Integration Areas

Speech Center

- Also called Broca’s area; located inferior to the frontal eye field, along the edge of the lateral fissure
- Found in the same hemisphere as Wernicke’s area (thus only in one hemisphere).

- This center regulates breathing pattern and vocalization for normal speech.
- It works in close association with Wernicke’s area and the motor areas.
What we know now about speech/language is the results of analysis of clinical disorders.

Defect in language and ability to speak = **Aphasia**

- **1861, Paul Broca**, French neurologist, described a patient who could say only one word...“tan”
- When Tan died, Broca discovered he had a left brain lesion
- Broca analyzed more patients with similar problems and all had problems in same brain area (which is now called “Broca’s area”).

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**Broca’s Area**

- Located in the frontal lobe, just superior to the lateral sulcus and anterior to the inferior part of the pre-motor cortex area.
- Is involved in the translation of thoughts into speech.
- Sequence of impulses are sent from this area to the premotor cortex that control the movement of larynx, pharynx and mouth while impulses reach the primary motor cortex to regulate the breathing muscles.
Symptoms of such damage to Broca's area:

- patient can understand language
- patient can not speak full sentences; they can only speak simple words
- Small words, such as conjunctions (and, or, but) and articles (the, an, a), may be omitted, leading to a "telegraph" quality in their speech.
- articulation of speech is affected; patients can read aloud only with difficulty and their attempts at the written word are also abnormal
- there is no speech motor paralysis (lips, tongue are OK); only slight right hand problems

This type of Aphasia = non-fluent aphasia

This example shows a conversation with a person with non-fluent Aphasia

M.E.: Cinderella...poor...um 'dopted her...scrubbed floor, um, tidy...poor, um...'dopted...Si-sisters and mother...ball. Ball, prince um, shoe...

Examiner: Keep going.

M.E.: Scrubbed and uh washed and un...tidy, uh, sisters and mother, prince, no, prince, yes. Cinderella hooked prince. (Laughs.) Um, um, shoes, um, twelve o'clock ball....

Examiner: So what happened in the end?

M.E.: Married.

Examiner: How does he find her?

M.E.: Um, Prince, um, happen to, um...Prince, and Cinderella meet, um met um met.

Examiner: What happened at the ball? They didn't get married at the ball.
M.E.: No, um, no...I don't know. Shoe, um found shoe...
In 1876, Karl Wernecki found that damage to another part of the brain caused language problems as well.

Symptoms:
- have fluent speech
- speech is in-comprehensible, makes no sense
- hearing/vision is OK, but they cannot understand, comprehend what they hear or see.

This type of aphasia = fluent aphasia

Wernecki eventually postulated a simple model of speech that is still viewed as correct to this day.

To speak a word that is seen, the following needs to happen:
- information needs to get to the primary visual cortex and association area
- integrated outputs converge on Wernicke’s area
- here these inputs are recognized as visual cues, spoken or written language
- once recognized, the information is relayed to Broca’s area
- Broca’s area then directs it to the primary motor cortex
Conversation with a fluent Aphasia patient

C.B.: Uh, well this is the ... the /dødøü/ of this. This and this and this and this. These things going in there like that. This is /sen/ things here. This one here, these two things here. And the other one here, back in this one, this one /gaš/ look at this one.

Examiner: Yeah, what's happening there?

C.B.: I can't tell you what that is, but I know what it is, but I don't now where it is. But I don't know what's under. I know it's you couldn't say it's ... I couldn't say what it is. I couldn't say what that is. This shu-- that should be right in here.

That's /bêlli/ bad in there. Anyway, this one here, and that, and that's it. This is the getting in here and that's the getting around here, and that, and that's it. This is getting in here and that's the getting around here, this one and one with this one. And this one, and that's it, isn't it? I don't know what else you'd want.
Thus comprehension of what we see or hear occurs in Wernicke’s area. This area then organizes coherent patterns of speech that are transferred to Broca’s area.

Broca’s area receives this information and now controls articulation of this speech pattern. It sends information to the primary motor areas to activate the appropriate facial and tongue muscles that will cause the desired words to be spoken.

People with non-fluent aphasia usually get very depressed because they are aware of their speech problems. It usually also involves some motor skill loss.

Those with fluent aphasia most often are not aware of their condition and also do not show many motor skill loss.

Data suggest there is a gender bias in the 2 types of Aphasias.

Conduction aphasia

Broca's area and Wernicke's area are connected by a bundle of nerve fibers called the arcuate fasciculus. Damage to the arcuate fasciculus causes a disorder called conduction aphasia.

