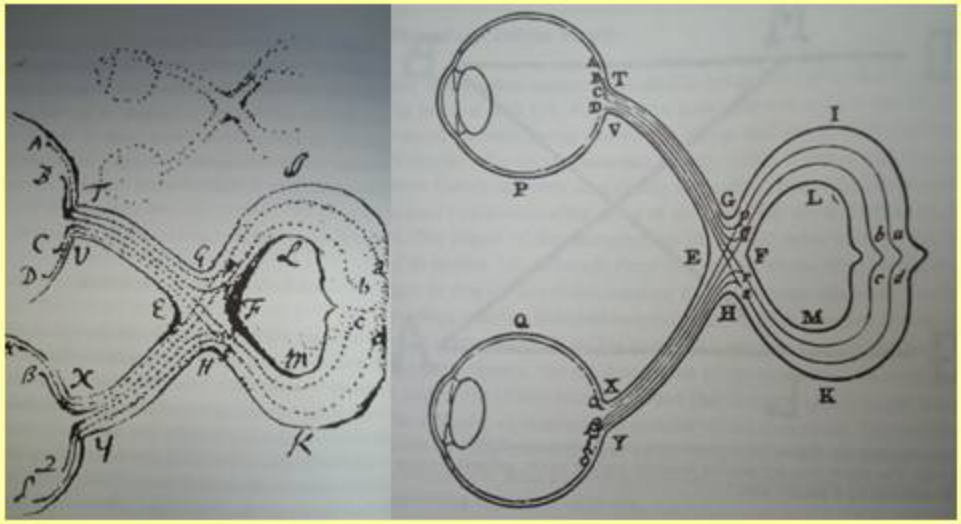
Gospel according to Matthew, Eadfrith. "Christi autem generation sic erat" or "The birth of Christ took place thus." Lindesfarne.



Chiasm

Newton 1704: deriving from optics, proposed a partial crossing in the optic chiasm.

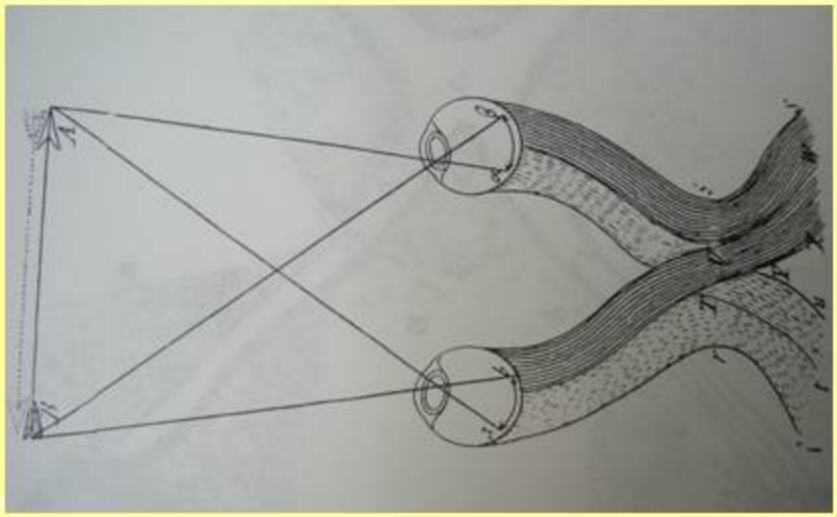
Not published until Harris' Treatise of Optics: 1775, after Newton's death.. Almost correct but shows the nerves fusing in the chiasm.



John Taylor 1738: student of Cheselden

Correct view. Taylor, probably basing his diagram on shrewd speculation, represented their independence. Fibres in the optic nerve diverged after the optic chiasm, with those from the left halves of each retina projecting to the left part of the brain, and vice versa. It took over a century before this was firmly established anatomically.

Taylor J, 1738 Le Mecanisme ou le Nouveau Traite de l'Anatomie du globe de l'oeil, avec l'usage de ses differentes parties, & de celles qui lui sont contigue«s (Paris: see Wade Perception 37, 2008)



Woolaston: 1824 due to die of a thalamic tumour describes the episodic half blindness (hemianopsia)

The first demonstration of partial decussation in mammals was by a man due to die in unusual circumstances……

An unusual suicide

Johann Bernhard Aloys von Gudden (June 7, 1824 - June 13, 1886) German neuroanatomist and psychiatrist b. Kleve, distinguished career concluding as head of the Munich Asylum. June 1886, a report signed by four psychiatrists: Dr. Gudden; Dr Hubert von Grashey (his son-in-law); Dr. Hagen and Dr. Hubrich, declared their king, **Leopold II of Bavaria**, anglophile, castle-builder and patron of Wagner, was paranoid, "Suffering from such a disorder, freedom of action can no longer be allowed and Your Majesty is declared incapable of ruling, which incapacity will be not only for a year's duration, but for the length of Your Majesty's life." The men had never met the king, nor examined him.

On 9 June 1886, a commission, including von Gudden arrived at Neuschwanstein to arrest Leopold. Forewarned, the king had the local police protect him,at bayonet-point and were also attacked by an elderly local baroness with her umbrella .

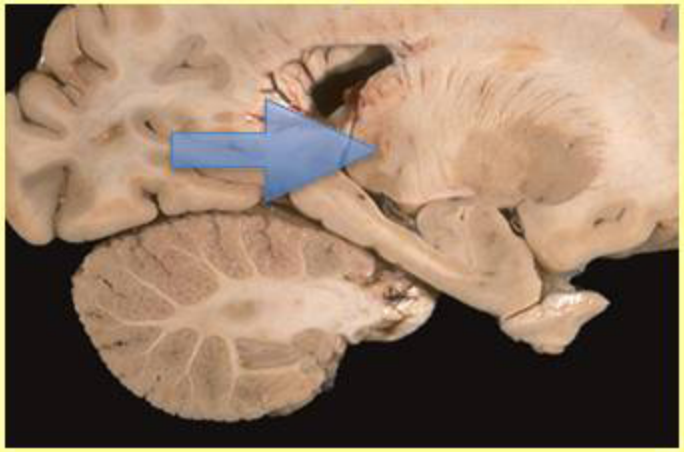
Too late for escape. At 4am, 12 June, 2nd commission arrived. The King was arrested, asking Dr. Gudden, "How can you declare me insane? After all, you have never seen or examined me before." Ludwig was transported to Castle Berg on the shores of Lake Starnberg, south of Munich.

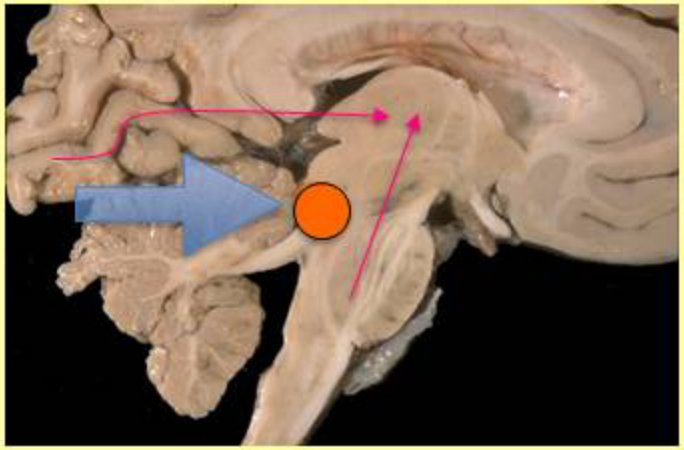
In the early evening on 13 June , Ludwig asked Gudden to accompany him on a walk along the shore of Lake Starnberg. Gudden agreed, ordering the guards not to follow them. At 11:30 that night, searchers found both dead, floating in the shallow water near the shore. Officially suicide by drowning. However he was a strong swimmer, the water was shallow, autopsy showed no water was found in his lungs. Doesn't explain Gudden's death. Was Ludwig murdered? The King's fisherman, **Jakob Lidl**, was made to swear an oath of silence "not to my wife, not on my deathbed, and not to any priest" ... The state has undertaken to look after my family if anything should happen to me" kept his oath, but left behind notes which revealed he had hidden behind bushes with his boat, waiting to row the king to where loyalists were waiting to help him escape. "As the king stepped up to his boat and put one foot in it, a shot rang out from the bank, apparently killing him on the spot, for the king fell across the bow of the boat."

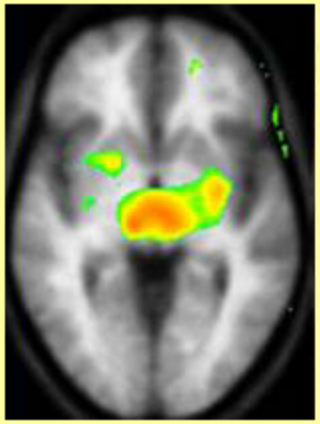
Gudden made many contributions in the field of neuroanatomy, especially in his work of mapping and describing the partial crossing in mammals (rabbits). Confirming Newton and Taylor. Not readily accepted.

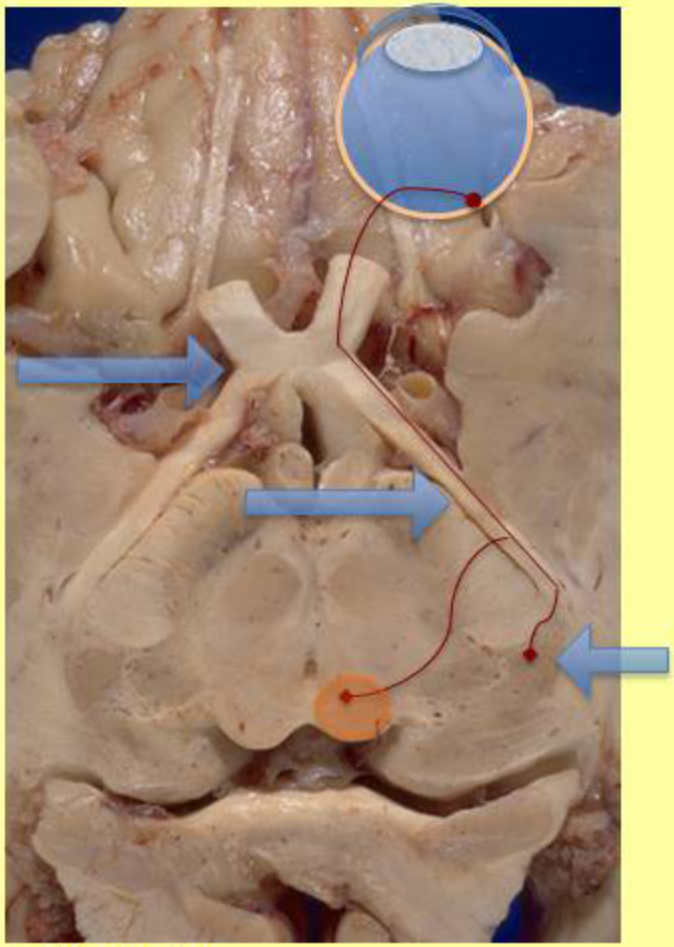
Birds do not cross in the chiasm and have crossing in the brain as proposed by Descartes. In fact the brain has a more interesting role in vision....

The thalamic relay of visual information: Lateral Geniculate Nucleus

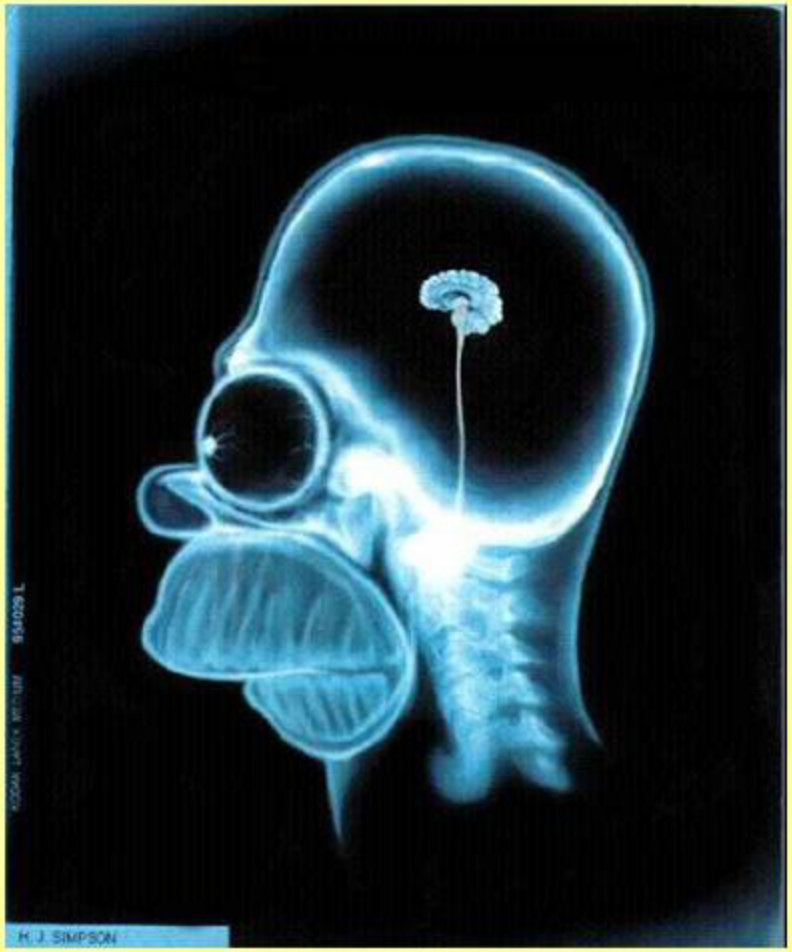








Thalamus a paired structure size and shape of walnut, the switchboard of the brain.
All Sensory input relays in the thalamus
Vision uses the **LGN** whose major input is **not** from the eyes.
85% of input is from
i) reticular formation in pons (arousal, attention, awareness, motor function and sleep)
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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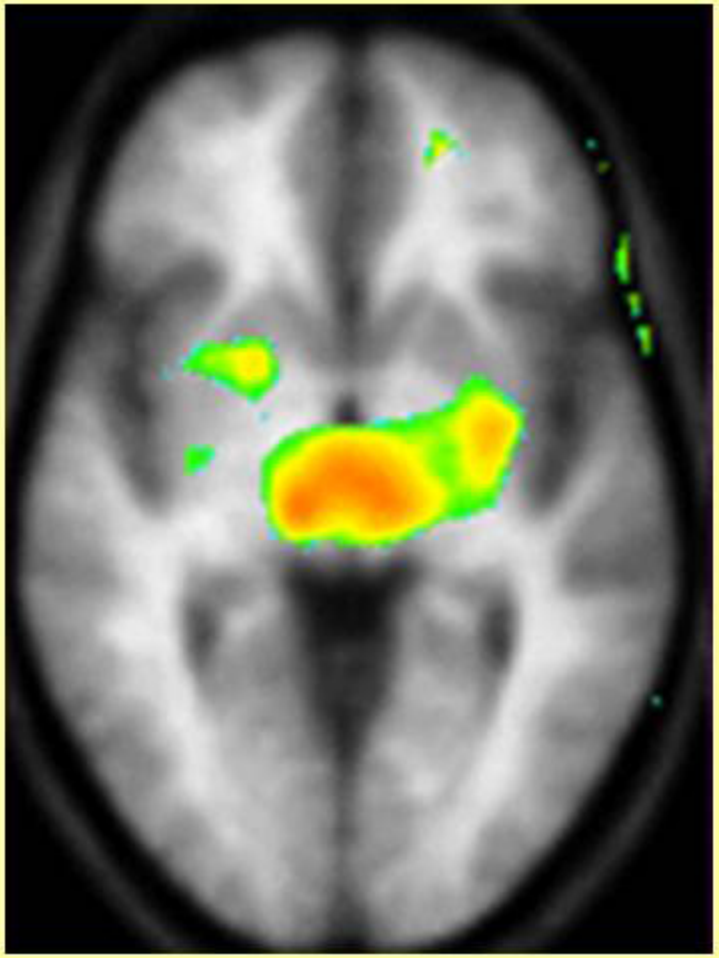


Lateral Geniculate nucleus

Parvo-cells: small slow conducting mostly from fovea

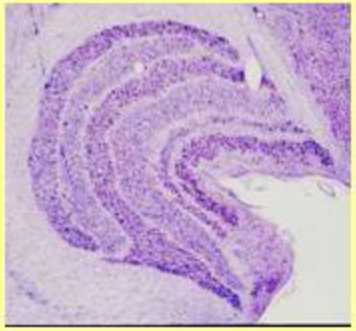
What information

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.



Ancient theories of the brain

First mention of brain is in Edwin Smith papyrus.

hieratic (priestly) script of the ancient Egyptian language 1700 BC, a copy of an earlier text 1000 yrs before.

48 cases, "I will treat, try to treat or will not treat".

Case 6 skull #. Describes the brain like corrugations which form in molten copper.

Diagnosis: You say an ailment not to be treated.

Heart was considered the seat of the mind and intellect.

Heroditus description of mummification tells us the the brain was scooped out via the nose.

The body was prepared for the afterlife without a brain!

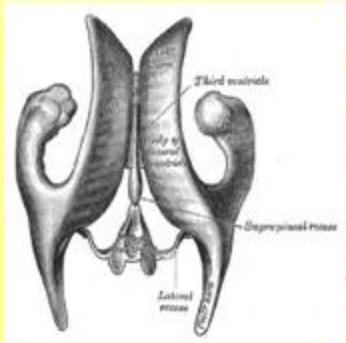
Medieval theories of the brain

Aristotle (384-322 B.C.) Cardio-centric theory of body functions (the heart as the acropolis of the body)

Plato (429-347 B.C.) and **Galen** (129-199 A.C.) Soul itself resides in the brain, where process of thought occurs, and the memory of images is stored. Origin of visual pathway located in anterior ventricle, where animal spirits could interact with the visual spirits carried by the optic nerve. (Wade). Theory incorporated into medieval philosophy

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

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



"Philosophy for the simple". (Philosophia pauperum)

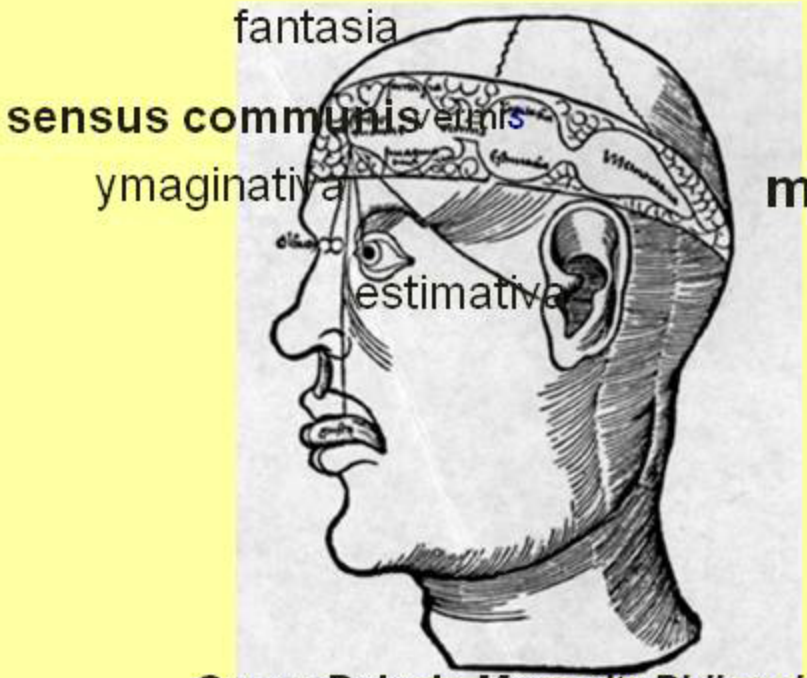
Albert of Orlamünde." (fl. late 13th c.), manuscripts of "Brother Albert, O.P." a Dominican teacher in Thüringen, who compiled these digests, a short textbook of natural philosophy and psychology which was used in schools throughout the Middle Ages.

In the chapter about the soul (De anima) he discusses the three ventricles of the brain.

The first cell (the lateral ventricles; considered as one cavity) received information from the special senses and the body; amalgamatedo into **sensus communis** "common sense". The vermis connects to 2nd cell (3rd ventricle). Images created from sensation interacted with the seat of reasoning in the second cell. Thought (cogitativa) and judgement (estimativa). The third cell (4th ventricle) was where memory resided.

Rete mirabile: Marvellous net, described by Herophilus and incorporated into Galenic teaching. Place where vital spirit from heart was converted to animal spirit. Animals have a well developed network whereas humans have circle of Willis.

Galen believed that the folds, gyri had no function. It was not until phrenology in the C19th that this view was challenged.



Gregor Reisch, *Margarita Philosohica (1504)*

Medieval depictions of the brain

Dissection of a man executed by drowning. Illustration (stylistic not naturalistic) shows structure within the cranial cavity with brain gyri inside it.

The text, however describes 3 chambers in the brain, referring to the ventricula (cell) doctrine mental function.

The crosshatching may be a representation of the rete mirabile. Karl Sudhoff

De Arte Phisicali e de Cirurgia *(1412) by John Arderne* (1307–1392), a master surgeon of Newark. personal experience treating and writing about injuries of war from the Hundred Years' War of the 14th century, which saw the first battles to use gunpowder.

man split from head to perineum. Show realistic representation of brain based on a dissection. Not referred to in txt. These illustrations are different from the more common diagrams of mental functions. Earliest depiction of realistic brain before linear perspective.

Salerno from around 1250. .

Leonardo da Vinci (1452–1519)

drawing illustrating how sight works c1489-92 sight was the most important of all the senses. adheres to the conventional view that the brain possessed three inter-connected ventricles, each which facilitated a particular stage in perception.

Also described the imprensiva, a brain structure that mediates between sense organs (such as the eye) and the senso comune. The term imprensiva has not been adopted by any anatomist before or after Leonardo.

The first ventricle, sensus communis, receives information gained from the senses. This travels to the second chamber thought and judgement. Leonardo believed that this was the site of the human soul, as illustrated in his Study of a human skull. a third chamber called the memoria, where information could be stored. Later following experiments with wax injection, confirms Galen's paired anterior ventiricle (lateral ventricles), he puts common sense in the middle ventricle. He puts intellect and imprensiva into the first.

