Outline of Brain Biology
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Contents

Note: To look up references, see the Consciousness Bibliography, listing 10,000 books and articles, with full journal and author names, available in text and PDF file formats at http://www.outline-of-knowledge.info/Consciousness_Bibliography/index.html.

BIOL>Zoology>Organ>Nerve>Brain

brain
Human brains {brain} have divisions and cephali [Braak, 1976] [Braak, 1980] [Brodmann, 1914] [Bullock et al., 1977] [Caplan, 1980] [Carter, 1999] [Carter, 2003] [Crick and Jones, 1993] [Crick and Koch, 1998] [Ewert, 1980] [Glynn, 1999] [Harrison et al., 2002] [Heeger et al., 2000] [Hilgetag et al., 1996] [Jastrow, 1981] [Johnson, 1986] [Kessel and Kardon, 1979] [Kimura, 1992] [Le Bihan et al., 2001] [La Cerra and Bingham, 2002] [Logothetis, 2002] [Logothetis et al., 1999] [Logothetis et al., 2001] [Mathiesen et al., 1998] [Rees et al., 2000] [Rempel-Clower and Barbas, 2000] [Schüz and Miller, 2002] [Shepherd, 1991] [Waxman, 2000] [Webster et al., 1994] [Young, 2002] [Zeki, 1993].

neuron number
Human brains have 10 billion neurons.

weight
Human brain is 2% of body weight. Larger brains can dissipate heat better.
Two genes control brain size.

size compared to body size
Brain size, energy, and metabolism vary with body size to the 3/4 power, as determined by blood-vessel or neuron-axon branching patterns.

species
Elephant-nosed fish {mormyrid} live in muddy water. Mormyrids have relatively large brains, because they have electric organs and electroreceptors.
Rays and sharks are predators and have relatively large brains.
Warm-blooded animals have relatively large brains, to improve predation.
Fruit eaters and carnivores have relatively large brains compared to insect and leaf eaters. Fruit eating and meat eating require smaller digestive systems.
Primates have big brains. Bigger brains require more time to mature, fewer babies, and longer time between babies, so primates live longer than most species. Larger relative neocortex size associates with bigger social groups in primates.

individuality
Brains differ greatly in structure and connectivity.

encephalization quotient

Most animals have similar brain-volume to body-volume ratios {encephalization quotient} (EQ). Mammals have ratio seven times more than average. Chimpanzees have ratio three times more than average. Dolphins have higher EQ than great apes.

peduncle

Brain has axon tracts {peduncle}.

gray matter

Cell bodies and unmyelinated axons {gray matter}| are 60% of brain volume. Unmyelinated axons are 55%. Cell bodies are 5%.

white matter

Myelinated axons {white matter}| are 40% of brain volume.

BIOL>Zoology>Organ>Nerve>Brain>Circuit

anterior attention network

Anterior cingulate gyrus, cortex, and basal ganglia make circuit {anterior attention network} that detects expected location. Cortex notes matches, and basal ganglia note mismatches.

attention shift

Dorsolateral prefrontal cortex, cingulate nucleus, frontal eye fields in area 8, posterior parietal lobe in area 7a, pulvinar nucleus, and superior colliculus change object attention {attention shift} [Astafiev et al., 2003] [Corbetta, 1998] [Kustov and Robinson, 1996] [Mountcastle et al., 1981] [Sheliga et al., 1994] [Shepherd et al., 1986] [Wurtz et al., 1982].

corticospinal motor tract

The largest descending fiber tract {corticospinal motor tract} has one million axons from primary motor, supplementary motor, and premotor cerebral cortex layer-5 pyramidal neurons to spinal cord segment neurons to control precise finger and toe movements. Spinal-cord axons initiate skilled muscle movements at alpha motor neurons. Pre-central gyrus has the most corticospinal motor-tract neurons.

Lateral corticospinal tract, only in mammals, controls voluntary muscles. Anterior corticospinal tract does not cross over and is for posture and trunk position.

DCML pathway

Signals from skin, muscles, tendons, and joints travel in spinal-cord dorsal column large and fast fibers to gracile nucleus and cuneate nucleus, then to thalamus medial lemniscus, then to post-central gyrus {dorsal-column-medial-lemniscal pathway} {DCML pathway}, which is for reflexes and rapid movement.

decussation

Axons from retina nasal halves, after traveling in optic nerve, cross over {decussation, axon} to other side in brain front middle optic chiasma.

extrapyramidal tract

Tracts {extrapyramidal tract} can include caudate nucleus, globus pallidus, putamen, red nucleus, reticular formation, and substantia nigra unmyelinated axons.

feedback circuit

Between thalamic and cortical regions, one connection is feedforward {feedforward circuit}, and the other is feedback {feedback circuit}. Connections never combine both.

feedforward

Feedforward axons begin in layers 2 and 3 and end in layer 4.

feedback

Feedback axons begin in layers 5 and 6 and end in layers 1, 2, 3, and 6. Feedback goes to larger regions than feedforward [Barone et al., 2000] [Bullier, 2001] [Bourassa and Deschenes, 1995] [Cauller and Kulics, 1991] [DiLollo et al., 2000] [Grossberg, 1999] [Grossenbacher, 2001] [Heimer, 1971] [Hupe et al., 1998] [Johnson and Burkhalter, 1997] [Lamme and Roelfsema, 2000] [Lamme and Spekreijse, 2000] [Kosslyn, 1980] [Kosslyn, 1994] [Kosslyn, 2001] [Ojima, 1994] [Pollen, 1995] [Pollen, 1999] [Pollen, 2003] [Rhodes and Llinás, 2001] [Rockland et al., 1997] [Rockland, 1994] [Rockland, 1996] [Rockland, 1997] [Rockland and Van Hoesen, 1994] [Salin and Bullier, 1995] [Supèr et al., 2001] [Wiener, 1947] [Williams and Stuart, 2002] [Williams and Stuart, 2003].

frontal lobe attentional network

Networks {frontal lobe attentional network} can be for attention, executive functions, decision making, voluntary movements, and stimulus conflict resolution [Mountcastle et al., 1981] [Wurtz et al., 1982].

internuncial neuron

Cerebrum, basal ganglia, brainstem, and cerebellum send to motor-neuron reciprocal-inhibition neurons {internuncial neuron}.

interoceptive system

Systems {interoceptive system} can control homeostasis and chemical changes. Hypothalamus can sense molecules that can cross blood-brain barrier. Circumventricular organs, brainstem area postrema, and cerebrum subfornical organs lack blood-brain barrier and can sense large molecules.

limb premotor recurrent network

Networks {limb premotor recurrent network} can spread positive feedback for limb command generation. Purkinje-cell bands converge on small nuclear-cell clusters in topographically organized recurrent circuits, with thalamic, motor cortical, rubral, pontine, and lateral-reticular neurons, which send commands to spinal cord along corticospinal and rubrospinal fibers.

nociceptive system

A pain-sensing system {nociceptive system} {nociceptive pain response} can use superior colliculus, spinal cord, and thalamus neurons. It has opiate receptors, so opiates can inhibit it. Tactile, nociceptive, and thermal receptor systems interact.

optic chiasma

Axons from each-retina nasal half, after traveling in optic nerve, cross over {decussation, optic nerve} to other side in brain front middle {optic chiasma}. Temporal-lobe half-retina axons, after traveling in optic nerve, remain on same side at optic chiasma, so visual-field right half goes to right lateral geniculate body and cerebrum, and left half goes to left.

premotor network

Brain networks {premotor network} can control eye movements using recurrent pathways.

functions Separate premotor networks control smooth and saccadic eye movements. Separate premotor networks control horizontal and vertical movements.

input

Premotor network receives vestibular-sense input from semicircular canals. Vestibular nucleus signals use velocity coding. On brainstem sides, medial-vestibular-nucleus neurons interconnect with prepositus-hypoglossius neurons and with intermediate types. Prepositus hypoglossius neuron signals use position coding. Brainstem sides interconnect through recurrent inhibitory pathway.

pyramidal tract

Mammalian tracts {pyramidal tract} can excite motor neurons and enhance reflexes. Muscle actions, but not skilled-movement learning or memory, require pyramidal tract, which is bigger if cortex is bigger.

septo-hippocampal system

Septum and hippocampus circuit {septo-hippocampal system} affects contextual and spatial memory.

short-term memory circuit

Perirhinal cortex receives multisensory input and sends to hippocampus, which sends to diencephalon {short-term memory circuit} to make short-term memory [Aksay et al., 2001] [Compte et al., 2000] [Courtney et al., 1998] [de Fockert et al., 2001] [Eichenbaum, 2002] [Fuster, 1973] [Fuster, 1995] [Fuster, 1997] [Gazzaniga, 2000] [Goldman-

Rakic, 1992] [Goldman-Rakic, 1995] [Goldman-Rakic et al., 2000] [Miller, 1999] [Miller et al., 1996] [Pochon et al., 2001] [Rao et al., 1997] [Romo et al., 1999] [Squire and Kandel, 1999] [Squire, 1992].

skin sensory circuit

Vibration, steady pressure, and light touch information goes from skin, to spinal-cord dorsal root, to brainstem lower end, to thalamus ventro-basal complex, and to primary somatosensory cerebral cortex {skin sensory circuit}. All senses have similar circuits.

somatosensory system

Body systems {somatosensory system} can have viscera, vestibular, proprioception, and kinesthesia systems and autonomic, homeostasis, and fine touch functions. Somatosensory system uses reticulum, monoamine nuclei, acetylcholine nuclei, hypothalamus, basal forebrain, insular cortex, S2 cortex, and medial parietal cortex.

spatial attention system

Body systems {spatial attention system} can regulate inferotemporal neurons and filter inferotemporal-area input from selected stimulus and memory, for pattern recognition.

spinocerebellar tract

Proprioception input goes to nucleus dorsalis, then to ipsilateral dorsal spinocerebellar tract or to contralateral ventral spinocerebellar tract, then to cerebellum, and then to cerebral cortex {spinocerebellar tract}. Dorsal and ventral spinocerebellar tracts are for movement initiation or for position information from muscle spindles, Golgi tendon organs, and touch receptors.

spinoreticular tract

Tracts {spinoreticular tract} can be for dull and chronic pain from soma.

spinothalamic tract

Diffuse touch, pressure, acute pain, and thermal fibers {spinothalamic pathway} {spinothalamic tract} {protopathic pathway} {spinothalamic system} go to substantia gelatinosa as unmyelinated fibers, cross to contralateral spinothalamic tracts, go through reticular system, go to thalamus ventral posterior nucleus, and end at cerebrum. Spinothalamic tract has small and slow feedback nerves for pain inhibition.

tectopulvinar pathway

Older unconscious visual pathway {tectopulvinar pathway} {tectofugal pathway} goes from tectum to superior colliculus, thalamus pulvinar nucleus, and parietal lobe and is for visual spatial orientation, orienting responses, and movement to focus attention. Geniculostriate and tectopulvinar pathways interact [Ramachandran, 2004].

tectospinal tract

Spinal-cord tracts {tectospinal tract} can be for reflex head turns.

vestibulo-ocular pathway

Pathways {vestibulo-ocular pathway} from retina to vestibular system to cerebellum can allow eye to track moving objects smoothly while head turns.

vestibulospinal tract

Spinal-cord tracts {vestibulospinal tract} can be for posture reflexes.

BIOL>Zoology>Organ>Nerve>Brain>Circuit>Vision

dorsal system

Circuits {dorsal system} {dorsal pathway} {vision-for-action} {where pathway} {how pathway} {high path for vision} {ambient system} can go from occipital lobe area V1 to mediotemporal (MT) area, parietal area PG, posterior parietal area (PPC), and dorsolateral prefrontal cortex [Bridgeman et al., 1979] [Rossetti, 1998] [Ungerleider and Mishkin, 1982] [Yabuta et al., 2001] [Yamagishi et al., 2001].

functions

Dorsal pathway processes object location, size, parts, and characteristics. It converts spatial properties from retinotopic coordinates to spatiotopic coordinates. It tracks unconscious motor activity and guides conscious actions, such as reaching and moving eyes.

output

Dorsal system sends to amygdala and hippocampus to form visual memories [Heimer, 1971].

ventral system

Circuits {ventral system} {vision-for-perception} {what pathway} {low path for vision} {focal system} can go from occipital-lobe area V1, through areas V2 and V3 and V4, to inferior temporal lobe area TE, limbic system, and ventrolateral prefrontal lobe [Bridgeman et al., 1979] [Epstein and Kanwisher, 1998] [Haxby et al., 2001] [Heimer, 1971] [Ishai et al., 2000] [Milner and Goodale, 1995] [Ungerleider and Mishkin, 1982].

functions

Ventral system is for recognition. It classifies stimuli shapes and qualities. It registers new category instances. It responds to patterns, shapes, colors, and textures, with earlier neurons for smaller and later neurons for bigger. It does not contain representations but organizes input into familiar packets.

output

Ventral system sends to amygdala and hippocampus to form visual memories.

BIOL>Zoology>Organ>Nerve>Brain>Code

brain code

Cerebrum spatiotemporal firing patterns {brain code} {cerebral code} can represent actions or perceptions.

switches

Neurons are switches. They contrast below-threshold with above-threshold.

coding

Contrast or mark sequences can be codes and carry messages. Each millisecond, axon locations either have or do not have spikes.

Times between spikes can code for timing intervals.

Number of spikes per second reflects average voltage difference at axon hillock.

coding: types

Perhaps, neuron code uses average number of spikes per 100 millisecond {firing rate code}. Perhaps, neuron code uses spike timing {temporal coding}, for synchronization and oscillation.

Perhaps, neuron code is probabilistic [Rao et al., 2002].

Perhaps, neuron code uses synchronous firings {synfire chain model} [Abeles, 1991] [Abeles et al., 1993].

Perhaps, neuron code uses precisely timed spike or burst {first-time-to-spike model} [VanRullen and Thorpe, 2001].

Perhaps, brain uses standing, traveling, rotating, or compression waves [Ermentrout and Kleinfeld, 2001].

contrast

Contrast is relative intensity, intensity difference or ratio.

contrast: space

ON-center neurons have excitation when input is on their receptive-field center and inhibition when input is on annular region, so they detect contrast between central and annular regions. OFF-center neurons have excitation when input is on annular region and inhibition when input is on center.

ON-center neurons pair with OFF-center neurons and work together to enhance contrast.

contrast: opposites

Opponent-process neurons detect receptor-input ratio and so contrast extremes.

contrast: categories

Categorization neurons use thresholds to establish and contrast categories.

contrast: orientation

Cortical neurons in orientation column pair with neurons in orientation column for perpendicular or other orientation. They also pair with neurons for no orientation. The pairs enhance contrast.

contrast: process

Neurons and neuron pairs find relative values and so contrast by lateral inhibition, spreading activation, and comparing opposite receptors.

contrast: boundaries

Contrast between two things marks a boundary or threshold. No value difference means both are the same, with no boundary, mark, point, or information. Markers/boundaries are information bits. Contrasts, markers, or boundaries are like ON or OFF, 0 or 1, YES or NO. Markers provide signs or landmarks, such as indexes, for references, to which other signs can relate.

contrast: boundaries and space

Boundaries are markers in space. The idea of space depends on the idea of boundary. Boundaries separate two regions, such as self and not-self or inside and outside.

bursting

Codes {bursting} can use spike bursts followed by quiet periods [Crick, 1984] [Koch, 1999] [Koch and Crick, 1994] [Lisman, 1997].

population coding

Perhaps, neuron code uses neurons with precise ranges {population coding} {pattern coding} {Across-Fiber Pattern theory}. For example, movement trajectories can be sums of many neuron outputs. Brains can store representations as values in neuron sets. Repeated input activates same neuron population. Similar input activates similar neuron population. Difference between two patterns is quantitative difference between populations. With population coding, patterns and concepts have geometry [Hahnloser et al., 2002] [Perez-Orive et al., 2002].

labeled line

Perhaps, for each stimulus, brain has one receptor and one neural path {labeled line}.

sparse coding

Perhaps, neuron code uses few neurons with precise location or distance {sparse coding} [Hahnloser et al., 2002] [Perez-Orive et al., 2002].

sparse temporal coding

Perhaps, neuron code uses few spikes with precise timing {sparse temporal coding} [Hahnloser et al., 2002] [Perez-Orive et al., 2002].

BIOL>Zoology>Organ>Nerve>Brain>Computation

brain computation

Brain performs computations {brain computation}. Brain scanning and brain lesion analysis shows that brain regions mediate brain functions {localism}. Brain regions have functions, and brain functions involve several brain regions coordinating sequentially and simultaneously [Carter, 1999].

input and output

Neuron populations receive input-signal sets and calculate output-signal sets. For functions, brain has several paths that make same output from same input.

All central-nervous-system input goes to cerebellum, reticular formation, and thalamus. Input that can eventually cause sense qualities goes to sense neurons in thalamus and then cerebrum. Brain inputs and outputs coordinate. For example, motor neurons and muscle receptors link.

input and output: global information

All brain information uses many neurons, which process only local information, but result is global [Black, 1991].

input and output: convergence

Inputs from different cortical regions {convergence region, vision} converge on cortical regions {convergence zone}. Convergence-zone output includes feedback to input cortical regions. Brain has more than 1000 convergence regions and more than 100 convergence zones.

input and output: distributed processing

Brain has many recurrent, lateral intracortical connections, and neurons receive from large spatial area. No neuron has simple direct circuit [Abbott et al., 1996] [Dayan and Abbott, 2001] [Rao et al., 2002] [Rolls and Deco, 2002] [Shadlen et al., 1996] [Zhang et al., 1998].

More than 50% of cortical neurons send output to distant cortical areas.

input and output: important information

Brain gives command to region with the most-important information.

coding

Information theory applies to neural coding, and one impulse can carry more than one information bit [Rieke et al., 1996] [Shannon and Weaver, 1949].

coding: repetition

Brain cells typically experience same correlations, associations, and comparisons many times. Processing in small brain region repeats often. Repetition improves efficiency as cells modify.

coding: electrochemical coding

Axon ion flows change voltage, and receptor-membrane neurotransmitters change voltage, so neuron coding is electrochemical.

coding: discrete coding

Neurons generate neurotransmitter packets and action potentials, rather than graded potentials, so information flows are discrete on-or-off sequences rather than continuously-varying voltages or currents.

coding: frequency code

Neuron impulse frequency indicates both time interval and intensity. Spike frequency F above normal frequency NF is constant C times power p of receptor displacement X from normal N: $(F - NF) = C * (X - N)^p$.

Neuron spike frequency never exceeds 800 spikes per second and never becomes 0. At rest, frequencies can be few per second or hundreds per second.

coding: information amount

If axon-hillock depolarization or no depolarization can happen every millisecond, millisecond intervals are either on or off. In 100 milliseconds, 2^{100} bits can travel down axon. 2^{100} bits is approximately 10^{30} bits, which is approximately 1000^{10} bits.

If number of possible letters, digits, and punctuation marks is 1000, 1000^{10} bits can represent ten-letter words, labels, indexes, or pointers, so one neuron acting for 100 milliseconds can code for any ten-letter word. One hundred thousand neurons acting for 100 milliseconds can code for any million-letter string. One hundred thousand neurons acting for 100 milliseconds can code for any million-dot image, if dots can have 1000 levels of gray and color.

One hundred neurons acting for one millisecond can code for any ten-letter word. One neuron acting for 10^7 milliseconds, approximately 3 hours, can code for any million-letter string or million-dot image.

coding: summation

Axons depolarize for percentage of time. In time intervals, such as ten milliseconds, so short that receptors do not have time to change, depolarization sequences with same total number of depolarizations have equivalent physiological effects, no matter in what order signals arrived. In these cases, axon coding is not a significant factor, and irregular conduction rates do not matter. Ten-millisecond intervals have 10 instants that can be ON or OFF, and so intervals have 2^{10} different possible sequences. However, such short time intervals have only 11 physiological possibilities: 0 to 10 total depolarizations.

computations

Neurons promote, amplify, block, inhibit, or attenuate signals. Neuron circuits can lower thresholds, switch signals, amplify signals, filter frequencies, set thresholds, control currents, direct flows, induce currents, control voltages, compare signals in time and space, add quantities, multiply quantities, and perform logical operations.