Patients with conduction aphasia usually have good language comprehension, because Wernicke's area is intact.

Although reading aloud is abnormal, conduction aphasics are able to read silently with good comprehension.
**Lateralization**

Refers to the differences between the two hemispheres

Right and left look the same. There are small anatomical but definite physiological/functional differences

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**Dominant / Non Dominant Hemisphere**

**Experiment**

- Na-Amytal injected into left or right internal carotid artery
- Subjects were asked to count down from 100
- If they stopped counting, it indicated the speech center was in that side where the drug was injected
It is known that 91% of the population is right handed.

96% of these right-handed people have the left brain as a dominant hemisphere.

70% of left handed people also have the left brain as a dominant hemisphere. 15% have a speech center in both hemispheres.

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### Dominant / Non Dominant Hemisphere

<table>
<thead>
<tr>
<th>Handiness</th>
<th>Dominant Speech Center</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Both</td>
</tr>
<tr>
<td>Right handed</td>
<td>96%</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Left handed</td>
<td>70%</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>

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The left hemisphere
- is specialized for spoken and written language
- specialized in sequential, analytical reasoning and in symbolization
- called the **categorical hemisphere** or the "**smart**" brain

15% of left handed people have the right hemisphere as the dominant one
- right side is concerned with identification of objects, faces
- also more specialized in insights, imagination, spatial relationships and music
- it is called the **representational hemisphere** or the "**artistic**" brain

Most people have a dominant hemisphere, sometimes obvious, sometimes not (many artists/musicians are left handed)

People where both hemispheres try to be dominant, sometimes end up with brain conflict (for example, dyslexia is most common in people with no dominant hemisphere)
Some general differences

<table>
<thead>
<tr>
<th>LEFT</th>
<th>RIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls right side of body</td>
<td>Controls left side of body</td>
</tr>
<tr>
<td>Involved in spoken/written language</td>
<td>Musical/artistical awareness</td>
</tr>
<tr>
<td>Numerical/scientific skills (smart brain)</td>
<td>Space/pattern perception</td>
</tr>
<tr>
<td>Ability to understand sign language</td>
<td>Insight/imagination (ah-ha brain)</td>
</tr>
<tr>
<td>Generates mental images to compare spatial relationships</td>
<td></td>
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</tbody>
</table>

Events (such as a stroke) in the hemispheres sometimes express themselves in strange ways

- damage to the dominant brain usually results in speech disorders
- patient with damage to the dominant brain usually become depressed/disturbed with their condition
- if the lesion occurs in the representational hemisphere (non-dominant), the patient sometimes don’t care or become euphoric, upbeat.
- lesion in the representational hemisphere can result in loss of face recognition although they recognize the voice that goes with that person
- sometimes they will also show **astereognosis**: inability to recognize objects when feeling them
**Sensory neglect**

- lesions in temporal lobe of representational hemisphere
- causes neglect of stimuli from the contra lateral side
- patients also tend to neglect their own contra lateral side of their body.

**Split brain syndrome**

Occurs when the corpus callosum is cut
Split brain syndrome

[Diagram of brain anatomy with labels for different brain regions and functions, comparing left and right hands and hemispheres.]
Split brain syndrome

When split-brain patients stare at the "X" in the center of the screen, visual information projected on the right side of the screen goes to the patient's left hemisphere, which controls language. When asked what they see, patients can reply correctly.

When split-brain patients stare at the "X" in the center of the screen, visual information projected on the left side of the screen goes to the patient's right hemisphere, which does not control language. When asked what they see, patients cannot name the object but can pick it out by touch with the left hand.

Split brain syndrome

When showing pictures or painting like the one in the left, a person with split brain will TELL you that he/she sees a bunch of veggies…but no face!

Recognizing faces are the domain of the Right Brain

When asked to draw with his left hand what he/she sees, they will draw a face but without the veggies.

Facial recognition and all other aspects of pattern recognition thus involves both brains working together: the left brain sees the individual parts (the 'puzzle' pieces), the right brain sees the completed puzzle but not the pieces. But together, they extract more information out of the whole…
The Diencephalon

- Central core of the forebrain
- Consists of three paired structures
  - Thalamus
  - Hypothalamus
  - Epithalamus
- Encloses and surrounds the third ventricle
The Diencephalon

**Thalamus**

- Makes up 80% of the Diencephalon
- Are paired oval masses of gray matter nuclei that make up the lateral walls of the third ventricle
- It functions as a relay station and integration area for:
  - sensory impulses that reach the cerebral cortex from the spinal cord and brain stem
  - motor impulses that originate from the cerebellum
  - allows for crude sensation of pain, temperature, pressure