Priority is given to information gained through sensory perception in Leonardo's theory. The imagination cannot visualise such beauty as is seen by the eye. This is because the eye receives the appearance of images or objects and transmits them through the sense organs to the understanding where they are judged. Forms created in the imagination are therefore inferior; ultimately they fade and die in the memoria. The eye, which is the window of the soul, is the chief organ whereby the understanding can have the most complete and magnificent view of the infinite works of nature; and the ear comes second, which acquires dignity by hearing things the eye has seen.

Malpighi 1666, microscopy supports this view.

Andreas Vesalius 1514-1564

Padua: Public dissection performed (unusually) with his own hands by Vesalius. In 1584 dissections were moved indoors.

Opposed ventricular theory; "Such are the inventions of those who never look into our makers ingenuity".

Animals had ventricles but not souls?

Shakespeare alludes to the ventricular theory in Love's Labours lost.

A foolish extravagant spirit full of forms, figures, shapes, objects, ideas apprehensions, motions, revolutions. They are begat in the ventricle of memory, nourished in the womb of pia mater.

However gyri shown in similar fashion to medieval images. Low status organ.

Thomas Willis 1621-1675
Gresham connection

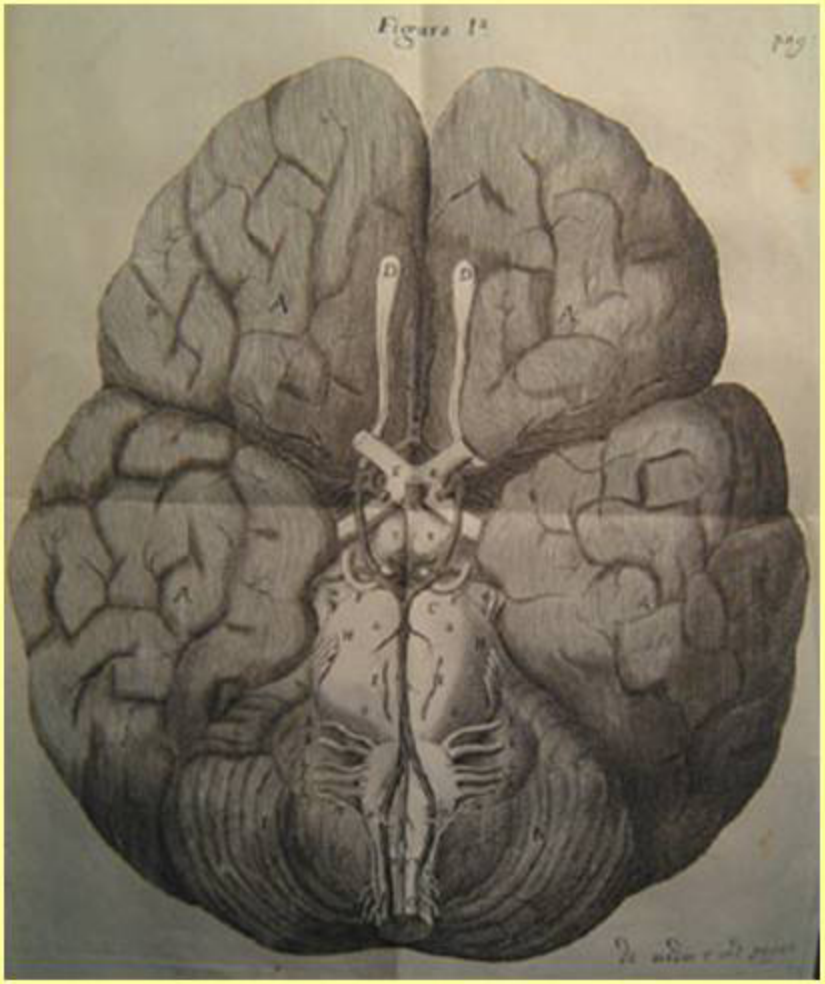
Importance of the cortex.

1664: published **Cerebri Anatomie** the first systematic approach to the functional anatomy of the brain. Opposed the concept of ventricular localization of brain function and proposed 3 areas in the brain: the corpus striatum received sensory input, converted to perception and imagination in the hard overlying tissue, corpus callosum, before passing on to **cerebral cortex** where they were stored as memories.

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

Charles Sherrington (1852–1952), "Thomas Willis practically refounded the anatomy and physiology of the brain and nerves… Willis put the brain and the nervous system on their modern footing so far as that could be then done".

Christopher Wren (1632–1723). familiar with anatomy, had performed many experiments, making models of muscles and eyes. He performed injections in animals with India ink and other substances into the carotid arteries, used by Willis & Lower to determine circulation of the brain and the physiological significance of the circle of Willis. Alcohol allowed retention of well-preserved specimens of brains with anatomical details for the artist. Gave up interest in physiology and anatomical drawing for architecture.



René Descartes 1596-1650

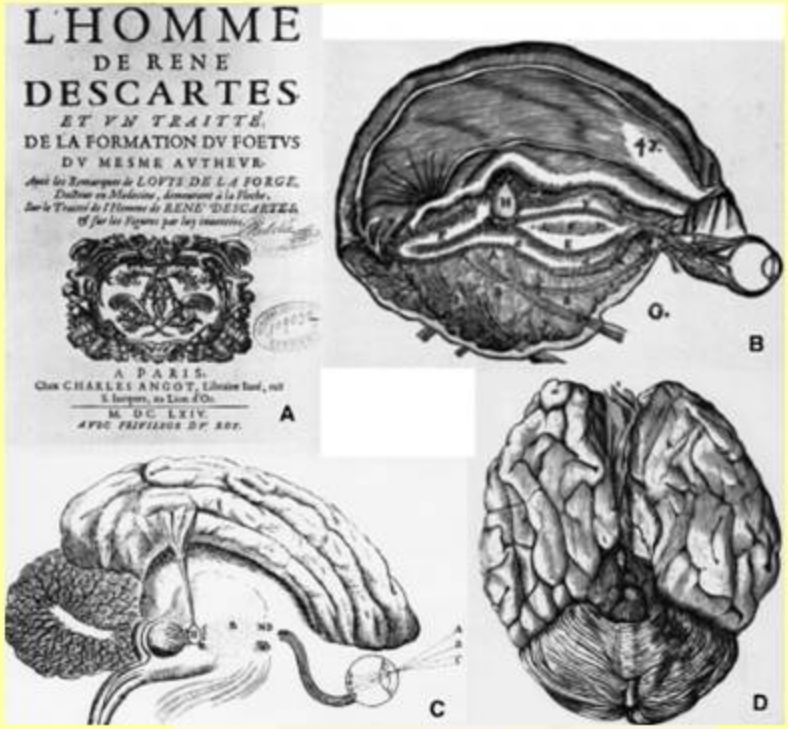
At the same time as Wren, an unknown artist illustrating **De homine** (1662) and in its French translation (**L'homme**) 2 years later made several illustrations of the brain. These are beautifully drawn but have become largely ignored as Descartes had no interest in the surface of the brain and was concerned with a mechanistic view of body function. His other illustrations are diagrammatic and the realistic illustrations are unrelated to the text of the book.

In the brain "was based" the soul, man's superior consciousness. The idea was illustrated by a figure illustrating a young man with a foot close to a fire. A nervous bundle goes from the foot, through the leg, body and neck, to reach the head. In the brain, the fire's painful stimulus would reach conciousness, where it is perceived. Matter and spirit are two life essences that man could not put together.

Cartesian duality between brain and mind. This idea remains one of the great enigmas.

Imaginary system of Descartes', purported that the pineal gland was the regulatory center processing sensory input by means of the activation of endogenous spirits.

Descartes' view of human beings as simple earth machines was criticized.



The anatomy lesson of Dr. Joan Deyman: Rembrandt 1606-69

Joris Fonteijn of Diest, Black Jan, notorious thief was condemned to death on 27 Jan 1656. Rembrandt was broke and had applied for cessio bonorum (bankruptcy).

The anatomy theatre was in the attic of the meat market, where the dissection took place on the 29th, following prayers to bless good coming from evil. Cold weather ideal.

The stomach and intestines were removed first, then the dissection of the brain. The assistant holding the skull cap is Gysbrecht Matthijsz Calcoen, a master of the Amserdam Guild of surgeons f.1552 as the surgeons seperated from Wooden Shoe and Ice Skate Manufacturers Guild.

Deyman was paid with 6 silver spoons worth 31 guilders 19 stuivers, for three demonstrations.

The painting was mostly destroyed by fire in 1723.

Petrus Camper
Samuel Thomas Soemmerring

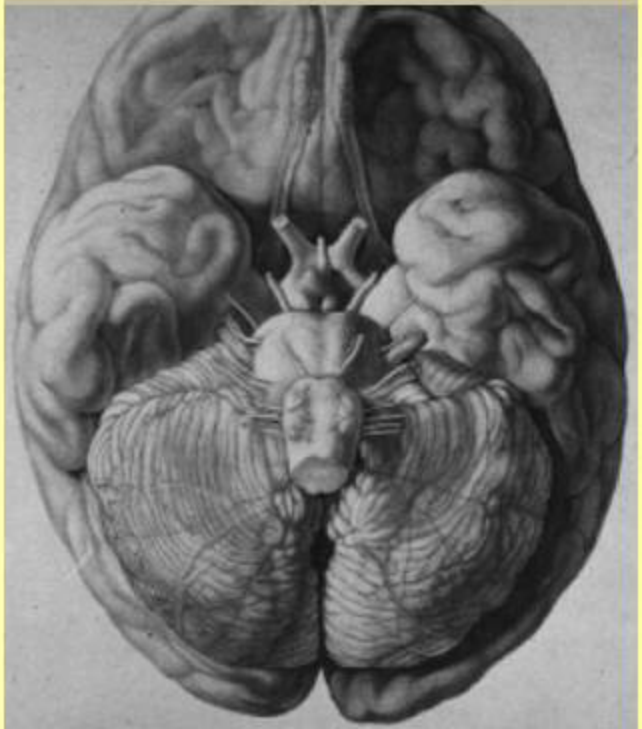
Pierre Camper (1722–1789): Surgeon, skilled in anatomical drawing and perspective. Precise studies of the anatomy of the head and brain. One of his main accomplishments was developing a "body calculus" in an anatomy book intended for art students. Instead of drawing skulls freehand, Camper drew them according to measurements obtained from 3 polarized points, precisely measured skulls with a system of straight lines and angles superimposed.

The Anatomy Lesson by Dr. Petrus Camper, oil on canvas, by Tibout Regters (1758)

Samuel Thomas Soemmerring (1755-1830)

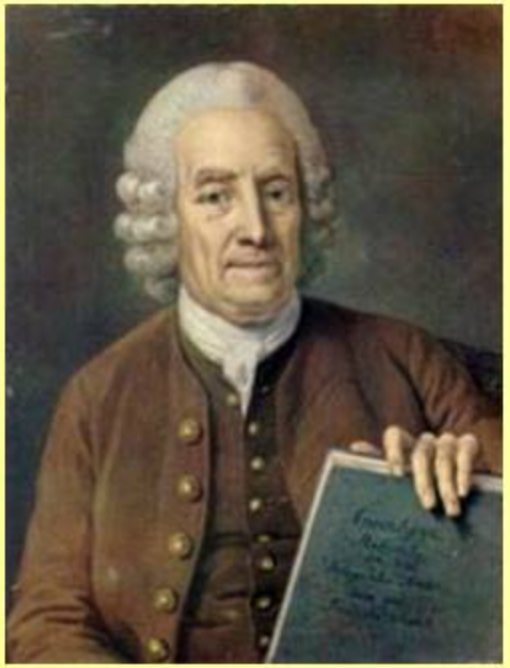
Q 1778 Göttingen. The Latin edition of Soemmerring's great anatomical atlas was translated by Bernhard Nathanael Gottlob Schreger (1766-1825). The plates for this edition were taken from the copperplate engravings based on Koeck's drawings which appeared in the original German edition of 1801 (348). "In preparing the drawings Soemmerring was less concerned with correct perspective than with the correct representation of the material rendering nature and its hidden aspects as closely as possible. Trained the artist, Christian Koeck, and carefully supervised the engraver, Ludwig Schmidt, for his work ***Über der Organ der Seele, 1796***

Über der Organ der Seele (1796)



Emanuel Swedenborg 1688-1772

In April 1745, Swedenborg was dining in a private room at a tavern in London. By the end of the meal, a darkness fell upon his eyes, and the room shifted character. Suddenly he saw a person sitting at a corner of the room, telling Swedenborg: "*Do not eat too much!*". *Frightened he returned home. Later that night, the same man appeared in his dreams. The man told Swedenborg that He was the Lord, that He had appointed Swedenborg to reveal the spiritual meaning of the Bible, and that He would guide Swedenborg in what to write. The same night, the spiritual world was opened to Swedenborg.*



B. Stockholm, son of a Lutheran bishop. lived in England from 1710 to 1713, and formed a lasting love for its culture.

Recognised the importance of the cortex, suggesting it was the highest sensory and motor structure of the brain. Suggested that cortical "glandules" described by Malpighi "little brains" ("cerebella") were functionally independent and connected by thin fibers (before neuronal theory). These fibers ran through the white matter down the spinal cord and then by way of nerves to parts of the body. the cerebella were the basis of sensation, thought, and movement. Also had the idea of organization of function in different parts of the cerebral cortex: correctly localizes control of the foot in the dorsal cortex (he called it the "highest lobe"), the trunk in an intermediate site, and the face and hand in the ventral cortex.

Later he experienced dreams and visions, a spiritual awakening, believing he was appointed by the Lord to reform Christianity. He claimed that the Lord had opened his eyes, so that from then on he could freely visit heaven and hell, and talk with angels, demons, and other spirits. For the remaining 28 years of his life, he wrote and published 18 theological works, of which the best known was *Heaven and Hell (1758*

His later years Swedenborg spent mostly in England, remaining a bachelor.

Influenced William Blake.

Alexander Munro Secundus


SECUNDUS

b Edinburgh 1733, third and youngest son of Alexander Monro primus.

Aged 12 he enrolled in an arts course at the University. In 1750 he began medical studies under his father, showing a talent for anatomy.

1783: Observations on the Structure and Functions of the Nervous System

Beautiful accurate drawings. No idea of brain function. The cortex is depicted as a thin featureless grey rind covering the white matter.

Sir Charles Bell 1774

q. Edinburgh, 1799. He and his brother had brilliant draughtsmen.

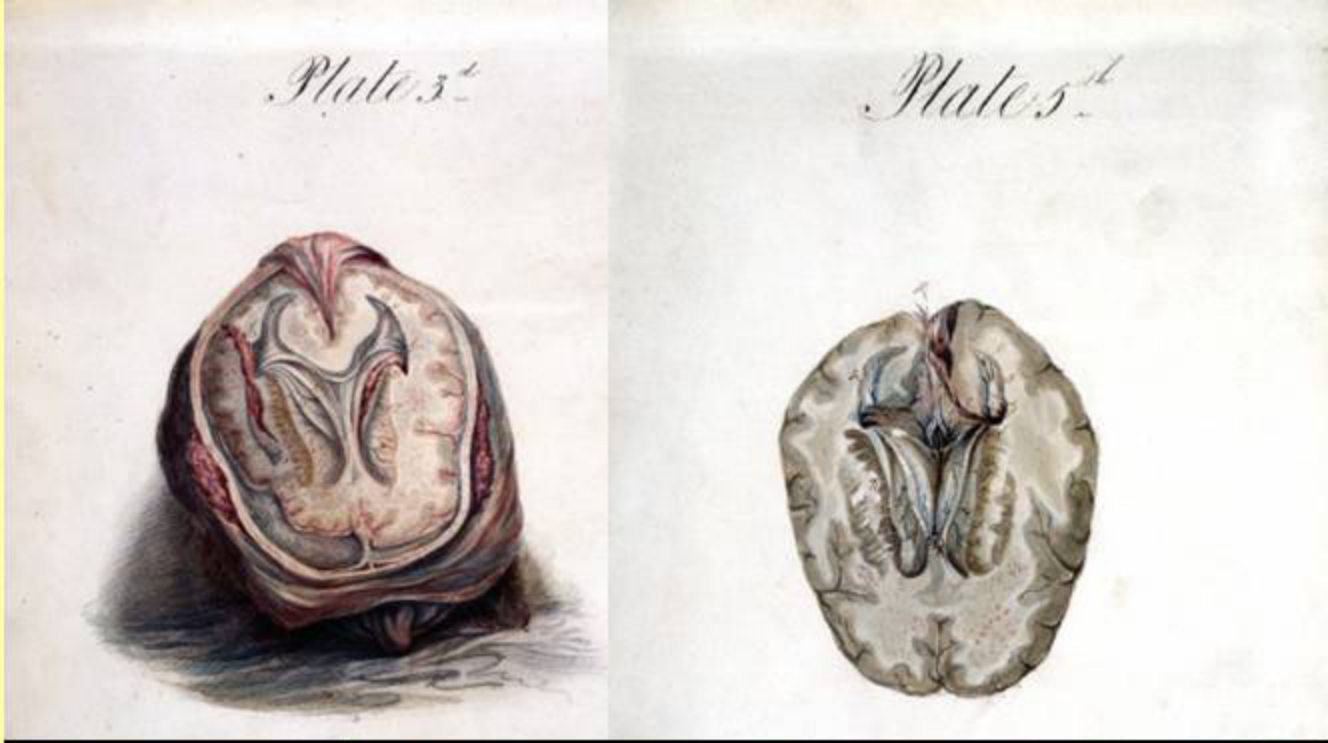
Taught anatomy at the Royal College of Surgeons (Ed). He and his brother illustrated and published two volumes of *A System of Dissection Explaining the Anatomy of the Human Body.*

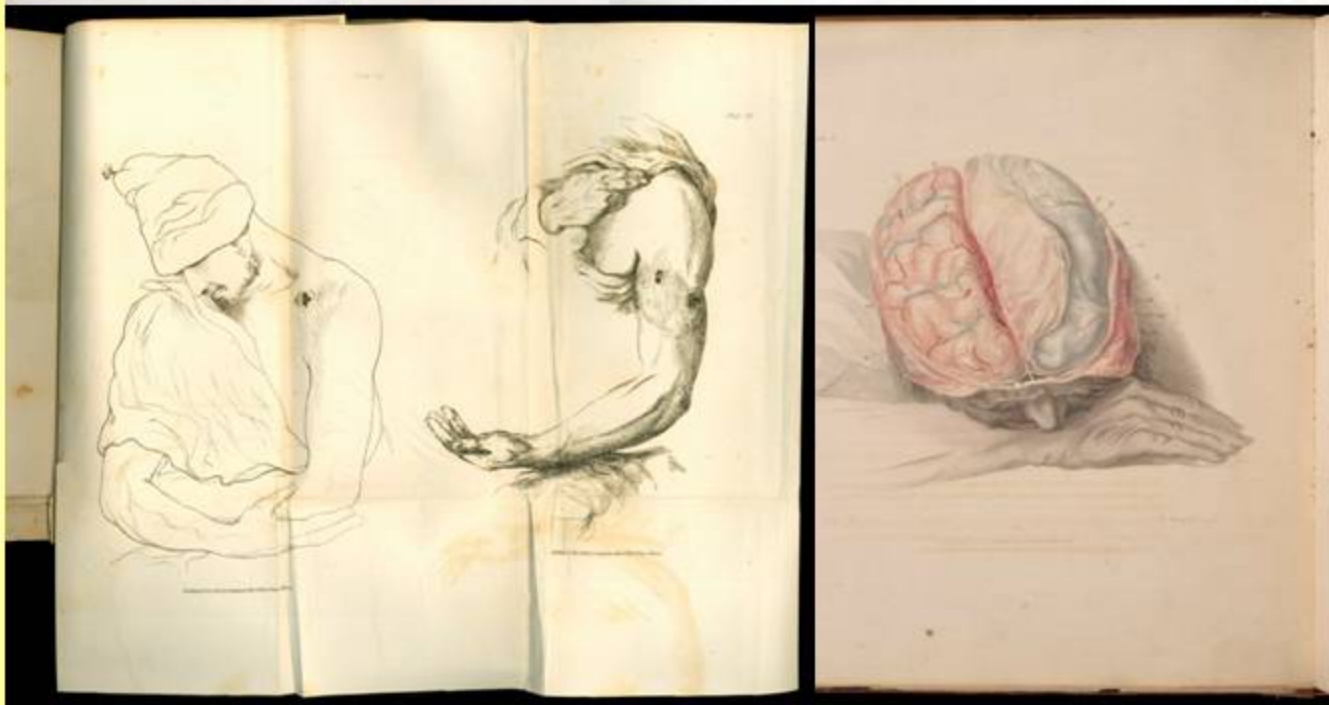
Published two additional volumes of their anatomical treatise in 1802 and 1804. His success, however, led to jealous opposition of local physicians, and he was barred from practice at the Edinburgh Royal Infirmary. He then moved to London in 1804, where he held a private surgery and school of anatomy. From 1812 to 1825, he ran, with his brother, the Great Windmill Street School of Anatomy, which had been founded by the great anatomist William Hunter (1718-1783). He also served as a military surgeon at Waterloo.

In the **B**rain the appearance is so peculiar, and so little capable of illustration from other parts of the body, the surfaces are so soft, and so easily destroyed by rude dissection, and it is so difficult to follow an abstract description merely, that this part of **A**natomy cannot be studied without the help of **E**ngravings.

Shows major parts of the brain also white and a uniform surface of grey matter.

However an obscure publication in 1782 by a 24 yr old medical student had already shown that the grey cortex was not a uniform structure.





Gennari

In 1776, whilst a medical student student at the University of Parma, Francesco Gennari 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 part of brain.

The cortex was not uniform in structure.