Most visual cortical neurons respond to line contrasting with background. Output maximizes if contrast is in receptive-field middle. Response falls off rapidly as contrast line moves to either side. Function looks like Gaussian distribution with large variance or looks like two sigmoidal functions joined at maximum. Most neurons behave like Gaussian HBF units, rather than multilayer-perceptron (MLP) sigmoidal units.

computations: potentiation

Nitric oxide from receptor neuron maintains sending-neuron long-term potentiation (LTP). Cyclic AMP second messenger sensitizes receptor neuron. NMDA glutamate receptors sensitize receptor neuron. Potentiation makes neuron reach threshold with lower input than normal excitation level.

computations: association by neurons

Interneuron can detect stimulus timing and amplitude between two pathways. Two pathways can both contact an interneuron that controls secondary circuit. If both pathways carry current simultaneously, secondary circuit maintains current. If both pathways carry no current or only one has current, secondary circuit has no current. Interneuron detects simultaneous pathway activation.

computations: conditional statement

Depolarization can happen only if all inputs to neuron are active. Depolarization can happen if one input to neuron is active. Depolarization can happen only if some inputs are active and some inactive.

computations: difference

Neurons compare signals to detect change or difference, rather than absolute values.

computations: feedback

Neuron circuits with excitatory and inhibitory feedback have short, synchronous discharges in local clusters.

computations: indexing system

Brains have index list to rapidly locate information.

computations: inhibition

Inhibition dampens neuron signals and more quickly returns neurons to resting states, allowing shorter time intervals and quicker responses. Between two stimuli, inhibition increases stronger signal and decreases competing weaker stimulus. Thus, inhibition can enhance weak stimulus that has only weaker stimuli nearby in space or time.

computations: inverse model

If supplied with sample responses, inverse model can predict input commands.

computations: movement initiation

Movement initiation and programming are separate asynchronous processes. Deciding to perform action corresponds to building positive feedback in limb premotor network.

computations: movement programming

Movement initiation and programming are separate asynchronous processes. Cerebellar cortex programs which movement to perform. Programming can happen while preparing movement or moving.

computations: positive whole numbers

Synaptic transmission uses neurotransmitter-molecule packets. Axon depolarizations are independent and countable. Therefore, neurons use whole number calculations and whole number ratios, with no fractions or real numbers. Because neurotransmitter molecules and axon depolarizations have no opposite, neurons use only positive numbers, never negative numbers.

computations: synchronizing

Neuron reciprocal interactions can synchronize signal phase, if reciprocal signal delay is less than one-quarter oscillation. Neuron excitatory reciprocal connections can find feature relations by enhancing, prolonging, and synchronizing neuron responses.

computations: timing

Brain uses time-delay circuits, inhibitory signals, and circuit-path rearrangements to time neuron events.

computations: transformations

Brain can use geometric ratios, translations, rotations, and orientations to represent distances and manipulate lines and shapes.

validation

Brain sends inputs along several paths to cross-validate processing and representations by comparing redundant process outputs.

association triad neuron mechanism

Interneurons can associate reflex-pathway nerve-cell states with other reflex-pathway nerve cell states {association triad neuron mechanism}.

interneurons

Nerve cells in pathways from sensation to action connect using interneurons for cellular associative learning. Interneurons laterally excite or inhibit main neurons.

process

Cell that is to learn inhibits interneuron. Interneuron excites learning cell and inhibits paired cell. Paired cell inhibits interneuron and learning cell.

Associative learning requires asymmetric connections. Both main neurons inhibit interneuron, but interneuron excites learning neuron and inhibits paired neuron. Paired cell inhibits learning cell, but learning cell does not synapse on paired cell.

process: input

Association requires simultaneous stimuli to both sense cells.

process: circuit

After stimuli cease, asymmetric association-triad circuit causes signals to continue to flow around neurons, keeping learning-cell electric potential smaller. This makes it easier to stimulate learning cell.

When paired stimuli end, paired cell stops inhibiting interneuron and learning cell, so interneuron excites learning cell more. Learning cell has decreased inhibition and so inhibits paired cell even more, keeping state going until unpaired stimuli disrupt positive feedback, so neurons return to normal.

simplicity

Association nerve triad is simplest associative learning system. One neuron alone can only sensitize or desensitize itself. Two neurons can only have reverberation. No other three-neuron arrangement can make a learning circuit.

Interneuron must have inhibition by path neurons, so interneuron voltage increases when stimulation stops. Interneuron must stimulate learning cell, so learning-cell voltage increases after stimulation stops. Paired cell must inhibit learning cell, so learning-cell voltage increases after stimulation stops. Interneuron must inhibit paired cell, so, as interneuron increases voltage, paired-cell inhibition decreases.

There must be no connection from learning cell to paired cell. If there is inhibition, stimulation end increases paired-cell inhibition on learning cell. If there is excitation, stimulation end decreases inhibition, but excitation mimics stimulation, so there can be no excitation between direct paths.

There is no interneuron excitation, because stimulation end only quiets them.

uses

Association does not detect current or no current in one or the other pathway, only simultaneous inputs.

uses: negative association

If sense cell inhibits learning cell, circuit still works by positive feedback but in reverse, so voltage difference becomes more. This makes learning cell more difficult to stimulate.

uses: attention

Association allows attention-like input acknowledgement.

uses: reflex control

Reflexes receive signals from sensors and activate muscles. Association triads can control reflexes by signals from other nerve pathways or from brain.

uses: time

Association triads can detect simultaneity in time.

uses: space

Association triads can detect simultaneity in space. Time can code spatial distance.

uses: intensity

Association triads can compare intensities. Time can code intensity.

labeled-line code

Nerve pathway {labeled-line code} itself indicates stimulus nature and spatial location.

neuromodulatory system

Cortex mechanisms enhance and suppress synapses and redistribute axon terminals among receptors {neuromodulatory system}. First, synapses receive non-specific input from cholinergic and noradrenergic neurons. Later, they receive input from both body sides [Crick and Koch, 1998].

redundancy of potential command

Command passes to region with the most-important information {principle of redundancy of potential command} {potential command redundancy} {redundancy of potential command}.

re-entry

Cortical-neuron axons from sense brain areas can re-enter brain areas {re-entry} {re-entrant pathway}. Re-entry synchronizes and coordinates but does not provide feedback. Most nerve pathways send signals back to starting points after one or more synapses. Memory depends on brain pathways that re-excite themselves.

Smith predictor

Control system models {Smith predictor} can predict responses if supplied with sample commands. Smith predictors combine delayed and undelayed control system models to build controller for systems with large time delays.

BIOL>Zoology>Organ>Nerve>Brain>Computation>Regions

lateral inhibition

Nearby neurons inhibit neuron {lateral inhibition}|, to increase contrast.

spreading activation

Excitation tends to spread through region {spreading activation} {spreading excitation}, to link regions.

BIOL>Zoology>Organ>Nerve>Brain>Electrical Activity

electroencephalography

People can measure scalp electric-voltage waves {electroencephalography}| (EEG).

cause

EEG wave voltages are sums of graded potentials in dendritic trees and their synapses [Creutzfeldt and Houchin, 1984] [Creutzfeldt, 1995] [Freeman, 1975] [Mountcastle, 1957] [Mountcastle, 1998] [Remond, 1984].

EEG potential changes are larger than neuron induced activity. Potential differences between cell bodies and neuron fibers influence EEG waves. Brain potential waves imply synchronized neuron activities, over distances more than two millimeters apart. Waves are coherent, not harmonic, across different cortical areas.

location

Electric waves appear in parietal lobe, then primary motor cortex and occipital lobe, and then prefrontal lobe.

amplitude

EEG wave voltages are 1 mV to 2 mV. To detect voltage change requires averaging hundreds of measurements to subtract noise. EEG can measure scalp potential differences less than 100 microvolts [Makeig et al., 2002].

correlations

Scalp evoked-potential changes in response to image, sound, or mental event [Galambos et al., 1981].

Anesthesia and responses to simple stimulus configurations can have prolonged brain potential synchronization. Brain-potential synchronization is less during awake states and complex situations.

Waves are large in tasks requiring activity integration across different cortical areas. Waves stop at perceptual-processing conclusion and motor-signaling beginning.

Waves do not carry information about stimuli nor relate to signals from individual neurons.

correlations: awake

Hippocampus has theta rhythm at 4 Hz to 10 Hz during active movement and alert immobility, synchronized between hemispheres and 8 mm along hippocampus longitudinal axis. Awake brain has synchrony, which increases with attention and preparation for motor acts. Brain potential synchronization is less when awake.

Other behaviors have local and bilaterally synchronous rhythm near 40 Hz.

200-Hz waves correlate with alert immobility.

A 12-millisecond phase shift goes from brain rostral to caudal pole, during alpha wave activity while awake.

Most waves during waking are in posterior cortex, lower than vertex.

correlations: sleep

EEG waves can differentiate seven sleep stages. Most waves during sleeping are in vertex and frontal lobe. Synchronous firing characterizes deep sleep and epilepsy.

Between waking and sleeping, brain wave change is abrupt in adults. Between waking and sleeping, brain wave change is slow in children.

correlations: slow-wave sleep

NREM sleep has low-frequency, high-amplitude waves. Non-REM-sleep phases 3 and 4 have low-frequency EEG waves {slow-wave sleep}.

correlations: REM sleep

Awake and REM sleep activation level has high-frequency, low-amplitude waves [Hobson, 1989] [Hobson, 1994] [Hobson, 1999] [Hobson, 1999] [Hobson, 2002] [Hobson et al., 1998].

correlations: other waves

EEG waves include bereitschaftspotential, contingent negative variation (CNV), and motor potential.

factors: age

EEG-wave localization, regularity, continuity, similarity from both hemispheres, synchrony from similar areas, and stability increase until age 35. Brain-wave amplitude decreases until age 35.

alpha blocking

Alpha waves disappear when eyes open or people have mental imagery {alpha blocking}, but some visual activities do not block alpha waves. If both visual hemispheres have damage, alpha rhythm stops.

alpha wave

EEG waves {alpha wave} can have frequency range 8 to 12 per second. Sleep or quiet rest has alpha waves. They have larger amplitude if brain has pathology. A 12-millisecond phase shift goes from brain rostral to caudal pole, during alpha wave activity while awake and during REM sleep [Varela et al., 2001]. Alpha-wave frequency increases until five or six years old.

auditory evoked potential

Electric potentials {auditory evoked potential} (AEP) happen after sounds [Creutzfeldt and Houchin, 1984] [Creutzfeldt, 1995] [Freeman, 1975] [Mountcastle, 1957] [Mountcastle, 1998] [Remond, 1984]. Scalp electrodes can record them.

sleep

AEP during waking and REM sleep are similar but differ from AEP during non-REM sleep. Early AEP do not fluctuate during sleep-waking cycle. Early thalamocortical activity causes middle AEP, which decrease amplitude from waking to stage-4 sleep but are normal in REM sleep.

Later, AEP amplitudes decrease from waking to stage-4 sleep but increase in REM sleep. P20 component reflects cerebral-cortex activity and increases from waking to stage-4 sleep but returns to waking level in REM sleep. REM sleep does not have latest AEP: P100 wave, P200 wave, and P300 wave.

beta wave

EEG waves {beta wave} can have frequency range 15 Hz to 25 Hz. Beta-wave frequency increases until 15 years old.

bispectral index

EEG {bispectral index} can measure anesthesia depth.

delta wave

EEG waves {delta wave} can have frequency range 1 Hz to 4 Hz. If sound is during REM-sleep delta-wave activity, no coherent 40-Hz oscillations begin [Creutzfeldt and Houchin, 1984] [Creutzfeldt, 1995] [Freeman, 1975] [Mountcastle, 1957] [Mountcastle, 1998] [Remond, 1984]. Delta-wave frequency increases until one year old.

evoked potential

Scalp potential {evoked potential} {event-related potential} changes in response to image, sound, or mental event [Galambos et al., 1981].

expectancy wave

Concentrating on probable signal arrival changes electroencephalograph potential {expectancy wave} (e-wave).

gamma wave

Awake but non-attentive animals have large-amplitude synchronized 25-Hz to 35-Hz oscillations {gamma wave} [Engel and Singer, 2001] [Keil et al., 1999] [Klemm et al., 2000] [Revonsuo et al., 1997] [Rodriguez et al., 1999] [Tallon-Baudry and Bertrand, 1999].

locations

Visual precentral and postcentral cortex, retina, olfactory bulb, thalamus, other brain nuclei, and cerebral neocortex have continuous and coherent 30-Hz to 70-Hz {40-Hz oscillation} electric potential oscillations.

All visual areas and both hemispheres synchronize cells. Visual field feature produces coherent 40-Hz oscillations separated by as much as 7 mm in visual cortex [Eckhorn et al., 1988] [Eckhorn et al., 1993] [Engel et al., 1990] [Friedman-Hill et al., 2000] [Gray and Singer, 1989] [Kreiter and Singer, 1992] [Ritz and Sejnowski, 1997].

Somatosensory and motor cortex potentials synchronize while thinking but vanish during actual movement.

cause

40-Hz oscillations happen when cells in different cortex or thalamus parts respond to linked stimulus parts [Crick and Koch, 1990] [Engel and Singer, 2001] [Metzinger, 2000].

attention

Oscillations synchronize more during focused attention [Mountcastle et al., 1981] [Wurtz et al., 1982].

induced gamma wave

When people perceive object with coherent features, 30-Hz EEG wave starts in occipital cortex 200 ms after stimulus and dies out after perceptual processing.

magnetoencephalography

People can measure magnetic fields caused by brain electric currents {magnetoencephalography} (MEG), using superconducting quantum interference devices (SQUID).

mu wave EEG

When people make or observe voluntary movement, EEG waves {mu wave} {μ wave} decrease. Mirror neuron activity blocks mu waves.

N400 wave

EEG waves {N400 wave} can be about semantic improbability, as opposed to semantic relatedness.

P300 wave

260 ms to 500 ms after rare stimuli, attention to object to recognize it or use it causes 40-Hz oscillations {P300 wave}, which correlate with event unexpectedness.

PGO wave

If people are conscious or dreaming, high-amplitude electrical waves {PGO wave} arise in pons, radiate to geniculate body, and then go to occipital cortex. Saccadic eye movements cause potential waves in cholinergic neurons in pons and go to lateral geniculate nucleus and occipital cortex. Signals from aminergic cells inhibit cholinergic neurons. PGO waves accompany desynchronization.

readiness potential

0.8 second earlier than planned voluntary movement, ipsilateral motor cortex EEG changes potential {readiness potential} to negative. Conscious willing feeling is later. 0.5 second earlier than unplanned voluntary movement, EEG changes potential to negative. Perhaps, consciousness can still stop or allow action before it has begins [Libet, 1993] [Libet et al., 1999]. Lateralized readiness potential is in contralateral cortex and happens after action selection.

sleep spindle

For activation, awake stage and REM sleep has high-frequency low-amplitude EEG waves. NREM sleep has low-frequency high-amplitude EEG waves. Stage II NREM sleep has distinctive EEGs {sleep spindle} {K-complex wave}.

theta wave

EEG waves {theta wave} in hippocampus can have frequency range 4 Hz to 8 Hz [Buzsáki, 2002] [Kahana et al., 1999] [Klimesch, 1999] [O'Keefe and Recce, 1993]. Theta-wave frequency increases until two to five years old. REM sleep has theta waves in hippocampus.

Transcranial Magnetic

Treatments {Transcranial Magnetic Stimulation} (TMS) can excite or inhibit brain regions to treat depression, obsession, stress, and mania [Cowey and Walsh, 2001] [Kamitani and Shimojo, 1999].

BIOL>Zoology>Organ>Nerve>Brain>Evolution

brain evolution

Brain evolved {brain, evolution}.

brain: parts

Brain is an enlargement and opening of spinal cord cranial end. First, slight enlargement formed rhombencephalon. Then, pons (bridge) evolved. Rhombencephalon evolved to myelencephalon and metencephalon. Above pons and further forward, rostrally towards nose, is mesencephalon. From midbrain roof, special motor cerebellum evolved, first becoming large and important in birds. Fourth-ventricle top became midbrain cerebral aqueduct. Rostral to midbrain is forebrain, with diencephalon and telencephalon [Cummins and Allen, 1998].

brain: processes

Neural structures evolved first reflexes, then associations, then feature surfaces and flows, then objects and events, then scenes and trajectories, and then histories and stories over space and time using language [Cummins and Allen, 1998].

brain: tissue

Neural tissue evolved from neuron to interneuron, ganglion, ganglia group, cortex, two-layer paleocortex, four-layer neocortex, and six-layer frontal lobe cortex.

design

Neural tissue and brains evolved opportunistically and did not follow design. Brains are not evolving teleologically to defined final state. Brains do not necessarily work efficiently.

motion

Originally, sensation led directly to motion. Brain evolved to separate perception from motion. Brain further evolved to integrate perception, memory, emotion, and goals. Brain then evolved to have consciousness.

dual origin hypothesis

Mammalian cortex has both caudal and rostral reciprocal pathways {dual origin hypothesis}. Birds have hyperstriatum and neostriatum. Hyperstriatum evolved like mammalian cortex. Neostriatum evolved from DVR.

pallium

Top and bottom cerebral neocortex layers are homologous to pallium. Reptile medial pallium evolves to mammal hippocampus major and subiculum. Reptile lateral pallium evolves to mammal olfactory cortex. Pallium receives from olfactory and limbic cortex, caudally.

ventricular ridge

Middle four cerebral neocortex layers are homologous to reptile dorsal ventricular ridge. Dorsal ventricular ridge receives from within itself, rostrally.

pallium

Reptiles have dorsal cortical plate {pallium}.

ventricular ridge

Reptiles have a two-layer ridge {ventricular ridge} {dorsal ventricular ridge} (DVR) behind brain ventricles.

BIOL>Zoology>Organ>Nerve>Brain>Cephali

rhombencephalon

Enlargement and opening of spinal-cord cranial end at hindbrain was earliest brain {rhombencephalon}|.

myelencephalon

Rhombencephalon evolved to medulla oblongata {myelencephalon}|, in hindbrain.

mesencephalon

Above pons and further forward, rostrally towards nose, is midbrain {mesencephalon}|.

metencephalon

Rhombencephalon evolved to medulla, cerebellum, pons, mamillary bodies, pituitary gland, and habenula {metencephalon}|, in hindbrain.

rhinencephalon

Brain regions {rhinencephalon}| {smell brain, rhinencephalon} can be near frontal lobe.

diencephalon

Rostral to midbrain are epithalamus, fornix, hypophysis, hypothalamus, subthalamus, thalamus, and third ventricle {diencephalon}|, in cerebrum and forebrain. All diencephalon regions connect to each other and to cerebral cortex.

telencephalon

Rostral to midbrain are cerebral cortex, white matter, and basal ganglia {telencephalon}|. Cerebral cortex has frontal, parietal, temporal, occipital, insular, and limbic lobes.

evolution

In amphibians, dorsal telencephalon became dorsal cortex and hippocampus. Medial telencephalon became septum, which connects to hippocampus. Lateral telencephalon did nothing, because amphibians have no dorsal ventricular ridge. Ventral telencephalon became striatum, for muscle control.

In reptiles, dorsal telencephalon became dorsal cortex and hippocampus. Medial telencephalon became septum. Lateral telencephalon became dorsal ventricular ridge, for senses and/or emotions. Ventral telencephalon became striatum.

In birds, dorsal telencephalon became hyperstriatum with wulst. Medial telencephalon became septum. Lateral telencephalon became dorsal ventricular ridge. Ventral telencephalon became striatum.

In mammals, dorsal telencephalon became cerebrum, including neocortex and hippocampus. Medial telencephalon became septum. Lateral telencephalon became laterobasal amygdala for emotions. Ventral telencephalon became striatum.

BIOL>Zoology>Organ>Nerve>Brain>Divisions

rhombomere

Bottom brain has eight repeated parts {rhombomere}, with one next to cerebellum and eight near spinal cord. Cells do not migrate from one rhombomere to another. Eighth cranial nerve comes from fourth rhombomere.

lower brain

Low brain part {lower brain} includes medulla oblongata, pons, and cerebellum.

hindbrain

Above spinal cord, bottom brain {hindbrain}| is medulla oblongata then pons.

midbrain

Above pons and further forward, rostrally towards nose, are cerebellar peduncles, inferior olive, quadrigeminal plate, nucleus accumbens, red nucleus, substantia nigra, tectum, and midbrain tegmentum {midbrain}|. All midbrain nuclei have ascending and descending axon tracts. Midbrain is for attention, controls aggressiveness, and predicts adjustments to visual perception that will result from movement, using signal {central kinetic factor} that codes displacement direction and speed.

endbrain

Rostral to midbrain are cerebral-cortex frontal, parietal, temporal, occipital, insular, and limbic lobes, white matter, and basal ganglia {endbrain}.

forebrain

Front brain {forebrain}| contains cerebrum diencephalon and telencephalon: amygdala, basal ganglia, cortex, hippocampus, olfactory bulb, and thalamus.

BIOL>Zoology>Organ>Nerve>Brain>Brainstem

brainstem

At fourth ventricle, above spinal cord, brain regions {brainstem}| can have cervical flexure and cephalic flexure and contain midbrain and hindbrain [Parvizi and Damasio, 2001] [Zeman, 2001]. Brainstem includes cranial nerve nuclei.

hindbrain

Hindbrain contains pons near midbrain and medulla oblongata near spinal cord.

midbrain

Midbrain has noradrenergic lateral reticular system, noradrenergic locus coeruleus, serotoninergic raphe nucleus, dopaminergic basal midbrain nuclei, cholinergic sense nuclei, and histaminergic nuclei.

Histaminergic nuclei project in net over brain.