The thalamus thus plays a key role in mediating sensation, motor activities, cortical arousal and even memory

**Hypothalamus**

- Located below the thalamus and forms the floor of the third ventricle
- The infundibulum, a stalk of hypothalamic tissue, connects the hypothalamus with the pituitary gland.
- Mammillary bodies
  - Small, paired nuclei bulging anteriorly from the hypothalamus
  - Relay station for olfactory pathways
The Diencephalon

Despite its small size, the hypothalamus contains several important nuclei that are instrumental in the regulatory process of homeostasis. It is of vital importance and few tissues in the body escape its influence.

- Regulates blood pressure, rate and force of heartbeat, digestive tract motility, rate and depth of breathing, and many other visceral activities
- Perception of pleasure, fear, and rage
- Maintains normal body temperature
- Regulates feelings of hunger, satiety and thirst
- Regulates sleep and the sleep cycle
- Control of endocrine functions: Produces releasing hormones that for example help to induce the release of hormones from the pituitary gland

Despite its small size, the hypothalamus contains several important nuclei that are instrumental in the regulatory process of homeostasis. It is of vital importance and few tissues in the body escape its influence.

The Diencephalon

Epithalamus

- Also called the epiphysis. It is the most dorsal part of the diencephalon, and contains the pineal gland.

- The pineal gland secretes melatonin under influence of the supra-chiasmatic nuclei from the hypothalamus and is, along with HT nuclei (such as pre-optic area), involved in sleep-wake cycle.

- Also contains the Choroid plexus - structure that secretes cerebral spinal fluid (CSF) into the ventricles
**The Brain Stem**

**Midbrain**

- Dorsal area of the midbrain (also called the **tectum**) contains nuclei within the white matter. They are collectively named the **corpora quadrigemina**
  - **Superior colliculi**: reflex center for movement of eyes, neck, head to visual stimuli
  - **Inferior colliculi**: reflex center for head trunk movement in response to auditory stimuli

**Pons**

- Contains mostly longitudinal conduction tracts for motor activities on ventral side (extension of the cerebral peduncles)
- Dorsal side contain lateral tracts that connect to cerebellum: **middle cerebellar peduncles**
- Also contain nuclei of Apneustic and pneumotaxic center (aid in control of respiration center located in Medulla) and **RAS**
The Brain Stem

**Pons**

- Inferior part of brain stem and blends into the spinal cord
- Ventral side contains the two large extension of the cerebral peduncles, descending from motor cortex.
- They are also called the **pyramids**.
- Pyramids cross over to opposite side right above the Spinal Cord. This is called the 'decussation of pyramids'.

**Medulla oblongata**

- Ventral side contains the two large extension of the cerebral peduncles, descending from motor cortex.
The Brain Stem

- Dorsal side of the medulla contains the **Inferior cerebellar peduncles**: 

- It connects medulla to cerebellum and relays information from motor cortex to cerebellum via the olivary nuclei

The Cerebellum
The Cerebellum

FUNCTION

• Acts to coordinate body movements

• Continually compares the brain's intention with the body's performance

• Promotes smooth, economical voluntary movements

Cerebrum - Cerebella Interactions

• Information for muscular motions is directed from the precentral gyrus, via the projection tracts and the cerebral peduncles to the spinal cord.

• The cerebellum is informed of these planned activities via the middle cerebellar peduncles.

• When muscles and joints move, information from the proprio-receptors is directed via ascending tracts and the inferior peduncles to the cerebellum.

• This informs the cerebellum on how the execution of planned activities is performed.

• The cerebellum then informs the cerebrum what corrective actions need to be taken via the superior cerebellar peduncles.
The Cerebellum

Dysfunctions associated with the Basal Nuclei and Cerebellum.

The following structures are directly or indirectly involved with somatic motor functions:

- Premotor Cortex of the cerebrum
- Primary motor area
- Substantia nigra and red nuclei in midbrain
- Basal nuclei
- Cerebellum
Disorders can be of two general types

1. **Hyperkinetic**: display of excessive and abnormal movement
   - Chorea: refers to a hyperkinetic movement with rapid, involuntary "dancing" movements
   - Athetosis: characterized by continuous, slow writhing movements
   - Ballism: involuntary movements that are intense and violent

2. **Hypokinetic**: display of extreme slow and rigid movements
   - Akinesia: difficulty in initiating movement and decreased spontaneous movement
   - Bradykinesia: slowness of movement

**Somatic Motor Disorders**

**Parkinson's Disorder**

Damage to the Substantia niagra and a loss of dopamine receptors in basal ganglia results in increased activity of the basal ganglia.

