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THE STRUCTURAL DIVISIONS OF THE BRAIN

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From an anatomical point of view, the brain consists both of a horizontal division, which is represented by the two, left and right cerebral hemispheres, together with all their functional characteristics, as well as of a three-component vertical division. The three-component vertical division comprises: 1) the brain stem, which had been named the reptilian brain by Mac Lean; 2) the paleomammalian cortex, and 3) the neocortex.

Keywords: horizontal division, brain stem, reptilian brain, paleomammalian cortex, neocortex.

From an anatomical point of view, the brain consists of a horizontal division, represented by the two cerebral hemispheres, as well as of a three-component vertical division.

A. When we refer to the horizontal division we must take into account both the left and the right cerebral hemispheres, together with all their functional characteristics.

The left cerebral hemisphere (in the right-handed individuals) plays a role in the generation and the understanding of the speech, in the logical and the deductive reasoning processes, in the analysis and the synthesis processes, in the ascertaining of the cause-effect relations, as well as in the control of the movements of the right hemibody.

The speech is an arbitrary and abstract mode to express the thought processes through the use of sentences and to present concepts or ideas through the use of words[1,2].

Most of the components of the speech system are located in the left hemisphere, which is the dominant hemisphere for the speech process in approximately 95% of the humans.

Nearly all the right-handed persons and about two-thirds or the left-handed people have this dominance of the left hemisphere.

Wernicke's area comprises an extensive region which comprises the posterior part of the superior temporal gyrus (Brodmann's area 22), including the planum temporale in the floor of the sylvian fissure, as well as the parietal-temporal-occipital junction area, which also includes the angular gyrus (Brodmann's area 39).

According to Augustine (2008)[3], these regions of the superior temporal gyrus which correspond to Brodmann's areas 42 and 22 make up Wernicke's region, which is an auditory association area.

The association of aphasia with right hemiplegia had been described for the first time by Broca (1861; 1863)[4,5].

Broca had named the inability to produce speech in the presence of intact comprehension "aphemie".

In 1864, Trousseau[6] had subsequently renamed this kind of disorders using the term of "aphasia". The Boca's area is equivalent to Brodmann's areas 45 and 44 and is located in the opercular and the triangular portions of the left inferior frontal gyrus.

The lesions located in the Broca's area are associated with a type of aphasia (motor, anterior, expressive, non-fluent) which is characterized by the inability of a patient to express himself through speech.

Thus, the initial studies had confirmed the neurologists' assertion that the left hemisphere was dominant for speech, for conceptual similarities, for details as well as for a gestalt synthesizer.

The right cerebral hemisphere (in the right-handed individuals) is both non-verbal and holistic, with a role in the perception and the systematization of the non-verbal information in music and prosody, in the analysis of the facial expressions, in the intuitive, formal, contextual spatial and topographic artistic functions, as well in the performance of the spatial movements and the control of the movements of the left hemibody.

Its functions are more visually related and less auditory.

There should be made a separation between the musical perception and the musical execution which are performed by the naive, casual listener and those of the music professional. Whereas a naive listener perceives the music in its overall melodic contour, the music professional perceives the music as a relation between the musical elements and symbols (language). Therefore, a naive listener perceives the music at the level of the right hemisphere, whereas the professional perceives the music at the level of the left hemisphere.

On the other hand, the musical execution (singing) appears to be a function of the right cerebral hemisphere, irrespective of the levels of the musical knowledge and training.

Thus, the right cerebral hemisphere perceives forms but is lacking a phonological analyser.

The functions of the two cerebral hemispheres should not be considered as being in opposition, but as the component parts of a whole, which are in a close relationship that cannot be considered as being either symmetry, nor dialectic, resonance, congruence or dialogue.

The corpus callosum connects the two cerebral hemispheres, ensuring the cooperation and the coordination of the activities.

This horizontal lateralization represents a characteristic which is found exclusively in humans.

Thus, the interhemispheric connection functions as a feature which allows each cerebral hemisphere to work as a coordinated unit.