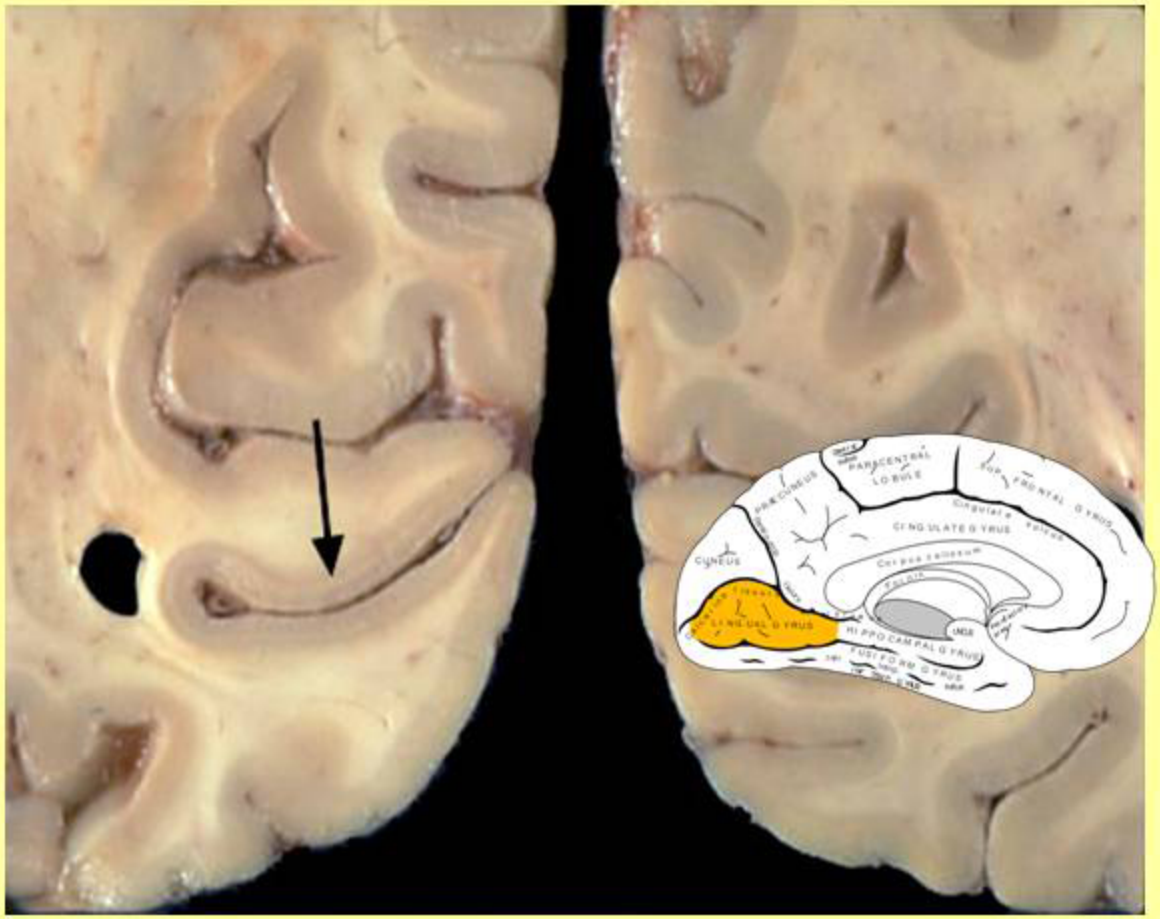
"I do not know the purpose for which this substance was created."

He published these observations in a book published six years later. ***De Peculiari Structura Cerebri.***

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

His discovery remained unrecognised for a century. Meanwhile credit went initially to Soemmering, who claimed he had found a stripe (but his was an artifact in the cerebellum) and to Felix Vicq-d'Azyr who described the stripe 4 years after Gennari's monograph, in ***Traite d'Anatomie***.

The stripe of Gennari is a band of nerve fibres which runs parallel to the surface of the cerebral cortex in the calcarine fissure of the occipital lobe. this region of the brain is called the **striate cortex**



On July 12, 1914, Grigori Rasputin, notorious mystic and confidant to the Russian Royal Family, was visiting his wife and children in his hometown, Pokrovskoye, in Siberia. Khionia Guseva, her face hideously disfigures by syphilis, stabbed Rasputin in the belly as he left church, seeing his entrails hanging out she screamed "I have killed the Antichrist.

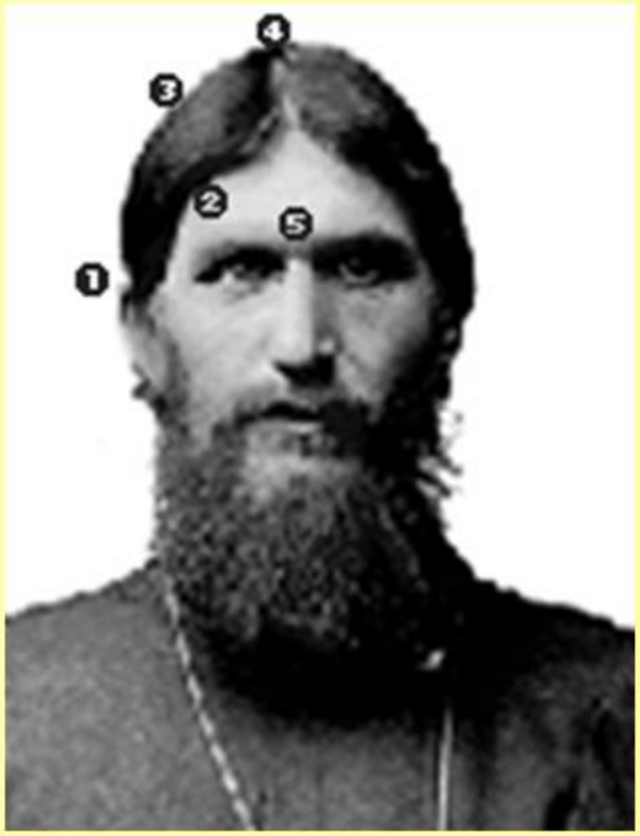
Rasputin recovered. Influence over the Tsaritsa had made him a dangerous threat to the empire. A group of nobles, led by Prince Felix Yusupov and the Grand Duke Dmitri Pavlovich, lured Rasputin to a fictional party for friends of Felix's wife, Princess Irina Alexandrovna. Fed rose cake laced with enough cyanide to kill 5 men, no effect. Yusupov offered him another, then another, but no signs of being poisoned. After drinking poisoned wine, Rasputin clutched his throat, and stood up. Yusupov asked him what the matter was, Rasputin said he had a slight throat irritation and asked for another glass of Madeira. At 2.30AM Yusupov made an excuse to go upstairs for a minute, where co-conspiriters were waiting. Dr. Lazavert had fainted from the stress. Yusupov took a revolver, went back down to the cellar to shoot the monk whilst the others smoked and talked upstairs. After the shooting in the cellar Rasputin appeared at last to be dead. Suddenly, his left eye opened; dragging himself to his feet he held onto the prince and whispered "Felix…Felix…I'll tell it all to the Tsarina". Yusupov screamed, freed himself and rushed upstairs shouting: "Purishkevich, shoot, shoot, he's getting away!" Rasputin was climbing up the cellar stairs on all fours, foaming at the mouth. They stared in horror. Finally Purishkevich shot. Missing with his first two shots eventually shot him in the shoulder and neck. Rasputin fell dead. As they came to inspect the body an eye opened. Yusupov frantically started beating Rasputin's body with a walking stick until he was pulled away. Purishkevich drove to the Petrovsky bridge, binding and gagging the body they dumped Rasputin off the bridge into the icy water. On the way down,the corpse hit the bridge splitting the head open.

Rasputin's ice encrusted body was later found with one hand free and trying to swim to the surface, and his lungs full of water, meaning that he was alive, and trying to breath.

Phrenological analysis of Rasputin

"he got the nickname "the holy devil". Even a superficial Phrenological diagnosis however will be sufficient to unmask the innate evil and the true personality of this imposter....A wide ear axis (1) stands for a strong dynamic energy (Destructiveness), which also is reflected in a strong vital energy. The tragic circumstances of Rasputin's death illustrate this:

The front is wide and protruding (5): well developed Perceptive faculties, practical mind limited to tangible reality. The skull becomes narrower towards the top, faculties like Ideality (2) and Spirituality (3) are notoriously absent. Low type without noble aspirations. The upper back of the head is extremely narrow: the faculties of Conscientiousness and Cautiousness will therefore be very weak. Thus: an audacious person, scrupless, without any conscience. The upper back of the head is very high (4): Self-esteem, reinforced by a strong Firmness. The skull is ogival shaped, rather than dome-shaped: absence of higher aspirations, low type. Whenever one comes into contact with individuals displaying this cranial configuration, caution should be taken! The narrow and high back of the skull, as well as the wide ear axis are an atavistic reminder to the skulls of pre-historic humanoids.



A Phrenological Analysis of Rasputin (1869-1917.)By Paul Bouts ("*Psychognomy*")

Franz Joseph Gall 1758-1828

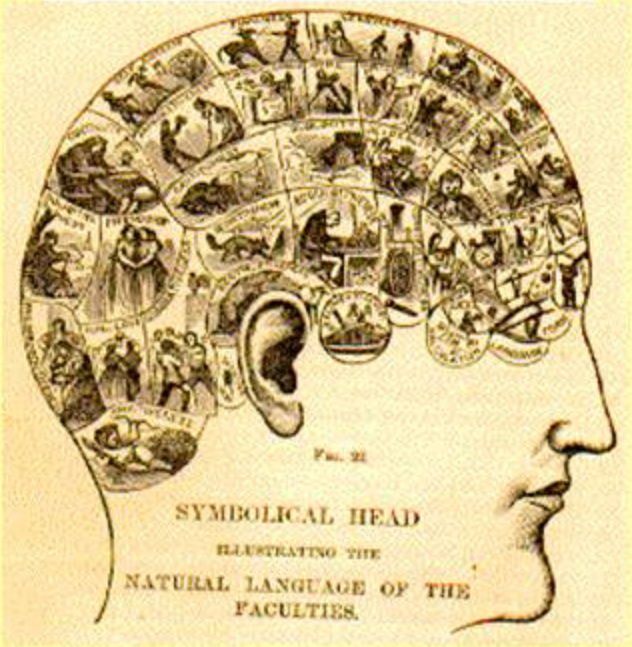
Noted at school that those boys with phenonemal memory also had "les yeux å fleur de téte" Bulls eyes. Proposed this was due to over development of the frontal lobes.

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. 1800, he developed "cranioscopy", a method to determine the personality and development of mental and moral faculties on the basis of the external shape of the skull. Cranioscopy skull-vision was later renamed to phrenology, study of mind, by his follower Johann Spurzheim.

Brain localization was revolutionary, contrary to religion (that the mind, created by God, should have a physical seat in brain matter). Established science also condemned these ideas for lack of scientific proof of his theory. His ideas were also not acceptable to the court of Franz Josef II (the brother of Marie Antoinette). Due to this opposition, Gall left his lecturer position in Austria. Banned because he is a threat to religion; he relocates to Paris in 1805.

The Anatomy and Physiology of the Nervous System in General, and of the Brain in Particular: he believed that man's moral and intellectual faculties are innate and that their manifestation depends on the organization of the brain, which he considered to be the organ responsible for all the propensities, sentiments and faculties. He proposed that the brain is composed of many subdivisions, organs, which would grow with use. This growth could be detected by associated changes detectable on the surface of the brain.



Different functions in different areas

White matter has conducting properties

Brain folded to save space.

Pierre Flourens 1794-1867

Different regions of the brain have different functions

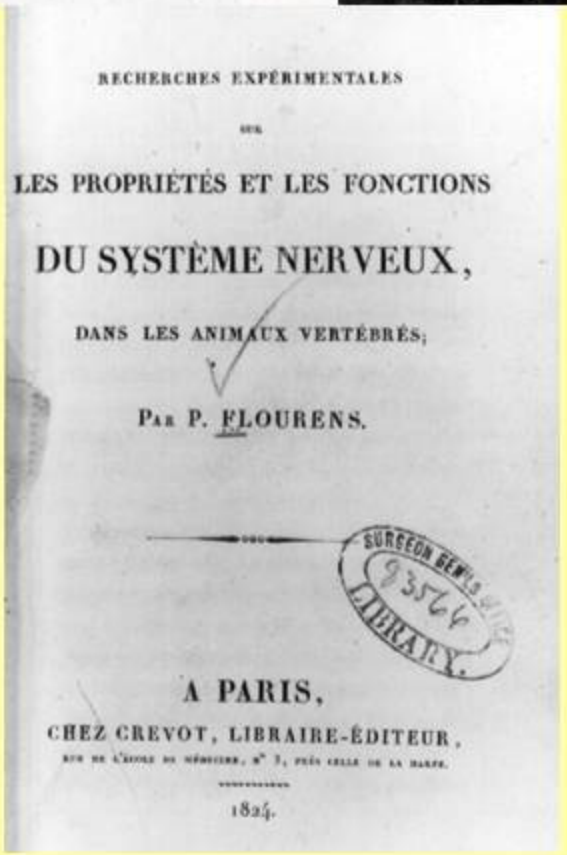
Q. Montpelier 1823 then moves to Paris. At the request of the Academieof Sciences he experimented on animals to test Gall's phrenology theory. Using selective surgical ablation he created localized lesions of the brain in rabbits and pigeons.

Removal of cerebral hemispheres, abolished perceptions, movement, and judgment. The removal of the cerebellum affected the animal's equilibrium and motor coordination, and destruction of the brain stem (medulla oblongata) caused death.

Cerebral hemispheres are responsible for higher cognitive functions (process of thought), the cerebellum regulates and integrates movements, and the medulla controls vital functions, such as circulation, respiration and general bodily stability.

Wherever the lesion there was severe impairment of judging, remembering and perceiving. Except sight. Lesions on one side of the brain created blindness on the other side of the body.

Unable to find specific regions for memory and cognition, suggested they were represented diffusely in the brain. Paradoxically used as support for Gall's emphasis on the cognitive function of the cortex.



RECHERCHES EXPÉRIMENTALES

SUR

LES PROPRIÉTÉS ET LES FONCTIONS

DU SYSTÈME NERVEUX,

DANS LES ANIMAUX VERTÉBRÉS;

PAR P. FLOURENS.

A PARIS,

CHEZ CREVOT, LIBRAIRE-ÉDITEUR,

1824.

First identification of the cortex with mental function: Language

Clinical studies in France and Germany, on patients with language difficulties, showed that higher mental functions had, indeed, a specific localization in the cortex.

1825 Bouillaud ***Traité clinique et physiologique de l'encéphalite, ou inflammation du cerveau:*** earliest study of localization of brain function. loss of articulate speech was associated with lesions of the anterior lobes

Pierre Paul Broca 1824-1880 (1870): At the Meeting of the Anthropological Society in Feb 1861, Broca was describing the relationship between brain size and intelligence. Gardner "**In 1871, Paul Broca a French Neurologist with a broad head wrote 5 vols to prove that the broader the head the greater the intelligence, and the French have particularly broad heads**"

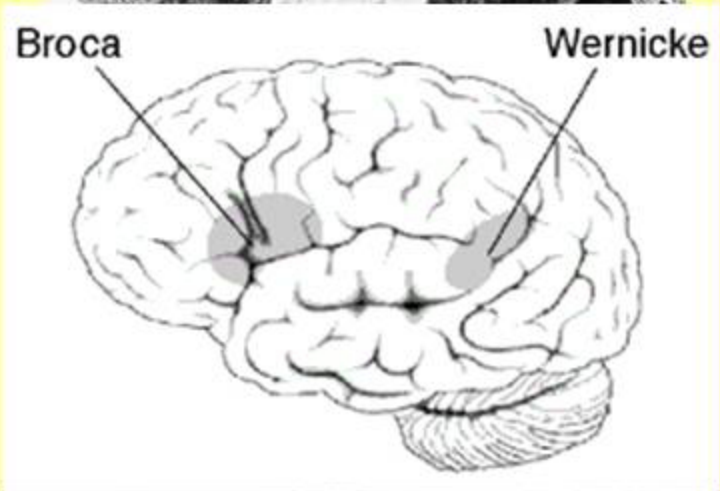
Aubertin cited his father-in-law Bouillaud's claim that speech localised in the frontal lobes, Broca challenged saying that if his aphasic patient "Tan" did not have such a lesion would Aubertin give up this ridiculous nonsense. The patient, M. Leborgne, had tertiary syphilis and severe language difficulties. The only word he could repetitively produce was 'tan'. He died conveniently on April 17th. The brain autopsy; Widespread damage to frontal lobes, including surface of left frontal area. Another pt M. Lelong could only utter 5 repetitive words. 'apheme' expressive aphasia. Lesion in same area.

Broca vindicated Bouillaud and Gall

Carl Wernicke 1848-1905: b. Silesia Prussia. 1874: Not all language defects were due to damage in Broca's area. He described location of brain injuries that caused aphasia. Superotemporal gyrus of dominant (usually right) hemisphere. Receptive aphasia: a major impairment of language comprehension, while speech retains a natural-sounding rhythm and a relatively normal syntax. Language as a result is largely meaningless

Gustav Fritsch (1837-1927) and Eduard Hitzig 1838-1907), Using dogs, electricalyl stimuled small exposed regions of the surface of the brain (cortex). Some areas caused muscle contractions in the head & neck, others caused contractions of the forelegs or hindlegs. Evidence for a fine localization of function in the cortex.

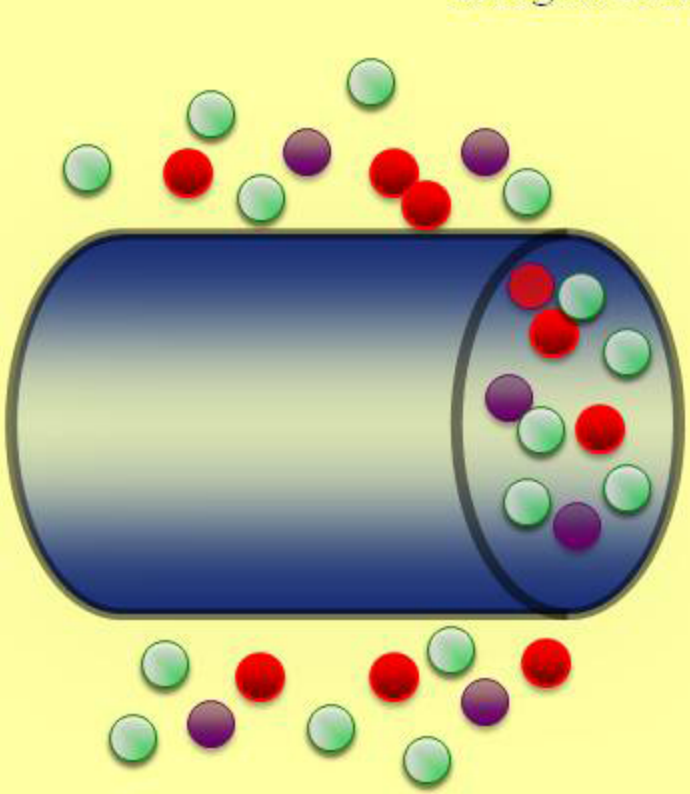
Feodor Krause stimulated the cortex of anesthetized patients undergoing brain surgery. He mapped the motor area accurately. **Wilder Penfield** in the 1940s.

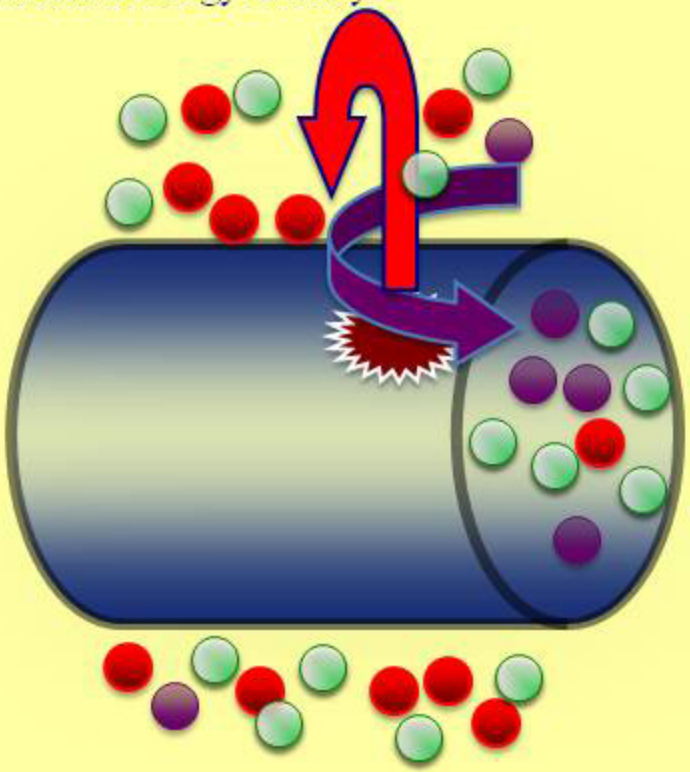


Generation of resting potential

Galvani discovers animal electricity.

Hodgkin & Huxley Plymouth Marine Biology/Trinity





Nerve cell contains and is bathed in salt Solution. Na^+/K^+/Ca^{2+} and Cl^-.
Active ATP-fuelled pump exchanges Na^+ for K^+
Develops an ionic gradient

Ion	K^+	Na^+	Ca^{2+}	Cl^-
Outside	5	150	2	150
Inside	100	15	0.0002	13
Ratio	**1:20**	**10:1**	**10,000:1**	**12:1**

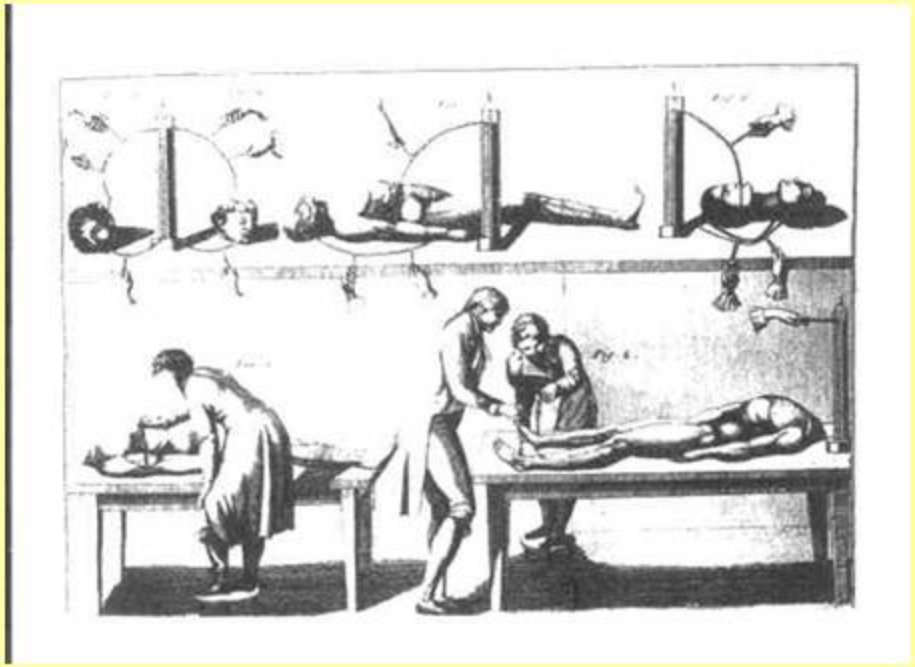
Giovanni Aldini (1762-1834)

Galvani: electrical activity is produced by activity of ***the cerebrum where it is extracted from the blood.***

Aldini: Nephew of Galvani who had applied electrical currents to animal muscles and nerves. In 1802, bizarre experiments. In Bologna, London and elsewhere, using the bodies of recently hanged and decapitated prisoners to apply electrical currents, in public shows.

electrical stimulation of the head and limbs evoked responses such as blinking and opening the eyes, facial grimaces, and tongue, eye and limb movements.