Cholinergic sense nuclei connect to cerebral cortex. Damage reduces cerebral activity and causes a dreamy state.

functions

Brainstem integrates signals for attention, sex, and consciousness. Consciousness requires higher brainstem.

area postrema

Regions {area postrema} can lack blood-brain barrier and can sense large molecules.

basal forebrain

Forward brainstem {basal forebrain}| damage affects event-time recall.

cochlear nucleus

Brainstem nucleus {cochlear nucleus} receives from cochlea hair cells.

lateral cervical nucleus

Brainstem nucleus {lateral cervical nucleus} sends to superior colliculi.

nucleus sagulum

Brainstem nucleus {nucleus sagulum} sends to superior colliculi.

perihypoglossal nucleus

Brainstem nucleus {perihypoglossal nucleus} sends motor input to superior colliculi.

poker chip

In vertebrates other than mammals, structure {poker chip} decides which of twenty behavior modes is most appropriate. Poker chip later evolves to become reticular formation.

posterior commissure nucleus

Brainstem nucleus {posterior commissure nucleus} sends motor input to superior colliculi.

prepositus hypoglossius

Brainstem nucleus {prepositus hypoglossius} receives from superior colliculi and sends to oculomotor system.

reticular formation

Mesencephalic reticular formation, intralaminar nuclei, and reticular nuclei {reticular formation}| {reticular activating system} {reticulum} {ascending reticular activating system} {extralemniscal system} {non-specific afferent system} {gating system} {ascending activation system} {midbrain reticular formation} {mesencephalic reticular formation} stimulate thalamus and cortex to cause waking and sleep states.

purposes

Reticular formation arouses, integrates signals, maintains consciousness, controls vital functions, modulates perception, forms and recalls memories, and coordinates motor behaviors.

purposes: consciousness

Consciousness involves thalamus reticular-activating-system ascending fibers.

damage

Damage to reticular formation causes coma, memory disorganization, sleep, reduced cortex energy, similar reactions to strong and weak stimuli, and poor behavior control.

electrical stimulation

Reticular-formation electrode stimulation can cause unpleasant feelings.

electrical stimulation: memory

Retention improves with reticular formation stimulation, which arouses brain. Stimulation does not affect retrieval. Stimulating other brain areas has no affect on retention.

biology: input

Reticular formation receives axons from sense pathways and cortex and has multisensory convergence sites. All senses activate ascending reticular formation, which mediates pain. Stimulating ascending reticular formation causes fear and avoidance behaviors.

biology: output

Interconnecting neurons with short axons run from lower brainstem to midbrain. Descending reticular formation acts on interneurons indirectly.

biology: chemicals

Serotonin affects reticular formation and attention system to synchronize cortex. Noradrenaline desynchronizes cortex.

biology: columns

Reticular formation has medial, median, and lateral columns, from anterior midbrain through pons, medulla, and spinal cord [Hobson, 1989] [Hunter and Jasper, 1949] [Magoun, 1952] [Moruzzi and Magoun, 1949] [Steriade and McCarley, 1990].

Medial column receives pyramidal tract, cerebellum, and sense axons from cortex and sends by ascending reticular activating system to intralaminar thalamic nuclei, which send to striatum and cortex, to activate cortex and control waking and sleeping.

Raphe nucleus median column, mainly dorsal raphe nucleus, sends inhibition to limbic system in median column.

Lateral reticular system for attention projects to spinal cord, hypothalamus, and brainstem lateral-column tractus-solitarius nucleus. Noradrenaline locus coeruleus lateral column sends attention information to limbic system and prefrontal lobes.

biology: evolution

Reticular formation is only in mammals but evolved from something similar in lower animals.

solitary tract nucleus

Brainstem nucleus {solitary tract nucleus} {tractus solitarius nucleus} receives from locus coeruleus, trigeminal nucleus, and vagus nerve and sends to parabrachial nucleus, which receives from GI tract, and ventral medial basal thalamus. Solitary tract nucleus, with taste cortex and thalamus, is for taste preferences and can detect nausea. NTS is satiation region and receives gut peptide cholecystokinin (CCK).

trigeminal nucleus

Brainstem nucleus {trigeminal nucleus} receives sensory C fibers and A-delta fibers caudally from spinal cord posterior horn lamina I and sends to ventral medial posterior thalamus, brainstem nucleus tractus solitarius, and brainstem parabrachial nucleus.

vestibular nucleus

Brainstem nuclei {vestibular nucleus} can be for balance.

zona incerta

Brainstem regions {zona incerta} can send motor input to superior colliculi.

BIOL>Zoology>Organ>Nerve>Brain>Brainstem>Hindbrain

sensory reticular formation

Ascending reticular-activating-system (ARAS) lowest-hindbrain component {sensory reticular formation} receives visceral, somatic, auditory, and visual axons from ascending sense axons and sends to neocortex through hypothalamus and thalamus. It has pain center and wakefulness or alertness center.

BIOL>Zoology>Organ>Nerve>Brain>Brainstem>Hindbrain>Medulla

medulla oblongata

Spinal-cord brainstem bulb {medulla, brain}| {medulla oblongata} includes basal ganglia and continues major nerve tracts. It relays auditory nerve sense and motor nerves, mediating phonation and articulation. It regulates cardiac action, chewing, tasting, swallowing, coughing, sneezing, salivation, vomiting, and sucking in newborns. Respiratory center maintains respiration. Some medulla-oblongata neurons make epinephrine.

amygdala

A limbic-system part {amygdala}| includes insula white matter.

location

Insula is in posterior frontal lobe and anterior temporal lobe.

input

Lateral amygdala receives sensations slowly from sensory cortex and fast from thalamus, and receives memories from medial temporal lobe. Central amygdala receives from lateral amygdala, prefrontal cortex, and basal amygdala. Basal amygdala receives from lateral amygdala, medial temporal lobe, and prefrontal cortex.

output

Amygdala dopamine neurons connect to cholinergic neurons in medial septal nucleus, nucleus accumbens, nucleus basalis magnocellularis, nucleus of diagonal band of Broca, hypothalamus regions for motivation and reward, and sense and motor cerebral cortex upper layers.

Amygdala sends to orbitofrontal prefrontal cortex, mediodorsal thalamic nucleus, and hippocampal formation.

Lateral amygdala sends to central amygdala. Central amygdala sends to lateral hypothalamus for blood pressure, paraventricular hypothalamus for hormones, motor cortex for stopping, and basal amygdala. Basal amygdala sends to central amygdala.

functions

Amygdala compares new stimulus to previous stimuli and signals differences to other brain regions. Using memory, amygdala participates in habituation and anticipation.

Amygdala {basolateral nucleus} affects aggression, dominance, submission, and territoriality behaviors. Amygdala regulates fear and emotional behavior. Amygdala regulates visceral activity. Amygdala affects vision and smell.

damage

Removal of, or injury to, amygdala does not affect memory.

drug

Cocaine affects sublenticular extended amygdala.

basal ganglia

Medulla ganglia {basal ganglia}| include amygdala, caudate nucleus, claustrum, external-capsule fibers, globus pallidus, internal-capsule fibers, lentiform nucleus, nucleus basalis of Meynert, nucleus dorsalis, putamen, septal nuclei, substantia nigra pars reticulata, and subthalamic nucleus.

input

Basal ganglia receive from basal-midbrain-nuclei dopaminergic neurons.

output

Basal-ganglia cholinergic neurons send to motor cortex for transmission to muscles [Langston and Palfreman, 1995].

functions

Basal ganglia assemble, select, and trigger automatic movements, perceptual motor coordination, ballistic movements, and proprioceptively controlled movements, using movement plans. They track moving visual objects, control eye movements, and process visual and multisensory data. They control tremor and muscle tone. Basal ganglia coordinate with neocortex and cerebellum for posture and complex voluntary movements.

caudate nucleus

Medulla basal ganglia {caudate nucleus} can inhibit globus pallidus. Caudate nucleus receives excitatory input from cerebral cortex and inhibitory input from thalamus, substantia nigra, and raphe. Caudate nucleus is for memory and obsessive behavior.

claustrum

Medulla basal ganglia {claustrum} can lie under cerebral cortex near insula and project to many cortex regions.

lenticular nuclei

Putamen and globus pallidus {lenticular nuclei} look striated because they have myelinated tracts.

motor reticular formation

Brainstem regions {motor reticular formation} can facilitate spinal mediated reflexes and transmit feedback from higher centers to primary receptors.

nucleus basalis of Meynert

Basal ganglia nuclei {nucleus basalis of Meynert} {nuclei of Meynert} {Meynert nuclei} {substantia innominata} can have cholinergic neurons and send to cerebral cortex.

nucleus dorsalis

Basal ganglia nucleus {nucleus dorsalis} receives proprioception input from spinal cord.

pallidum

Brainstem regions {globus pallidus} {pallidum} can receive from red nucleus and inhibit thalamus and subthalamic nucleus. Dopamine neurons can cause rigidity if overstimulated. Choline neurons can cause hyperkinesis, chorea, and athetosis if overstimulated.

polysynaptic loop

Basal ganglia connect to thalamus, then to cortex, then back to basal ganglia {polysynaptic loop}.

putamen

Medulla basal ganglia {putamen} can receive excitatory input from cerebral cortex and inhibitory input from thalamus, substantia nigra, and raphé nucleus. It inhibits globus pallidus. Putamen is for memory, motor skill, and obsessiveness. It has nearby-space maps, used in motor control.

raphe dorsalis

Brainstem regions {raphé dorsalis} can send motor input to superior colliculi.

raphe nuclei

Medulla nuclei {raphé nuclei} can secrete serotonin, make peptide substance P, start light sleep, and modulate pain, using spinal-cord dorsal-horn presynaptic inhibition.

septum medulla

Forebrain basal ganglia {septal nuclei} {septum, medulla} can receive from hippocampus and reticular formation and send to hippocampus, hypothalamus, and midbrain. Septal nuclei have trophotropic centers. They can control aggressiveness. They organize sexual thoughts, emotions, and action. They are in or near region that causes pleasure when excited.

striatum

Putamen, globus pallidus, and caudate nucleus {corpus striatum} {striatum} are near thalamus. They look striated because they have myelinated tracts.

no layers

Corpus striatum neuron types mix but not in layers.

maps

Most maps in mammalian cortex connect to maps in corpus striatum.

functions

Corpus striatum integrates learned automatic movement sequences, such as voluntary eye movements.

input

Some striatum neurons receive from thousands of cortical neurons that send 10-Hz to 40-Hz oscillating signals {interval timer}. Stimuli synchronize oscillations. Oscillators then go on oscillating. Second stimuli make substantia nigra send dopamine to striatum. Striatum remembers signal pattern. If starting signal repeats, dopamine repeats.

output

If pattern matches, striatum signals to thalamus, which informs cortex.

respiratory center

Medulla regions {respiratory center} can send excitatory signals along phrenic nerve to diaphragm.

subthalamic nucleus

Nuclei {subthalamic nucleus} {Luys nucleus} {Luys body} {nucleus of Luys} {body of Luys} can be near hypothalamus, inhibit globus pallidus, and send to thalamus. Damage causes ballistic movement.

BIOL>Zoology>Organ>Nerve>Brain>Brainstem>Hindbrain>Pons

pons

Fiber bridge {pons}| from hindbrain side to opposite cerebellum side holds major nerve tracts connecting cerebellum and cortex, in both directions, and connects thalamus to olive. Cerebral cortex motor regions influence pons. Pons controls heart, lungs, eye movements, muscle tone, walking, and running. It mediates protective and orientation reflexes.

locus coeruleus

A pons region {locus coeruleus}| can receive feedback from sense cortex and send to spinal cord, hypothalamus, tractus solitarius nucleus, sensory cerebral cortex, and cerebellum Purkinje cells [Foote and Morrison, 1987] [Foote et al., 1980] [Hobson, 1999]. Locus coeruleus contains few thousand neurons and is largest noradrenaline nucleus.

transmitters

Locus-coeruleus neurons contain neuropeptide Y (NPY) and galanin peptide transmitters.

functions

Locus coeruleus suppresses tonic vegetative regions. It regulates attention, pleasure, energy, motivation, and arousal. It causes deep sleep. REM sleep, cataplexy, grooming, and feeding depress it. Interruptions and multimodal somatosensory stimuli, including pain, excite it. Locus-coeruleus electrical stimulation causes fear and anxiety.

pneumotaxic center

A pons region {pneumotaxic center} receives from nerves that sense alveoli stretching and inhibits breathing.

tegmentum

A pons regions {tegmentum} can include reticular formation and be for attention.

BIOL>Zoology>Organ>Nerve>Brain>Brainstem>Midbrain

cuneate nuclei

Midbrain ganglia {cuneate nuclei} can receive texture, form, and vibration information in medulla ipsilateral cuneate tracts and send to thalamus, cerebrum, and cerebellum. Maps are smaller than in other areas.

gracile nuclei

Midbrain nuclei {gracile nuclei} can receive texture, form, and vibration information in medulla ipsilateral gracile tracts and send to thalamus, cerebrum, and cerebellum. Maps are smaller than in other areas.

inferior colliculi

Midbrain nuclei {inferior colliculi} can send to superior colliculi. They have auditory functions and control eye movements.

inferior olive

Brainstem regions {inferior olive} (IO) can send to cerebellar Purkinje cells.

nucleus accumbens

Midbrain striatum nucleus {nucleus accumbens} receives excitatory dopaminergic pathway from frontal lobes and ventral tegmentum and receives from basal and lateral amygdala. It sends to ventral pallidum. Nucleus accumbens mediates emotions and movements. Benzodiazepine anti-anxiety agent and antipsychotic agents block dopaminergic pathway activation. Regular drug use and other reward stimuli increase delta FosB transcription factor, which causes sensitization and degrades slowly, in nucleus accumbens.

optic tectum

Vertebrates other than mammals have vision cell layer {optic tectum} over large ventricle. Mammals have superior colliculi instead. In amphibia and fish, fibers from retina to tectum keep growing and changing. Mostly unimodal sense pathways go from cerebral cortex to tectum. Tectum makes eye saccades to focus attention-getting object on fovea. Divergence in individual tectum-nuclei loops explains how large recruited tectum-neuron population can form composite command observed at tectum.

parabrachial nuclei

Posterior upper brainstem region {parabrachial nuclei} (PBN) receives from sensory trigeminal nucleus and nucleus tractus solitarius and sends motor input to superior colliculi and motor output to hypothalamus and ventral medial basal thalamus.

periaqueductal gray

Pons and thalamus nucleus {periaqueductal gray} (PAG) has opiate receptors and makes endorphins.

periolivary nucleus

Brainstem nucleus {periolivary nucleus} near olive sends to superior colliculi.

posterior upper brainstem

Brainstem regions {posterior upper brainstem} can contain periaqueductal gray, parabrachial nucleus, monoamine nuclei, and acetylcholine nuclei. Damage to posterior upper brainstem causes coma.

quadrigeminal plate

Brainstem regions {quadrigeminal plate} can have superior and inferior colliculi.

red nucleus

Brainstem nucleus {red nucleus} {ruber nucleus} receives from amygdala and sends to hypothalamus paraventricular nucleus {stria terminalis}. It works similarly to motor cortex.

substantia nigra

Brainstem regions {substantia nigra} {substantia nigra pars reticulata} can send to superior colliculus to control eye movement. Substantia nigra cholinergic neurons connect to sense and motor neurons in caudate nucleus and putamen in basal ganglia. Basal ganglia and other midbrain dopamine neurons inhibit caudate nucleus, corpus striatum, and thalamus to coordinate motor function and automatic movement. Alzheimer's disease degenerates substantia nigra neurons.

superior colliculi

Mammal midbrain dorsal surface has large symmetrical bumps {superior colliculi} that mediate light accommodation, eyeball movements, body movements for vision, orientation, and attention [Aldrich et al., 1987] [Brindley et al., 1969] [Celesia et al., 1991].

anatomy

Superior colliculus has seven alternating cellular and fibrous layers with few interneurons, eight types of synaptic terminals, and broad dendrite arbors. Superficial layers I to III and deep layers IV to VII have topographic motor maps and associated visual and touch maps.

Superior colliculus removal causes failure to detect contralateral visual stimuli.

anatomy: input

Superior colliculus efferent neurons for eye movements receive input from substantia nigra.

Superior colliculus deep layers receive vision information ipsilaterally from lateral suprasylvian visual area and anterior ectosylvian visual area, not from striate visual cortex.

Deep layers receive somatosensory input from anterior ectosylvian sulcus dorsal part, contralateral sensory trigeminal complex, dorsal column nuclei, lateral cervical nucleus, and spinal cord. Contralateral sensory trigeminal complex receives C fibers and A-delta fibers.

Deep layers receive auditory input from anterior ectosylvian sulcus Field AES region, inferior colliculus contralateral brachium, inferior colliculus external nucleus, nucleus sagulum, and dorsomedial periolivary nucleus.

Deep layers receive motor input from frontal eye fields, motor cortex, zona incerta, thalamus reticular nucleus, posterior commissure nucleus, perihypoglossal nucleus, contralateral superior colliculus, locus coeruleus, raphé dorsalis, parabrachial nuclei, reticular formation, and hypothalamus.

Deep layers receive from basal ganglia through substantia nigra pars reticulata. Deep layers receive from cerebellum deep nuclei, including medial and posterior interposed nuclei.

anatomy: output

Superior colliculus deep layers send to thalamus, opposite superior colliculus, brainstem, and spinal cord. Superior colliculus deep layers connect to sense and motor cerebral cortex and to brainstem and spinal cord, to position peripheral sense organs. Deep layers also send contralaterally to tegmentum and spinal cord to reposition eyes, head, limbs, ears, and whiskers.

neurons: receptive field

Superior-colliculus neurons have central ON zones surrounded by lower sensitivity areas, not like retina and lateral-geniculate-nucleus ON-center-neuron or OFF-center-neuron receptive fields. Receptive fields are larger than in lateral geniculate or cortex neurons. Border is inhibitory {suppressive zone}. The most-effective stimulus is smaller than receptive field. Moving or flashing stimuli are more effective than stationary ones. Movement direction is more effective. Slow movements are more effective than rapid ones. Repeating same stimulus produces response habituation.

neurons: noxious

Superior colliculus neurons {nociceptive-specific neuron} (NS) can respond to noxious stimuli. Superior colliculus neurons {wide dynamic range neuron} (WDR) can respond to all mechanical stimuli, but especially to noxious mechanical or thermal stimuli.

neurons: multisensory

Superior colliculus neurons are 25% unimodal and 75% multisensory. Multisensory and unimodal neurons typically require 100 milliseconds to process information, but some multisensory neurons take 1500 milliseconds.

neurons: auditory

Superior colliculus has four auditory neuron types. Compared to cortical auditory neurons, superior colliculus auditory neurons are more insensitive to pure tones and more sensitive to spatial location, interaural time, and intensity differences. They respond better to moving stimuli, have directional selectivity, habituate to repeated stimuli, and have restricted receptive fields with maximal-response regions.

neurons: somatosensory

Superior colliculus somatosensory neurons respond to hair or skin stimulation, have well-defined receptive fields, prefer intermediate-velocity or high-velocity stimuli, habituate rapidly, are large, have best regions, have no inhibitory surrounding areas, and have no directional selectivity.

neurons: movement field

Midbrain neuron receptive fields {movement field} are like sense-neuron receptive fields. Neurons with similar movement fields are in same superior colliculus region. If neuron activity exceeds threshold, amount above threshold determines saccade movement velocity and distance.

eye movement

Mammal superior colliculi and non-mammal optic tectum process multisensory information, shift attention, and control voluntary and involuntary eye and other sense-organ movements, for orientation and attention. Stimulation shifts eyes, ears, and head to focus on stimulus location. High intensity causes withdrawal or escape.

Anteromedial superior colliculi stimulation causes contralateral, upward, and parallel conjugate eye movement.

Lateral superior colliculi stimulation causes conjugate, contralateral, and downward movement.

To initiate eye movement to periphery, caudal superior colliculus, which represents peripheral visual space, has pre-motor activity.

Visual fixation involves neurons in rostral superior colliculus.

eye movement: saccade

Superior colliculus neurons {motor error neuron} can generate low-frequency, long-duration discharge to signal difference between current eye position and target position. Superior colliculus neurons can initiate saccades and determine speed, direction, and amplitude [Corbetta, 1998] [Schall, 1991] [Schiller and Chou, 1998]. Saccade initiation and velocity, duration, and direction specification are separate processes. Saccade commands are many-neuron vector sums.

superior olive

Brainstem regions {superior olive} can measure time and intensity differences to differentiate auditory-signal arrival times. Olive sides {lateral superior olive} (LSO) receive inputs from both ears for intensity-level-difference detection. Olive middle {medial superior olive} (MSO) receives inputs from both ears, for time-difference detection. Neurons have time-difference ranges.

ventral tegmentum

Brainstem region {ventral tegmentum} {ventral tegmental area} (VTA) is for pleasure and motivation. Dopamine neurons inhibit nucleus accumbens, mesolimbic system, frontal cortex, and sensorimotor cortex.

BIOL>Zoology>Organ>Nerve>Brain>Cerebellum

cerebellum

Cerebellar cortex {cerebellum}| is for smooth, continuous, and rapid movement. Cerebellar activity is never conscious. Peripheral vision, cerebellum, and vestibular system find body positions.

functions

Cerebellum maintains balance, posture, equilibrium, and muscle tone. It sets appropriate voluntary-muscle motor control, rates, forces compared to resistance, movement directions, and coordination.

functions: comparator

Cerebellum works as comparator. Motor cortex sends to spinal cord to initiate voluntary actions and to cerebellum to inform about intended movements. Proprioceptive nerve input goes to cerebral cortex and then to cerebellum to report actual movements. Cerebellum sends to motor cortex and spinal cord to correct movements.

functions: damping

Damping involves inhibiting agonist and antagonist contractions to eliminate muscle tremor, for smooth movement.

functions: error control

Error control involves initial strong muscle contraction and subsequent antagonist-muscle contraction.

functions: feedforward

Sense delays prevent feedback alone from controlling fast and accurate biological movements. Cerebellum uses predictive, feedforward control.

functions: gain

Perhaps, cerebellum controls amplification gain in spinal and brainstem reflexes. Cerebellum can subtract adjustable signal from fixed-gain saccadic circuit.

functions: precision

Cerebellum compares sense stimuli about actual performance with movement program received from cerebrum, measures error, and corrects movement. For example, it regulates smooth eye movements by tuning reflexes using Purkinje cells.