The callosal disconnection at the level of either the interhemispheric or the intrahemispheric connections can lead to a wide range of neurological syndromes, including apraxia, aphasia, agnosia, alexia, as well as unilateral agraphia.

The interactive processes which take place between the two cerebral hemispheres in the normal, undivided brain can lead to a further modulation of such strategic differences, reducing them in some of the cases, while in others causing their enhancement.

Moreover, even in the divided brain, undivided subcortical processes might provide a surprising degree of interhemispheric cross-talk.

However, the corpus callosum plays an important role in the interhemispheric transfer of learned discrimination, of sensory experience and of memory[1,2].

B. The three-component vertical division refers to:

1) the brain stem, which had been named the reptilian brain by Mac Lean;

2) the limbic system, or the paleomammalian cortex and

3) the neocortex.

1) The brain stem is the portion of the central nervous system which is located rostral to the spinal cord and caudal to the cerebral hemispheres.

The net-like appearance of the brain stem neurons had led to the designation of "reticular formation", a term that had been originally used in a purely descriptive anatomical sense[1,2].

The reticular formation (RF), which begins the spinal cord and extends up to the level of the midbrain, plays a major role in the sleep-wakefulness cycles in both animals and humans. It occupies a significant portion of the dorsal brain stem and consists of a network of reticular fibres which enters in synaptic connections with, and modulates numerous ascending and descending fibre tracts[1,2].

The nuclei of the reticular formation receive afferent information from all the sensory (visual, auditory, etc.) receptors and from the motor system, as well as from other major structures of the brain, and project their axons upwards and downwards to virtually all the regions of the nervous system[1,2].

Through their connections with the thalamus, with the hypothalamus and directly with the cerebral cortex, they can send information to, and receive it from all the areas of the cortex. There are ascending (or forward) as well as descending (or backward) connections between the nuclei of the reticular formation.

The reticular formation is also known as the reticular activating system and the reticular inhibitory system[1,2,7–9].

The role of the reticular formation through the ascending activating system (AAS) and the ascending inhibitory system (AIS) is related to the awakening or to the getting to sleep, as well as to the modulation of the cerebral cortex.

After becoming awake, the cortex allows the combination between all the modalities of sensory processing (sight, hearing, touch, etc.) and the conscious thought and experience processes in order to ensure the focusing on some of the inputs and to suppress others.

The neocortex contains two major classes of neurons: the glutamatergic excitatory neurons and the gamma-aminobutiryc acid (GABA) inhibitory interneurons, but there is limited knowledge about the production and the organization of the neocortical interneurons, and especially concerning the inhibitory interneurons (Brown et al. 2011)[10].

According to Lehmann *et al.* (2012)[11], the functioning of the cerebral cortex depends critically on the precise balance between the excitatory and the inhibitory neurotransmitter systems.

The excitation is mediated through the glutamate by the pyramidal neurons, as well as by a special class of local neurons located in the cortical layer IV, the spiny stellate cells. The inhibition is mediated through the gamma-aminobutyric acid (GABA) by the cortical interneurons, which regulate the degree of the glutamatergic excitation through the filtering of the input and the regulation of the output of the projection neurons[11].

The GABAergic interneurons, the "non-pyramidal cells" of the cerebral cortex, show a wide range of different forms of dendritic and axonal arborisations, which had been used for their morphological classification ever since their first description by Ramon y Cajal in 1952[12–16].

There are about five times more glutamatergic neurons than GABAergic neurons in the neocortex.

The disturbances in the development of the GABAergic interneurons, and consequently in the delicate balance between excitation and inhibition, can lead to neurological or neuropsychiatric diseases such as epilepsy, autism, and schizophrenia[17–20].

There is a type of GABAergic interneurons which are lost during the ageing process, and that this loss might be the reason for the functional degradation which is found in the old animals[11].

Additionally, the brainstem and the mesencephalon coordinate and control the basic functions such as self-protection and reproduction, as well as the regulation of the cardiac activity, of the blood circulation and of the respiration.

2) The limbic system (the visceral brain). In 1937, Papez[21] had described a closed neuronal circuit (the Papez circuit) which linked the hippocampus with the cingulate cortex, through the mammillary bodies and the anterior thalamus[1,2].