He wanted to prove that he was stimulating the brain, but in fact he was not, because electrical current, however strong, would be blocked by the thick bones of the skull. He was actually stimulating the muscles directly.



Mary Wollstonecraft Shelley (1797-1851), was impressed with the possibility of generating life in dead tissues by means of electrical stimulation. Her gothic romance "Frankenstein, or Modern Prometheus", published in 1818, She said "Perhaps, a corpse would be reanimated; galvanism had given token of such things.".

Developments in microscopy neuronal theory

C19th: debate about the organization of the nervous system. Using similar methods different conclusions; because of poor resolution.

Reticularists: nervous system consisted of a large network of tissue, or reticulum, formed by the fused processes of nerve cells.

Neuronists: thought the nervous system composed of unit called cells.

Purkinje 1787-1869: Anatomist b. Libochovice, Bohemia (Czech), studied medicine and philosophy at the University of Prague, q1819;

1837, despite low magnification and poor resolution of the microscope used, discovered the first neurons to be identified, (large cells in cerebellum).

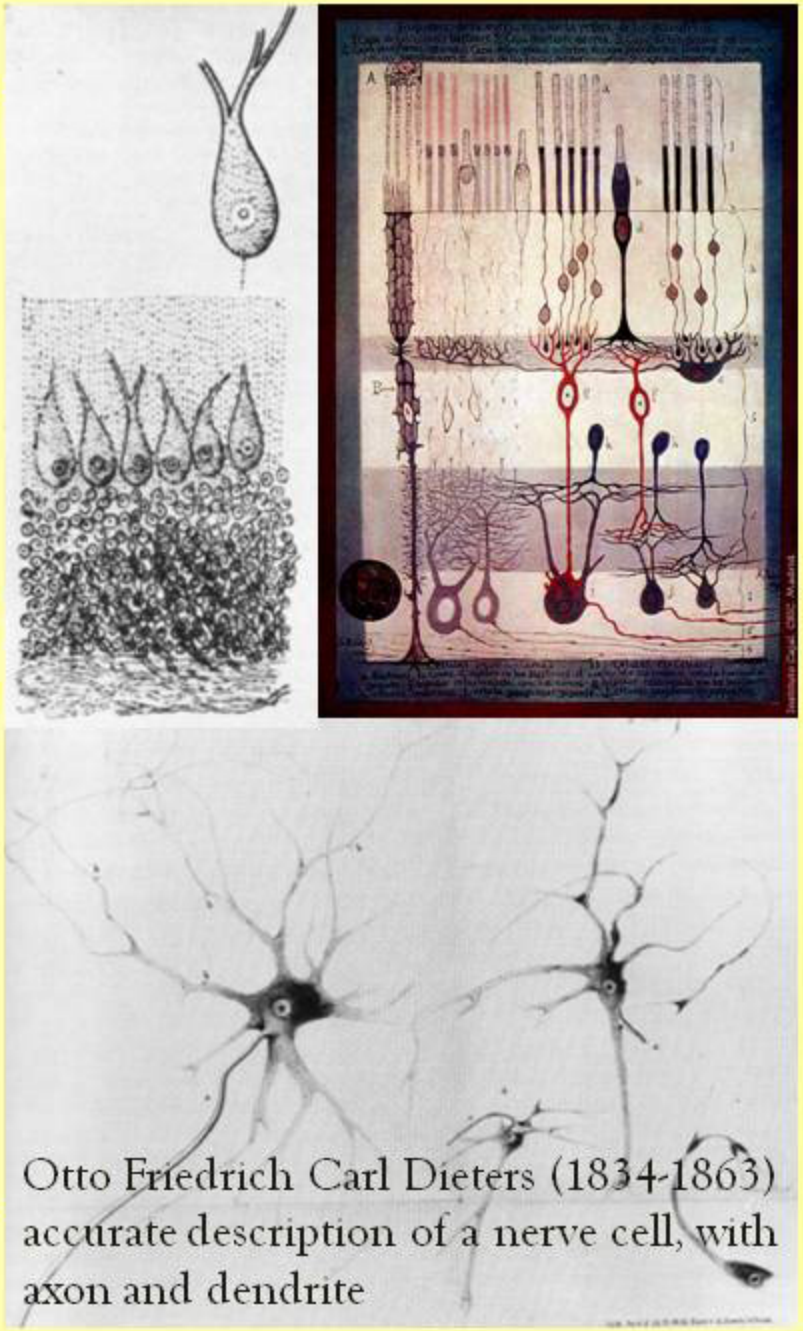
1838 Theodore Schwann and Matthias Schleiden proposed that the cell was the basic functional unit of all living things

Golgi impregnation, fixing brain in K^+ bichromate/ammonia, then immersion in a silver nitrate solution. The stain visualizes a small number of cells; stained at random complete, cell body, axon and dendrites are clearly visible. He himself was mistakenly a reticulararist.

1887, Cajal started using Golgi's method of staining nervous tissue, and pioneered an improved method, which involved immersing tissues in fixative and silver nitrate a second time.

The term 'neuron' was introduced in 1891. The axis cylinder was then named the 'axon' by **Rudolph von Kollicker**, and the protoplasmic processes were called 'dendrites' by **Wilhelm His**.

1897, Sir Charles Sherrington described the junction between nerve and muscle, and named it the synapse (from the Greek roots syn, meaning 'together,' and haptein, meaning 'to clasp').



Otto Friedrich Carl Dieters (1834-1863) accurate description of a nerve cell, with axon and dendrite

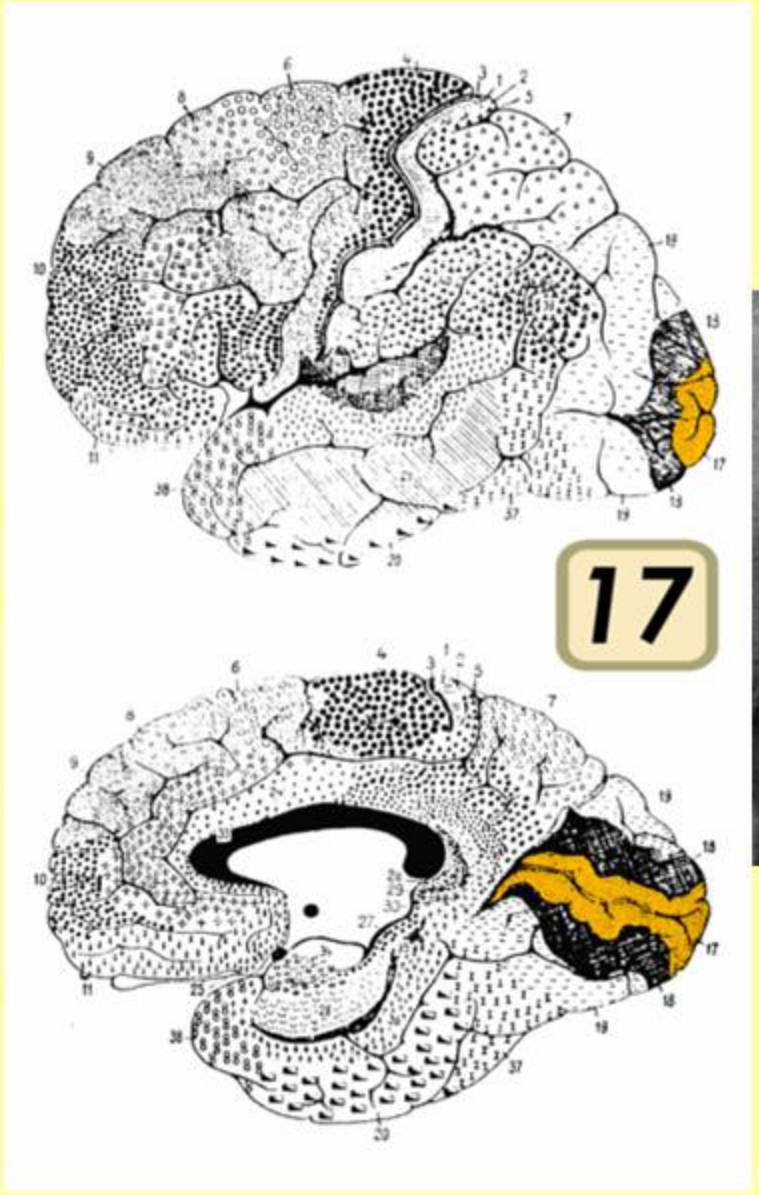
Arrangement of different types of neurones are distinct in separate areas of the cortex.

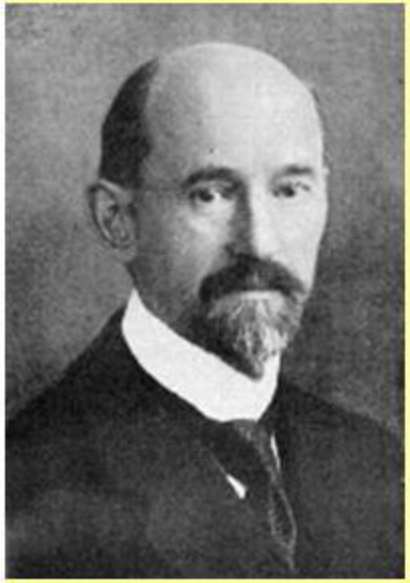
Korbinian Brodmann (1868–1918) German neurologist studied organization of neurons he observed in the cortex using the Nissl stain. Classified cortex into 52 distinct regions from these cytoarchitectonic features.

Worked in 1901 with **Cécile and Oskar Vogt** at the private institute "Neurobiologische Zentralstation" in Berlin, and in 1902 in the Neurobiological Laboratory of the University of Berlin.

In 1915 he joined the Kaiser-Wilhelm-Institut für Hirnforschung (Institute for Brain Research).

In 1909 he published his original research on cortical cytoarchitectonics in ***"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)*





Localisation of vision to the occipital lobe

Bartolomeo Panizza (1785 – 1867) b. Vicenza. q Padua, studies at Bologna and Pavia.

Follower of Gall, the first to attribute visual function to the posterior cortex.

He examined brains of pts blind after strokes and experimental lesions in animal brains, concluding the occipital brain was crucial for vision.

1855 **Osservazioni sul nervo ottico** (Observations on the Optic Nerve).

his discovery was largely ignored possibly because of the prevailing theory of the thalamus as the highest sensory centre and the cortex associated with intellectual function. None of Gall's areas for example, had sensory or motor function.

It took a horrible war to prove him correct.

Battle of AntietamSeptember 17, 1862

Gen. McClellan confronted Lee's army of Northern Virginia at Sharpsgurg Maryland. At dawn Hooker's division assaulted Lees left flank, beginning the bloodiest single-day battle in American history, with about 23,000 casualties. Musket 300m/s 1 ounce. Minie ball rifle.

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. dazed and in shock, bleeding heavily from the scalp, he dragged himself to the rear and received first aid from the regiment's surgeon, **Dr. George W Lovejoy**, who reported his "patient was conscious and answered questions rationally." He was then carried to a barn in Keedysville. 25 Sep moved, to Mount Pleasant Hospital in Washington

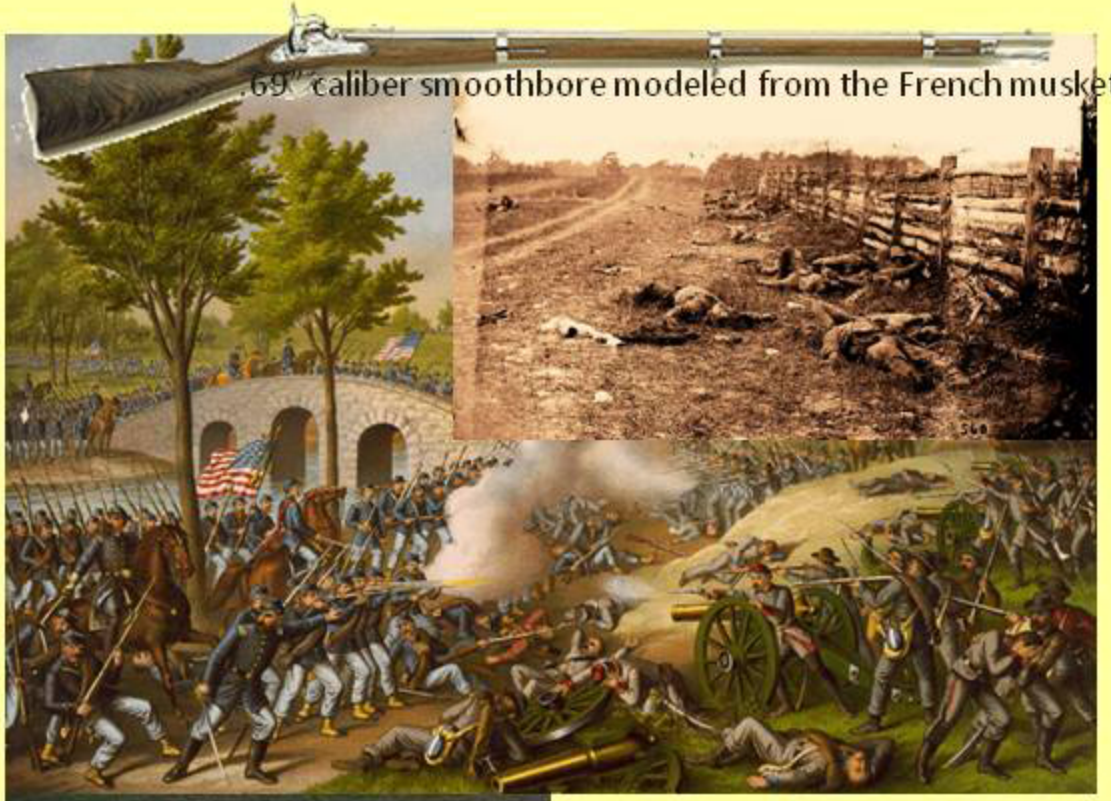
Assistant Surgeon **Thomas Carroll**; general condition of the patient was good; suppuration had commenced; no febrile action existed, the pulse was regular, sleep not materially disturbed, mind clear and manifesting no signs of compression of the brain, or inflammation of its membranes. Swelling subsided, leaving a prominence, 1"in high, and 3" long of brain substance, in which the pulsation of the arteries could be seen.

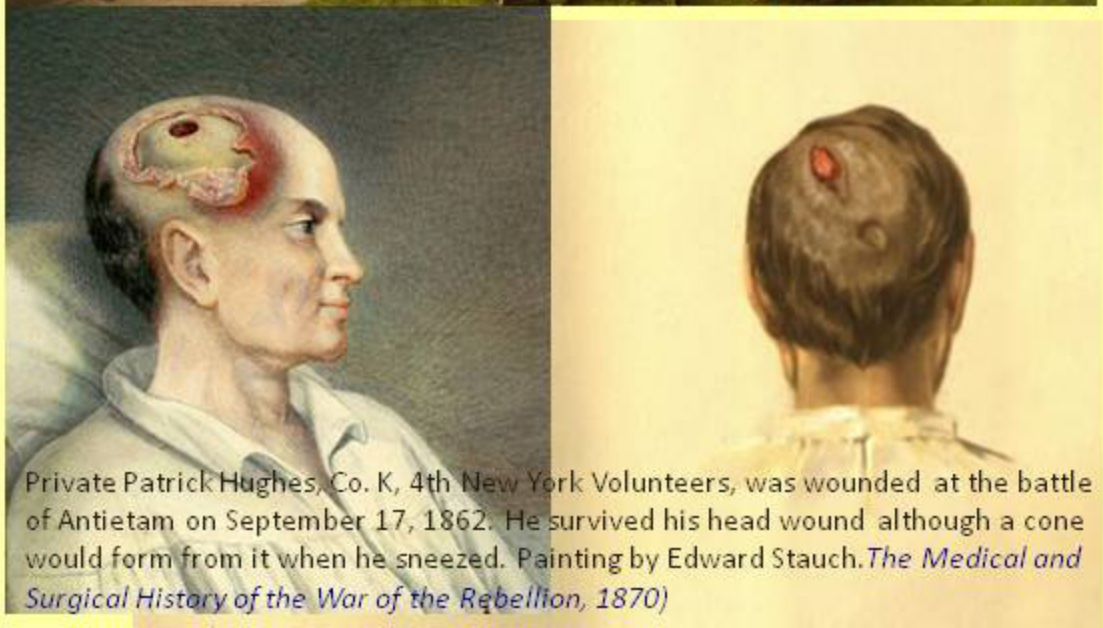
Examined 8 yrs later by **Dr. W.W. Keen and William Thomson**, he complained that the sight in his right eye was poor, however whiskey affected him as usual and his sexual power was undiminished! *The wound of entrance is marked by a slight depression in the bone, the wound of exit by a hollow 2half by 2", and 1" deep. No bone has closed this opening, but the scalp and hair dip down into the hollow. The arterial pulsations are barely perceptible.*

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.

Newton's hemidecussation in the chiasm thus correct.

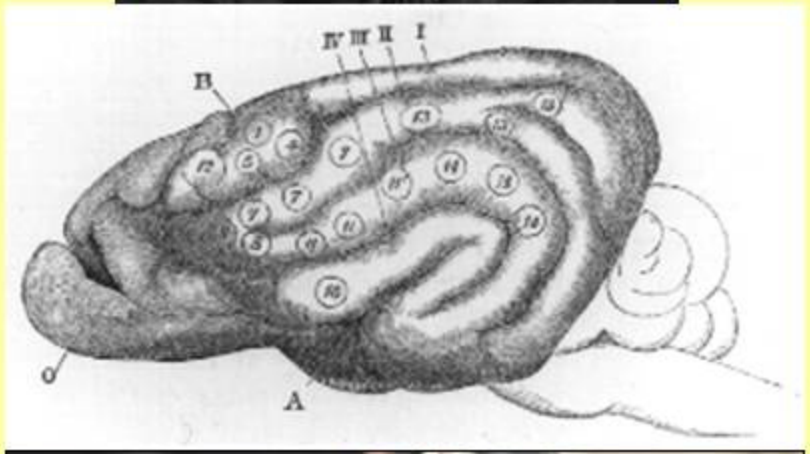




Private Patrick Hughes, Co. K, 4th New York Volunteers, was wounded at the battle of Antietam on September 17, 1862. He survived his head wound although a cone would form from it when he sneezed. Painting by Edward Stauch. *The Medical and Surgical History of the War of the Rebellion, 1870)*

David Ferrier 1843-1928

West Riding Lunatic Asylum, electrical stimulation of brain cortex of animals: detected 15 different areas related to the precise control of movement. He removed areas of brain where movement was elicited and demonstrated the abolition of the corresponding motor function. Ferrier predicted how these areas corresponded on human brain, correctly predicted the localization of a brain tumour in a patient with paralysis in the fingers and forearm allowing Mr. **Macewen**, a surgeon, to remove the tumor with great accuracy.



Ferrier contradicted Flouren and others regarding cortical localization. Friedrich Goltz, was unable to abolish localized functions in dogs even when he carried out extensive hemispheric lesions. Public dispute between Goltz and Ferrier, Goltz's surgical lesions spared some motor and sensory cortex.

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

Vehemently opposed by **Herman Munk** at Berlin Vetinary School. His experiments showed the 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 to cause macular scotoma.

Summary of knowledge at the dawn of 20th century

The brain was thought to consist of white matter covered with a unifom rind (cortex). **Gennari** showed this was incorrect and since the cortex showed distinct areas wondered if this represented localisation of function. **Gall** proposed that different parts of the brain had different functions. **Broca** showed that function (speech) was indeed localised. **Ferrier** confirmed movement was controlled by a central strip; But where was vision located?

Strokes, brain injury in war and animal experiments, confirmed that occipital lobe was the site of vision. Furthermore Newton, Taylor and Descartes were correct, the left side of the field is represented in the right side of the brain. Ferrier 's flawed experiments suggested that the parietal lobe may also have something to do with visual recognition

Salomen Eberhard Henschen: University of Uppsala, 1892: Summarised literature where brain damage had caused visual loss and in whom an autopsy was available. Concluded that in every case damage occurred on the inside surface of the back of the brain involving a deep groove, the calacarine fissure. Confirms Gennari that the part of the cortex with a stripe has a special function; this function was vision. Furthermore vision was mapped; the upper part of the field is represented on the lower bank of the fissure, the lower field on the upper.

He also concluded that the centre of the field mapped to the front of the sulcus. It would take **another horrible war** to show this deduction was incorrect.