It regulates premotor networks by inhibiting and disinhibiting motor-control actions that begin in brainstem, sensorimotor-cortex, and spinal-cord premotor networks. To control movement, Purkinje cells first exert increased inhibition on deep nuclei excited by cerebral cortex and sense information. Then, inhibition decreases, and deep nuclei send excitatory output to pons and red nuclei, which send to motor cortex.

functions: prediction

Prediction involves comparing information received from eyes, body, and cerebrum, to calculate when to slow and/or stop motion.

functions: progression

Progression involves muscle contraction in sequence, to coordinate and time.

functions: sensation

Cerebellum coordinates information from different senses. Skin touch receptors send to separate cerebellum areas. Cerebellum reacts more quickly to auditory stimulus than visual stimulus. Cerebellum reacts faster to higher intensity and multiple sensory stimuli.

Cerebellum affects sense accuracy, sense quickness, sense timing, short-term memory, attention, emotions, and planning. Lateral cerebellum affects perception, pattern recognition, and cognition.

functions: timing

Perhaps, cerebellum is for timing. Perhaps, parallel fibers are delay lines, and climbing fibers are clock read-out mechanisms. When parallel fiber and climbing fiber activation coincide, Purkinje cells fire to activate antagonist muscles and stop movements at intended targets.

One climbing fiber synapses on one Purkinje cell. Perhaps, cerebellar clock activates proper Purkinje-cell assemblies at right time.

learning

Cerebellum learns movement timing and guides learning in deep nuclei. It stores learned-skill model or memory within six hours, so skill becomes automatic.

learning: long-term depression

Increased dendritic calcium concentration induces cerebellar long-term depression (LTD). Cerebellar LTD reduces excitatory input to Purkinje cell. LTD can decrease synaptic weights, using climbing fiber input as training signals, Purkinje cell firing as postsynaptic factor, and/or parallel fiber synaptic activity as presynaptic factor. LTD at basket-cell and stellate-cell spiny synapses maintain excitatory input to Purkinje cells [Eccles et al., 1976].

cells: basket cell

Basket cells lie in Purkinje cell dendrites.

cells: flocculus neuron

Flocculus neurons send corrective signals for movements.

cells: Golgi cell

Golgi cells lie in middle layer between Purkinje cells.

cells: granule cell and parallel fiber

Granule cells are small neurons, have high density, and are the most common. Granule-cell-axon parallel fibers pass through middle layer, contacting one Purkinje cell many times, to outer layer, where they split, form straight line, and extend horizontally through outer layer. Parallel fiber is perpendicular to hundreds of Purkinje cell dendrite trees and contacts each once.

cells: Purkinje cell

Purkinje cells are large neurons that have tree-shaped flat dendrite planes, which converge onto one trunk into Purkinje cell. Purkinje cell membrane has 150,000 synapses, ten times more than other neuron types, mostly from granule cells. Purkinje cell axons inhibit Golgi cells and granule cells in cerebellar nuclei, which send axons to brain pyramidal and extrapyramidal tracts.

cells: stellate cell

Stellate cells lie beside Purkinje cell dendrites and have fibers that run horizontally through outer layer, mainly through one Purkinje cell dendrite tree.

biology

Cerebellum anatomy is the same in all vertebrates. Cerebellum has surface area equal to one cerebral hemisphere. It has more than half of all brain neurons. It has more folding than cerebrum.

Low-threshold cerebellar receptive fields and neurons align with nociceptive punishment signal fields and neurons.

biology: damage

Cerebellum damage decreases muscle tone, causes slowing and trembling, and fails to stop movements on time. One-side damage causes flexion on one side and extension on other. Within 45 minutes, cutting spinal cord stops flexions and extensions. Cutting after 45 minutes does not stop flexions and extensions. Cerebellum damage in early life does not affect behavior.

biology: evolution

During human evolution, cerebellum expanded at same rate as cerebrum.

biology: input

Sensory cerebellum receives tactile, visual, and auditory nerves. Cerebellum lobes have body-surface tactile representations.

biology: output

Motor cerebellum has reverberatory circuit to higher motor centers, regulates voluntary movements, organizes somatotopically, and has archicerebellum and neocerebellum. Motor cerebellum maintains muscle tonus, posture, and equilibrium.

biology: waves

Cerebellum has electrical waves lasting 150 to 200 milliseconds, at 0.02 mV to 0.12 mV.

biology: layers

Inner deep granule-cell layer has closely packed granule cells, as well as scattered Golgi cells that inhibit nearby granule cells. Middle Purkinje-cell layer has one Purkinje-cell row, surrounded by smaller basket cells. Wide outer-molecular layer has Purkinje cell dendrites that spread in plane and stellate cells that contact dendrites.

biology: pathways

Cerebellum receives excitatory input from vestibular-system mossy fibers or pons climbing fibers. Mossy fibers from vestibular system synapse with Golgi cells and granule cells. Mossy fibers from Golgi cells and granule cells send to Purkinje cells and process intersensory information. Pons climbing fibers synapse with granule, Golgi, Purkinje, basket, and stellate cells. Purkinje cells inhibit Golgi cells and granule cells.

biology: peduncles

Cerebellum attaches to posterior brainstem by three pairs of stalks {cerebellar peduncle}, which contain both afferent and efferent nerve fibers. Superior, middle, and inferior tracts join cerebellum to midbrain. Tract {superior peduncle} comes from neocortex. Tract {middle peduncle} {brachium pontis} comes from pons. Tract {inferior peduncle} comes from inner-ear vestibular apparatus.

biology: hemispheres

Cerebellum has two lateral parts {cerebellar hemisphere}, which have many small folds {folia}, connected by thin central worm-shaped part {vermis}. Vermis has inferior part that controls gross motor coordination and superior part that controls fine motor coordination. Gray-matter outer cover {cerebellar cortex} is over white matter {medullary body}.

biology: nuclei

Four deep nuclei are in cerebellar white matter. All vertebrates have the oldest cerebellum part {archicerebellum} {vestibulocerebellum}, in center {flocculus} {nodule, cerebellum}, which has afferent and efferent connections in inferior peduncle, mainly with inner-ear vestibular semicircular canals {maculae}. Cerebellum has small inferior portion {flocculonodular lobe}, for balance, position, head position changes, acceleration, deceleration, and angular movements. Fibers from retina, eye movement nuclei, and cortex terminate in vestibulocerebellum. The second oldest part {paleocerebellum} {spinocerebellum} corresponds to anterior lobe and posterior vermis and receives touch, pressure, thermal, and proprioceptive input from inferior-peduncle ascending spinal-cord and brainstem pathways. Skin, muscle, and tendon receptors send performance information about rate, force, and movement direction, especially propulsive movements such as walking and swimming.

Cerebellar Model Articulation Controller

Perhaps, cerebellum has static associative memories {Cerebellar Model Articulation Controller} (CMAC) that implement locally generalizing non-linear maps between mossy-fiber input and Purkinje-cell output. Granule and Golgi cell-network association layer generates sparse expanded mossy-fiber-input representations. Adjustable weights couple large parallel fiber vector to Purkinje-cell output units with graded properties.

pattern

Adjustable pattern generator (APG) model can generate elemental burst command with adjustable intensity and duration. It models positive feedback between cerebellar nucleus cell and motor cortical cell.

climbing fiber

Excitatory input {climbing fiber} from inferior olive goes to one Purkinje cell, making 300 synapses, to fire Purkinje cell. Perhaps, climbing fiber makes error-and-training signals to adjust parallel-fiber synaptic weights, teaching Purkinje cells to recognize patterns signaled by input vectors and to select movements that reduce errors. Perhaps, cerebral cortex activates climbing fiber input, to train cerebellum to recognize appropriate contexts for generating same movements more automatically.

microzone

Inferior-olive small neuron clusters, with similar receptive fields, stimulate parasagittally-oriented cerebellar Purkinje-cell strips, which send to cerebellar nuclear-cell common cluster {microzone}.

mossy fiber

Spinal-cord and brainstem excitatory axons {mossy fiber} synapse on more than 40 granule-cell glomeruli and deep-cerebellar nuclei. Mossy fiber also directly contacts 250 Purkinje cells but cannot fire them. Mossy fiber influences 200,000 Purkinje cells. Mossy fibers have sensory properties, but Purkinje and nuclear cells do not respond to somatosensory stimulation.

neocerebellum

The newest and largest cerebellum part {neocerebellum} {pontocerebellum} is anterior and posterior cerebellar lobes, for skilled or complex movements and intentions. Neocerebellum receives from pons and sends through superior peduncle.

parallel fiber

Excitatory axons {parallel fiber} from cerebellum send to Purkinje cell dendrites. Perhaps, parallel fibers provide input vectors. Parallel fibers form sequential-activity lines, with one synapse per Purkinje cell. Parallel fibers can induce long-term depression.

Purkinje cell

Cerebellum has seven million large neurons {Purkinje cell}, which receive 200,000 synapses on planar dendritic spines and send inhibitory GABA output to cerebellar deep nuclei.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum

cerebrum

A forebrain region {cerebrum}| {cerebral hemispheres} {cerebral cortex} above midbrain includes telencephalon and diencephalon. Cerebrum initiates behavior, causes consciousness, stores memories, and controls internal stimuli.

size

Human cerebral cortex is 2000 square centimeters in area and 300 cubic centimeters in volume.

neurons

Cerebral cortex has more than one billion neurons. Half are pyramidal cells. Surface folding increases area and density. Cerebrum has 100,000 to 300,000 neurons per cubic millimeter.

parts

Mammal cerebrum includes neocortex and hippocampus.

layers

Mammal cerebral-cortex layers average 2 millimeters thick, differing in thickness among the 52 Brodmann areas. Layers are on outside, with axon fibers on inside. Macrocolumns and their minicolumns go through all layers.

Limbic system typically has three-layered allocortex. Cingulate gyrus and insula have three to six cortex layers in juxtallocortex. Human cerebral hemispheres have six-layered neocortex. Top three layers are only in genus Homo and act as a unit. Cortex has only one inhibitory-cell layer.

layers: general

Layer 1 has horizontal cells. Layer 2 has small, round, granular cells. Layer 3 has pyramidal cells. Layer 4 has closely packed granular cells. Layer 5 has large and numerous pyramidal cells and has large spindle neurons, which begin after birth in anterior cingulate and frontal area FI and are for attention and self-reflection. Layer 6 has spindle-like small cells.

layers: detail

Top layer 1 contains pyramidal cell apical dendrites from other layers in macrocolumn and axons from other cortical areas, with few neuron cell bodies. Layers 2 and 3 have superficial pyramidal cells. Layers 1, 2, and 3 {superficial layers} receive from their column, other cortex, and thalamus matrix neurons. Layer 4 has many excitatory spiny stellate cells but few pyramidal neurons. Layer 4 has sublayers IVa, IVb, IVc, and IVc in visual cortex. Layers 5 and 6 {deep layers} have pyramidal cells, some with dendrites to layer 1, that send to cortex, thalamus, superior colliculus, and spinal cord.

layers: input and output

Layers 1 and 2 and layer-3 upper part receive from other cortical-area layer 4. Layers 1 and 2 and layer-3 upper part send to other cortical-area layer 5. Layer-3 lower part receives from outside cortex and sends to layers 1 and 2 and layer-3 upper part. Layers 2 and 3 mostly connect to layers 2 and 3, either laterally or through U-shaped fibers going down into white matter and then back up. Layers 2 and 3 also send to layer-3 lower part and to layer 4 for feedforward responses. Some layer-2-and-3 superficial neurons send output to layers 5 and 6. Layer 4 receives from layer 6 and from outside cortex. Layer 4 sends mainly to layers 1 and 2 and layer-3 upper part. Layer 5 receives from layers 1 and 2 and layer-3 upper part, from whole cortex. Layer 5 sends to layer 6, spinal cord, brainstem, basal ganglia, and hypothalamus. Layer 5 neurons do not project to other cortical areas, thalamus, or claustrum. Layer 6 receives from layer 5. Some layer-6 neurons receive from layer 4C. Layer 6 sends short vertical axons back to layer 4 and outputs to thalamus. Some layer-6 neurons send to thalamus, lateral geniculate nucleus, and claustrum.

layers: connections

Lateral axons are within all layers. Ascending and descending fibers connect all layers. Adjacent cerebral cortex areas always connect to each other. Distant cortical regions connect reciprocally.

input

Cerebrum receives from higher brainstem and limbic system. Brainstem or limbic system damage reduces cerebrum activity, and people enter dreamy state.

Ascending fibers to cerebral cortex have slow, long lasting NMDA receptors.

Excitatory input comes from ipsilateral cerebral cortex, and inhibitory input comes from contralateral cortex. Cerebral cortex mainly inhibits lower brain. It does not control older brain parts but interacts with them.

Cortical motor areas receive input from association areas, corticospinal tract, thalamus, post-central gyrus somaesthetic area, and frontal lobe motor areas.

input: topography

Cortical neurons separated by less than several hundred microns receive similar input and send similar output.

input: multisensory

Cortical neurons for multisensory information lie next to cortical areas for one sense. Superior-temporal, intraparietal, frontal, and prefrontal lobes are for multisensory convergence [Bruce et al., 1986].

input: synapses

70% of excitatory synapses on cerebral-cortex superficial pyramidal neurons are from less than 0.3 millimeters away. Few come from outside cerebral cortex. Average cortical-neuron effect on other neurons is 0.050 to 5 millivolts. Probability of one synapse causing a spike is 0.1 to 0.5.

Cortical neurons have dendritic trees with diameter 0.3 millimeters. Most neurons receive 100 synapses from 100 neurons and send to 100 other neurons. 8000 neurons eventually affect cortical neurons.

input: processing

Training, learning, and willing have widespread cortical activity and take one second.

Consciousness involves coordinated synchronized impulses in cerebral cortical neurons for over 100 milliseconds. Perhaps, impulses are high-frequency bursts, rate codes, oscillations at 40 Hz, or other synchronized impulses. Visual consciousness involves cortical layers 5 and 6. Cortical layer 4 receives input. Cortical layers 2 and 3 are for unconscious processing.

output

Motor and sense cortex sends axons to cerebellum, basal ganglia, and hippocampus, which send axons to thalamus and cortex, with no reciprocity.

Cerebral-cortex descending fibers can cause lower-brain-neuron long lasting subthreshold depolarization.

Cerebrum primary sense areas send to nearby secondary areas and nowhere else. Secondary sense areas send to other-hemisphere corresponding area, other same-hemisphere secondary areas, and cerebral association areas. Association areas interconnect.

output: synchronization

Cerebral-cortex superficial-pyramidal-cell axons travel horizontally in same cortical layer 0.4 to 0.9 millimeters and then make terminal clusters on other superficial pyramidal cells. The skipping pattern aids neuron-activity synchronization.

output: divergence

As signal travels farther into cerebrum, neuron receptive-field sizes increase and features to which neurons respond become more complex, because later areas receive input from several earlier areas.

output: feedback

Later areas send signals back to earlier areas.

damage

People with no cerebrum can sleep, awake, smile, and cry. They feel no danger or hunger and have no spontaneous behavior.

Damage to cortex causes poor memory retrieval and poor habit inhibition. Cortex loss does not affect general consciousness.

allocortex

Limbic system cortex {allocortex} {archicortex} typically has three layers.

association cortex

Cortical regions {association cortex} can record pattern and feature shapes, sizes, types, strengths, and indexes. Association cortex uses serial and parallel detectors at sensory field points to find perceptual features and associate them with similar patterns.

vector field

Associative cortex receives spatial and temporal chemical and electrical signal-intensity patterns from neuron arrays and then distributes spatial and temporal chemical and electrical signal patterns to neuron arrays, including self. Spatial and temporal pattern is like wave front or vector field. Association cortex transforms, and so maps, input field to output field. Mapping uses tensors. Vector-field output vectors are input-vector functions. Vector fields have gradients, flows, constancies, covariances, and contravariances. For example, before intention to move and before movement begins, non-motor cortex has activity. Brain compensates for body movements that change sensor and muscle positions.

levels

Primary associative cortex tracks interactions, combinations, correlations, constancies, covariances, and contravariances among neural signals.

Secondary associative cortex creates absolute time and space, through body-position and surrounding comparisons, as body, head, and eyes move. Spaces have one, two, two and a half, or three dimensions for different uses. Model locates sense organs and muscles in three-dimensional time and space, as objects where events happen. Three-dimensional space-time does not depend on body and has vertical, front, right, and left. Absolute space-time allows perspective changes and unites perception and action.

Tertiary associative cortex is only in human brain and coordinates intermodal sense information.

barrel field

Rodent somatosensory-cortex regions {barrel field} can be for sensations from same-side whiskers (Thomas Woolsey and Hendrik van der Loos) [1975]. Neuron groups {barrel, neuron} can respond first for one whisker, respond later for nearby whiskers, and respond even later for farther whiskers. Barrels feed back to previous barrels. Thalamus also has barrel-like regions {barreloid}. Brain stem has barrel-like regions {barrelet}.

Passive signal reception has refractory periods, but active exploration has no refractory periods. Active exploration has priming.

Brodmann area

Brain hemispheres have 52 regions {Brodmann area}, classified by cortical-layer thickness. Average human Brodmann area is two square inches. Brodmann areas can have one to six distinct physiological subregions, each one-centimeter square. For example, area 17 has one map.

central fissure

A cleft {central fissure} {central sulcus} {rolandic sulcus} lies between pre-central gyrus and post-central gyrus.

cerebral dominance

Humans perform some mental functions predominantly in left or right cerebrum {cerebral dominance}.

convolution in brain

Cortex folds on itself {convolution, cortex}| in set patterns.

cingulum

From corpus callosum to gray matter {cingulum} are myelinated axons.

corpus callosum

In placental mammals, 800 million axons {corpus callosum}| connect left and right cerebral hemispheres [Aboitiz et al., 1992] [Kretchmann and Weinrich, 1992].

Brain also has smaller connections between hemispheres.

processing

Corpus-callosum posterior splenium relays visual information from left visual field to speech area.

damage

Cutting corpus callosum causes epileptic-like brain firing.

split brain

Cutting all connections between left and right hemispheres can show psychological functions performed by hemispheres. Cutting only corpus callosum makes no change, because other connections can still carry signals.

After cutting, people cannot match unseen object felt by the hand to seen object felt by right hand. Two separate experiences or discriminations can happen simultaneously.

Both hemispheres know words, pictures, and metaphorical relationships. Both hemispheres are aware.

Will, consciousness, motivation, and coordination are only slightly depressed, except for short concentration lapses. Perception, object location, and space orientation stay the same.

Either hemisphere can activate, depending on task, sex, age, handedness, education, and training.

Over time, functions performed by hemispheres become more alike.

brainstem

Brainstem dismay, embarrassment, or amusement feelings, generated in one hemisphere by threat, risk, or teasing perceptions, can cause body movements, emotions, attention, and orientation.

isocortex

Mammal neocortex cerebral hemispheres {isocortex} can have six layers.

juxtallocortex

Cingulate gyrus and insula {juxtallocortex} have three to six cortex layers.

left hemisphere

A brain hemisphere {left hemisphere}| stores categorical relationships and organizes movements in right limbs.

functions

It has region, between occipital, parietal, and temporal lobes, for mathematical thinking. It is better at propositional speech. It predicts how words will sound. It stores learned skills. It directs right-hemisphere left-limb control. It has relatively more neurons and fewer axons, so connections are shorter for analyzing details.

damage

Damage to left posterior hemisphere harms language coding. Large damage to left hemisphere causes language ability loss but does not affect automatic language.

lissencephaly

Cortex can not fold and is smooth {smooth brain} {lissencephaly}.

neocortex

Cortex {neocortex}| {new forebrain} can be only in mammals, for sense memory [Abeles, 1991] [Allman, 1998] [Braitenberg and Schüz, 1991] [Braitenberg, 1984] [Felleman and Van Essen, 1991] [Mountcastle, 1957] [Mountcastle, 1998] [Passingham, 1993] [Peters and Rockland, 1994] [Peters et al., 1991] [Rockel et al., 1980] [White, 1989] [Zeki, 1993]. It has uniform neuron structure.

regions

In humans, neocortex has at least 52 distinct cellular areas. Cat neocortex has 36. Rat neocortex has 13. In some primates, striate cortex differs from motor cortex, with giant Betz cells, in laminar organization, cell number, cell types, and general connectivity patterns.

planum temporale

Upper-temporal-lobe region {planum temporale} controls complex movements and language processing.

precuneus

Nuclei {precuneus} can be about autobiographical memory.

receptive field

Sense neurons have spatial regions {receptive field} from which stimuli can come [Kuffler, 1952] [Ratliff and Hartline, 1959]. Retinal neurons have receptive fields with center circle and surrounding annulus with opposite polarities {center-surround organization}.

retinotopic map

Vision has topographic maps {retinotopic map}, in which fovea has more points than surround.

right hemisphere

Hemispheres {right hemisphere}| can have relatively fewer neurons and more axons, so connections are longer. It can recognize larger patterns. It has region, between occipital, parietal, and temporal lobes, for spatial thinking. It analyzes visual and spatial relations. It gives direction sense. It can perceive shapes by touch. It recognizes faces. It understands interpersonal acts. It does more distance judging. It judges temporal order such as simultaneity and time differences. It synthesizes whole situation to develop emotional response.

language

Right hemisphere cannot express speech but can comprehend spoken and written language. It can judge word meaning from sound but cannot make sound from visual image. It comprehends all grammatical word classes, except difficult, abstract, or rare words. It cannot comprehend proposition. It cannot group using tokens. It is better at automatic speech and skilled motor acts. It can solve simple arithmetic problems.

music

Right hemisphere is for intonation, background noise elimination, music, and chords.

sensorimotor cerebral

Ventrobasal thalamus and ventral tegmentum dopaminergic neurons stimulate cerebrum {sensorimotor cerebral cortex}.

sensory cortex

Cerebral hemisphere posterior parts {sensory cortex} receive, preserve, and elaborate information from external world. Three million sense-neuron axons go to cerebral cortex.

somaesthetic cortex

Cortex regions {somaesthetic cortex} can be for touch, have double body-surface representation, depending on number of surface skin receptors, and discriminate among touch sensations.

somatosensory cortex

Cortex regions {somatosensory cortex} can receive touch information from thalamic-relay nucleus on somatosensory area 1 {area S1}, which sends to somatosensory area 2 {area S2}. Attention affects somatosensory cortex [Steinmetz et al., 2000].

somatosensory map

Brain has touch topographic map {somatotopic map} {somatosensory map} behind central fissure. Largest areas are for body regions used most frequently for tactile orientation and analysis, such as face, forepaw, and forelimb. Somatotopical and visual body-surface representation is upside down in vertebrate brains. Somatosensory-map hand region changes size, if hand exercises more. Body-movement topographic map in front of central fissure aligns with somatosensory map.

sylvian fissure

A cleft {lateral fissure} {sylvian fissure}| is between temporal lobe and parietal lobe.

temporal parietal occipital region

Brain color-processing regions {TPO region} {temporal parietal occipital region} can be at temporal-lobe, parietal-lobe, and occipital-lobe junction near angular gyrus. It also represents sequences and order. It connects touch, hearing, and vision. Perhaps, left side is multisensory, and right is spatial [Ramachandran, 2004]. TPO region expanded greatly from mammals to humans. Perhaps, it is for moving in trees as hands grasp branches.

topographic map in brain

Brain has two-dimensional neuron arrays {topographical mapping} {topographic map, brain}| for analysis [DeYoe et al., 1996] [Dow, 2002] [Hübener et al., 1997] [Horton and Hoyt, 1991] [Swindale, 2000] [Tootell et al., 1998] [Van Essen et al., 2001].

locations

Vision has topographic maps in retina, lateral geniculate nuclei, area V1, and area V2, for analyzing color, movement, disparity, orientation, size, and spatial periodicity. Audition has at least six topographic maps in primary auditory cortex and surrounding cortex, for analyzing tones and locations. Touch has at least four topographic maps in somatosensory cortex and surrounding cortex, for analyzing surface texture and shape. Proprioception has at least four topographic maps, for analyzing muscle stretching, compressing, and twisting.