Mac Lean (1952)[22] had described the Papez circuit as the "visceral brain". He had later proposed the term "limbic system" as the anatomical substrate of emotions and behaviour.

Since a great deal of the emotional expressions is of a visceral or anatomic nature, Mac Lean had suggested that this system might dominate the domain of visceral activity. He therefore linked the term "limbic system" with the medial areas of the cerebral hemispheres, which are involved in the balance and the control of the emotions and of the emotional expressions.

Thus, it had been demonstrated that the limbic system (the visceral brain) or the paleomammalian cortex controls all the functions of the body, as well as our entire emotional life (anger, fear, panic, pleasure, happiness, the sexual behaviour, affectivity, the paternal attachment, the altruistic urges, love, etc.). Consequently, this is the location where all the intense emotions are generated.

The functions of the hypothalamus. Although this small region of the brain might seem to be of a lesser importance, the reality is in fact totally opposite, it being the centre of numerous, and also widely diverse important functions which are associated with the survival of the organism and with the perpetuation of the species[1,2].

The hypothalamus controls the endocrine system: through the projections of the magnocellular neurosecretory neurons located in the posterior pituitary (or neurohypophysis); through the parvocellular neurosecretory cells, which are projecting to, and terminating in the median eminence (these neurons control the endocrine output of the anterior pituitary (or adenohypophysis) and thereby the peripheral endocrine organs); as well as through the autonomic nervous system. The posterior pituitary neurohormones, vasopressin and oxytocin, are primarily involved in the control of the osmotic homeostasis, as well as of the various aspects of reproductive function, respectively[1,2].

Nevertheless, the hypothalamus, which is considered to be "the brain of the brain", contains the integrative systems that, through the agency of the autonomic nervous system and of the endocrine effector system, control the water balance, the electrolyte balance, the temperature regulation, the alternation between sleep and wakefulness, the food ingestion, the energetic balance, the blood glucose levels, the metabolic processes, as well as the reproductive function and the immune response, together with many emotional behaviours[1,2].

The hypothalamus influences the responses of both the sympathetic and the parasympathetic nervous systems, which are division of the autonomic nervous system.

The peptides which are secreted by the parvocellular neurons reach the portal vessels and stimulate or inhibit the secretion of the pituitary gland.

The magnocellular neurosecretory system releases the neurohypophysial hormones oxytocin and vasopressin in the general circulation through the posterior pituitary gland[1,2].

The hormones are substances which are secreted either by the endocrine glands, or directly by specialized nerve cells (neurohormones). They are carried by the blood flow towards various parts of the body where they regulate for a certain period of time the growth processes and the normal functions of the body.

The neurotransmitters (adrenalin, noradrenalin, dopamine, serotonin, acetylcholine and gamma-aminobutyric acid (GABA)) are chemical substances which convey messages between the nerve cells.

The signals, or the messages which propagate through a nerve fibre are modalities for the transmission of information within the nervous system, that lead finally to the expression of various moods, emotions and states of mind.

The hypothalamic chemical substances which act at the level of a series of endocrine organs, such as the pituitary gland, the thymus and the adrenal glands, can cause the release of catecholamines which fulfil within the body, their role of neurotransmitters and/or hormones, the dopamine, the adrenalin, the noradrenalin and the endorphins being the most important representatives of this class of biological substances.

The endorphins are peptide neurotransmitters which are present in the pituitary gland and in the hypothalamus, they having analgesic properties that are similar to those of the encephalins.

They bind to the opiate receptors located at the level of the brain, and their release has the role to control the intenseness of the pain, to induce states of euphoria, anxiety or anger, as well as to supress or to increase the immune response.

It is well known that each individual person is composed of both soma and spirit. However, if the soma is easier to be studied, it is much more difficult to investigate and to explain the spirit, that is, the mind, the psyche, the consciousness and the subconscious.

Nevertheless, all the things which take place at the spiritual level cannot be separated from the processes that take place within the body. Every change which takes place at the level of the somatic or the physiological processes leads to corresponding alterations of the psyche, of the mental-emotional state, of the consciousness, and thus of the spirit.