Discovery of the map of vision

Russo-Japanese war

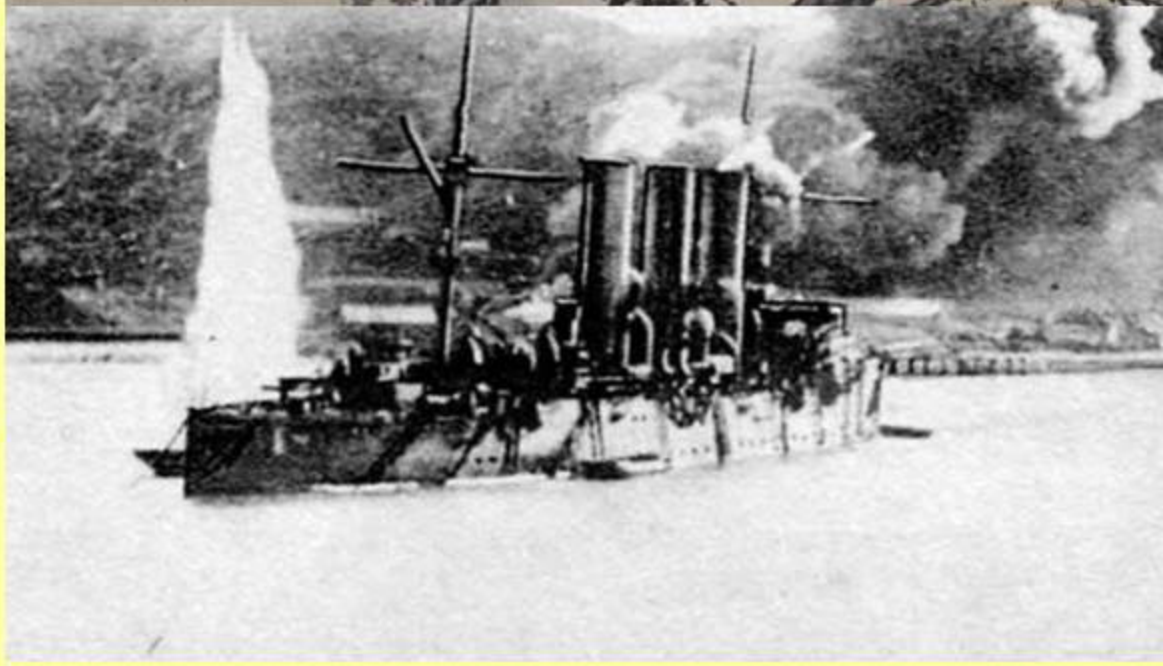
The Meiji era (1868-1912) period when Japan welcomed Western influences. Germany became the primary source for dissemination of modern medical knowledge, (previously the Dutch for 250 years during the Edo era). Within a 40-year span, Japan's physicians made significant contributions in all medical fields

Control over Korea and Liaodong peninsula (Port Arthur) brought Russia and Japan into competition after the Boxer Rebellion.

Japan declared war on 8 February 1904. However, three hours earlier, the Imperial Japanese Navy attacked the Russian Far East Fleet at Port Arthur. Damaging capital ships that withdrew to defensive positions.

Japs capture hilltop in Dec. From here long-range artillery shelled the Russian fleet, which was unable to retaliate effectively and was unable to escape the Japanese blockade fleet. 4 Russian battleships and two cruisers were sunk , the last battleship was scuttled later. The sinking of all capital ships of the Russian fleet in the Pacific, is the only example in military history when such devastation inflicted by land-based artillery against warships.

Land battles involved 500,000 troops.



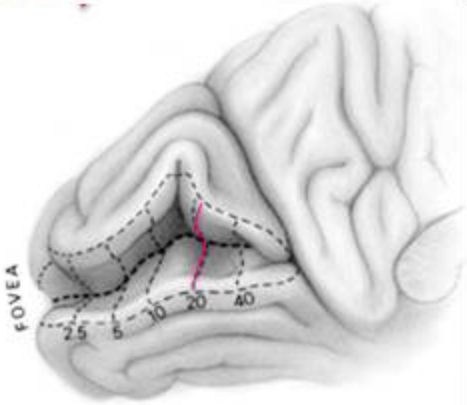
Tatsuji Inouye

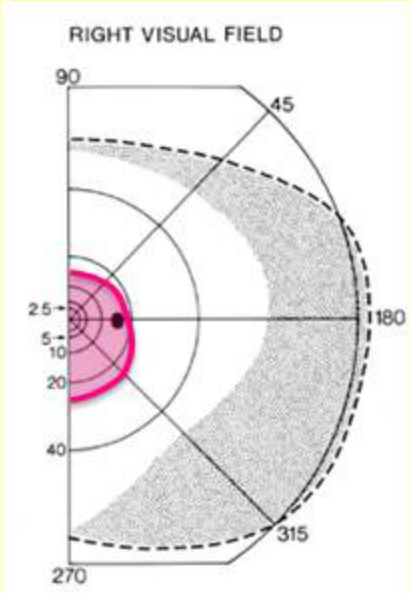
Russians equipped with new **Mosin-Nagant Model 91**. Small diameter 7.6mm, High velocity 620 m/s. Colonel Sergei Ivanovich Mosin designed the bolt and receiver, the Belgian Emile Nagant, designed the magazine system.

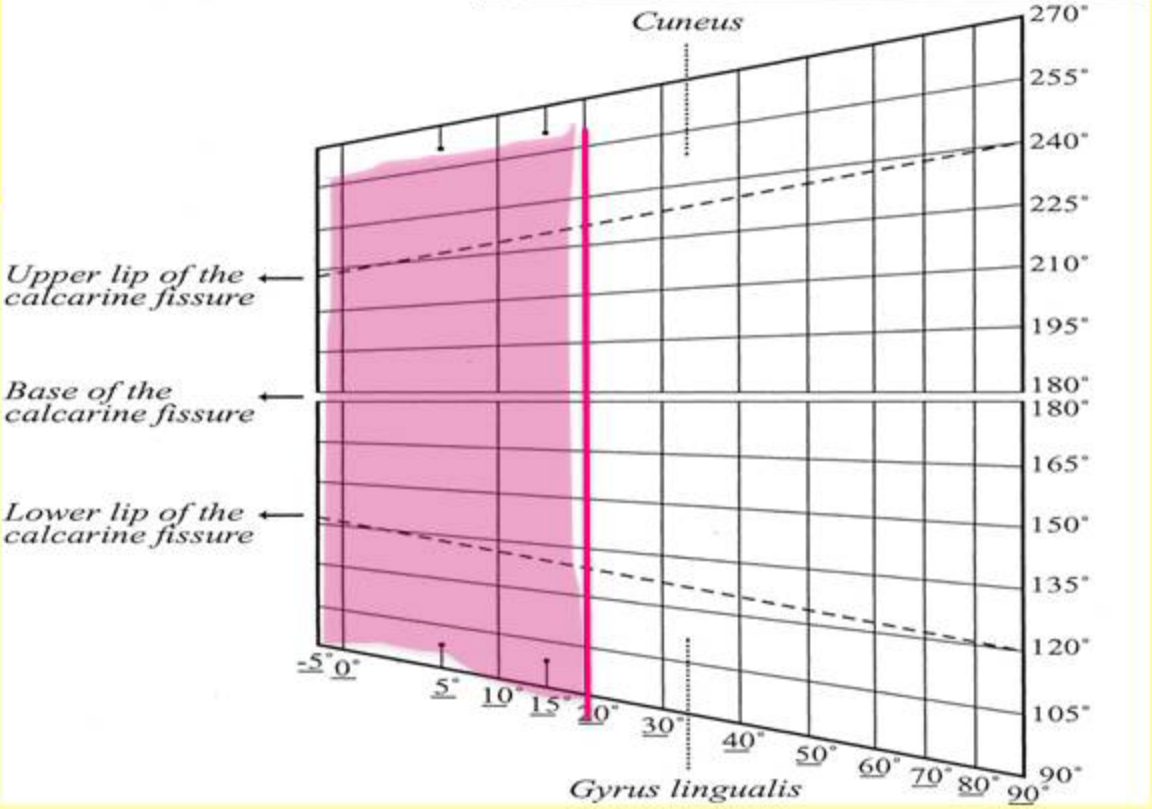
As a young Japanese ophthalmologist, Dr. Inouye examined soldiers with visual defects for their pension board.

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.



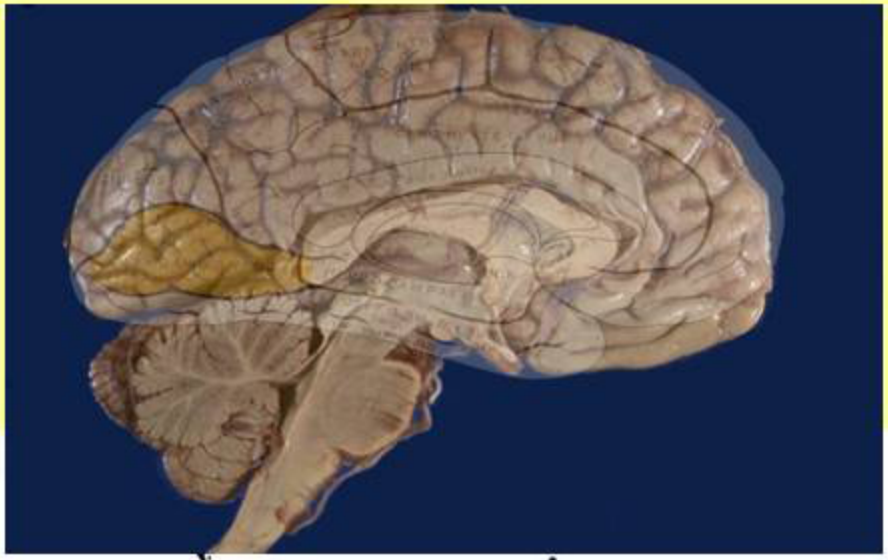


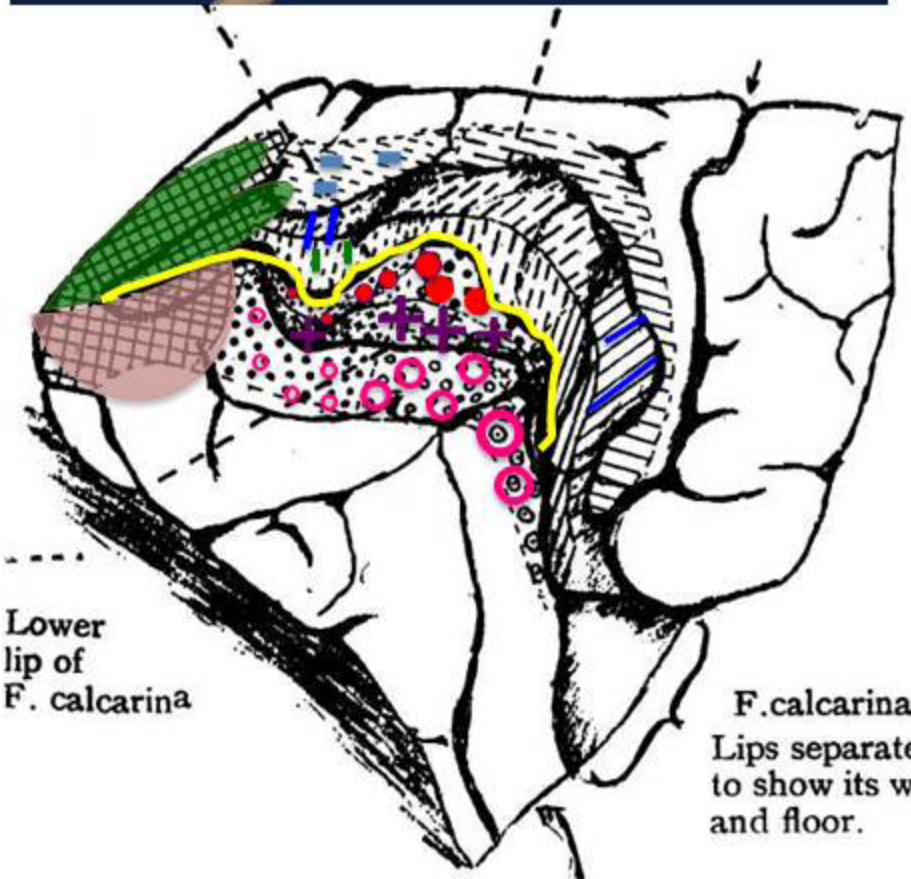


WW1 Gordon Holmes

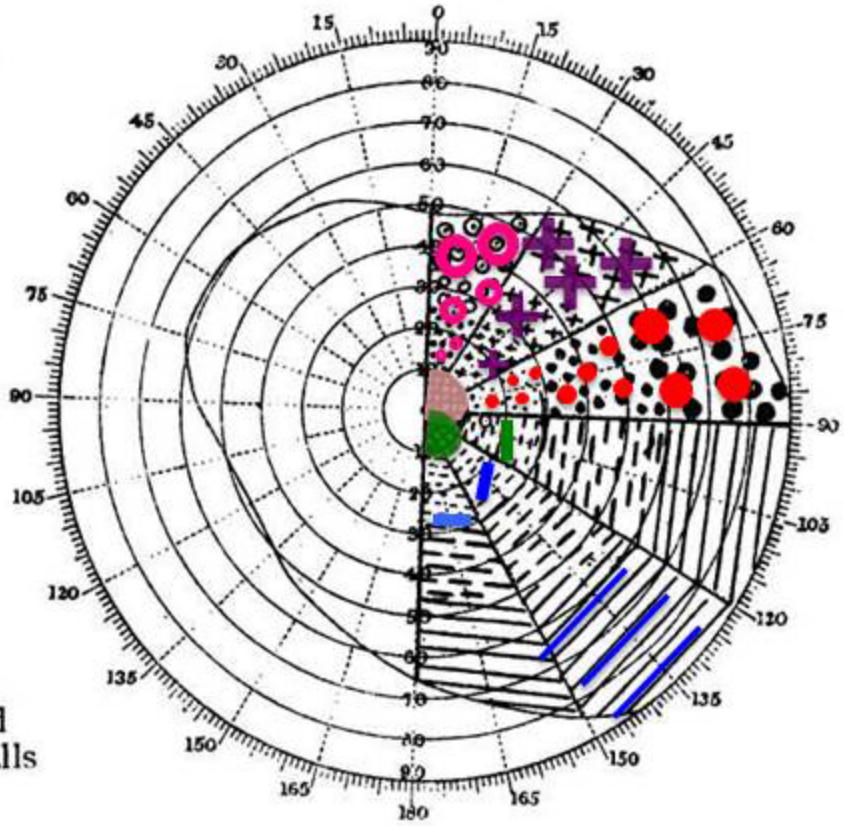
the British Mk. I helmet design: an inverted bowl stamped out of a single piece of manganese alloy, M-1917 helmet increased protection for the wearer by 10 % which was made up of 13% Mn .036" thick. could withstand a .45 caliber pistol bullet at 10'.

I was called up in the war and sent to a hospital. I dressed wounds, applied iodine, gave enemas, did blood transfusions. If the doctor ordered: "Brecht, amputate a leg!", I would reply, "Certainly, Your Excellency!", and cut off the leg. If I was told, "Perform a trepanning!" I opened the man`s skull and messed about with his brains. I saw how they patched fellows up, so as to cart them back to the Front as quickly as they could...
(Bertold Brecht, German playwright and poet, 1918)





F.calcarina.
Lips separated
to show its walls
and floor.



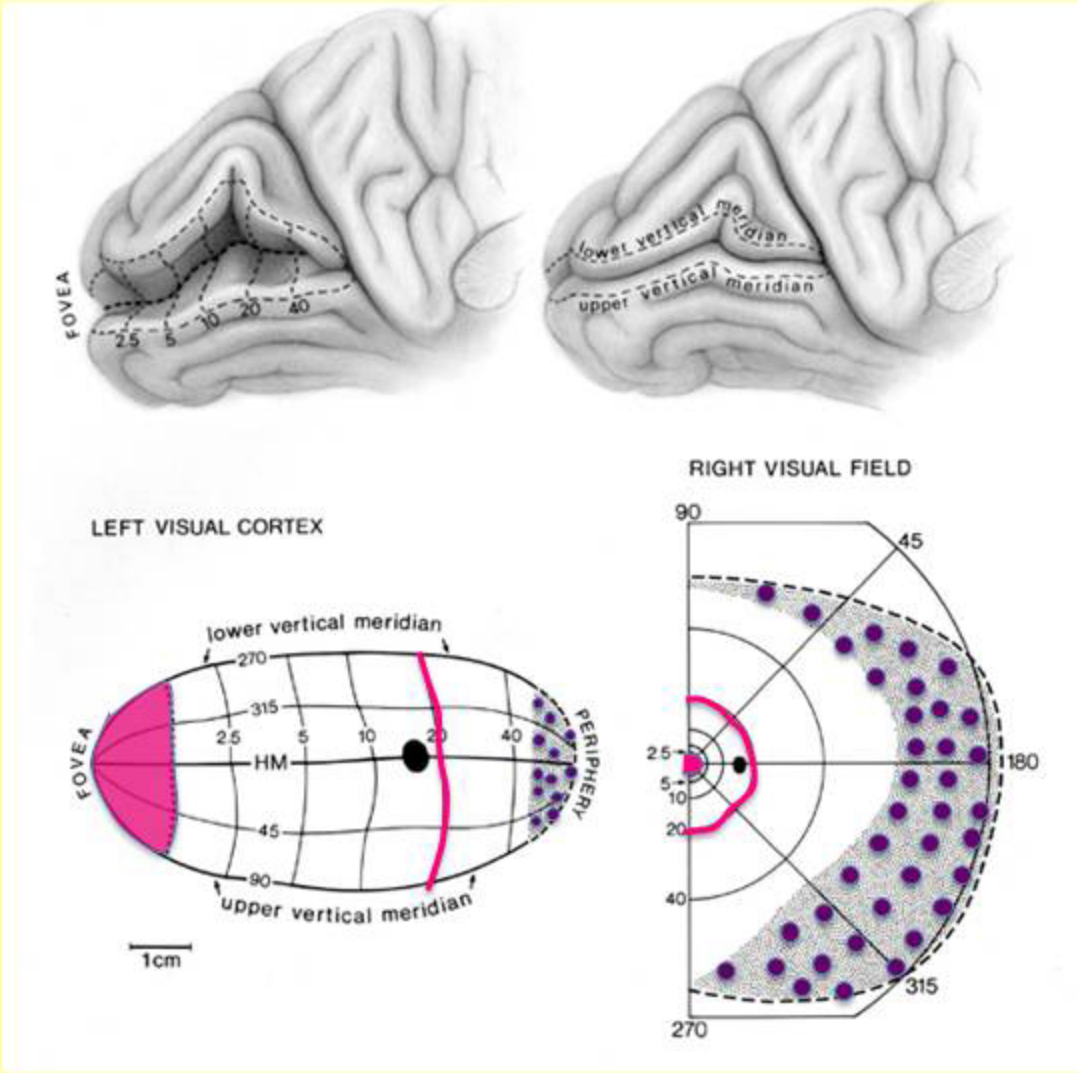
Modern mapping

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

magnification of central vision: Brain area devoted to the central 1o 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° 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° eccentricity. The temporal crescent representation only 5% of surface area of primary visual cortex. The representation of central vision is highly magnified compared with peripheral vision, so that the cortical .

shadows cast by retinal blood vessels (angioscotomas) are represented in striate cortex of the squirrel monkey



Visual cortex

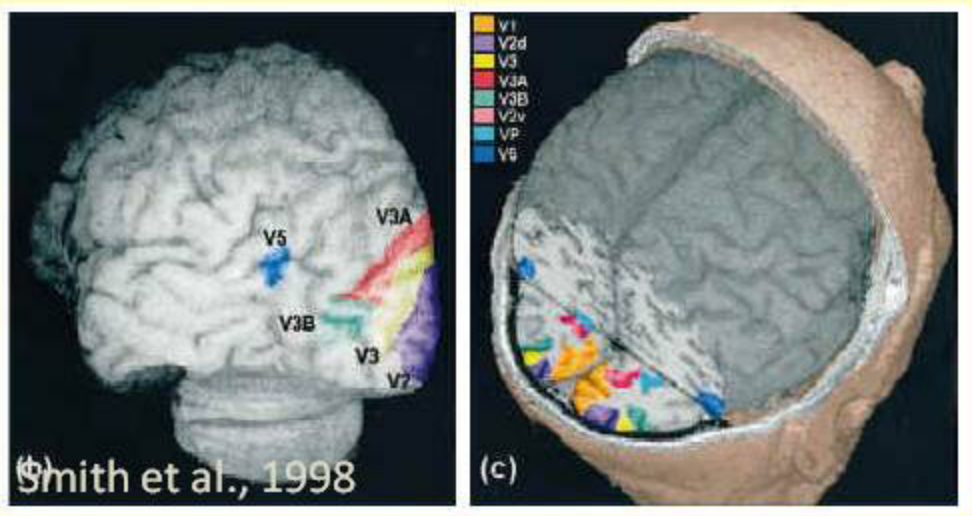
Visual stimuli activate part of the brain called visual cortex; Located around a fold (called the calcarine sulcus) between the 2 lobes at the back. Occipital Lobes

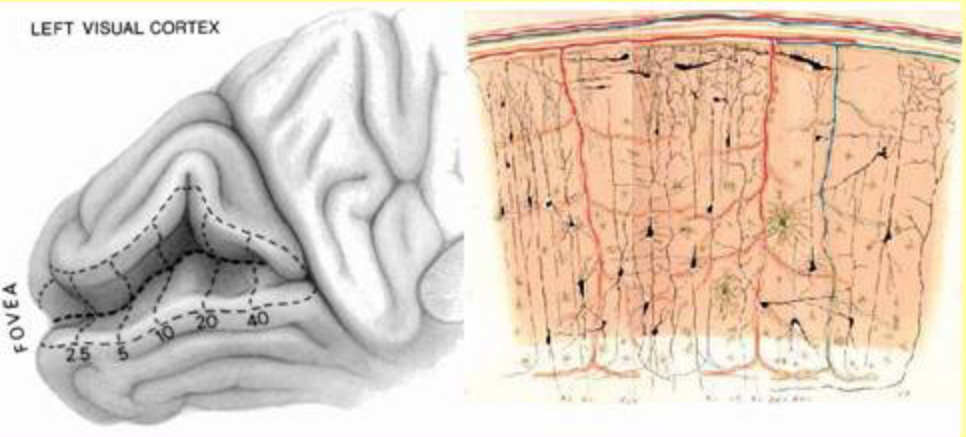
Stimuli on the left activate the right side of the brain