Motor control also uses at least four topographical maps.

Sense and motor maps align and connect. Brain maps in different brain areas are not homogeneous and not isotropic.

layers

Maps can have neuron layers.

processing

Neurons that process signals from neighboring positions or times are near each other.

processing: number

Neuron number is proportional to processing amount. In touch maps, hand has more neurons and larger area than back. In retinotopic maps, fovea has more neurons and larger area than whole surround.

processing: inhibition

Connections within map are mostly inhibitory. Lateral inhibition enhances contrast and suppresses noise.

Topographic maps with diffuse connections and large receptive fields are beside maps with specific connections and small receptive fields, so map sets work at different spatial and temporal scales.

processing: filling-in

Maps can extrapolate and interpolate.

processing: space

Coordination among two-dimensional topological maps allows two-and-a-half-dimensional and three-dimensional representations.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Cerebral Column

hypercolumn

In visual cortex, columns {hypercolumn} of 100 cells, one millimeter diameter, can detect stimuli from one spot in visual field, from both eyes. Hypercolumn can detect orientation, from 0 to 180 degrees, and depth, and so perspective, size, shape, and surfaces. Hypercolumn macrocolumns can receive from left or right eye. Hypercolumn cells use several visual-field region sizes. Cells can be simple, complex, and hypercomplex.

macrocolumn

Neuron columns {macrocolumn} can share functional properties for one body-surface patch [Buxhoeveden and Casanova, 2002] [Koulakov and Chklovskii, 2001] [Mountcastle, 1957] [Mountcastle, 1998] [Rakic, 1995].

properties

Macrocolumn is 0.4 to 1.0 millimeters diameter. It goes through all six cortical layers. It has 100 minicolumns. It is plastic.

bands

It makes interdigitating curved planes. Somatosensory neurons responsive to skin stimulation alternate with neurons for joint and muscle receptors, every 0.5 millimeters. New-World monkeys do not have ocular dominance columns.

cause

Perhaps, self-organizing competition and cooperation, during development and learning, cause macrocolumns.

minicolumn

Macrocolumn units {minicolumn} are in all reptile, bird, and mammal cortex. Column is 23 micrometers to 65 micrometers diameter, thin hair size. It contains 110 to 250 neurons. It organizes around bundle of 12 apical dendrites. It goes through all six cortical layers. It is 30 micrometers apart in human cortex.

processing

Within ocular-dominance macrocolumns, minicolumn orientation columns can prefer lines and edges that tilt same angle from vertical {orientation tuning, minicolumn}. Superficial-layer recurrent excitation coordinates distant minicolumns.

growth

Cortex grows by adding minicolumns, which travel from inside to outside. Perhaps, self-organizing competition and cooperation, during development and learning, cause minicolumns.

ocular dominance column

Minicolumns {ocular dominance column} can have 3000 input axons and 50,000 output axons. Signals to column from right or left eye ocular dominance process faster. Visual-cortex hypercolumns have equal numbers of both ocular dominance columns [Hubel and Wiesel, 1968] [Hubel, 1988] [Horton and Hedley-White, 1984] [LeVay et al., 1985].

Ocular dominance columns are independent units 0.4 to 0.5 millimeters apart. They have bands for same orientation or same eye.

Ocular dominance columns are only in Old-World monkeys, apes, and humans, and not in New World monkeys.

orientation column

Minicolumns {orientation column} can have 3000 input axons and 50,000 output axons [Blasdel and Lund, 1983] [Blasdel, 1992] [Das and Gilbert, 1997] [LeVay and Nelson, 1991]. Orientation column is an independent unit. It has 120 cells, all for one orientation. Columns are 0.4 to 0.5 millimeters apart.

bands

Columns have bands for same orientation or same eye.

functions

Cells can detect stationary objects at locations. Cells for larger areas can check for movement and flashing, often from one direction only. Cells can check for corners, lengths, and trajectories. Orientation columns can extract contours, as curve envelopes, or can output cell-signal mean values, most-active-neuron signals, or pulse patterns.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Diencephalon

fornix

Diencephalon nerve-fiber band {fornix} connects amygdala and hippocampus to septum, preoptic area, and hypothalamus.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Diencephalon>Epithalamus

epithalamic nuclei

Nuclei {epithalamic nuclei} near thalamus include habenular nuclei, pineal gland, and habenular commissure.

habenular commissure

Fibers {habenular commissure} connect habenular nuclei in epithalamus.

habenular nuclei

Epithalamic nuclei {habenular nuclei} can receive from thalamus.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Diencephalon>Hypothalamus

hypothalamus in brain

Foremost ventral brainstem {hypothalamus, brain}| connects to limbic system within temporal lobe.

input

Hypothalamus receives excitation and inhibition from non-sense and non-motor cortex that organizes emotions and behavior.

output

Hypothalamus has dopaminergic nuclei, cholinergic nuclei, and histaminergic nuclei that project in net over whole brain.

Hypothalamus makes orexin, which goes to lateral-hypothalamus receptors.

hormones

Hypothalamus parvocellular neurons respond to adrenal glucocorticoid hormones to decrease corticotrophin-releasing-factor production.

Hypothalamus sends to gland regulators to control hormone production and sends to sympathetic and parasympathetic nervous systems.

nuclei

Hypothalamic nuclei include arcuate, dorsomedial, mamillary, paraventricular, optic chiasm, preoptic, posterior, suprachiasmic, supraoptic, tuber cinereum, and ventromedial nuclei. Sensory hypothalamus has mamillary bodies. Ergotropic centers are in hypothalamus posterior. Trophotropic centers are in hypothalamus rostral part, septum, and preoptic region.

functions

Hypothalamus is for aggression, submission, fighting, flight, rage, attention, aversion, and fear.

It is for sex behavior and sex inhibition, using sex hormone receptors. It organizes copulation in front hypothalamus and septal area.

It is for appetite, eating, digestion, micturition, and defecation. It organizes body metabolism, heat production, body temperature, and circulation.

Hypothalamus is for repose, sleep, and wakefulness. Sensory hypothalamus carries wakefulness impulses from reticular formation to thalamus.

Hypothalamus does not initiate behavior.

evolution

At first-ventricle bottom, chordates had secretory cells that evolved to make hypothalamus.

arcuate nucleus

Hypothalamus regions {arcuate nucleus} can have main proopiomelanocortin (POMC) neurons and send to limbic system and brainstem. POMC is precursor of MSH.

processing

Arcuate nucleus has region for appetite and region for satiation. Ghrelin gut peptide stimulates appetite region. PYY gut peptide inhibits appetite region. Leptin hormone stimulates satiation region and inhibits appetite region. Insulin hormone stimulates satiation region and inhibits appetite region. Satiety region sends alpha-MSH to MC4 second-satiation-region receptors. Appetite region sends AgRP to second satiety region, neuropeptide Y (NPY) to second appetite region, and melanin concentrating hormone (MCH) peptide.

dentate gyrus

hypothalamus region {dentate gyrus}.

dorsomedial hypothalamic nucleus

Hypothalamic ganglia {dorsomedial hypothalamic nucleus} can be for ejaculation.

lateral hypothalamic nucleus

Hypothalamic nuclei {lateral hypothalamic nucleus} can be for hunger.

mamillary bodies

Hypothalamus nuclei {mamillary bodies} can be for long-term memory.

motor hypothalamus

Hypothalamus regions {motor hypothalamus} can be main below-cortex limbic-system part, control reflex pupil dilation, and integrate autonomic nervous system, together with old cortex. Fore part is for parasympathetic nerves.

Back part is for sympathetic nerves. It has richest blood supply, reciprocally connects blood vessels to pituitary gland, and regulates pituitary-hormone secretions.

functions

It affects homeostasis, regulates body temperature, regulates water metabolism and excretion, and regulates food intake. It makes overall sexual behavior pattern and has pleasure center related to sex behavior.

paraventricular nucleus

Hypothalamic nucleus {paraventricular nucleus} receives from amygdala and sends to posterior pituitary.

posterior hypothalamic nucleus

Tuberal region has nucleus {posterior hypothalamic nucleus}, beside arcuate nucleus, that connects with lateral mamillary nucleus.

preoptic nucleus

Hypothalamic nuclei {preoptic nucleus} can have trophotropic centers. Medial preoptic area is about maternal behavior.

suprachiasmic nucleus

Light on retina signals optic-nerve retinohypothalamic tract, which signals hypothalamus nuclei {suprachiasmic nucleus} {suprachiasmatic nucleus} (SCN), which causes daytime pineal-gland melatonin-production reduction by inhibiting paraventricular nuclei.

supraoptic nuclei

Hypothalamic nuclei {supraoptic nuclei} can project to posterior pituitary.

tuber cinereum

hypothalamic nucleus {tuber cinereum}.

ventromedial hypothalamic nucleus

Hypothalamic nuclei {ventromedial hypothalamic nucleus} can be for satiation.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Diencephalon>Thalamus

thalamus

Above hypothalamus is golf-ball-sized ellipsoidal region {thalamus}|.

functions

Thalamus is for attention, respiration, short-term memory, and long-term memory. It can detect sensations, temperature, pain, and moderate skin stimulation. It identifies objects and initiates avoidance behavior. In mammals and humans, it directs attention to language. It affects autonomic system.

Thalamus has feeding center that controls eating behavior. It has satiety center that has glucose receptors.

anatomy

Ventral reticular nucleus is thin shell that surrounds walnut-sized dorsal thalamus. Thalamus has few intrinsic neurons.

anatomy: nuclei

Thalamic nuclei include anterior, centromedian, dorsolateral, dorsomedial, intralaminar, lateral geniculate for vision, medial geniculate for audition, multimodal, pulvinar, reticular, ventral anterior, ventral lateral, ventral posterior, and ventrobasal complex for somatosensation [Jones and Peters, 1986] [Jones, 1985] [Sherman and Guillery, 2001].

input

Main inputs to cortex first pass through two dozen thalamus regions. Glomeruli and glia surround incoming sense-nerve axons. Thalamus has projection areas for skin regions, with subareas for touch, pressure, muscle, and joint movement. Thalamus has input neurons for taste and for taste and touch.

Number of cortical fibers projecting back to thalamic nuclei is much larger than number of fibers from senses to thalamus.

output

All nuclei have matrix cells with diffuse projections. Thalamus has as many outputs as inputs but has no axon collaterals.

Thalamus inhibits optic tectum in lower vertebrates.

Core relay neurons send to cortex layer 4. Matrix neurons send to cortex layers 1, 2, and 3. Clustered neurons {core neuron}, such as magnocellular and parvocellular neurons, excite layer 4 in small cortex regions. Other neurons, such as koniocellular neurons, send to layers 2 and 3 in larger cortical regions {matrix neuron} [Jones, 2002].

damage

Non-specific thalamus damage causes consciousness loss. Thalamic damage can cause sense or motor loss.

processing

Input causes one spike and then 100 milliseconds of inhibition. Thalamic neurons can replicate sense input or can burst in 30-Hz to 40-Hz pattern unrelated to input. Thalamus reticular nucleus can switch lateral geniculate nucleus into burst mode.

anterior thalamic nucleus

Limbic-system anterior-thalamus region {anterior thalamic nucleus} {anterior sensory thalamus} relays affective visceral information to cortex and controls ergotropic behavior through sympathetic nervous system.

centromedian nucleus

Thalamic nucleus {centromedian nucleus} {centrum medianum nucleus} sends to cerebellum and corpus striatum.

dorsolateral thalamic

Thalamic ganglia {dorsolateral thalamic nucleus} can send to parietal lobe.

dorsomedial thalamic

A limbic-system part {dorsomedial thalamic nucleus} can receive from olfactory lobe and amygdala and send to frontal lobe and hypothalamus.

geniculostriate pathway

Lateral geniculate nucleus sends, through optic radiation {geniculostriate pathway, brain}, to occipital lobe visual cortex area V1. Geniculostriate and tectopulvinar pathways interact. Lateral geniculate nucleus damage causes poor acuity.

intralaminar nuclei

Thalamus medullary-laminae nuclei {intralaminar nuclei} {intralaminar complex} (ILN) {nucleus circularis} can have neurons organized in torus and include geniculate bodies. ILN surrounds medial dorsal nucleus. Other thalamic nuclei are principal nuclei.

purpose

Loops through striatum, pallidum, and thalamus underlie arousal and awareness.

input

Intralaminar nuclei receive from reticular formation for arousal, spinothalamic system for temperature and pain, trigeminal complex for temperature and pain, cerebellum dentate nuclei for proprioception, globus pallidus for motor feedback, periaqueductal gray for emotion, substantia nigra for emotion, amygdala for emotion, and vestibular nuclei for body position.

Laterodorsal tegmentum, peduncle, and pons cholinergic neurons excite excitatory thalamocortical-relay-neuron nicotinic receptors, and those cholinergic neurons inhibit inhibitory thalamic-reticular neuron muscarinic receptors, resulting in new excitation. Basal forebrain cholinergic and noradrenergic axons go to Layer I and to lower layers. Ventrobasal nucleus sends to Layer IV.

output

Intralaminar nuclei connect, with collaterals to nucleus reticularis, to striatum, pulvinar, all cortical layers 1 to 3, except visual cortex and inferotemporal cortex, and basal ganglia.

Intralaminar nucleus {centrum medianum} {entromedian nucleus} stains differently, is for will, and sends to motor cortex and striatum.

Intralaminar-nuclei matrix neurons can send to Layer I, to modulate lower layers. Intralaminar-nuclei core neurons can send mainly to Layer V and VI, to carry main signals.

damage

Strokes in thalamoperforating arteries {paramedian arteries} can damage both ILN. Both-side damage ends waking consciousness [Baars, 1995] [Bogen, 1995] [Cotterill, 1998] [Hunter and Jasper, 1949] [Kinney et al., 1994] [Koch, 1995] [Llinás and Paré, 1991] [Minamimoto and Kimura, 2002] [Newman, 1997] [Purpura and Schiff, 1997] [Schlag and Schlag-Rey, 1984].

koniocellular neuron

Lateral geniculate nucleus has six separate cell layers, four parvocellular layers at top with small cells and two magnocellular layers at bottom with large cells. Between layers are cone-shaped cells {koniocellular neuron} that code for blue-yellow opponency, the difference between S cones and L+M cones [Calkins, 2000] [Chatterjee and Callaway, 2002] [Dacey, 1996] [Nathans, 1999].

lateral dorsal nucleus

Thin thalamic nuclei {lateral dorsal nucleus} can be in anterior, be for memory and emotion, and send to anterior cingulate gyrus.

lateral geniculate nucleus

Thalamus nucleus {lateral geniculate nucleus}| (LGN) is for object identification [Przybyszewski et al., 2000] [Shepherd, 1998] [Sherman and Guillery, 2001] [Sherman and Koch, 1998].

input

LGN receives from all senses except olfaction, especially from retinal ganglion neurons. It is sensitive to eye position. It has dermatomal segments to represent body sensations.

Thalamus receives much more feedback from cortex than it sends to cortex. Such positive and negative feedback probably applies learned and innate information to bias stimulation, which predicts stimuli [Koch, 1987] [Mumford, 1991] [Mumford, 1994] [Rao and Ballard, 1999].

LGN has circular receptive fields.

output

LGN sends, through optic radiation {geniculostriate pathway, vision}, to visual cortex area V1 in occipital lobe. Geniculostriate and tectopulvinar pathways interact.

LGN sends to somaesthetic cortex.

LGN sends to overlapping, multiple lateral geniculate nucleus cells {relay cell}. Through dendrodendritic connections, LGN affects neurons up to five millimeters away.

Neurons inhibit themselves.

damage

Damage to lateral geniculate causes poor acuity.

anatomy: layers

Lateral geniculate nucleus has six separate cell layers, four parvocellular layers at top with small cells and two magnocellular layers at bottom with large cells. Parvocellular and magnocellular core neurons send to one cortex region.

LGN layers 1, 4, and 6 are for opposite-side eye. Layers 2, 3, and 5 are for same-side eye. Layer 1 and 2 neurons respond to OFF, at any wavelength. Layer 3 and 4 neurons respond to ON or OFF, at wavelength range. Layer 5 and 6 neurons respond to ON, at wavelength range. Layer 3 and 4 neurons have opponent cells for red-green and blue-yellow.

anatomy: magnocellular

Magnocellular cells receive from bipolar cells with bigger dendrite trees and send transient signals to visual-cortex layer 4c-alpha and layer 6. These large cells are for temporal resolution, movement, and flicker. Optic-tract axons from right and left eyes synapse on separate magnocellular neurons, in bands.

anatomy: parvocellular

Parvocellular cells receive from midget cells and send sustained signals to visual-cortex layer 4cbeta. Small cells are for color, spatial resolution, texture, shape, depth perception, and stereopsis [Merigan and Maunsell, 1993] [Schiller and Logothetis, 1990].

anatomy: koniocellular

Between layers are koniocellular neurons {matrix cell} that code for blue-yellow opponency, the difference between S cones and L+M cones [Calkins, 2000] [Chatterjee and Callaway, 2002] [Dacey, 1996] [Nathans, 1999]. Koniocellular cells go to several regions.

anatomy: Y cells

Y cells maintain activity after moving object crosses receptive field, using cortico-thalamic feedback.

color processing

Brain has four opponent processes. Cell can react oppositely to red and green or green and red. Cell can react oppositely to blue and yellow or yellow and blue. Luminance is sum of red and green. Comparisons cross, so the three colors add orthogonally.

magnocellular layer

Magnocellular cells {magnocellular layer} receive from bipolar cells with bigger dendrite trees and send transient signals to visual-cortex layer 4c-alpha and layer 6. These large cells are for temporal resolution, movement, and flicker. Optic-tract axons from right and left eyes synapse on separate magnocellular neurons, in bands.

massa intermedia

Fibers {massa intermedia} link left and right thalamus.

medial dorsal nucleus

Peanut-sized thalamus nuclei {medial dorsal nucleus} can be for emotions and receive from and send to amygdala and prefrontal cortex, mostly orbitofrontal cortex. Intralaminar nuclei surround it.

medial geniculate nucleus

Thalamus nuclei {medial geniculate nucleus} can be for sound; receive from cochlea, lateral lemniscus, and inferior colliculus; and send to temporal lobe.

medial lateral thalamic nucleus

Lateral thalamic nuclei {medial lateral thalamic nucleus} can be for memory.

medial lemniscus

Thalamic regions {medial lemniscus} can mix input from touch receptors, thermoreceptors, and nociceptors along spinothalamic tract. Descending inhibition enhances contrast between stimulated area and adjacent regions or admits only certain input to higher levels, and so affects attention.

midget cell

Parvocellular cells receive from bipolar cells with small dendrite trees {midget cell} and send sustained signals to visual-cortex layer 4cbeta. Small cells are for color, spatial resolution, texture, shape, depth perception, and stereopsis [Merigan and Maunsell, 1993] [Schiller and Logothetis, 1990].

motor thalamus

Thalamus regions {motor thalamus} can connect to basal ganglia, cerebellum, motor neocortex, vagus nerve, and hypothalamus and is in visceral and autonomic system.