For its part, every change induced by stress which occurs at the level of the spirit, of the state of mind and of the emotional state influences the homeostasis and induces somatic injuries through the destruction of the natural biochemical balance.

Thus, the cortisone, the adrenaline and the adrenocorticotropic hormone (ACTH) cause the exhaustion of the body and to an important reduction of the immune response.

Hence, our thoughts play an important role in the definition of our physical condition and of the immune state of the body, this being one of the main reasons for the development of the psychoneurology and psychoimmunology which are grouped together in the discipline of psychoneuroimmunology.

The subjects with elevated levels of stress as a response to certain events of the everyday life have an extremely low level of the immune response, which had been determined to be at only one-third compared with the one found in the individuals with normal reactions, without stress, without anxiety and without threatening conditions.

Whenever we are ill, we can consciously use the visualization, self-hypnosis and the relaxation techniques in order to increase the capabilities of the body for healing through biofeedback.

The yoga practitioners and the shamans had known for centuries that any biological function can be controlled by the individual.

In comparison with these, the problem which confronts our culture consists of the difficulty to reach a state of deep relaxation, which offers the possibility to achieve the control of our thoughts and of our body, as well as that of our health condition and of the state of homeostasis.

The aging process is rather the result of the development of a hormonal and neurochemical imbalance, which leads to a slow and progressive destruction of the state of homeostasis, than that of a somatic degradation process.

Hence, it had been ascertained the existence at the level of the hypothalamus of a so called “aging clock”, with shows significant reductions of the hormone and neurotransmitter levels in the old animals compared with the young ones.

However, the human brain is extremely plastic, and thus its functioning can be adequately improved.

Although the brain represents only 2% of the weight of the whole body, it consumes approximately 20% of the energy of the organism.

At any age, the dimensions of the brain are decreased in an environment which is poor from the point of view of the stimuli, while they increase in an enriched environment. The cognitive stimulation leads to the increase in the number of the circulating positive T lymphocytes, fact which indicates that the immune response can be also modulated voluntarily.

In other words, the mentation, the relaxation and the optimism can have an impact on the immune system, besides many other influences.

The neuroplasticity is the ability of the brain to change through reorganization as a response to the actions of both extrinsic and intrinsic factors, this property wielding usually a positive influence at any age.

Today it is known fact that new neurons are generated continuously from the endogenous stem cells located in the region of the dentate gyrus in the hypothalamus and in the periventricular zone.

The exposure to a diversified environment leads to a striking increase in the number of new neurons, the result being the enrichment of the behavioural and cognitive performances. This plastic response is relevant because it helps in the explanation of the beneficial effects of the active life on the structure and function of the brain.

Until now there had been identified the following essential elements for an healthy brain: the presence of changes, the existence of challenges, the physical exercise, the diet, the affection, the meditation, the perception, reduced levels of stress, the physiological sleep, music, etc.

The new experiences lead to the reduction of the age dependent degradation, fact which had been demonstrated by the decrease in the accumulation of lipofuscin.

The limitation of the caloric intake has been associated with a number of benefits for the health.

The reduction of the caloric intake leads to an increase in the number of the synapses, as well as to an improvement of the synaptic architecture and performances. The diets which are rich in polyphenols and in polyunsaturated fats (omega 6 and omega 3, both fish meat and fish oil, rape, soya) have an antioxidant and anti-inflammatory action. Certain polyphenols which are found in cocoa have very strong anti-inflammatory and antioxidant effects, besides the fact that they induce neurogenesis and contribute to the improving of the memory and of the learning processes. Omega 3 protects the nerve cells against the aggressions from the environment and against the cognitive decline, optimizes the neuroplasticity and the synaptic efficiency, and contributes to the improvement of the learning capabilities, as well as of the memory and sleep. The interventions which reduce the stress and promote the wellbeing, the prosocial behaviours, the compassion, the kindness, the mindfulness, as well as the caring have a beneficial influence on the neuroplasticity. The depression and the stress lead to volume loss at the level of the hippocampus, as well as to a reduction in the immune response.