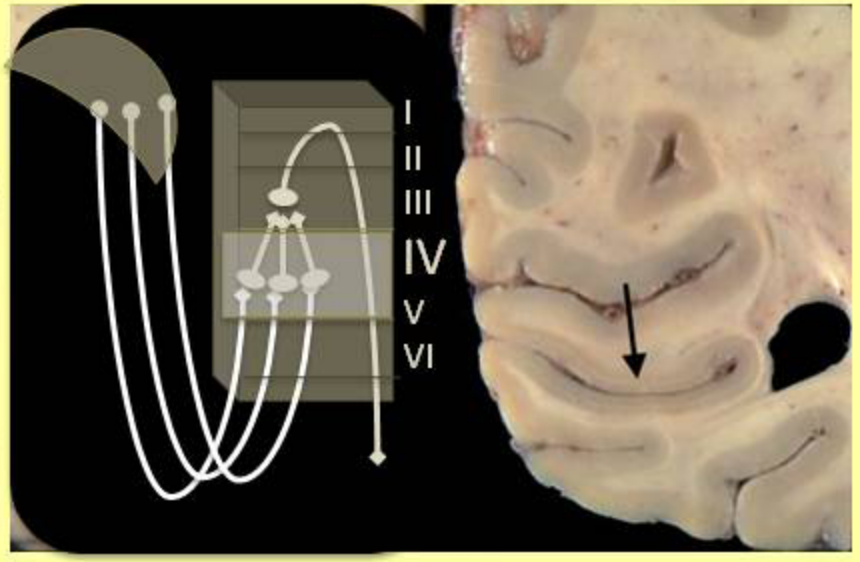
Striate cortex, V1, area 17. Thin sheet of grey matter on surface of brain overlying white matter, folded to maximise area, a plate of cells 2mm thick. $200x10^6$ cells (LGN only $1.5x10^6$)

6 Layers

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

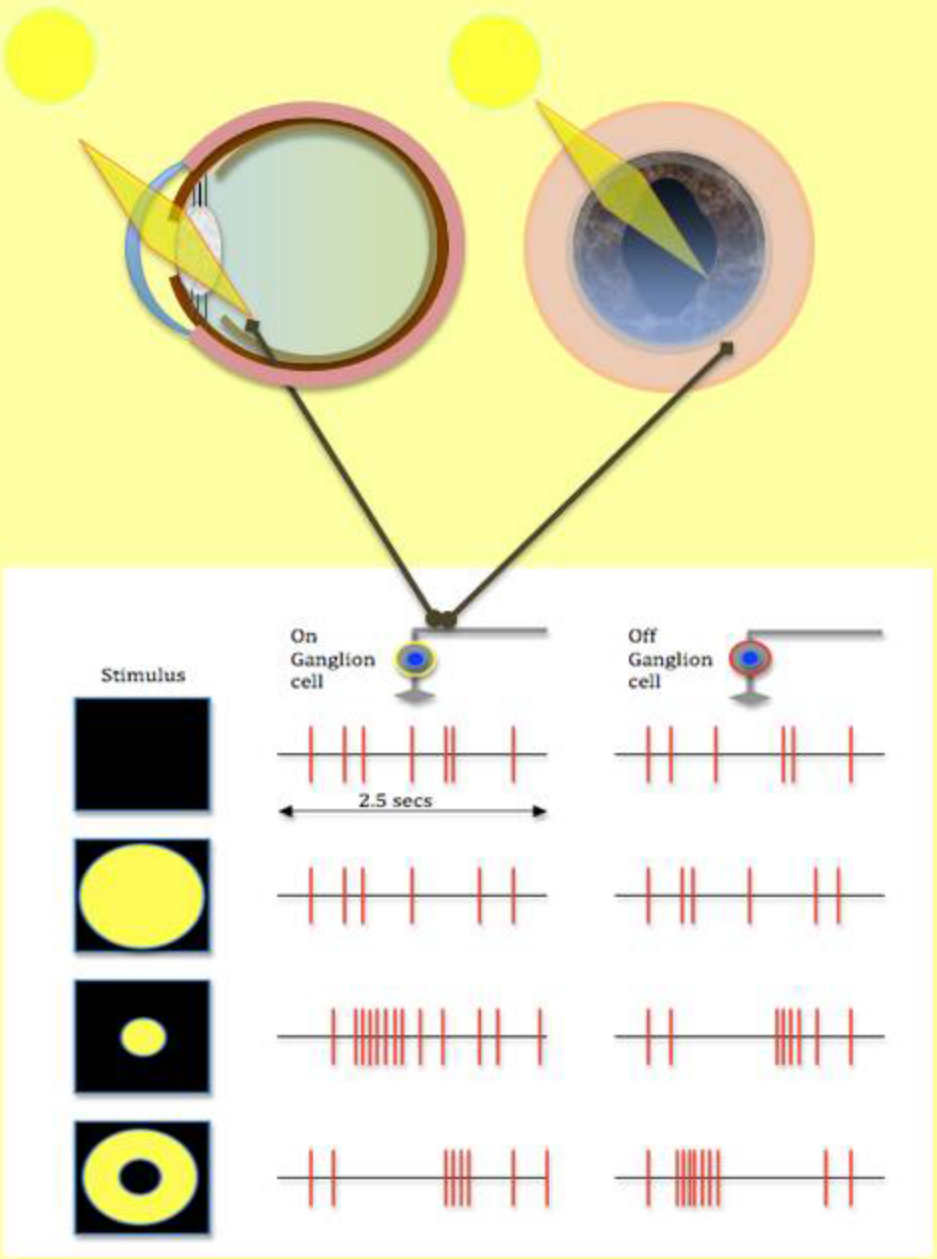






Receptive fields

- Hartline: limulus crab axon: Stimulating receptors inhibited neighbouring axons.
- 1950: Setphen Kuffler (Wilmer, John Hopkins) records from cat retina with electrodes inserted through sclera. In dark steady irregular firing 2-20/sec! In diffuse light?...
- Shining small spots: areas were found that increased rate, others that decreased rate. About equally distributed.
- Moving away from on centre the spontaneous rate was inhibited. Turning light off a quick burst. Centre surround.
- An on-center cell fires at increased rate when a small spot was shone in the center of the receptive field. moving the spot of light a small distance away from the center of the receptive field, suppressed the spontaneous firing of the cell.
- An *off-center* cell does the opposite: small center from which off responses were obtained, and a surround that gave on responses.
- In nature, dark objects are as common as light ones, (like this text). The eye developed both on-center cells and off-center cells to pass on this information.



Cell responses in visual brain

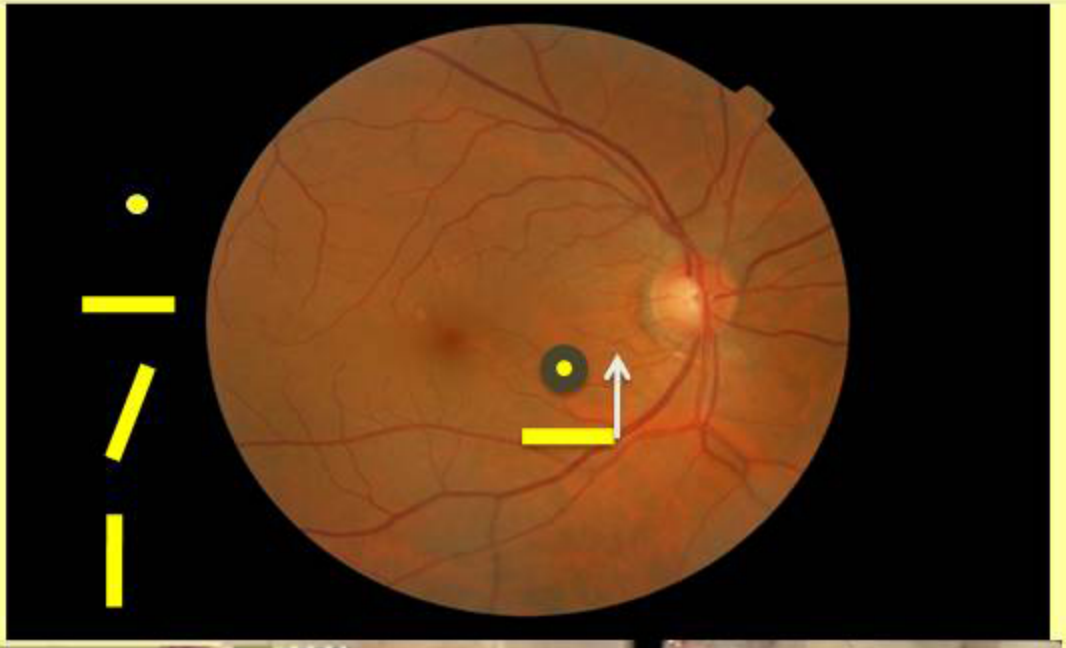
1952 **R. Jung** and coworkers in Freiburg looked at the activity of single cells in the cortex. The striate cortex didn't seem to respond to light shone on the retina.

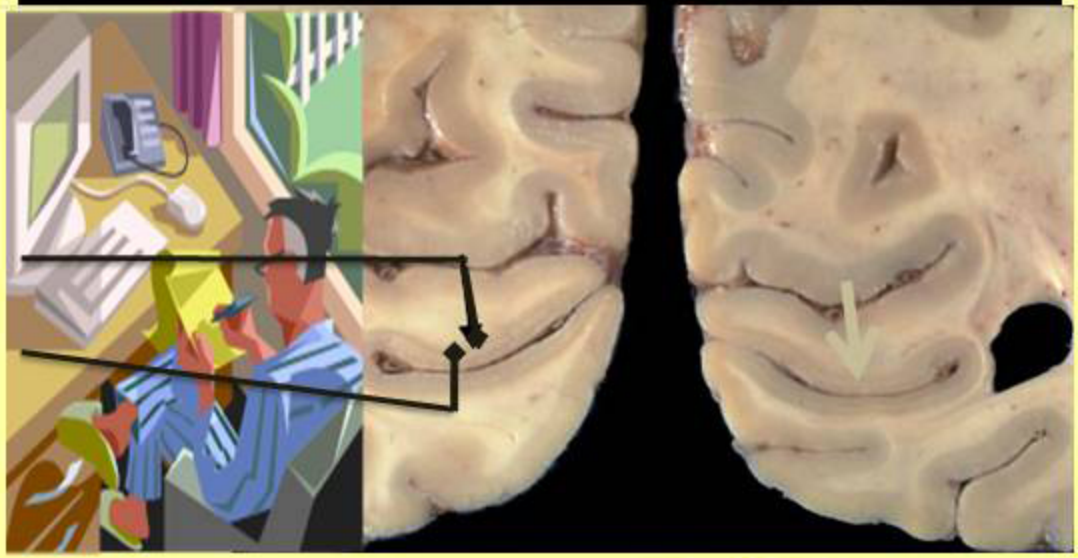
1959 **David Hubel** and **Torsten Wiesel** post-doc fellows in Kuffler's laboratory in Baltimore.

Shone spots of light shone onto a screen in front of a cat. Recorded from a single neuron in the striate cortex with a micro-electrode. The spots and annuli used by Kuffler to discover the properties of retinal cells didn't elicit any response in the brain.

Then when inserting a glass slide with a black dot the brain cell fired off like a machine gun. It was not the black dot but the shadow of the edge of the slide.

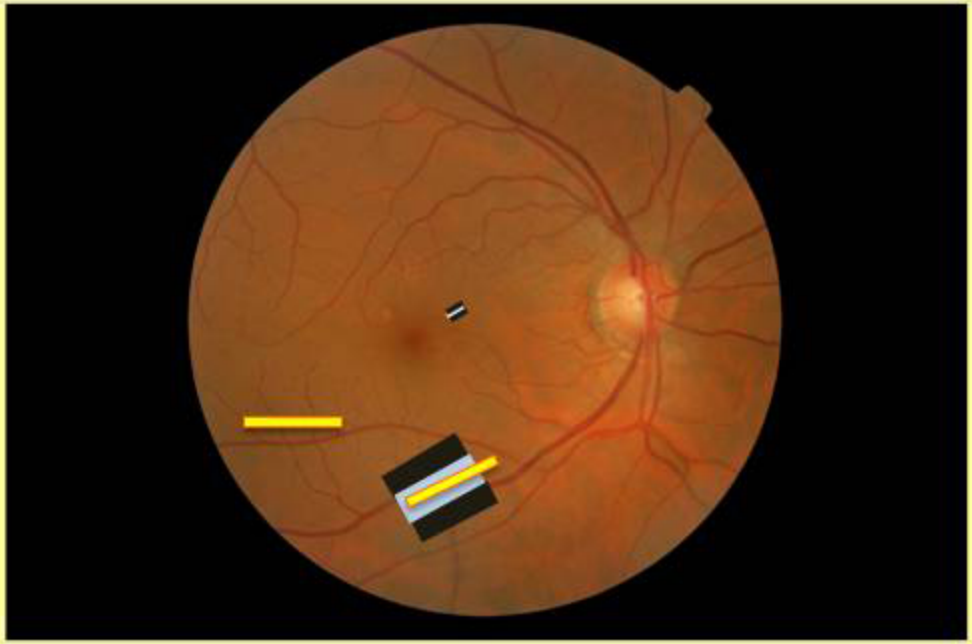
The brain cell was responding to lines of a specific orientation.





David Hubel

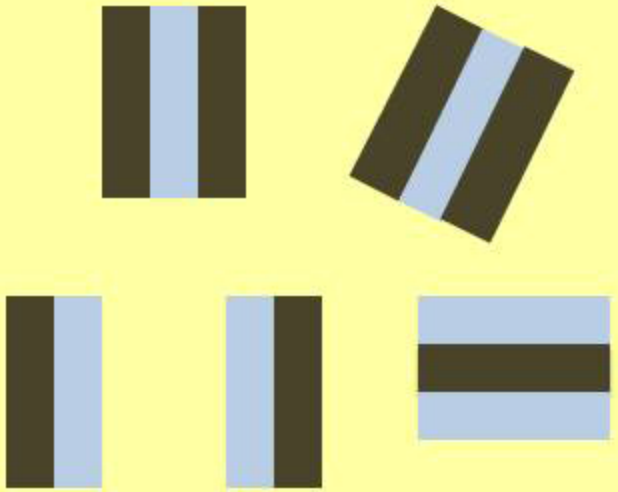
Different types of cortical cells: Simple cells



The stimulating band could be a light on a dark background (a slit) or a 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



In the monkey visual cortex, about 70 to 80 percent of cells respond to bands of light projected with a specific orientation.

In the cat, all cortical cells seem to be orientation selective,

Properties of simple cells

cell responds best to particular orientation of the bar of light.

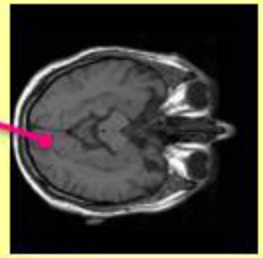
the response, decays as orientation tilts as little as 10^0 to either side, further tilting causes response to decline to zero. (the difference between one o'clock and two o'clock is 30 degrees).

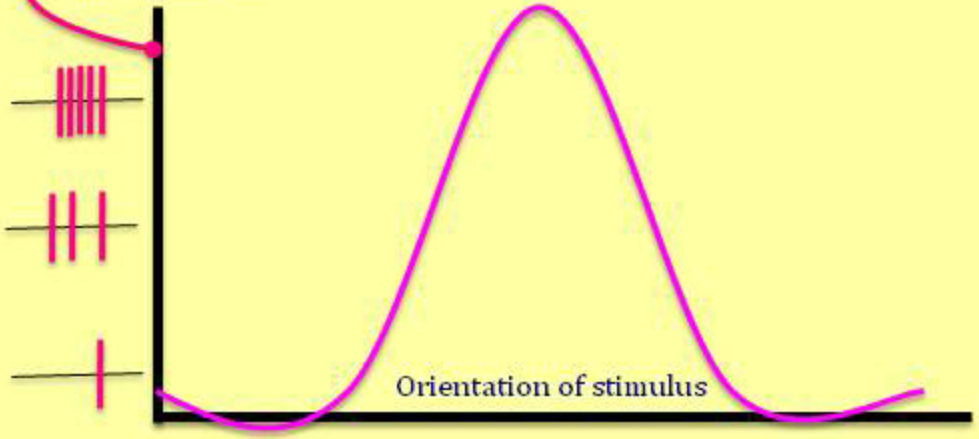
A typical orientation-selective cell does not respond at all when the line is oriented 90 degrees to the optimal.

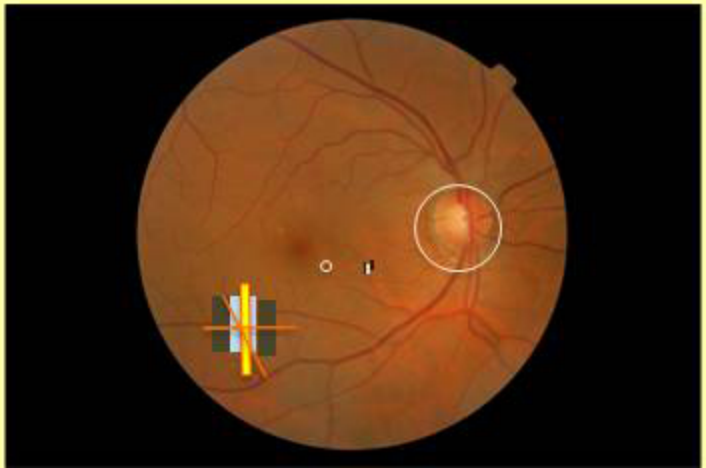
Unlike cells at earlier stages in the visual path, these orientation-specific cells respond far better to a moving than to a stationary line. That is why, we stimulate by sweeping the line over the receptive field. Flashing a stationary line on and off often evokes weak responses however the preferred orientation is always the same as a moving line.

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

In periphery 1^0 (288µm)







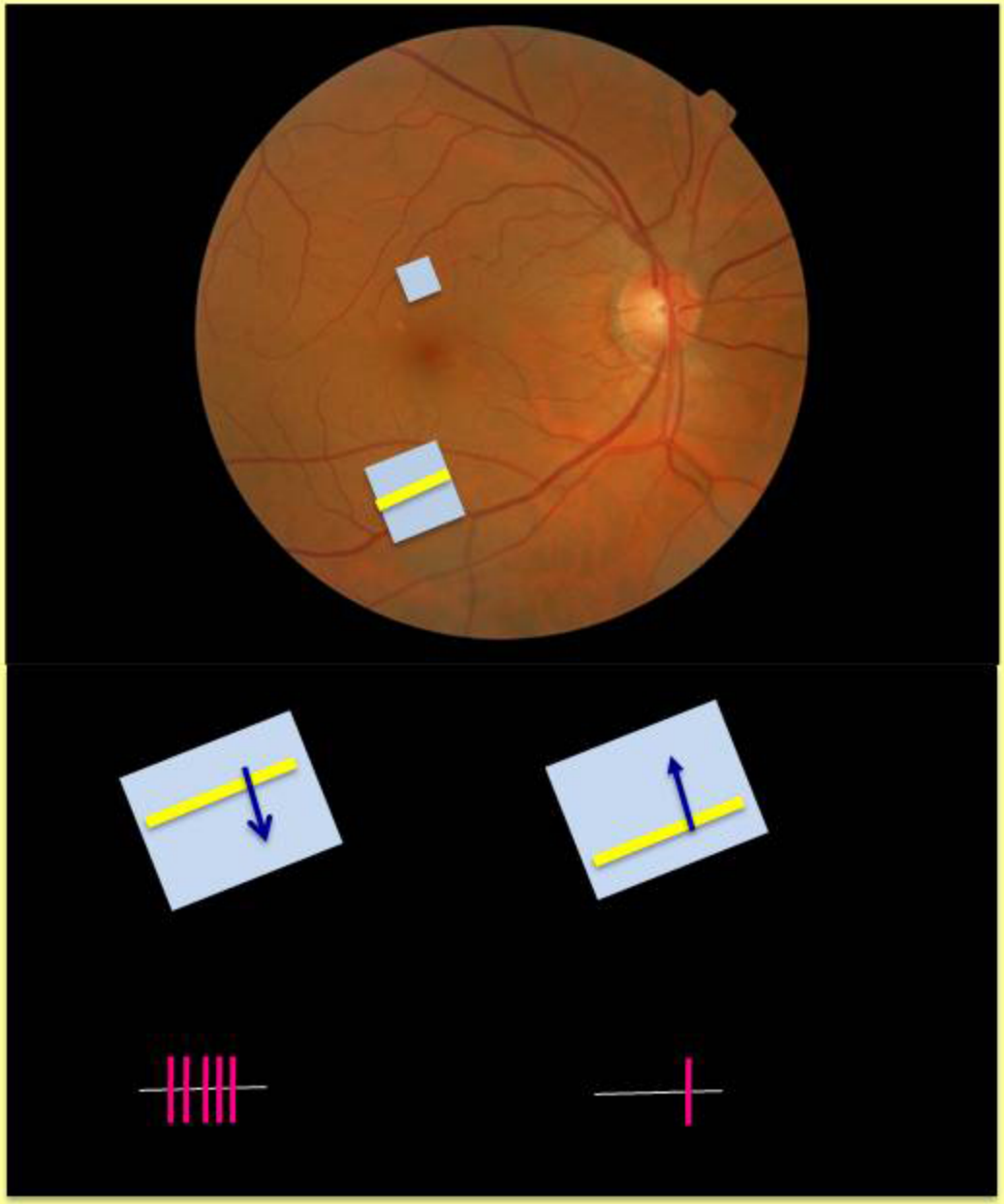
Complex cells

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, moving the stimulus brings out another kind of specific response. Instead of firing equally to movements both across and back, some cells respond better to one direction, the reverse may even elicit no firing of the cell.