parvocellular layer

Parvocellular cells {parvocellular layer} receive from midget bipolar cells with small dendrite trees and send sustained signals to visual-cortex layer 4cbeta. Small cells are for color, spatial resolution, texture, shape, depth perception, and stereopsis [Merigan and Maunsell, 1993] [Schiller and Logothetis, 1990].

pulvinar nucleus

Thalamus nuclei {pulvinar nucleus} can have inferior, lateral, and medial nuclei that are for attention, are multisensory, and receive from superior colliculus and retinal ganglion cells [Desimone et al., 1990] [Grieve et al., 2000] [Kinomura et al., 1996] [LaBerge and Buchsbaum, 1990] [LaBerge, 2000] [Rafal and Posner, 1987] [Robinson and Cowie, 1997] [Robinson and Petersen, 1992]. Pulvinar nucleus excites posterior parietal and inferior temporal lobes for external stimuli. Nucleus sides {lateral pulvinar nucleus} inhibit cerebral cortex to suppress irrelevant events, increase resolution, minimize receptive fields, and specify attention focus.

reticular nucleus

Thin cell sheet {reticular nucleus} {nucleus reticularis thalami} (nRt) surrounds thalamus and has only inhibitory GABA neurons. Reticular nucleus receives from most axons to and from neocortex and interacts with its own neurons. It sends output to thalamus, to organize sleep rhythms, such as deep-sleep spindling and delta waves, and select sense channels to cortex.

semilunaris nucleus
thalamus nucleus {semilunaris nucleus}.

sensory thalamus
Thalamus regions {sensory thalamus} can have reverberatory circuit from reticular formation and hypothalamus to cortex. It carries wakefulness impulses. It mediates contact, temperature, and pain consciousness. It has anterior, lateral geniculate, medial-lateral, pulvinar, semilunaris, and ventral centrum medianum nuclei.

ventral anterior thalamic nucleus
Motor nucleus {ventral anterior thalamic nucleus} receives from cerebellum and globus pallidus and sends to corpus striatum.

ventral centrum medianum nucleus
thalamus nucleus {ventral centrum medianum nucleus}.

ventral lateral thalamic nucleus
Motor nucleus {ventral lateral thalamic nucleus} receives from cerebellum and globus pallidus and sends to cerebral motor cortex.

ventral medial basal nucleus
Thalamic region {ventral medial basal thalamus} receives from parabrachial nucleus and nucleus tractus solitarius and sends to posterior insula.

ventral medial posterior nucleus
Thalamic region {ventral medial posterior thalamus} receives from trigeminal nucleus and sends to posterior insula.

ventral posterior thalamic nuclei
Thalamic region {ventral posterior thalamic nuclei} includes sensory ventral posterolateral nucleus and ventral posteromedial nucleus. It receives from medial lemniscus, spinothalamic tract, and trigeminal nerve and sends to postcentral gyrus.

ventrobasal complex
Thalamus nucleus {ventrobasal complex} receives from dorsal column nuclei and sends to primary somatosensory cortex.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Frontal Lobe

frontal lobe
Cerebrum has frontal region {frontal lobe}| [Barcelo et al., 2000] [Brickner, 1936] [Churchland, 2002] [Colvin et al., 2001] [Damasio and Anderson, 2003] [Dennett, 1969] [Eliasmith, 2000] [Fuster, 2000] [Nakamura and Mishkin, 1980] [Nakamura and Mishkin, 1986].
purposes
Frontal lobe stores systematic semantic concepts and relationships. It analyzes and stores somatosensory, visual, and auditory information. It anticipates motor and cognitive effects. It is about attention, arousal, anxiety, and mood. It affects spatial, recognition, and short-term memory.
purposes: behavior
Frontal lobe establishes action plans and maintains motivations. It controls movement schedule and sequence. It regulates motor, emotional, sexual, and appetitive behaviors. It controls bipedal posture and habituation. It determines energy level and interests. When preparing for motion, frontal-cortex neurons have high-frequency oscillations.
damage
Frontal-lobe damage can impair voluntary movements and delayed responses. Damage can cause hyperactivity, after one day. Damage can eliminate chronic pain responses. Damage can cause no-emotion states. Damage can prevent solving problems that have multiple answers or that require multiple object views. Damage can cause repeated behavior {perseveration, frontal lobe}, as shown by Wisconsin card-sorting test. Damage can cause impaired associational learning. Damage can reduce introspection and daydreaming. Damage can prevent goals. Damage can cause people not to know that they are deficient.

anatomy

Frontal lobe connects to nucleus accumbens, locus coeruleus, hypothalamus, limbic system, precentral cortex, striatum, and posterior parietal, prestriate, and temporal lobes.

attention

Attention affects frontal lobe [Huerta et al., 1986] [Schall, 1997].

anterior cingulate gyrus

Frontal-cortex midline gyrus {anterior cingulate gyrus} {anterior cingulate cortex} (ACC) is for attention, consciousness, voluntary control, and pain. It measures pain unpleasantness. It has Brodmann areas 24, 25, 32, and 33. Multisensory cells resolve conflicts between signals, such as Stroop effect.

Broca area

Left-frontal-lobe inferior regions {Broca's area} {Broca area}, above lateral sylvian fissure, in front of motor cortex, control speech muscles that make grammatical language [Di Virgilio and Clarke, 1997].

Broca's area and Wernicke's area connect {arcuate fasciculus}.

Broca's area seems to have existed in Homo habilis.

cingulate gyrus

Frontal-lobe midline region {cingulate gyrus}| surrounds corpus callosum.

entorhinal area

Frontal-lobe areas {entorhinal area} {entorhinal cortex} can connect to hippocampus, dentate gyrus, sensory frontal lobe, temporal lobe, cingulate neocortex, and olfactory cortex. Entorhinal cortex receives from olfactory bulb. Entorhinal cortex sends sense input to hippocampus.

damage

Entorhinal cortex loss causes inability to consciously remember facts or events, such as new category members or unique examples. Damage does not affect perceptual-motor skills with no conscious internal representations, such as mastering task over several sessions or retrieving previously acquired factual knowledge.

evolution

Entorhinal cortex developed early in evolution.

insula of frontal lobe

Frontal-lobe interior orbital surface posterior part {insula, brain}| {insular cortex} includes amygdala and hippocampus. Posterior insula receives from ventral medial posterior thalamus and ventral medial basal thalamus and sends to anterior insula, which sends to anterior cingulate and ventromedial frontal lobes. Insula controls trophotropic behavior through parasympathetic nervous system. Anterior insula responds to pictures of self. Insula receives from taste neurons. Insula helps recognize consonants.

left lateral frontal lobe

Left lateral frontal lobe {left lateral frontal lobe} stores word meanings, together with Wernicke's area [Churchland, 2002] [Dennett, 1969] [Eliasmith, 2000]. Damage blocks understanding of verb classes but not noun classes.

lingual gyri

Damage to fusiform and lingual gyri {lingual gyri} causes no color perception.

mirror neuron

Frontal-lobe neuron system {mirror-neuron system} {mirror neuron}, in rostral ventral premotor area F5, allows perception, understanding, and action imitation. Neurons are active when people perform actions and when other people perform same actions. Brain connects voluntary-muscle commands, proprioception, visual perception, and sounds.

theories

Perhaps, action recognition recreates motor-brain-area motor action {direct-matching hypothesis}. Perhaps, perceptual brain areas analyze perceptions by context, body parts used, and motions caused {visual hypothesis} [Ramachandran, 2004] [Rizzolatti et al., 1996].

orbitofrontal cortex

Frontal-lobe regions {orbitofrontal cortex} {Brodmann area 11} can be above eye orbit bones, be for smell and affective values, and process learned stimulus-reward associations. It develops before prefrontal cortex.

orbito-frontal lobe

Brain regions near eye {orbito-frontal lobe} can be for planning, priorities, unexpected, and attention.

premotor frontal lobe

A frontal-lobe region {premotor frontal lobe}, Broadmann area 6, between medial motor cortex and dorsomedial prefrontal cortex, stops movements, blocks repetition, coordinates muscles, and is for rehearsal before action or imagination.

rostral frontal lobe

Frontal-lobe rostral regions {rostral frontal lobe} can connect to thalamus, hypothalamus, and septum. Rostral frontal lobe is for inherited and acquired social behavior. Large rostral frontal-lobe lesions cause little attention to others' feelings and behavior, failure to greet friend or newly introduced stranger appropriately, emotionless conversation, and failure to say good-bye properly.

supplementary motor area

Prefrontal regions {supplementary motor area} (SMA), between medial motor cortex and dorsomedial prefrontal cortex, can receive from higher sense regions. SMA applies memories, goals, feelings, and will. It sends to premotor regions, which coordinate and integrate signals sent to motor cortex, and to midline, where brain sequences actions to fit plan {motor plan}. It has readiness potential and lateralized readiness potential.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Frontal Lobe>Hippocampus

hippocampus

In insula are hippocampus major {horn of Ammon} and hippocampus minor {hippocampus}| [Freund and Buzsáki, 1996] [Parra et al., 1998].

functions

Hippocampus is for long-term and short-term memory. It is necessary to store new memories, but conscious associative fact and event memory also requires other brain regions. Hippocampus is for motivation, reward, rehearsal, and space. It controls ergotropic behavior through sympathetic nervous system. It detects movement direction, head attitude with respect to body, and movement sequence. Neurons can find relations among facts and experiences. Neurons can find fact and experience conjunctions, while neocortex builds learning structures.

damage

Hippocampus damage blocks habituation to repeated stimulation. Hippocampal formation and parahippocampal cortex loss causes inability to consciously remember facts or events, such as new category members or unique examples. Damage does not affect perceptual-motor skills with no conscious internal representations, such as mastering task over several sessions or retrieving previously acquired factual knowledge. Hippocampus damage does not affect perception, consciousness, habits, skills, language, classical conditioning, instrumental conditioning, or motor control.

damage: Alzheimer's

In Alzheimer's disease, basal-forebrain cholinergic-neuron degeneration causes low hippocampal choline acetyltransferase activity.

input

Parahippocampal gyrus and hippocampus have multisensory cells.

output

Hippocampus sends through septum and nucleus accumbens to hypothalamus. It sends to cholinergic neurons at forebrain base, nucleus basalis magnocellularis, medial septal nucleus, and nucleus of diagonal band of Broca. It connects to medial temporal lobe.

process: memory

Brain stores memory only if cerebral neocortex sends information to three different areas close to hippocampus and then into hippocampus itself. Hippocampus then passes message back through medial temporal lobe to originating site in cerebral neocortex.

process: place

Spatial information travels from thalamus to neocortex to hippocampus. Hippocampus has non-topographic cognitive space map, stored in pyramidal place cells. Place-cell fields are stable and form in minutes [Brown et al., 1998]. Place cells increase firing when body is at that location [Ekstrom et al., 2003] [Frank et al., 2000] [Nadel and Eichenbaum, 1999] [O'Keefe and Nadel, 1978] [Rolls, 1999] [Scalaidhe et al., 1997] [Wilson and McNaughton, 1993] [Zhang et al., 1998]. Place cells also recognize textures, objects, and contexts. For example, they fire only when animal sees face (face cell), hairbrush, or hand.

waves

Hippocampus has 4-Hz to 10-Hz theta rhythm during active movement and alert immobility, synchronized between hemispheres in 8-mm region along hippocampus longitudinal axis. Other behaviors have local and bilaterally synchronous 40-Hz rhythm. A 200-Hz wave associates with alert immobility. Awake brain has synchrony, which increases with attention and preparation for motor acts. When neocortex desynchronizes with low-voltage rapid potentials, hippocampus synchronizes with theta waves. When neocortex synchronizes, hippocampus desynchronizes.

hippocampal formation

Frontal lobe has hippocampus major, hippocampus minor, and subiculum {hippocampal formation}.

place cell

Spatial information travels from thalamus to neocortex to hippocampus. Hippocampus has non-topographic cognitive space map, stored in pyramidal place cells. Some hippocampus neurons {place cell, hippocampus} increase firing when body is at that location [Ekstrom et al., 2003] [Frank et al., 2000] [Nadel and Eichenbaum, 1999] [O'Keefe and Nadel, 1978] [Rolls, 1999] [Scalaidhe et al., 1997] [Wilson and McNaughton, 1993] [Zhang et al., 1998]. Place-cell fields are stable and form in minutes [Brown et al., 1998]. Place cells also recognize textures, objects, and contexts. For example, they fire only when animal sees face (face cell), hairbrush, or hand.

spatial view cell

Primate hippocampus has some neurons {spatial view cell} that fire only when viewing or recalling a location (with 30 degrees), no matter what head orientation or body location.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Limbic System

limbic system

A brain region {limbic system}| {threshold system} {limbic lobe} on frontal-lobe interiors surrounds brainstem. In mammals, limbic system includes amygdala, caudate, cingulate gyrus, entorhinal cortex, fornix, hippocampus, hypothalamus, olfactory cortex, pyriform cortex, preoptic, putamen, septum, and thalamus. It receives from hypothalamus and basal ganglia. It sends to sense and motor cerebral cortex. It connects to sympathetic nervous system for activity and parasympathetic nervous system for relaxation.

Limbic system organizes essential drives, controls visceral processes, and involves emotions, fear, anger, flight, defense, and instincts. It does not integrate emotions.

evolution

Limbic system developed in primitive fish and is the most-ancient cerebral-hemisphere part. Limbic system is more important in mammals that rely on smell more than vision and less important in aquatic mammals and primates.

damage

Damage reduces cerebrum activity, and people enter dreamy state.

mesolimbic system

Body systems {mesolimbic system} can make cholecystokinin (CCK) peptide and dopamine (DA) catecholamine and send to other limbic system neurons in nucleus accumbens, lateral hypothalamus, ventral tegmentum, olfactory tubercle, and amygdala central nucleus. Schizophrenia causes mesolimbic-system hyperactivity.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Occipital Lobe

occipital lobe

Cerebrum rear {occipital lobe}| is for vision, perceptual judgment, memory, and association.

input

Occipital lobe receives from lateral geniculate nucleus, mostly onto layer 4 [Allman, 1998] [Allman and Kaas, 1971] [Zeki, 1974] [Zeki, 1993].

Layer 4 keeps input from two eyes separate. Alternating ocular-dominance-column bands, 0.5 millimeters wide, are for input from same ipsilateral side or opposite contralateral side.

Cortical layers above and below layer 4 have neurons that receive from both eyes. Binocular neurons differ slightly in eye connection alignment, allowing distance judgments.

Occipital lobe also receives from lower brain centers.

damage

Occipital lobe damage causes blindness. Cortical area V1, V2, and V3 damage affects perception and pattern recognition, leaving only ability to perceive intensity. Left-occipital lesion and corpus-callosum posterior-splenium lesion cause alexia without agraphia.

anatomy

Simple cells have well-defined excitatory and inhibitory regions in receptive fields [DeValois and DeValois, 1988] [Hubel and Wiesel, 1959] [Hubel and Wiesel, 1962] [Hubel, 1988] [Livingstone, 1998] [Spillman and Werner, 1990] [Wandell, 1995] [Wilson et al., 1990].

Complex cells do not have well-defined excitatory and inhibitory regions [Allman et al., 1985] [Gallant et al., 1997] [Lamme and Spekreijse, 2000] [Shapley and Ringach, 2000].

Complex-neuron receptive fields are larger than simple-neuron fields and have up to 100 degrees of visual angle.

processing

Some visual-cortex neurons distinguish between familiar and unfamiliar objects. Some neurons recognize faces. Some neurons respond only to face, hairbrush, or hand. Some neurons respond to face only if eyes point in direction. Some neurons store object locations. Some neurons predict eye-movement direction.

blob in brain

Visual-cortex layers 2 and 3 neuron groups {blob} and layers 4B, 5, and 6, separated by 0.4 to 1.0 millimeters, detect color and brightness, but not orientation, at space point [Conway et al., 2002] [Lennie, 2000] [Livingstone and Hubel, 1984] [Livingstone and Hubel, 1988] [Michael, 1978] [Michael, 1981]. Blob center-surround cells are for white-black and black-white, red-green and green-red opponent, and red-green and blue-yellow double opponent.

calcarine cortex

Visual-cortex layer-4 neurons {calcarine cortex} receive input from lateral geniculate nucleus and other brain sites. Cortical layers 3, 2, 1, and 6 repeat neural array in visual-cortex layer 4.

input

One quarter of neurons use input from right eye. One quarter use input from left eye. One quarter use input from both eyes with right eye dominant. One quarter use input from both eyes with left eye dominant.

Half have receptive fields with excitatory center. Half have inhibitory center.

Half are for shape and color detection. Half are for texture and motion detection.

100 billion neurons converge on 100 million output neurons in visual-cortex layer 5 and lower-4.

point processing

For space plane-surface points, brain has 30 neurons to detect features, such as line-segment orientation. The 30 neurons are in a circle and cover ranges, such as orientations.

receptive fields

Brain has neurons with different-size receptive fields, to detect different-size features, from point size, 0.1 millimeters, to whole-visual-field size, 1000 millimeters.

density

Neurons are denser at brain points corresponding to retina center and are less dense for retina edge.

maps

Visual cortex has maps for shape, depth, color, motion, and texture that interconnect. For features, visual cortex has repeated maps to represent different times in sequence.

number

Space plane-surface points have 4*2*2*30*5 = 2400 visual-cortex neurons. If point number is 1,000,000, then black-and-white representation requires 2,400,000,000 neurons. Color requires 7,200,000,000 neurons. If times differ by 200 milliseconds over three-second intervals, neuron number for visual information totals 100,000,000,000.

circumstriate cortex

Occipital and temporal lobe region {circumstriate cortex} codes patterns and motion relations.

color blob

Visual-cortex superficial layers have color-sensitive neuron clusters {color blob}, at macrocolumnar intervals.

dorsolateral visual area

Region near ventral temporal lobe {dorsolateral visual area} {area DL} detects visual stimuli length, width, and stimulus position. It detects light-on-dark, dark-on-light, and contrast. It has large excitatory receptive fields, larger than optimum stimulus. It sends to inferotemporal cortex.

ectosylvian visual area

Occipital regions {ectosylvian visual area} can send to superior colliculi.

extrastriate cortex

Around striate cortex are areas V2, V3, and V4 {extrastriate cortex, brain} [Bullier et al., 1994] [Hadjikhani et al., 1998].

feature detector

Visual-cortex neurons respond to orientation, size, contrast, motion direction, motion speed, color, length, and depth {feature detector} in visual space. Neurons are switches that route messages, and states contain messages. Nerve signals from other neurons, muscles, and glands affect feature detectors. Feature detection is generalized associative learning, which can cause actions.

inferior occipital lobe

Visual association area 18, area 19, and posterior area 37 {inferior occipital lobe} bilateral damage prevents unique object recognition and feature retrieval. Area 18 and 19 bilateral damage prevents color perception.

intermediate medial

Visual-cortex left striate region {intermediate medial hyperstriatum ventrale} (IMHV) is for filial imprinting.

left posterior occipital lobe

Occipital regions {left posterior occipital lobe} can combine individual letters into one chunk {visual word form} and discriminate between words and non-words 200 milliseconds after input.

left ventral occipital lobe

Words and pseudo-words, but not consonant strings, excite occipital region {left ventral occipital lobe}.

occipito-parietal lobe

Occipital-lobe and parietal-lobe regions {occipito-parietal lobe} can be for thinking about two seen things simultaneously.

parastriate cortex

Occipital-lobe region {parastriate cortex} damage can cause blindness or word blindness.

posterior lunate sulcus

Occipital-lobe area V4 and V4A region {posterior lunate sulcus} analyzes color and color constancy.

posterior occipital lobe

Occipital-lobe regions {posterior occipital lobe} can be for concrete low-complexity knowledge.

posterior prestriate area

Occipital regions {posterior prestriate area} can attend to color, motion, or form.

V1 brain area

Occipital regions {V1 brain area} {area V1} {primary visual cortex} {Brodmann area 17} {striate cortex} {striate occipital cortex} {area OC} can be for primary vision perception [Brewer et al., 2002] [Dantzker and Callaway, 2000] [Preuss, 2000] [Preuss et al., 1999] [Sawatari and Callaway, 2000] [Vanduffel et al., 2002].

input

Area V1 receives from lateral geniculate nucleus.

output

Area V1 sends feedback {shifter circuit, vision} to lateral-geniculate-nucleus left-and-right-eye layers, which excite or inhibit cortical-area activity [Ahmed et al., 1994] [Budd, 1998] [Douglas et al., 1995] [Felleman and Van Essen, 1991] [Fries, 1990] [LeVay and Gilbert, 1976] [Saint-Cyr et al., 1990] [Sherk, 1986] [White, 1989].

Area V1 sends orientation information to area V2 and then to area V5.

Area V1 sends object recognition and color information to area V2, then to area V4, and then to inferotemporal cortex.

Area V1 sends object location and movement information to area V2, then to area V5, and then to inferior parietal cortex.

Area V1, area V2, area V3, and mediotemporal cortex layer-5 pyramidal cells send to superior colliculus superficial layers and to pons nuclei.

Layer-6 pyramidal-cell axon collaterals synapse on aspinous inhibitory interneurons [Callaway and Wiser, 1996].

anatomy

Striate occipital cortex has visual-field map accurate to one millimeter. Map has ocular dominance columns for both eyes. Map has orientation columns, in which preferred orientation shifts through complete cycle in 0.5 to 1 millimeter. Thousands of orientation and ocular dominance columns cross each other at right angles. Neurons that prefer particular spatial frequency, color, or size also cluster [Engel et al., 1997] [Gur and Snodderly, 1997].