**Huntington's Disorder**

An autosomal dominant inherited disease (chromosome 4).

It manifests itself by a degeneration of inhibitory GABA-ergic neurons that project to the putamen (basal ganglia)

Symptoms include hyperkinetic chorea movements that gradually increase and incapacitate the patient. Dementia follows and patients die usually within 10-15 years after onset of problems.
### Disorders of the Cerebellum

Damage to the Cerebellum results in poor posture, poor equilibrium and **ataxia** (disorders of movement coordination).

The gait of a person's walking is usually wide based and drunken-like.

Voluntary movements are accompanied by intention tremor (can't move a finger in a straight line) and **dysmetria** (past-pointing; can't hit the object pointed at).

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### Other functional Brain Systems

**Limbic System**

**Reticular Activating System**
Because of extensive growth of the hemispheres, connections between the cerebral cortex (where our consciousness resides) and the limbic system have decreased dramatically.

A few connections exist which explains that we can modify our emotional behavior and our emotional behavior can modify our thinking.

However, it also explains in part why our emotions can not be turned on and off at will and that the emotional response generally outlasts the stimuli that initiate them.

Emotions involve:
- cognition (the awareness)
- affect (the feeling itself)
- conation (urge to take action)
- physical changes (such as hypertension, sweating, heart rate changes,..)
The major connections in the limbic system are:

- **the fornix**, which connects the **mammillary bodies** (located anteriorly and function as relay stations for the olfactory nerve) in an arch like fashion with the **hippocampus** and **amygdala**.

- The anterior nuclei of the thalamus project to the **cingulate gyrus**, which arcs over the fornix and backwards, making connections with the amygdala.

Connections exist with the hypothalamus.
Limbic System

The hippocampus has particular use in short-term memory and spatial navigation.

For example, London's taxi drivers are required by law to know the most direct routes between numerous places in the city. A study revealed that the relevant regions of the hippocampus were larger in these drivers than in the general public. The organ also had larger volumes in more experienced drivers.

It becomes damaged in Alzheimer's Disease, leading to memory problems and disorientation.

Extreme damage can result in anterograde amnesia: loss of ability to form new memories although older memories may be safe.

In the movie “50 first dates”, 10 second Tom suffered from severe anterograde amnesia.

Limbic System

The amygdala (Greek for 'almond') is an oval group of neurons about an inch long. It has a primary role in processing of long term memories and memory of emotional reactions, particularly fear.

Electrical stimulation of the human amygdala humans leads to feelings of fear and apprehension.

Damage to the amygdala disrupts the ability of an emotionally charged stimulus to elicit an unconscious emotional response; patients not only lose their ability to fear, they also do not recognize anger in others.

Many phobias are linked to the amygdala since it aids in the interpretation of emotion in the facial expressions of others.

These brain scans via fMRI show brain activity in empathy-generating centers of the limbic system (e.g. the amygdala) in normal individuals (left) and in psychopathic individuals (right) when they are exposed to violent images.
This pair of images shows fMRI scans of study participants while they are trying to remember object locations. Activity in the hippocampus is stronger in healthy elderly controls (left) compared with people with mild cognitive impairment (right).

The limbic system thus allows us to be consciously aware of our emotions (what we feel and how we think) and is at the basis of emotional responses taking over logical ones and visa versa.

Even though the communications between cortex and limbic system are reduced compared to our "mammalian ancestors", we still show plenty of emotional driven behaviors.

The fact that the hippocampus and amygdala are concerned with long term memory, explains for example how we immediately correlate emotional stimuli with memory.

The importance of olfaction is obvious if we think how odors can trigger emotions and memories

The **Limbic System** is thus our **emotional brain**. It is thus not surprising that psychosomatic illnesses originate in the limbic system (due to the connections with the hypothalamus) and that damage to certain areas in the limbic system results in personality changes, emotional instabilities.
Reticular Activating System

Extends through the central core of the brainstem

Neurons in here project to hypothalamus, thalamus, cerebellum and spinal cord

It governs the arousal of the brain as a whole and keeps the cortex in an alert conscious state.

Reticular Activating System

RAS also acts as a filter to filter out and relay only the important sensory information to the cortex

99% of all sensory information is filtered as unimportant at any moment

Activity of RAS is inhibited by sleep centers in hypothalamus and is depressed by alcohol, tranquilizers.

The dampening effect is removed by LSD