Larger receptive fields 0.5^0

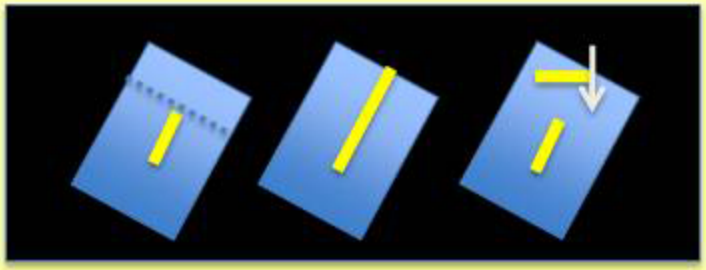


Hyper-Complex cells

End-stopped complex cells:

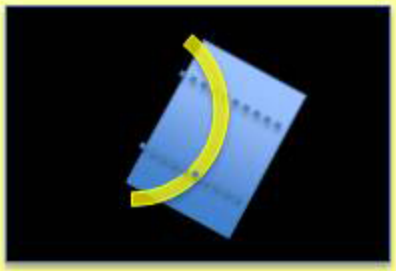
For an *end-stopped cell*, lengthening the line improves the response up to some limit, but exceeding that limit in one or both directions results in a weaker response

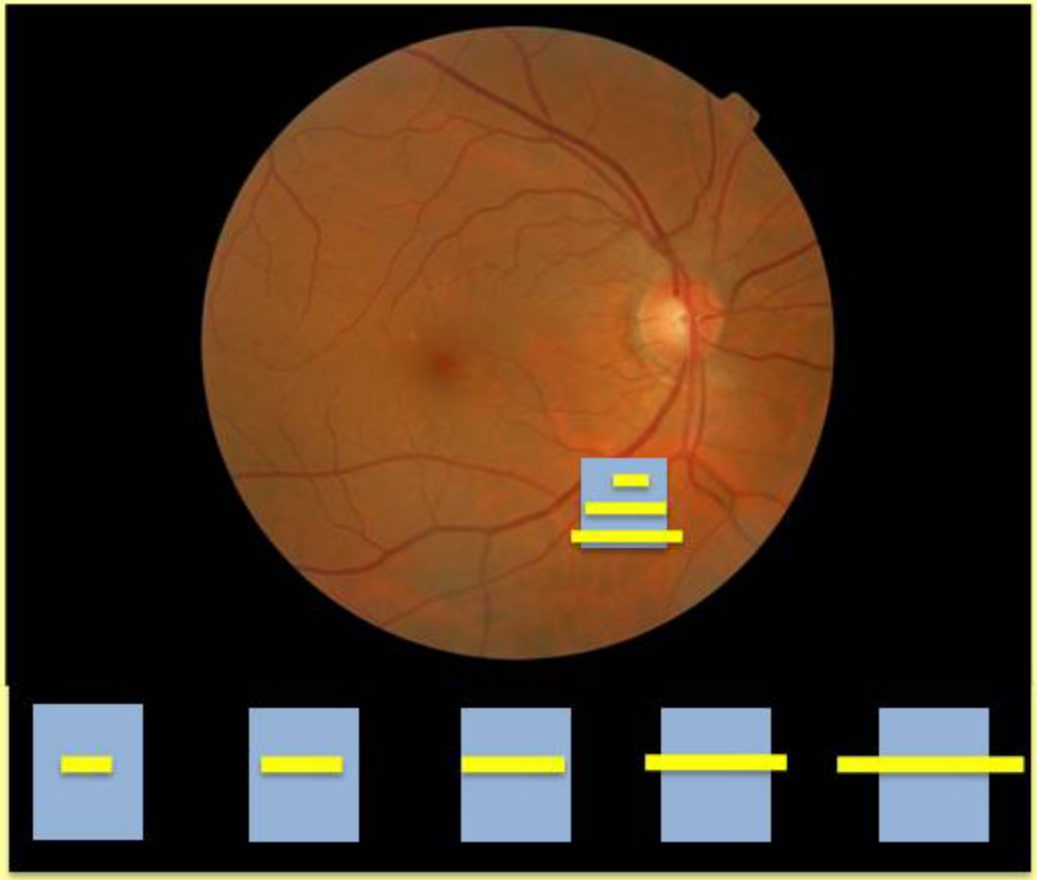
End stopped cells type 2

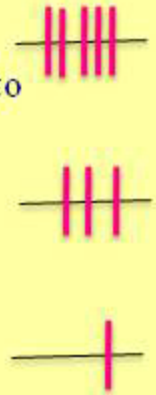


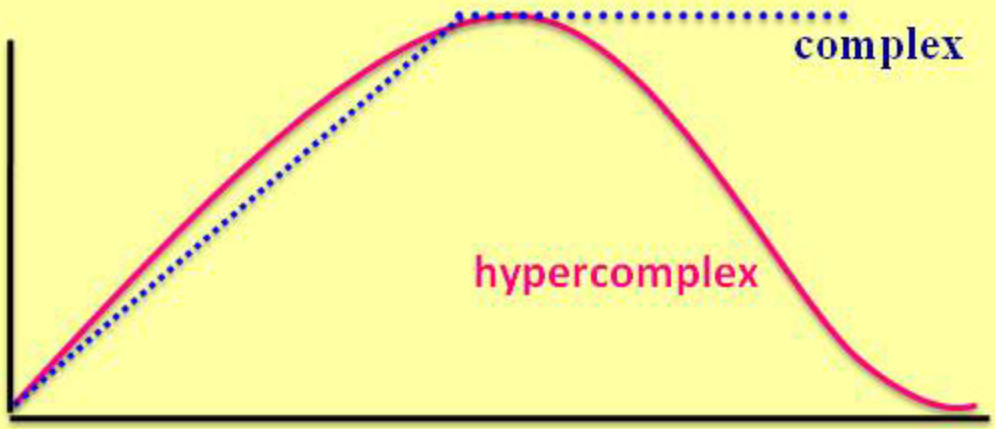
The inhibitory bit has same orientation as the excitatory line.

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









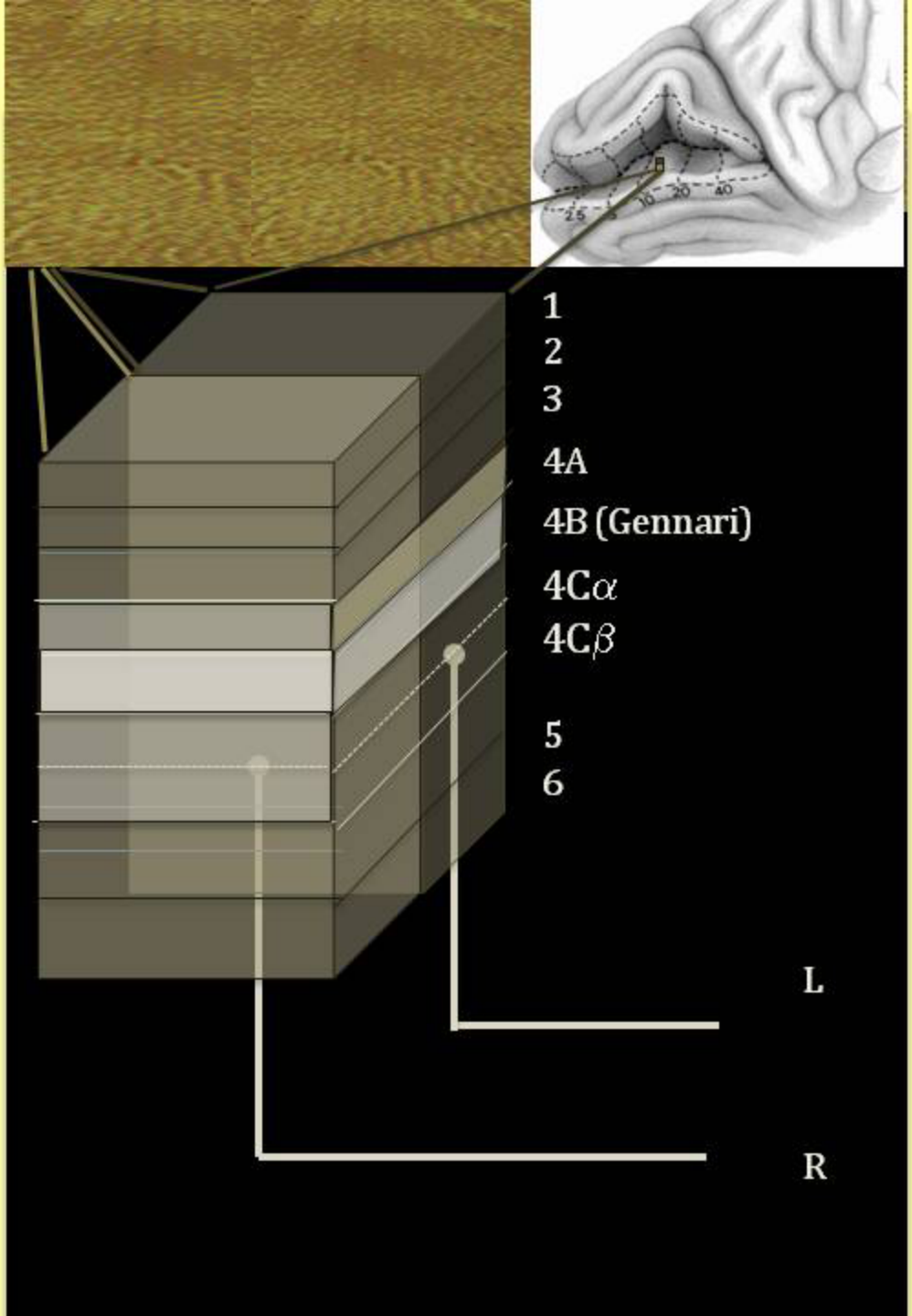
Columnar organisation

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.

After relay the information is passed onto cells 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. The dominance is located in only middle layers. Above and below this cells are arranged in collections called blobs that in some species (primates) are co-located with the columns (but may not be the case with other animals).

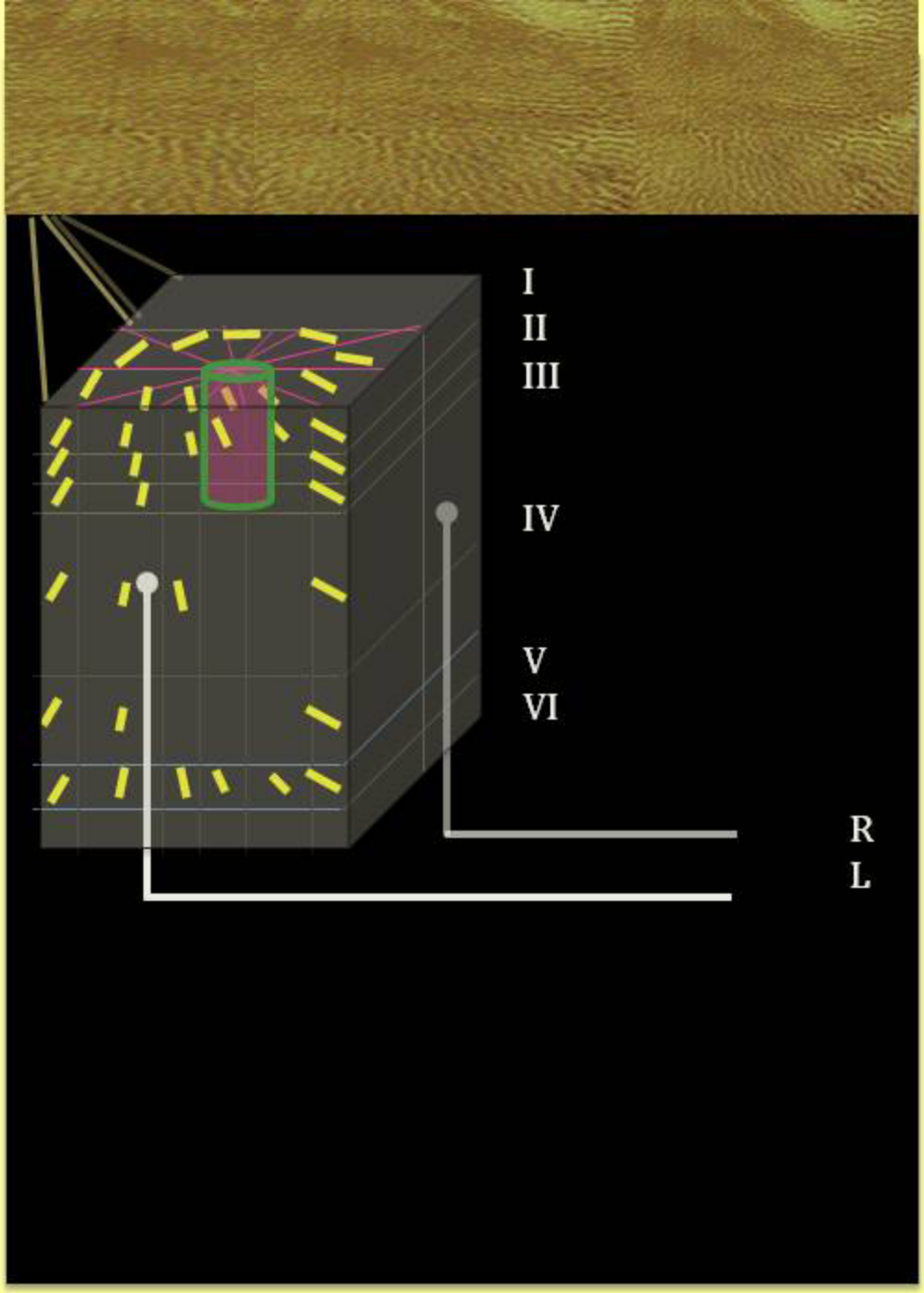


information extracted in the visual cortex

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.

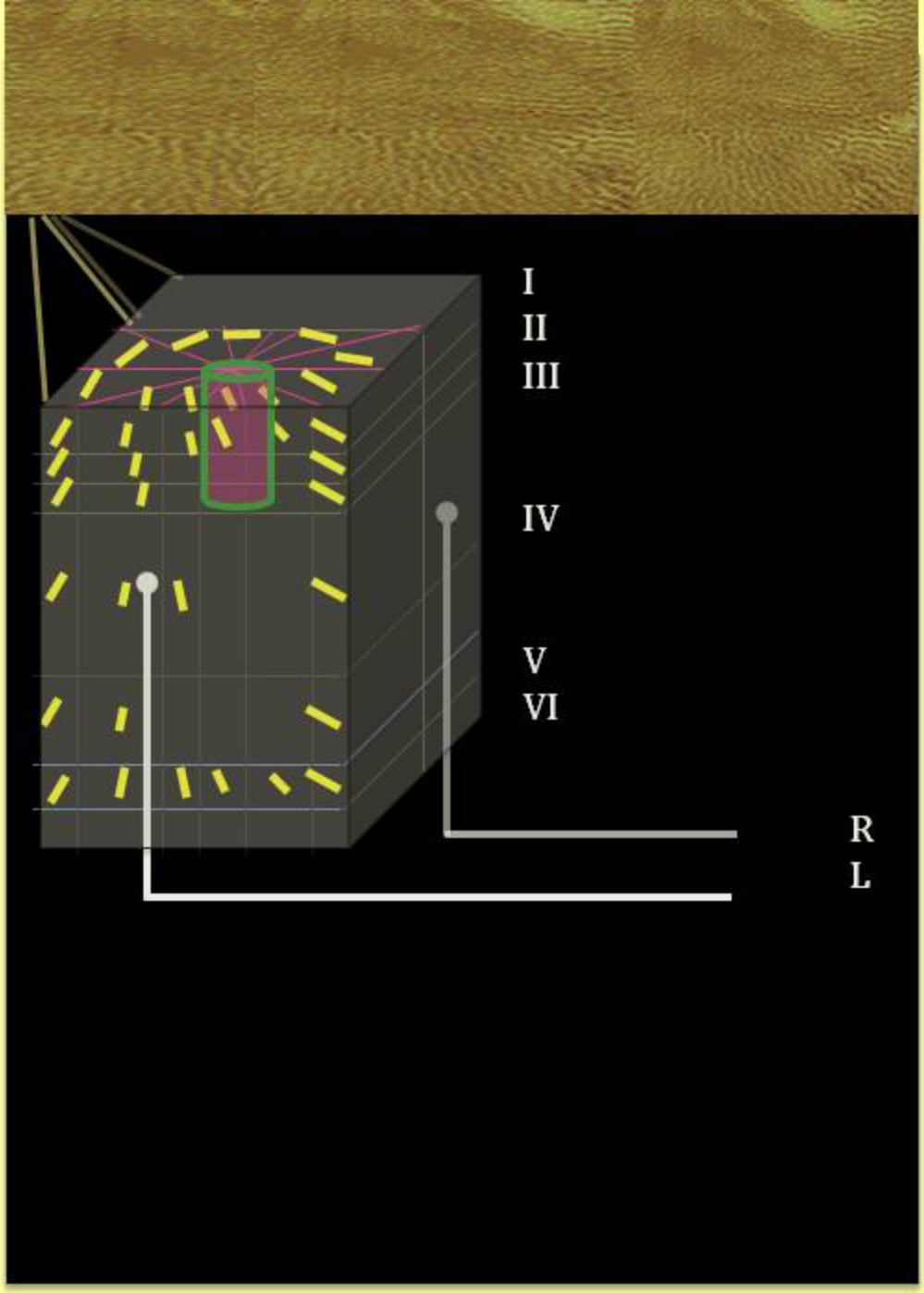


information extracted in the visual cortex

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,

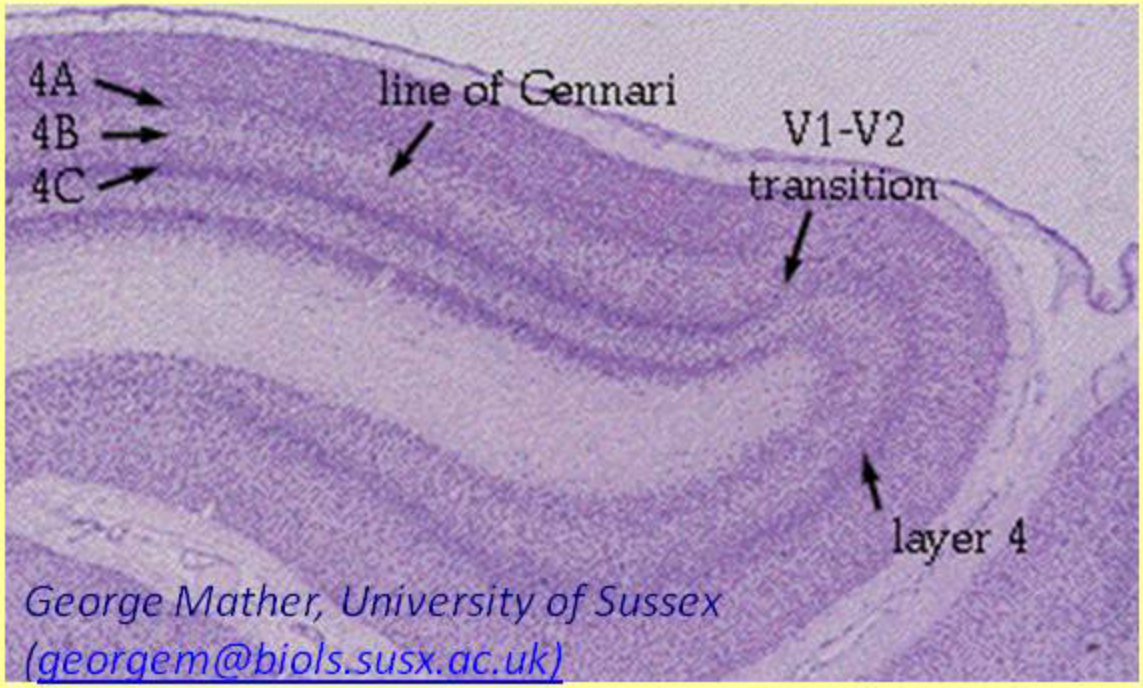
Red-green cells respond to local color contrast (red next to green) compare the relative amounts of red-green in one part of a scene to the next-door part of the scene. color constancy (Edwin H. Land retinex theory).



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).

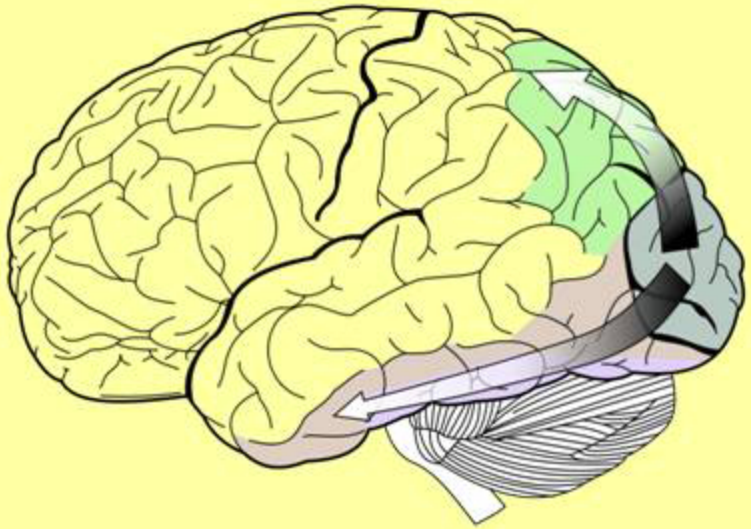


Visual area V2

First of the visual association areas. Long common border with V1.from which it receives connections.

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.



Extrastriate processing

V2 input:

Thalamus: Pulvinar (its largest nucleus in man).

V1 striate cortex: mapping of the visual field onto V2 is the mirror-image of the V1

Staining for metabolic enzyme **cytochrome oxidase**: pattern of alternating **thick** and **thin stripes**, separated by a pale **interstripe** region.