Around striate cortex are areas V2, V3, and V4 {extrastriate cortex, vision} [Bullier et al., 1994] [Hadjikhani et al., 1998].

processing: edge

Most area-V1 neurons respond best to one light or dark edge-or-thin-bar orientation. Edge or bar can be stationary, moving, or flashing.

processing: line

Concentric circles on retina are parallel lines in V1.

processing: letters

Area V1 is active while visualizing letters, even with eyes closed. V1 anterior part, for parafoveal input, is more active for large size letters. V1 posterior part, for foveal input, is more active for small size letters.

processing: binocular

Striate cortex combines signals from both eyes, as do most cells in visual cortex.

processing: attention

Attention affects area V1 [Brefczynski and DeYoe, 1999] [Fries et al., 2001] [Gandhi et al., 1999] [Ito and Gilbert, 1999] [Ito et al., 1995] [Kastner and Ungerleider, 2000] [Motter, 1993] [Niebur and Koch, 1994] [Niebur et al., 1993] [Niebur et al., 2002] [O'Connor et al., 2002] [Roelfsema et al., 1998] [Somers et al., 1999] [Watanabe et al., 1998].

factors: saccade

Spontaneous area-V1-neuron activity decreases when eye moves {saccadic suppression, V1} [Bridgeman et al., 1975] [Burr et al., 1994] [Castet and Masson, 2000] [Haarmeier et al., 1997] [Ilg and Thier, 1996] [McConkie and Currie, 1996].

Saccade target object excites some V1 cells and more V2 cells.

evolution

All mammals have areas V1 and V2, which combine visual, auditory, and tactile sense data. Perhaps, more trunk-and-neck flexibility and limb development allowed those areas.

V2 brain area

Occipital regions {V2 brain area} {area V2} can be for stereoscopic vision [Engel et al., 1997] [Heydt et al., 2000] [Levitt et al., 1994] [Livingstone and Hubel, 1981] [Livingstone and Hubel, 1987] [Merigan et al., 1993] [Peterhans, 1997] [Roe and Ts'o, 1997] [Thomas et al., 2002] [Tootell et al., 1998] [Wong-Riley, 1994].

Almost all area V2 neurons receive input from both eyes. Color, location, and shape have alternating area-V2 bands. Nearness and farness cells detect distance. Area V2 neurons have bigger receptive fields than neurons in area V1. V2 neurons can respond to illusory edges, hidden and seen shapes, or figure-ground differences.

output

Almost as many neurons send to area V1 from area V2 as send from V1 to V2.

V3 brain area

Occipital regions {V3 brain area} {area V3} can be for depth of vision [Burkhalter and Van Essen, 1986] [Lyon and Kass, 2002] [Newsome and Pare, 1988] [Newsome et al., 1986] [Newsome et al., 1989] [Tootell et al., 1997] [Zeki, 2003]. Nearness and farness cells detect distance. Some cortical-area-V3A neurons respond to gaze angle.

V4 brain area

Ventral-system occipital regions {V4 brain area} {area V4} are for color perception and have topographic maps. Lunate sulcus posterior part and superior temporal sulcus anterior part are for color and color constancy. Area V4 responds to all wavelengths and line orientations but does not respond to movement. Some neurons are sensitive to spots or rectangles. Nearness and farness cells detect distance. Area-V4 visual neurons also respond to somatosensory stimuli [Burkhalter and Van Essen, 1986] [Newsome and Pare, 1988] [Newsome et al., 1986] [Newsome et al., 1989] [Tootell et al., 1997] [Wachtler et al., 2003] [Zeki, 1973] [Zeki, 1983] [Zeki, 1993]. Perhaps, cells are in color columns.

attention

Attention affects area V4 [DeWeerd et al., 1999] [Ghose and Maunsell, 2002] [McAdams and Maunsell, 1999] [Treue and Martinez-Trujillo, 1999].

color

Some cells are opponent, and some double-opponent. Some cells are for specific colors, orientations, and shapes. Some cells are for any color differences [DeValois and DeValois, 1975].

V6 occipital brain area

Ventromedial occipital-lobe regions {V6 occipital brain area} {area V6, occipital lobe} can be for color.

ventromedial occipital lobe

Ventral and medial occipital lobe region {ventromedial occipital lobe} damage causes color vision loss. Practice can reduce damaged region.

ventroposterior occipital lobe

Ventral and posterior occipital regions {ventroposterior occipital lobe} {area VP} can be for color.

visual buffer

In occipital lobe, maps {visual buffer}, with retina input, can segregate figure from ground during perception and store images.

visual cortex

Vision cortex {visual cortex}| measures surface area and spatial frequency. It has same number of stellate neurons as pyramidal cells. Cerebral cortex has more than 30 visual or mixed areas, and half have maps with input from retina. Primates have more than 21 visual areas: V1, V2, MT, and M. V1 has calcarine fissure.

input

It receives excitatory axons one-third from same-side lateral geniculate nucleus and reticular nuclei. It receives inhibitory axons two-thirds from same-side locus coeruleus. It does not receive many axons from association areas or from other brain half.

output

It sends to superior colliculus, lateral geniculate nucleus, and area-17 and area-19 superficial pyramidal neurons, up to three millimeters away.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Parietal Lobe

parietal lobe

A brain region {parietal lobe}| between frontal and occipital lobes and above temporal lobe is for movement, orientation, calculation, and recognition. It controls symbol use, spatial orientation, maps, space in general, body-side consciousness, numerical and logical relations, and sense associations. It understands speech parts, passive voice, and possessive case, in different subregions. It is for language, learning, and memory. It, mostly inferior parietal, participates in memory retrieval.

Attention affects parietal lobe [Bisley and Goldberg, 2003] [Colby and Goldberg, 1999] [Gottlieb et al., 1998].

damage

Parietal lobe damage disrupts memory, spatial cognition, and attention. Parietal lobe damage causes anomalous body experiences. Non-dominant, usually right, posterior parietal lobe damage can cause hemi-neglect and anosagnosia.

angular gyrus

Parietal lobe regions {angular gyrus}| can be for reading and writing, detect number concepts such as cardinality and ordinality, and connect speech-behavior auditory information to visual information. Perhaps, left side is multisensory, and right is spatial [Ramachandran, 2004]. Angular gyrus expanded greatly from mammals to humans.

area A1

Parietal-lobe regions {primary auditory cortex} {area A1} {A1 area} can be adjacent to Wernicke's area and receive from medial geniculate nucleus, which receives from inferior colliculus, which receives from nucleus {lateral lemniscus nucleus}, superior olive, and cochlear nuclei. Lateral lemniscus nucleus receives from superior olive and cochlear nuclei. Superior olive receives from dorsal, posteroventral, and anteroventral cochlear nuclei and both ears. Cochlear nuclei receive from cochlea {spiral ganglion} auditory neurons.

processing

Y cells maintain activity after moving object crosses receptive field, using cortico-thalamic feedback.

auditory cortex

Parietal regions {auditory cortex}| can be for hearing, sound, octaves, and tone patterns. It has frequency-sensing neuron field perpendicular to intensity-sensing neuron field.

processing

Specific brain places recognize sounds in word, speech, or sentence. Special places are for object names, word productions, writing, remembering words, and speaking spontaneously.

No matter the musical scale, people prefer octave tuned slightly higher than exact 2:1 frequency ratio.

damage

Primary hearing area destruction causes only high-tone loss. Bats can hear even with damaged primary auditory areas.

corticofugal network

Auditory-cortex regions {corticofugal network} can learn sound patterns and send dopamine feedback to itself and higher regions.

dorsal parietal lobe

Parietal-lobe back regions {dorsal parietal lobe} can be for well-being feeling.

grasping cell

Cells {grasping cell} can respond to grasping.

inferior parietal lobe

Inferior parietal lobe regions {inferior parietal lobe} (IPL) {caudal inferior parietal lobe} can have two main parts, LIP and 7a. Both LIP and area 7a receive input from thalamus medial pulvinar nucleus. Area LIP sends to superior colliculus and frontal eye fields to execute saccadic eye movements. Area 7a sends to polymodal cortex, limbic system, and prestriate cortex, to detect retinal locations and eye and head positions. Right or left Brodmann-area-7 damage causes hemi-neglect.

left anterior parietal lobe

Speech area damage {left anterior parietal lobe} can harm syntax, sequential organized speech, and skilled movements but not affect phoneme, word, logic, or grammar production or understanding.

left inferior parietal lobe

Left inferior parietal region {left inferior parietal} damage affects color-perception achromatopsia in fusiform gyrus, motion-perception akinetopsia in mediotemporal region, face perception in prosopagnosia, and feelings that there are imposters in Capgras syndrome [Nordby, 1990] [Perrett et al., 1992] [Scalaidhe et al., 1997] [Tranel and Damasio, 1985].

left inferoparietal

Association area {left inferoparietal} damage can cause various language problems.

left parieto-occipital

Association area {left parieto-occipital} damage can cause various language problems.

left posterior parietal lobe

Speech area damage {left posterior parietal lobe} can interfere with language acquisition and harm paradigmatically-organized speech production and understanding, but not affect syntax and organized speech.

lunate sulcus

Posterior area V4 and V4A regions {lunate sulcus} can analyze color and color constancy.

motor cortex

Human parietal-lobe regions {motor cortex}| {area M1} {Brodmann area 4} {precentral gyrus} {pre-central gyrus} {motor strip} can have two or three million motor neurons, control purpose, initiate voluntary movements, activate habits, cause automatic movements, and specify muscle positions needed at movement completion. Pre-central gyrus contains most corticospinal motor tract neurons.

output

Motor-cortex pyramidal neurons send to extrapyramidal-motor-system alpha and gamma motor neurons, to coordinate and initiate fast and precise movements. Motor neurons excite spinal cord neurons, which excite special muscle fibers in muscle spindles. Primary motor cortex connects to basal ganglia, thalamus, and other cerebral cortex [Bullock et al., 1977].

processing

Muscles move to reach specified muscle positions, as registered by muscle sensors. Motor cortex programs movements by controlling lower-level reflexes. Once started, motor program cannot stop, only change. Motor cortex neurons align by movement direction. Neurons signal particular limb-movement direction. Actual movement is sum of vectors. Primary motor cortex M1 activity shifts with intended-arm-movement coordinates [Amirikian and Georgopoulos, 2003] [Bullock, 2003] [Dean and Cruse, 2003] [Evarts, 1968] [Miall, 2003].

In isotonic movement, motor cortex and red nucleus neurons give intense burst, at frequency corresponding to movement velocity and duration corresponding to movement duration. In isotonic movement, Purkinje cells give bursts or pauses, to inhibit positive feedback to antagonists or allow positive feedback to agonists. In isometric movement, motor cortex and red nucleus neurons give intense burst, at frequency corresponding to force and duration corresponding to force rate. Motor cortex and red nucleus neurons can also have tonic output.

Sense information selects motor-program parameters to initiate program, to define movement endpoint through proprioception, and to guide subsequent adaptive process that mediates motor learning. Sense feedback shapes motor map, and vice versa.

Y cells maintain activity after moving object crosses receptive field, using cortico-thalamic feedback.

Muscle activity initiation always begins unconsciously in cerebrum. Conscious control can affect final motor nerve signals.

damage

Damage to motor cortex does not change learned mammal behavior patterns.

voluntary movement

Mammals have voluntary behavior and move bodies and appendages to specific space points {voluntary movement}.

voluntary movement

The two million motor neurons of human parietal-lobe motor-cortex area M1 initiate voluntary movements and specify muscle positions needed after movements. Muscles move to reach specific muscle positions, as registered by muscle sensors. Motor-cortex pyramidal neurons send to spinal-cord lateral corticospinal tract, which controls voluntary muscles by controlling reflexes.

vectors

Motor-cortex neurons contract specific muscle fibers, which move in relative direction from zero length change up to maximum length change. Fiber movements have magnitude and direction and so are vectors.

vector sums

Individual cortical cells have few connections to nearby neurons, so individual-neuron activation cannot provide enough signal strength to start or maintain movements {motor act}. Motor acts require multiple neuron pathways to achieve precise movement timing. Motor acts generate large precisely coordinated temporal-signal sequences to activate muscles. In contralateral superior colliculus, average neuron vector directs eye movement, or eye and head movement, to target object, using body-centered coordinates.

Neurons for attention to target control motor neurons. Brains control movements using few independent parameters. Motor acts require coordinated temporal motor-neuron activation and inhibition. To move limbs or body parts in specific directions, motor-cortex neurons contribute fiber movement. Total limb or body-part movement is sum of vectors and moves limb or body part from starting position to final position, using body-centered coordinates. Motor cortex accounts for starting position, finds vector sum, and moves to intended final position. Proprioceptive sense information defines starting and ending positions [Amirikian and Georgopoulos, 2003] [Bullock, 2003] [Dean and Cruse, 2003] [Miall, 2003].

input

Input from attention, planning, and drive neurons goes to all motor neurons.

movement-control parameters

Movement control uses several independent parameters. For isotonic movements with constant force, motor-cortex neurons fire for duration corresponding to movement duration, at rate corresponding to movement velocity. For isometric movements with no motion, motor-cortex neurons fire for duration corresponding to force duration, at rate corresponding to force.

MT area

In primates, parietal regions {area MT} {MT area} can analyze small object and large background motions and orientation. Adjacent neurons detect slightly different orientations in one direction and opposite orientations in perpendicular direction. MT also participates in recognition memory.

post-central gyrus

Parietal-lobe anterior-edge regions {post-central gyrus} can be tactile and kinesthetic sense areas. Its SI topographic map has Penfield homunculus.

posterior parietal lobe

Parietal lobe has posterior region {posterior parietal lobe} (PP) [Andersen, 1995] [Batista and Andersen, 2001] [Bisley and Goldberg, 2003] [Bruce et al., 1986] [Colby and Goldberg, 1999] [Glickstein, 2000] [Gross and Graziano, 1995] [Snyder et al., 2000].

input

Posterior parietal lobe receives from visual, auditory, and proprioceptive cortex.

output

Posterior parietal lobe sends to inferior-temporal-lobe superior temporal sulcus superior boundary, spinal cord, brainstem, prefrontal lobe, and frontal lobe.

functions

Posterior parietal lobe detects sense location, size, orientation, and motion direction. It represents attended object locations. It is for attention, shape transformations, category and spatial coordinate interactions, spatiotopic mapping, and spatial relations. In humans, it is about spatial cognition, in right hemisphere, and language understanding, in left hemisphere. It registers movement consequences, such as current eye position. Eye position multiplies receptive-field event [Zipser and Andersen, 1988]. It plans and initiates limb movements in primates. Map in cortical area 6 computes locations in nearby space, using body-based coordinates, and can guide orienting responses, like tectofugal pathway. Cortical area 7b has map of nearby space for motor control. Neurons respond to both receptive field changes and eye or head position [Andersen et al., 1985] [Andersen et al., 1997] [Pouget and Sejnowski, 1997] [Salinas and Abbott, 1995].

suprasylvian visual area

Parietal regions {suprasylvian visual area} can send to superior colliculi.

Wernicke area human

In primates, left-inferior parietal-lobe association regions {Wernicke's area} {Wernicke area} can be in left-superior temporal lobe below lateral fissure, next to primary auditory cortex, at vision, audition, and somaesthetic cortical junction. Wernicke's area has no connections to limbic system. Broca's area and Wernicke's area connect through arcuate fasciculus.

damage

Wernicke's area damage causes alexia, agnosia, tactile aphasia, and word deafness but does not affect writing or hearing. Disconnecting Wernicke's area from motor centers causes apraxia. Wernicke's aphasia causes bad semantics, paraphasia, imprecise words, circumlocutions, and neologisms, but speech is fluent, rapid, articulated, and grammatical.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Prefrontal Lobe

prefrontal lobe

Cerebral neocortex {prefrontal lobe}| {prefrontal cortex} can be behind frontal lobe [Carmichael and Price, 1994] [Fuster, 1997] [Goldberg, 2001] [Grafman et al., 1995] [Miller and Cohen, 2001] [Passingham, 1993] [Preuss, 2000].

functions

Prefrontal lobe activates brain, is for attention, is for emotion cognition, controls respiration and autonomic system, causes initiative and persistence, foresees consequences, and forms intentions.

Lateral prefrontal cortex is for temporary storage in working memory. Anterior cingulate in medial prefrontal cortex is for executive functions and coordinates information about self. Ventral prefrontal and orbital cortex is for emotions and participates in memory retrieval.

input

Prefrontal lobe has many dendrite D1 and D5 dopamine receptors. Prefrontal cortex receives from mediodorsal thalamic nucleus.

output

Of all neocortex, only prefrontal sends directly to hypothalamus. It also sends to basal ganglia striatum and globus pallidus.

damage

Prefrontal lobe damage causes selfishness, bad manners, inability to concentrate, failure to plan, inability to think abstractly, and indifference.

evolution

Lateral prefrontal cortex is only in primates. Ventral prefrontal lobe, orbital cortex, and medial-prefrontal-cortex anterior cingulate are only in mammals.

dorsolateral prefrontal cortex

Brain top and side regions {dorsolateral prefrontal cortex} can be for spatial coordinates and categorization. It looks up information in associative memory to access stored information for working memory. It uses model similar to cerebellar model to control muscle movement and learn new physical skills.

attention

Dorsolateral prefrontal cortex, cingulate nucleus, frontal eye fields in area 8, posterior parietal lobe in area 7a, pulvinar nucleus, and superior colliculus shift attention.

rule

Ventrolateral prefrontal cortex, Brodmann areas 44, 45, and 47, and dorsolateral prefrontal cortex, Brodmann areas 9 and 46, process conditionals. They develop after orbitofrontal cortex and before rostrolateral prefrontal cortex. Orbitofrontal cortex processes rules.

task

Rostrolateral prefrontal cortex, Brodmann area 10, can process task sets. It develops after dorsolateral and ventrolateral prefrontal cortex.

prefrontal medial subgenual region

Prefrontal regions {prefrontal medial subgenual region} can be for meaning and mood.

prefrontal ventromedial cortex

Prefrontal regions {prefrontal ventromedial cortex} can be for sense integration.

BIOL>Zoology>Organ>Nerve>Brain>Cerebrum>Temporal Lobe

temporal lobe

Side brain regions {temporal lobe}| can receive information about features, orientations, balance, and sound and have speech-recognition systems. Inside area is for short-term memory, affective memory, and association.

input

Middle-temporal-lobe V5 area detects pattern directions and speed gradients. Medial superior temporal lobe dorsal area detects heading. V2 and V4 areas detect non-luminance-contour orientations. V4 area detects curved boundary fragments. Inferotemporal lobe (IT) detects shape parts. IT and CIP detect curvature and orientation in depth from disparity.

output

Temporal lobe sends to limbic system.

damage

Temporal-lobe lesions can cause the feeling that one has previously witnessed a new situation. Temporal lobe removal decreases pattern discrimination, color vision, fear reactions, learning sets, and retention. Temporal lobe electrical stimulation causes fear, sadness, or loneliness. Removing both temporal lobes makes monkeys fail to recognize objects, be hypersexual, exhibit compulsive oral behavior, not be afraid of things that used to cause fear, and be less aggressive {Klüver-Bucy syndrome, monkey} [Klüver, 1933].

anterior inferotemporal area

Anterior and inferior temporal-lobe region {anterior inferotemporal area} {area TE} responds to color, shape, and texture over large areas. It detects curves, corners, blobs, and other features. It receives from posterior inferotemporal and medial temporal and sends to prefrontal, medial temporal, and striatum. It has no topographic maps. Eye or head movements do not affect it [Wang et al., 1996].

anterior temporal lobe

Temporal-lobe {anterior temporal lobe} damage can block fact retrieval and affect speech.

fusiform gyrus

Extrastriatal gyrus {fusiform gyrus}| in middle and inferior ventral temporal lobe and ventral occipital lobe stores categories, shapes, and patterns. Fusiform gyrus contains area V4, which detects color. A fusiform-gyrus region {fusiform face area} can detect faces [Cowey and Heywood, 1997] [Damasio et al., 1980] [Gallant et al., 2000] [Hadjikhani et al., 1998] [Haxby et al., 2000] [Kanwisher et al., 1997] [Meadows, 1974] [Ramachandran, 2004] [Sakai et al., 1995] [Tong et al., 2000] [Tootell and Hadjikhani, 2001] [Vuilleumier et al., 2001] [Wade et al., 2002] [Zeki, 1990] [Zeki et al., 1991] [Zeki et al., 1998].

damage

Fusiform and lingual gyri damage causes no color perception.

inferotemporal cortex

Brain has inferior temporal cortex region {inferotemporal cortex}| (IT) [DiCarlo and Maunsell, 2000] [Gross, 1998] [Gross, 2002] [Logothetis and Sheinberg, 1996] [Tamura and Tanaka, 2001] [Tanaka, 1996] [Tanaka, 1997] [Tanaka, 2003] [Tsunoda et al., 2001] [Wang et al., 1996] [Young and Yamane, 1992].

functions

IT affects visual recognition by visual cortex. IT analyzes complex visual stimuli and discriminates visual forms. IT is for attention and visual memory. IT selects object to view.

IT responds best to new stimuli. If new visual feature matches the original, brain suppresses half of inferotemporal neurons activated by visual feature. One-third of inferotemporal neurons decrease response to familiar or repeated stimuli.

Some inferotemporal neurons recognize individual faces at different views, face prototypes, or poses, ignoring brightness.

