James Wenceslaus Papez, His Circuit, and Emotion

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Abstract

James Papez worked on the anatomical substrates of emotion and described a circuit, mainly composed of the hippocampus, thalamus and cingulum, and published his observations in 1937. However, such an idea existed before him, as evidenced by the rudimentary indications from Paul Broca, and Paul MacLean added some other structures like, septum, amygdala, and hypothalamus in its ambit and called it the limbic system. Paul Ivan Yakovlev, proposed a circuit which also referred to orbitofrontal, insular, anterior temporal lobe, and other nuclei of thalamus. Further works hinted at cerebellar projections into this system and the clinical picture of aggression, arousal and positive feeding responses with stimulation of cerebellar nuclei, attests its possible role. Finally, the work of Heinrich Klüver and Paul Bucy of the United States of America on ablating the temporal lobes and amygdala and the resultant behaviour of the animals, almost incontrovertibly adduced evidence for the operation of a neural circuitry in the genesis of emotion. Additionally, Papez circuit may also be concerned with memory and damage to its various components in Parkinson's disease, Alzheimer's disease, Korsakoff's syndrome, semantic dementia, and global amnesia, where cognitive disturbance is almost universal, lends credence to its putative role.

Keywords: Emotion, James Papez, Kluver-Bucy syndrome, memory, papez circuit

James Papez, an American neuroscientist who pioneered the study of comparative neuroanatomy, was born in 1883 and died in 1958. He identified a circuit in the mammalian brain which subserves emotional experience and the eponym, Papez circuit, is firmly established in the medical vocabulary.

Papez worked in the secluded laboratory of the Cornell University and was virtually immersed in the practice of examining slides of the brain under the microscope in splendid isolation, in keeping with his placid, noninterfering and retiring personality, totally devoid of any gimmick, guile, or vanity. He worked on the established facts about the hypothalamus already advanced by Walter Canon (1871–1945), Philip Bard and Wilder Penfield (1891–1976), CJ Herrick, and other eminent neuroscientists before him and identified the circuit after injecting rabies virus into the hippocampus of a cat and monitoring its sojourn through the brain.[1-3] The Papez circuit starts from the hippocampal formation, known as subiculum, and traverses through the fornix, mammillary bodies, and then through the mammillothalamic tract, often known as tract of Vicq d' Azir, synapses in the anterior thalamic nucleus. From there, and it reaches the cingulum, courses round the entorhinal cortex and returns to the hippocampal formation and is about 350 millimeters in length.[4-6] He published his observations in 1937 in a landmark paper entitled, "*A proposed mechanism of emotion*" in the journal Archives of Neurology and Psychiatry.[7] He wrote,

> "*The central emotive process of cortical origin may be conceived of as being built up in the hippocampal formation and as being transmitted to the mammillary body and then to the tract of Vicq d' Azir (mammillothalamic tract) and thence through the anterior thalamic nuclei to the cortex of the gyrus cinguli… Radiation of the emotive process from the gyrus cinguli to other regions in the cerebral cortex would add emotional colouring to psychic processes occurring elsewhere… It is evident that the proposed mechanism of emotion will have to stand the test of experiment and clinical experience if it is to be useful in science… The hypothalamus, the anterior thalamic nucleus, the cingulate gyrus, the hippocampus and their interconnections, constitute a harmonious mechanism which may elaborate the functions of central emotion as well as participate in the emotional expression*."

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It is to be noted that the concept of an anatomical substrate for emotion did not start with the works of James Papez. In 1907, the Bavarian neuropathologist Christfried Jakob (1866–1956) alluded to the visceral brain and conceived the presence of an internal brain which subserves viscera-emotive mechanisms, and he based his hypothesis on the experiments on the degenerating brain of apes and dogs, as well as, autopsied materials from the human brain.[8]

The inferomedial aspect of the brain when dissected, looks like a limbus and that is why Paul D. MacLean (1913–2007), the influential American physiologist and psychiatrist, preferred to call the circuit the limbic system after some modifications and some researchers named it the Papez-MacLean circuit. Importantly, McLean proposed the model of Triune Brain in the evolution of the vertebrate forebrain and behavior. It consists of the reptilian complex or the R-complex, paleomammalian complex or the limbic system, and the neomammalian complex or the neocortex. The reptilian complex is made up of the basal ganglia and is concerned with instinctive behavioral patterns such as aggression, dominance, territorial control, and ritualistic patterns. The paleomammalian complex consists of the septum, amygdala, hypothalamus, hippocampal complex, and the cingulate cortex and in 1952, MacLean introduced the term limbic system to refer to this part of the brain.[9] This was a concept of momentous import and the limbic system is believed to develop early in the course of evolution of the mammalian brain. This is thought to be responsible for motivation or conation and emotion related to sexuality and reproductive behavior, feeding, and parental practice. The ultimate component of the mammalian brain, the neocortex, functions in the sphere of language, abstraction, planning, and perception. However, in recent times, MacLean's idea about the triune brain has met with serious criticisms and many contemporary comparative neuroanatomists question the oversimplification in the phylogenetic evolution of the behavioral patterns, vouchsafed in such a complicated structure as the human brain.[10,11]