Pale Interstripes: Largest input from V1

thin stripes: from blobs

Thick stripes. receive input from inter-blob regions of layers 2 & 3. Part of the **magnocellular** pathway

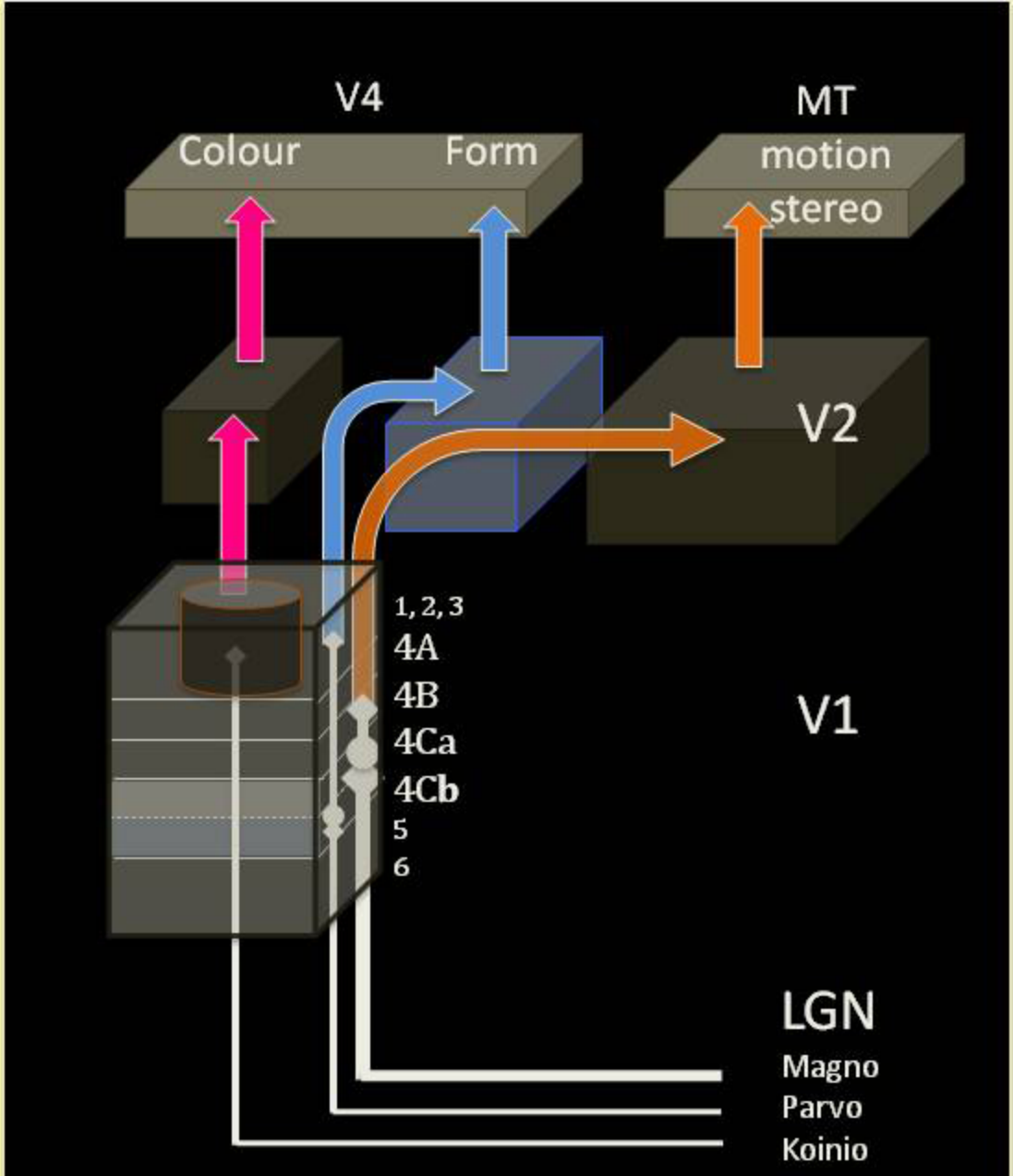
V2 output:

thin stripes, and **interstripes**: project to V4, a part of the **parvocellular** pathway.

Thick stripes: project to MT

(M and P not totally separate: connections between thin and thick stripes, 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

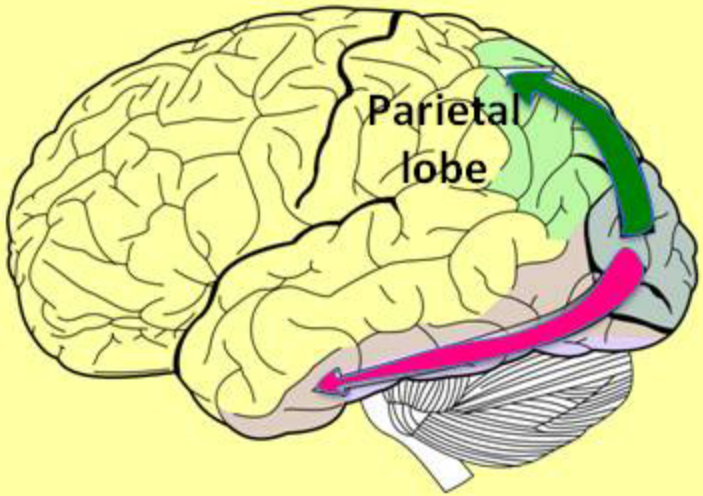


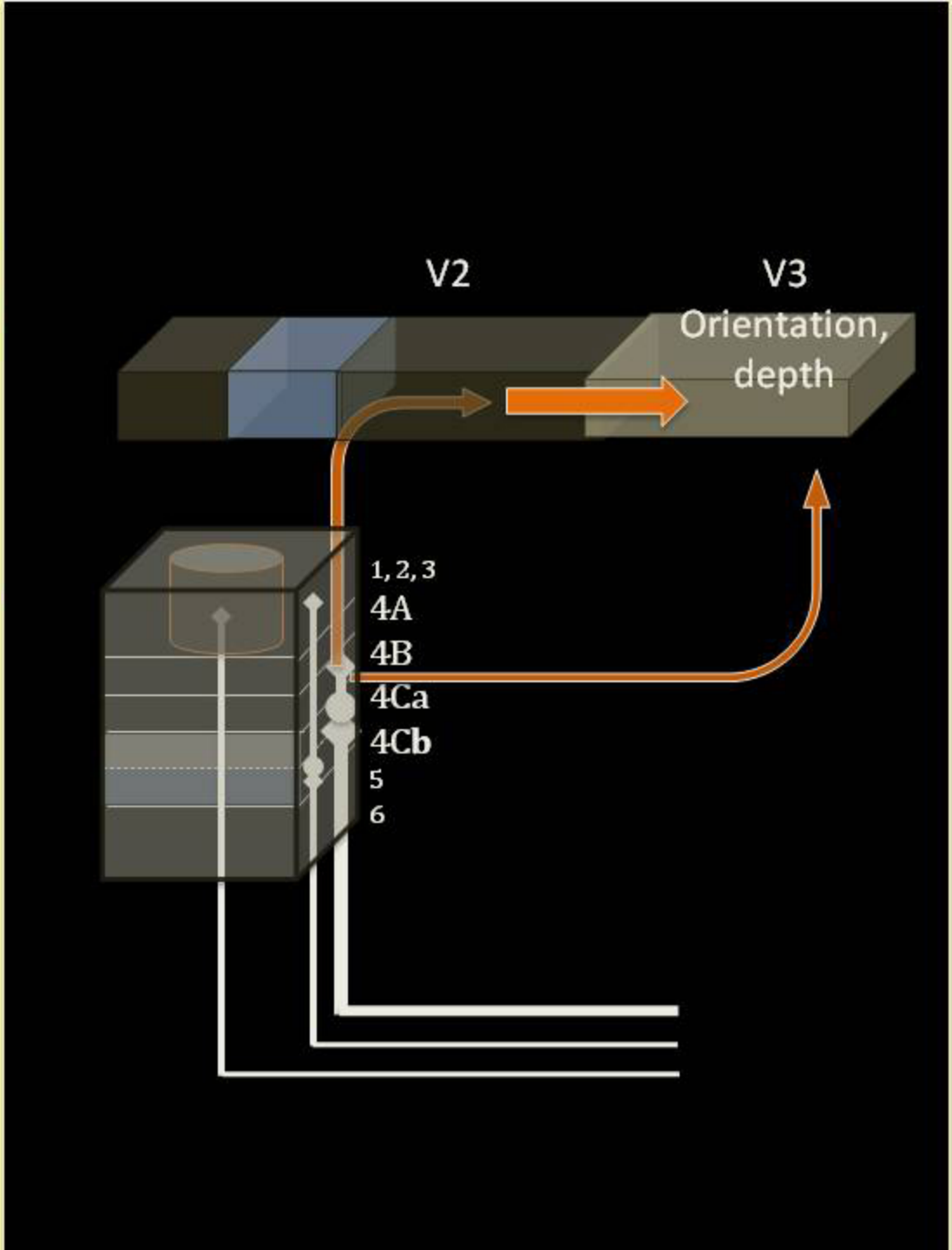
Compartmentalization of visual information from the lateral geniculate body to extrastriate cortex, according the scheme proposed by Livingstone and Hubel (Science 1988)

V3:

This area receives 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 a few are colour sensitive. Part of the dorsal stream. V3 is part of a larger area, named the **dorsomedial area (DM)**, which contains a representation of the entire visual field. Neurons in DM respond to motion of large patterns in the visual field.

Representation of the upper field is in **ventral posterior, VP**. weaker connections from the primary visual area, and stronger connections with the inferior temporal cortex. More recently shown to contain a more complete visual representation, referred to as the **ventrolateral posterior area (VLP)**

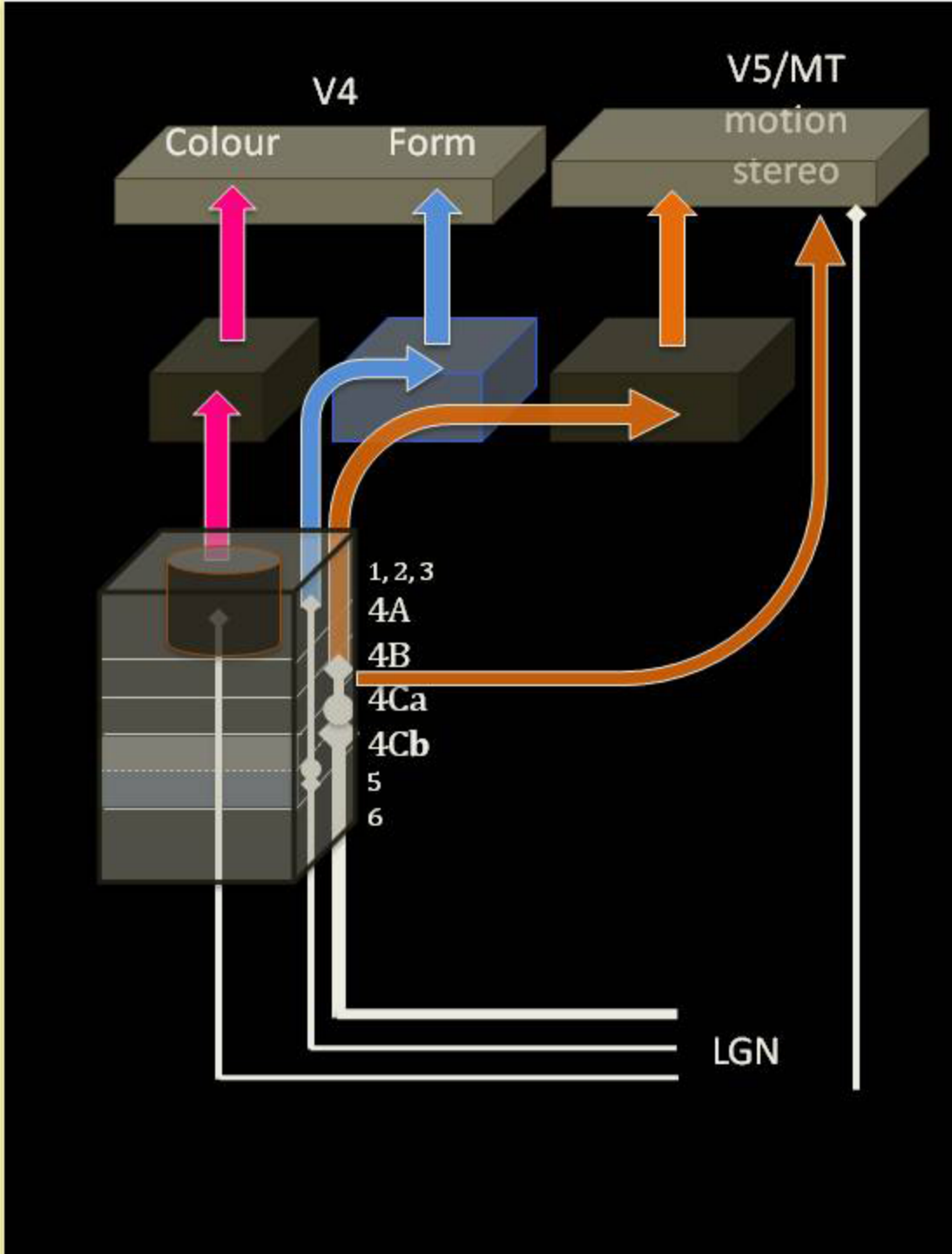




Further processing (extra-striate areas)

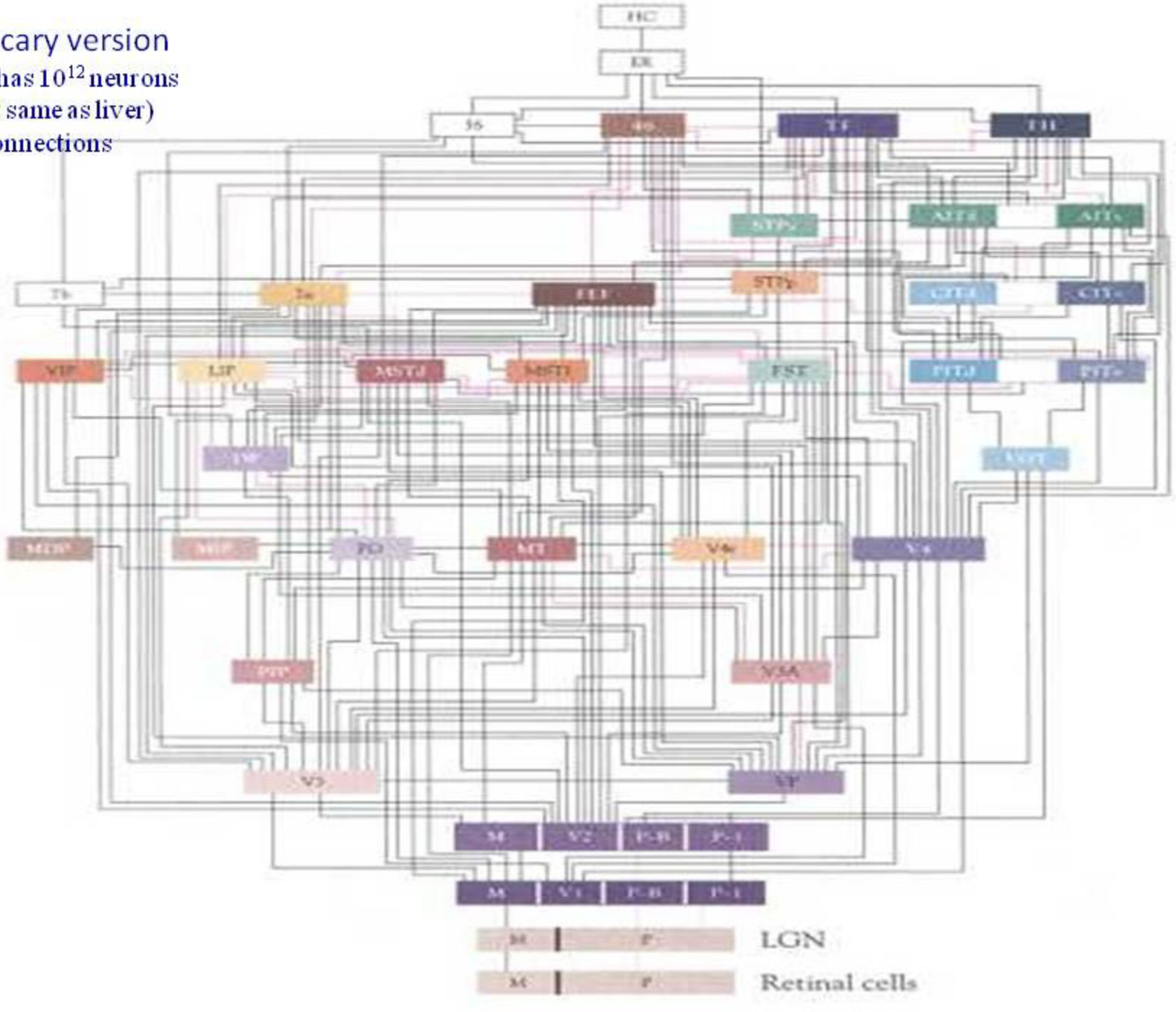
V4: Discovered by Semir Zeki. It receives input mainly from the thin and interstripe regions of V2, but also has connections from V1 and V3. contains many cells that are colour selective, for colour analysis, cells are also found with complex spatial and orientationpreference, suggesting that the area is also important for spatial vision.

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

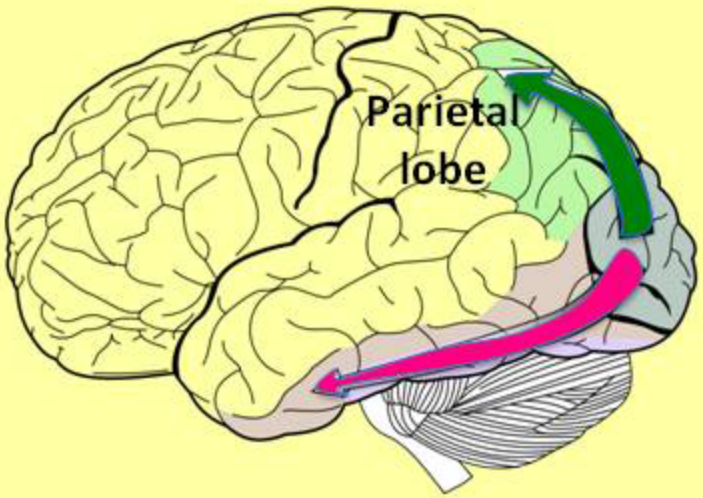


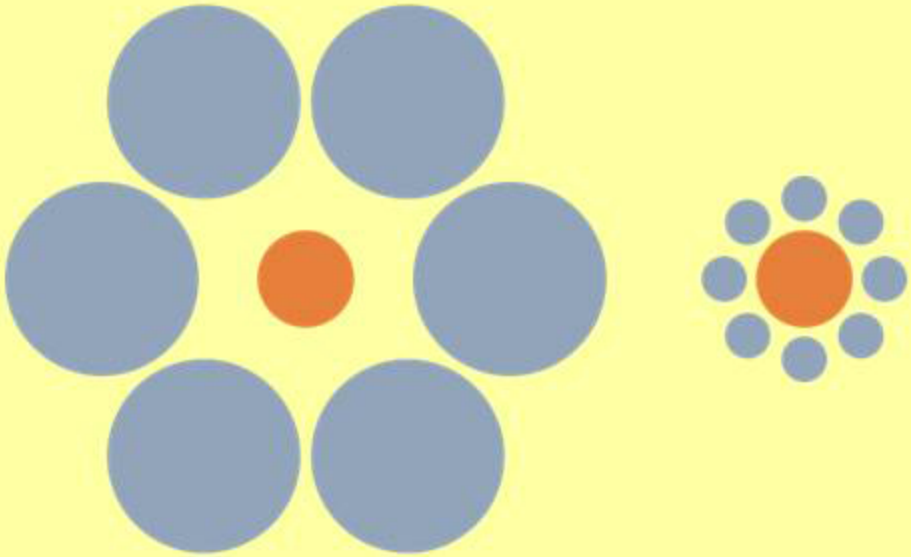
The scary version

Brain has 10^{12} neurons
(about same as liver)
10^{15} connections



The friendly version





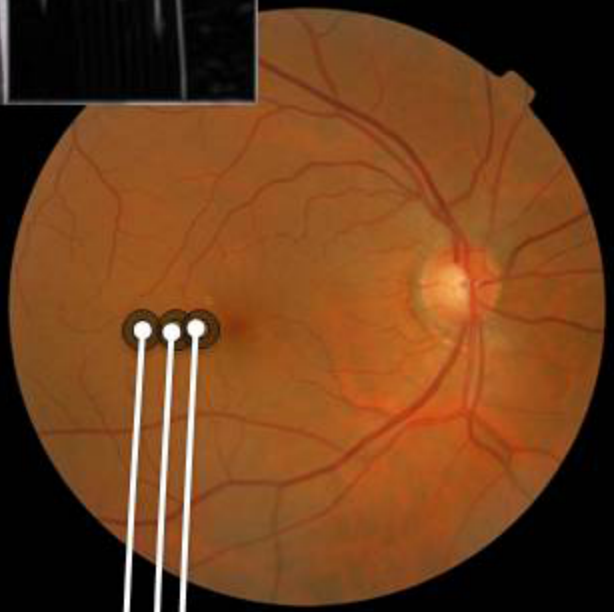
Two streams for visual processing: "**where**/**what**" or "**action**/**perception**" streams) Ungerleider and Mishkin

The ventral stream ("**what** pathway, object identification") travels to the temporal lobe. Interacts with attention and memory. Provides a description of objects in the visual world and also assesses their significance.

The dorsal stream ("**where** pathway" spatial processing) goes to the **parietal lobe**. the perception and interpretation of spatial relationships, accurate body image, and the learning of tasks involving coordination of the body in space

A controversial simplification: Supported by Ebbinghaus illusion: distorted perceptual judgements of a perception corrected by action, such as grasping when no distortion occurs.

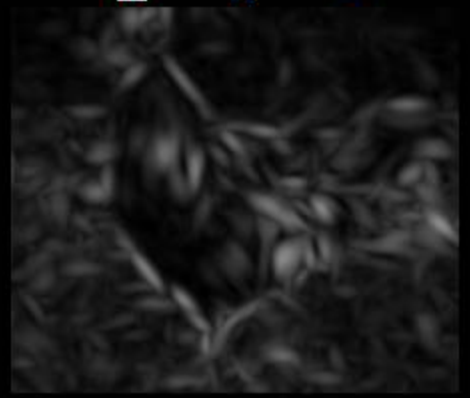
Constructing visual scene



V4
Colour
Form

V5
motion
stereo

V2



1, 2, 3
4A
4B
4Ca
4Cb
5
6

I
2
3 Complex cells
4 Simple cells
5
6

V1

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