Some inferotemporal neurons respond to stimulus actively held in memory and receive back projections from prefrontal cortex [Miyashita et al., 1996] [Naya et al., 2001] [Sheinberg and Logothetis, 2001].

input

IT receives from dorsolateral visual area.

output

IT sends to object recognition centers and attention and orientation systems.

damage

Inferior temporal lobe damage causes inability to categorize or discriminate.

left anterior inferotemporal

Area 20 and 21 {left anterior inferotemporal} damage impairs object naming, though people can describe objects, have good grammar and phonetics, and name actions and relationships [Wang et al., 1996].

left anterior temporal lobe

Temporal pole {area 38} {left anterior temporal lobe} damage impairs object naming, though people can describe objects, have good grammar and phonetics, and name actions and relationships.

left temporal lobe

Verbal-acoustic areas {left temporal lobe} can be for phoneme and word understanding.

medial temporal lobe

Temporal regions {middle temporal lobe} {medial temporal lobe} (MT) {mediotemporal cortex} {V5 brain area} {area V5} can encode motion perception and respond to movement and movement direction but not to wavelength. MT can detect movement direction, from visual texture [Albright, 1993] [Allman and Kaas, 1971] [Andersen, 1997] [Britten et al., 1992] [Britten et al., 1996] [Cook and Maunsell, 2002] [Ditterich et al., 2003] [Goebel et al., 1998] [Goldstein and Gelb, 1918] [Heeger et al., 1999] [Hess et al., 1989] [Heywood and Zihl, 1999] [Huk et al., 2001] [Humphreys, 1999] [Mather et al., 1998] [Parker and Newsome, 1998] [Salzman and Newsome, 1994] [Salzman et al., 1992] [Schall, 2001] [Shadlen et al., 1996] [Tootell and Taylor, 1995] [Tootell et al., 1995] [Tolias et al., 2001] [Williams et al., 2003] [Zeki, 1974] [Zeki, 1991] [Zihl et al., 1983].

MT neurons can code for depth [Bradley et al., 1998] [Cumming and DeAngelis, 2001] [DeAngelis et al., 1998] [DeAngelis and Newsome, 1999] [Grunewald et al., 2002] [Maunsell and Van Essen, 1983].

memory

Medial temporal lobe stores long-term declarative explicit memories. MT also participates in recognition memory.

attention

Attention affects medial temporal lobe [McAdams and Maunsell, 2000] [Saenz et al., 2002] [Treue and Martinez-Trujillo, 1999].

anatomy

MT includes amygdala, entorhinal cortex, hippocampus, parahippocampal gyrus, perirhinal cortex, and Brodmann areas 28, 35, 36, and 37.

input

MT receives from V1 and superior colliculus. Parahippocampal and perirhinal cortex both receive from somatic, auditory, and visual sensory cortex. Entorhinal cortex receives from parahippocampal and perirhinal cortex. Hippocampus DG region receives most from entorhinal cortex and some from parahippocampal and perirhinal cortex, not from neocortex. Hippocampus CA3 receives from DG. Hippocampus CA1 receives from CA3. Subiculum, in hippocampal formation, receives from CA1.

output

MT sends to superior colliculus, posterior parietal lobe, lateral intraparietal lobe, ventral intraparietal lobe, medial superior temporal lobe, and frontal lobe. MT connects through pons nuclei to cerebellum to control body and eye movements. Subiculum sends to rhinal cortex, which sends to sensory cortex.

damage

MT damage over wide area impairs factual knowledge retrieval but not information about categories or object features. Damage impairs smell but nothing else. Damage does not affect attention. Damage also affects emotions. Damage causes retrograde amnesia and affects all senses.

evolution

All primates have visual area 5.

middle superior temporal area

Middle superior temporal region {optical flow field} {middle superior temporal area} (MST) encodes motion perception, especially texture flows.

non-medial temporal region

Lateral temporal regions {non-medial temporal region} can include polar region, inferotemporal area, and posterior parahippocampus and retrieve factual knowledge, but not skill, perception, or motor control.

parahippocampal area

Region near hippocampus {parahippocampal area} includes rhinal cortex, with medial temporal lobe memory system and multisensory convergence. Parahippocampal area region {parahippocampal place area} responds most to places, not objects.

perirhinal cortex

Cortex near nose {perirhinal cortex} damage causes inability to consciously remember facts or events, such as new category members or unique examples. Damage does not affect perceptual-motor skills with no conscious internal representations, such as mastering task over several sessions or retrieving previously acquired factual knowledge.

posterior inferotemporal cortex

Posterior inferior temporal region {posterior inferotemporal cortex} (PIT) receives from ventral-pathway area V4 and sends to anterior inferotemporal cortex. Attention affects it [DeWeerd et al., 1999].

posterior superior temporal lobe

Posterior superior temporal regions {posterior superior temporal lobe} can be at temporal-occipital-parietal junction, be for associative memory, and retrieve representations and concepts [Bruce et al., 1986].

posterior temporal lobe

Posterior temporal-lobe regions {posterior temporal lobe} can be for consonant strings, words, speech fluency, and categorical knowledge. Visual association area-18, area-19, and posterior-area-37 bilateral damage prevents unique object recognition and feature retrieval.

right temporal lobe

Right temporal lobe region {right temporal lobe} controls spatial relationships, form manipulations, and visual discriminations.

superior temporal gyrus

Superior temporal lobe gyrus {superior temporal gyrus} represents sounds.

superior temporal sulcus

Superior temporal lobe sulcus {superior temporal sulcus} (STS) detects head or face movement, separate from viewing angle or recognition. Anteriorly, in area V4 and V4A, it analyzes color and color constancy. It detects shapes and textures. Posterior cingulate, medial frontal gyrus, and superior temporal sulcus are about imagining how other people feel.

V6 temporal brain area

Temporal regions {V6 temporal brain area} {area V6, temporal lobe} can be for locations.

ventral temporal lobe

Ventral temporal-lobe regions {ventral temporal lobe} can control attention and consciousness.

BIOL>Zoology>Organ>Nerve>Brain>Ventricle

ventricle in brain

Central brain spaces {ventricle, brain}| are down middle, hold cerebrospinal fluid, and connect to spinal cord fluid tube. Beneath septum pellucidum, first two ventricles connect through hole to third ventricle, which is between right and left hypothalamus lobes. Tectum covers third ventricle in back. In front of third ventricle are septal and preoptic areas. Fourth ventricle is in hindbrain.

cerebral aqueduct

Fourth-ventricle aqueduct {cerebral aqueduct} is in midbrain.

septum pellucidum

Almost transparent tissue {septum pellucidum}, in cerebrum beneath corpus callosum, separates first and second ventricles.

BIOL>Zoology>Organ>Nerve>Brain>Neural Correlates Of Mind

neuronal correlates of consciousness

Forebrain neural activities can correlate with sense qualities {neuronal correlates of consciousness}| (NCC) [Alauddin et al., 2003] [Calvin, 1996] [Calvin, 1996] [Calvin, 1998] [Cotterill, 1998] [Changeux, 1983] [Crick and Koch, 1992] [Crick and Koch, 2003] [Crick, 1979] [Crick, 1994] [Dehaene and Changeux, 2004] [Dehaene and Naccache, 2001] [Dehaene, 2001] [Dehaene et al., 2003] [Dragunow and Faull, 1989] [Fried et al., 1998] [Graziano et al., 2002] [Greenfield, 1995] [Greenfield, 2000] [Han et al., 2003] [Jasper, 1998] [Koch and Davis, 1994] [Koch, 2004] [Lechner et al., 2002] [Li et al., 2002] [Llinás et al., 1998] [Slimko et al., 2002] [Taylor, 1998] [Yamamoto et al., 2003].

brain processes

Consciousness is not about brain processes, because they are at low level. Algorithm high-level code must use low-level code for processor. Brain processes do not yet reveal higher code or algorithm.

brain regions

Consciousness can be a whole-brain, many-connected-region, few-connected-regions, or one-brain-region property [Chalmers, 2000] [Metzinger, 2000] [Mollon and Sharpe, 1983] [O'Regan and Noë, 2001] [Pessoa et al., 1998] [Teller, 1984] [Teller and Pugh, 1983].

Perhaps, brain has sets of different neurons, whose information, interactions, or processing is necessary and/or sufficient for consciousness aspects.

Awakeness depends on nuclei below cortex and thalamus that excite, or remove inhibition from, cortex and thalamus non-specifically, but these nuclei do not directly make sense qualities.

Sense qualities depend on cortex and thalamus, but cortex and thalamus regions project to local or distant cortex and thalamus locations, so no region relates to sense qualities.

complexity

Many non-conscious processes involve complex computations, and brain can learn complex non-conscious processes. Many widespread brain processes have no association with consciousness. Both unconscious and conscious processes involve neurons with high firing rates and/or large chemical changes.

feedback

Perhaps, consciousness requires feedback in brain pathways. Illusions can switch between two different sense qualities or perceptions about same figure or image. Perception depends on memory and thalamocortical feedback.

iteration

Perhaps, experience involves iteration, but repetition delays processing and limits discrimination.

Probably, experience does not use iteration, repetition, waves, vibrations, oscillations, or anything periodic, because such processing limits information.

mind requirements

Consciousness requires information from objects and events outside brain, information transfer from receptors to processors, and effector controls. Information channels from objects and events to brain to effectors must have enough information capacity and speed. Channels have reverse channels to provide feedback and synchronization. Information codes must express all physical relations.

physiology

Perhaps, cell membrane polarizations and depolarizations; chemical concentration changes from manufacture, destruction, or transfer; or cell structure changes at synapses or dendrites have biochemical and biophysical effects that cause experience. Perhaps, brain-pathway cellular-connection changes cause experience. Consciousness-causing activity must last long enough to allow integration and be short enough to prevent signal overlap. Neuron activity affects other neurons, so correlations can be widespread and indirect.

similar neurons

Perhaps, brain has "consciousness neurons" that have similar ion channels, shapes, receptors, axons, synapses, and/or biochemistry. Perhaps, some neuron feature is necessary and/or sufficient for consciousness aspects. However, no neuron properties or events, including connections, directly relate to sense qualities.

visual pathways

Testing visual nerve pathways {visual pathways} can reveal neural activity related to visual sense qualities. Consciousness uses brain regions for attention, shape, and planning and goals [Chalmers, 2000] [Ffytche, 2000] [Kanwisher, 2001] [Lumer, 2000] [Lumer et al., 1998].

Scientists know visual pathways better than other sense pathways [Andersen et al., 1990] [Baizer et al., 1991] [Barbas, 1986] [Felleman and Van Essen, 1991] [Karnath, 2001] [Kennedy and Bullier, 1985] [Lewis and Van Essen, 2000] [Maunsell and Van Essen, 1983] [Rockland and Pandya, 1979] [Saleem et al., 2000] [Salin and Bullier, 1995] [Van Essen and Gallant, 1994] [Zeki and Shipp, 1988].

visual pathway level 01

Level 01 is from Retina to Lateral Geniculate Nucleus [LGN]. Damage affects sight, but processing is not sufficient for consciousness. Though retinal-cell distribution causes lower visual acuity outside fovea, sense qualities do not seem to have much lower acuity. Only two color-receptor types are in fovea, but sense qualities seem to have all colors. Few color receptors are outside fovea, but sense qualities seem to have all colors. Though retina has blind spot, people do not notice it. Eye movements can cause fuzziness, but sense qualities do not show much blurring. Blinking can cause darkness, but sense qualities are not black then.

visual pathway level 02

Level 02 is LGN, in Thalamus, to area V1. Damage affects sight, but processing is not sufficient for consciousness. LGN modulates stimuli received from retina, so it does not determine sense qualities, because retina does not.

visual pathway level 03

Level 03 is Superior Colliculus [SC] to LGN. Damage does not affect sight. SC just controls saccades.

Level 03 includes Pulvinar Nucleus and other brainstem nuclei to areas V1, V2, and SC. Damage does not affect sight. Brainstem nuclei just control gaze, pupil size, blinking, and daily rhythms.

Level 03 includes area V1 or Brodmann 17, in dorsal and ventral pathways, to areas V2, V3, PIP, V3A, PO, V4t, V4, MT, and MSTl. Damage affects sight, but processing is not sufficient for consciousness. Area V1 codes motions and objects separately, but these unite in sense qualities. People do not use V1 in dreams, which have sense qualities. V1 neuron responses stay the same when ambiguous-figure sense qualities alternate. V1 neuron responses can change with unconscious blinking, eye movement, and fast color alternation, though sense qualities stay the same.

visual pathway level 04

Level 04 is area V2, V2 dorsal [V2d], and V2 ventral [V2v], in dorsal and ventral pathways, to areas V3, VP, PIP, V3A, PO, V4, V4t, VOT, VIP, MSTd, MSTl, FST, and FEF. Damage affects sight, but processing is not sufficient for consciousness. V2 codes shape, contrast, depth, motion, edges, and figure separately, but these unite in sense qualities.

visual pathway level 05

Level 05 includes areas V3, V3 dorsal [V3d], and V3 ventral [V3v] in dorsal pathway to PIP, V3A, PO, MT, V4t, V4, VIP, LIP, MSTd, FST, FEF, and TF. Processing is not sufficient for consciousness. V3 codes for fast response, not object images.

Level 05 includes Ventral Posterior [VP], in ventral pathway, to PIP, V3A, PO, MT, V4, VOT, VIP, LIP, FST, FEF, and TF. Processing is not sufficient for consciousness. VP neuron responses reflect both retinal stimulation and sense qualities.

Level 06 includes Posterior Intraparietal [PIP] and Posterior Parietal complex [PPcx], in dorsal pathway, to PO, MT, V4, DP, and 7a. Processing is not sufficient for consciousness. PIP just controls attention.

visual pathway level 06

Level 06 includes V3A, in ventral pathway, to PO, MT, V4, DP, LIP, MSTd, MSTl, FST, and FEF. Processing is not sufficient for consciousness. V3a codes only for shape, but sense qualities include other features.

Level 07 includes Medial Dorsal Parietal [MDP], in dorsal pathway, to PO and 7a. Processing is not sufficient for consciousness. MDP codes for fast response, not object images.

visual pathway level 07

Level 07 includes Medial Intraparietal [MIP], Intraparietal dorsal [IPd], and Intraparietal anterior [IPa], in dorsal pathway, to PO and 7a. Processing is not sufficient for consciousness. MIP codes for fast response, not object images.

Level 07 includes Parietal-Occipital [V6] [PO], PO anterior [POa], PO anterior-internal [POa-i], PO anterior-external [POa-e], Lateral Occipital Parietal [V7] [LOP], Lateral Occipital Caudal [LOC], and Dorsal Medial Occipital complex [DMOcx], in dorsal pathway, to MDP, MIP, MT, V4t, DP, VIP, LIP, MSTd, MSTl, 7a, and FEF. Processing is not sufficient for consciousness. PO codes for fast response, not object images.

Level 07 includes Medial Temporal [V5] [MT], MT caudal [MTc], Temporal A [TA], TA anterior [TAa], Temporal E [TE], TE anterior [TEa], TE medial [TEm], TE antero-dorsal [TEa-d], TE antero-ventral [TEa-v], TE anterior-medial [TEa-m], TE1, TE2, TE3, TE1-3, TE1-3 dorsal [TE1-3d], TE1-3 ventral [TE1-3v], and Temporal E Occipital [V8] [TEO], in dorsal and ventral pathways, to PO, V4t, V4, VIP, LIP, MSTd, MSTl, FST, FEF, 46, and Prefrontal. Processing is for objects. Most neurons are about perception.

Level 07 includes V4 transitional [V4t], V4t anterior [V4ta], and V4t posterior [V4tp], in ventral pathway, to PO, MT, V4, MSTd, MSTl, FST, and FEF. Cells can track sense qualities and unsensed alternative-figure perception.

Level 07 includes V4, in ventral pathway, to MT, V4t, DP, VOT, LIP, FST, PITd, PITv, FEF, CITd, CITv, AITv, 46, TF, and TH. Cells can track sense qualities and unsensed alternative-figure perception.

visual pathway level 08

Level 08 includes Dorsal Prelunate [V7] [DP], in dorsal pathway, to LIP, MSTd, MSTl, FST, 7a, FEF, and 36. Processing is not sufficient for consciousness. DP codes for fast response, not object images.

Level 08 includes Ventral Occipital Temporal [V8] [VOT], Occipital Temporal A [OA], and OA anterior [OAa], in ventral pathway, to PITd and PITv. Processing is for space.

visual pathway level 09

Level 09 includes Ventral Intraparietal [VIP], VIP*, VIP lateral [VIPl], and VIP medial [VIPm], in dorsal pathway, to LIP, MSTd, MSTl, FST, 7a, and FEF. Processing is not sufficient for consciousness. VIP codes for fast response, not object images.

Level 09 includes Lateral Intraparietal [LIP], LIP dorsal [LIPd], and LIP ventral [LIPv], in dorsal pathway, to VIP, MSTd, MSTl, FST, 7a, FEF, 46, and TF. Processing is not sufficient for consciousness. LIP codes for fast response, not object images.

Level 09 includes Medial Superior Temporal dorsal [MSTd], MSTd anterior [MSTda], and MSTd posterior [MSTdp], in dorsal pathway, to VIP, LIP, FST, PITd, PITv, 7b, 7a, FEF, STPp, and TF. Processing is not sufficient for consciousness. MSTd codes for fast response, not object images.

Level 09 includes Medial Superior Temporal lateral [MSTl], MST medial [MSTm], and MST complex [MSTcx], in dorsal pathway, to VIP, LIP, FST, 7a, FEF, and STPp. Processing is not sufficient for consciousness. MSTl codes for fast response, not object images.

Level 09 includes Floor of Superior Temporal [FST], Ventral Superior Temporal [VST], and VST complex [VSTcx], in ventral pathway, to VIP, LIP, MSTd, MSTl, PITd, PITv, 7a, FEF, STPp, and TF. Processing is for space.

Level 09 includes Posterior Inferior Temporal dorsal [PITd] and Inferior Temporal complex [ITcx], in ventral pathway, to FST, PITv, FEF, CITv, AITd, AITv, and 46. Cells track whether sensation is on or off.

Level 09 includes Posterior Inferior Temporal ventral [PITv], in ventral pathway, to FST, PITd, FEF, CITd, CITv, AITd, AITv, TF, and TH. Cells track whether sensation is on or off.

visual pathway level 10

Level 10 includes Brodmann 7b [7b], in dorsal pathway, to 7a, STPp, and 36. Processing is not sufficient for consciousness. 7b codes for fast response, not object images.

Level 10 includes Brodmann 7a [7a] and 7a lateral, in dorsal pathway, to 7b, FEF, STPa, AITd, 36, 46, TF, and TH. Processing is not sufficient for consciousness. 7a codes for fast response, not object images.

Level 10 includes Frontal Enterofrontal [Brodmann 8] [FEF], in dorsal and ventral pathways, to 7a, STPp, CITd, CITv, AITd, and 46. FEF integrates fast responses and object perception.

Level 10 includes Superior Temporal Parietal posterior [STPp], Temporal-parietal [Tpt], Temporal-Parietal-Occipital [TPO], TPO caudal [TPOc], TPO intermediate [TPOi], TPO rostral [TPOr], Parietal Temporal G [PG], and PG anterior [PGa], in dorsal and ventral pathways, to 7b, FEF, CITd, CITv, STPa, 46, TF, TH, Striatum, and Prefrontal. Processing is for space, shape, and texture, but STPp has no topographic maps.

Level 10 includes Caudal Inferior Temporal dorsal [CITd], in ventral pathway, to FEF, STPp, AITd, AITv, 46, and TH. Processing is for shape and texture, but STPp has no topographic maps.

Level 10 includes Caudal Inferior Temporal ventral [CITv], in ventral pathway, to FEF, STPp, AITd, AITv, 46, TF, and TH. Processing is for shape and texture, but STPp has no topographic maps.

visual pathway level 11

Level 11 includes Superior Temporal Parietal anterior [STPa], in dorsal and ventral pathways, to AITd, 36, 46, TF, TH, 35, ER, Striatum, and Prefrontal. Processing is for shape and texture, but STPp has no topographic maps.

Level 11 includes Anterior Inferior Temporal dorsal [AITd], in ventral pathway, to STPa, 36, 46, TF, TH, Striatum, and Prefrontal. Processing is for shape and texture, but STPp has no topographic maps.

Level 11 includes Anterior Inferior Temporal ventral [AITv], in ventral pathway, to STPa, 36, 46, TF, TH, 35, HC, Striatum, and Prefrontal. Processing is for shape and texture, but STPp has no topographic maps.

visual pathway level 12

Level 12 includes Brodmann 36 [36], in dorsal pathway, to Brodmann 46, TF, TH, 35, ER, and HC. Processing is not sufficient for consciousness. Brodmann 36 codes for fast response, not object images.

Level 12 includes Brodmann 46 [46], in dorsal and ventral pathways, to Brodmann 36, TF, TH, and ER. Brodmann 46 integrates fast responses and object perception.

Level 12 includes Temporal F [TF], in ventral pathway, to Brodmann 36, 46, and ER. Processing is about high-level object perception.

Level 12 includes Temporal H [TH], in ventral pathway, to Brodmann 36, 46, and ER. Processing is about high-level object perception.

visual pathway level 13

Level 13 is Brodmann 35 [35], in dorsal pathway, to ER. Processing is not sufficient for consciousness. Brodmann 35 codes for fast response, not object images.

visual pathway level 14

Level 14 is Entorhinal area [ER], in dorsal and ventral pathways, to HC. ER integrates fast responses and object perception.

visual pathway level 15

Level 15 includes Hippocampus [HC], in dorsal and ventral pathways. HC integrates fast responses and object perception. Processing is for memory.