To prove that MacLean's idea of the triune brain is invalid, physiologists refer to the works of Paul Broca (1824–1880), from France, who described the medial aspect of the brain, more than hundred years ago, as the le grand lobe limbique or the limbic lobe in 1878, meaning limbus or a curved rim. In 1948, Paul Ivan Yakovlev (1894–1983), a Russian neuroscientist who migrated to the United States of America, proposed a circuit for emotion which differed from the one described by Papez and MacLean, and it involved the orbitofrontal, insular and anterior temporal lobe cortices, the amygdala and dorsomedial nucleus of the thalamus.[12] However, in 1952, McLean met Papez at the Cornell University, thoroughly discussed the anatomy of emotion with him, and included the forebrain, hypothalamus, amygdale and the septum in the ambit of the limbic system and over time, the concept of emotional expression has been extended to include the prefrontal cortex, as well.[9] Heimer and Nauta (1916–1994), working in the United States of America and later, Heimer and Van Hoesen expanded the horizon of the functional anatomy of the limbic system, as we understand today.[13,14] Recent works suggest that the cerebellum is also operative in the expression of emotion and possibly the circuit starts, not with the hippocampus but with the numerous connecting cerebellar fibers. This is proved by the fact that cerebellar lesions seem to have an inhibitory effect on the circuit and electrical stimulation of the anterior cerebellum causes arousal, aggression, and positive feeding responses.[15]

Based on the experiments by Papez, it was initially believed that the circuit he described in 1937 was involved with emotion. The persistence of pleasant or tortured emotional feelings, long after an event has passed, has been interpreted in terms of the physiology of hippocampal after-discharge and the consequent on-going hippocampal electrical activity. The circuit connects the hypothalamus and the cortex and acts as the emotional system of the brain. He wrote, "*The cingulate cortex projects to the hippocampus, and the hippocampus projects to the hypothalamus by way of the bundle of axons called the fornix. Hypothalamic effects reach the cortex via a relay in the anterior thalamic nuclei*." His views were not readily accepted and once he lamented to a friend in 1942 that no one seemed to have taken his view seriously since very few asked for the reprints. However, in 1939, interest in the circuit was kindled by the work of Heinrich Klüver (1897–1979) and Paul Bucy (1904–1992), of the United States of America, a psychiatrist and a neurosurgeon,

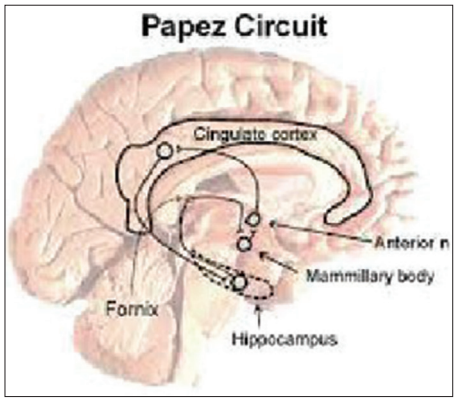

Figure 1: Figure of Papez Circuit. Source: www.quora.com

Figure 2: James Papez. Source: www.pintrest.com

respectively, who reported before the American Neurological Association that bilateral destruction of most of hippocampus and temporal lobes in the rhesus monkeys led to a kind of psychic blindness, manifested by visual agnosia, oral exploration of objects, hypermetamorphosis or excessive visual attentiveness, placidity and loss of natural fear or rage, to the extent that they were not scared in the presence of snakes. Other notable features included hypersexuality, and change in eating behavior and thus, the view of Papez was vindicated to a large extent.[16,17] The first case report of human Klüver-Bucy syndrome came from Terzian and Dalle-Ore in 1955, who described an adult male with bilateral temporal lobectomy developing almost all the features of the syndrome.[18] Marlowe *et al*. described the first complete case in 1975 in a 20-year-old male subject with herpes simplex encephalitis.[19,20]

Apart from the role of Papez circuit in the field of emotion, some workers have found evidence that memory too, has its roots there. There is some experimental evidence that there is a strong synchronization of theta waves in the hippocampus and the anterior ventral thalamus. Since the theta waves are concerned with issues such as memory and learning, a number of workers have suggested that the Papez circuit may be involved in mnemonic functions and some scientists have narrowed it down to even to the realm of spatial and episodic memory.[21,22] Mammillary bodies project massively to the anterior thalamus through the Vicq d' Azir and damage to this tract, ventral anterior nucleus, and ventral lateral nucleus can result in memory and language impairment and amnesia is the resultant complication.[23-25] The fornix, a bundle of nerve fibers, is equally central to cognitive functions and damage to this tract may result in amnesia,[26,27] Finally, changes in the structure of the Papez circuit have been documented in conditions such as Alzheimer's disease, Parkinson's disease, semantic dementia, Korsakoff's syndrome, and transient global amnesia, where amnesia is a recognized feature.[28-32]

Everything gainsaid, in spite of evident flaws in the works of James Papez on a hitherto unknown circuit for the control of emotion, as shown by later researchers, his ideas continue to merit serious study. Commenting on his works, Mark Bear, Barry Connors and Michael commented in the book, "*Neuroscience: Exploring the Brain*" published in 2007,

> "*Reflecting on the earlier work of Cannon, Bard and others, American neurologist James Papez proposed that there is an 'emotion system,' lying on the medial wall of the brain, that links the cortex with the hypothalamus… Papez believed that the experience of emotion was determined by activity in the cingulate cortex and, less directly, other cortical areas. Emotional expression was thought to be governed by the hypothalamus. The cingulate cortex projects to the hippocampus and the hippocampus projects to the hypothalamus by way of the bundle of axons called the fornix. Hypothalamic effects reach the cortex via a relay in the anterior thalamic nuclei*."[33]

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Conflicts of interest

There are no conflicts of interest.

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