The insomnia is associated with cognitive deficits, with learning and memory deficits and with metabolic imbalances, as well as with the reduction of the neurogenesis processes and of the neurotrophic factor, all of which are crucial for many of the components of neural plasticity.

3. The neocortex, or the cerebral cortex, is the thinking substrate of the central nervous system, which represents the essential feature which differentiates humans from animals. It encases the two older components of the brain, the reptilian brain and the paleomammalian cortex.

There are different types of functional areas at the level of the cerebral cortex, including receptive areas and projection areas. According to this view, the cerebral cortex can be divided into four general functional categories: the sensory cortex, the motor cortex, the unimodal association cortex, and the multimodal association cortex.

The neocortex is also the seat of the cognitive functions (memory, judgement, intellect, speech) which help us to remember the past and to anticipate the future. This structure is also responsible for all our voluntary actions.

The receptive areas are related to specific sensory modalities and they include the primary somatosensory, the primary visual, the primary gustatory, the primary olfactory, the primary vestibular and the primary auditory areas of the cerebral cortex.

The anterior cortex (the frontal lobe) is the motor unit of the brain. It formulates intentions, organizes them into programs of actions, and coordinates the execution of the program. The corticofugal fibers are fibers which arise from all areas of the cerebral cortex. These projections convey impulses which are related to the motor functions, to the modifications of the muscle tone and of the reflex activity, to the modulation of sensory perceptions, as well as to the alterations of the awareness and of the state of consciousness[23].

In addition to the primary and to some well-defined secondary sensory or motor projection areas, there are also cortical association areas which are related to correlating, interrelating and interpreting the information that reaches the cerebral cortex.

The association areas receive impulses from various cortical regions. At the level of the association areas reside the ultimate functional capacities of the human brain.

The remaining portion of the cerebral cortex, which is classified as a tertiary, or multimodal association area in the human brain, consists of regions of integration, association, and correlation. These areas receive information from several different sensory modalities, and based on them they offer us a complete image of our surroundings[1,2].

The multimodal association areas are critical for our abilities to communicate by using the speech, to use the reason, to extrapolate future events based on the present experiences, to make complex action and speech plans, as well as to imagine and create things that have never existed before.

On the other hand, with regard to the associations which underlie the most complex of the human capabilities, there are very probably heteromodal and supramodal association cortical areas that provide the anatomical basis for our ability to read, write, speak, learn, think, reason, remember, and ultimately create new concepts and ideas.

Each level interacts, and is integrated, with higher and lower levels through ascending and descending connections. There are subcortical loops which connect the cortex, the thalamus, the amygdala and the hypothalamus, as well as an indirect loop that connects the striatum with the thalamus[24].

The subcortical loops are presumed to play a certain role in the amplifying and/or the modulating of the cortical activity.

The amygdala adds an emotional tone to the visual input.

The researchers had discovered biochemical substances which are associated with the processes of sleep, euphoria, anxiety, aggression, concentration, learning, etc.

The deep brain had evolved before the development of speech and it operates through primary impulses, unrestrained drives, emotions, actions, instincts and symbols instead of verbal concepts.

The deep mind is therefore instinctual, it acting at the level of the unconscious. The thinking component of the brain had required millions of years of psychic development.

However, in humans, the new developmental levels of the brain need to be integrated with the older ones because they cannot work separately. The connections between them improve the communication, while the consciousness needs to be opened towards the influx originating from the lower, repressed levels of the mind.

Consequently, it is also necessary for the inferior brain to be more receptive to the directions originating at the level of the superior brain in the guise of suggestions and images.

CONCLUSIONS

From an anatomical point of view, the brain consists of a horizontal division, represented by the two cerebral hemispheres, as well as of a three-component vertical division. This horizontal lateralization represents a characteristic which is found exclusively in humans. The three-component vertical division refers to: 1) the brain stem, which had been named the reptilian brain by Mac Lean; 2) the limbic system, or the paleomammalian cortex; and 3) the neocortex.

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