Theories of pain, up to Descartes and after neuromatrix: what role do they have to develop future paradigms?

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Abstract. The article represents a synthesis of literature about antique, medieval and modern pain theories. In short there are described the most relevant theories about noception and pain. Chronologically there are presented the discoveries in physiology, anatomy, histology and other methods and investigations of pain. There is discussed the character of past pain theories and its influence on elaboration of the new ones. There was elaborated the hypothesis about the neuromatrix theory and impact of human microbiota on pain perception or other comorbidities with psychological and pain component.

Key words: history of medicine, pain theories, neuromatrix, human microbiota.

Introduction
Periodically, in the scientific medical journals are published articles on the history of medicine, including in the field of pain. The result of working in the archives of medical history of the enthusiasts, is already synthesized, integrated and accessible today, to practically everyone. Although it is impressive, viewed from a historical perspective, the amount of knowledge held is somewhat constant, finite as available information, in particular, relative to the scale of today’s information age.

Consequently, most authors give the same data, depending on the possibility of access to archives or the degree of documentation in the field, data, that are seen from one point of view or another. Thus, traditionally, there are presented the ancient and medieval theories (up to Descartes), philosophical of pain, which reflect the thinking, culture and conceptions of the world of the civilization of that time [1, 2, 3].

The modern age is reflected in the structural and functional theories of pain, starting from noceptor and reaching the central nervous system. Typically, they describe the microscopic level of structures, which at this level maintain certain functions (potentials of action, coded by intensity and frequency or centrifuge axiomatic biochemical flow) [1–3, 7].

The theories and contemporary models of pain (control gate theory, neuromatrix theory, multidimensional model of pain etc.) hold the full conceptual power at present. And these theories are based on structures and functions, which, however, in the light of today's technology, are viewed, described and explained on a submolecular, informational or oversized interaction scale.

Undoubtedly, sooner or later, these theories and patterns will be updated with new ones...

In view of the above, I propose, however, an article of history of pain theories... Why another article on pain theories?

I consider, that new generations of specialists in training, would be useful to review the evolution of pain theories over the centuries. These theories, in their time, were the basis for the development of pain-fighting methods and techniques, the pharmacological industry with analgesics, institutional and national organizational measures to fight pain. The new theories of pain go beyond the pure pharmacological and physical approach to pain, requiring a biopsychosocial, multidimensional and interdisciplinary approach.
I intend not break the “traditions” of displaying history articles, but up to a certain point. After that, I will try, based on “history”, to formulate a hypothesis of a (future?) pain theory: what beyond neuro-axis? Because, “Progress is not an accident, but a necessity... It is a part of nature”. (Herbert Spencer [1820–1903], Social Statistics).

**Pain Theories up to Descartes**

The ancient theories of pain reflected the philosophical ideas of time about life, existence, perception of the world, based on empirical reflections. Their essence is presented in Table 1.

The main questions about pain, have remained unresolved for centuries: pain appears as a result of the activity of a dedicated neural device or is the product of a less specific process?

**Modern age: from specificity of structures and functions to gate control theory**

Until the second century. XIX, it was thought that the senses depend on the transport of some substance out of the brain or heart.

Century. XIX has been characterized by the co-existence of three concepts: (1) pain is an emotion (the ancient philosophers and the psychologists of the times); (2) pain is a sensation, with sense organs and own transmissions (Avicenna, Schiff); (3) Intense stimulation of other related systems that serve other sensations generates pain over a certain threshold (Erb, psychologists, doctors).

One of the arguments, against the theory of pain specificity, was that pain can also be produced by mechanical, thermal or chemical stimuli, which are different in terms of the receptive structure and the nociceptive pathway. The polemics in the “specificity theory” continued until the 1970s, XX century.

The most important findings on nociception and pain between 1911 and 2003 years, are listed in Table 2.

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**Table 1. The ancient concepts of pain (synthesis 1–3, 7)**

<table>
<thead>
<tr>
<th>Century,</th>
<th>Homer</th>
<th>Telemachus, son of Ulises and Penelope (Iliad and Odyssey), use opium to relieve pain and drive out sadness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIII BC</td>
<td>Hippocrates of Kos</td>
<td>Pain comes from the body fluids. The heart is the main organ of pain perception (Fig. 1)</td>
</tr>
<tr>
<td>Approx. 460–370 BC</td>
<td>Platon</td>
<td>Pain, as well as pleasure, is a passion for the soul</td>
</tr>
<tr>
<td>437–347 BC</td>
<td>Aristotle</td>
<td>Evil spirits penetrate the body through various injuries. The heart is the center of the senses. He did not consider pain as a special sense, but was an emotion</td>
</tr>
<tr>
<td>384–322 BC</td>
<td>Galen</td>
<td>The brain is the organ of the senses, and the pain was placed in the sphere of sensations</td>
</tr>
<tr>
<td>130–201 AD</td>
<td>Avicenna</td>
<td>Pain is an independent feeling, different from touch or thermal</td>
</tr>
<tr>
<td>Dark ages</td>
<td></td>
<td>Pain exists everywhere outside of the human body. This, being sinful, suffers. Only prayer (or fire) can alleviate the pain. Pain and suffering is a divine test</td>
</tr>
<tr>
<td>980–1037 AD</td>
<td>René Descartes</td>
<td>The body is a machine. I think, therefore I am</td>
</tr>
<tr>
<td>1596–1650</td>
<td>Isaac Newton</td>
<td>Neural messages are the vibration of the substance in the nerves</td>
</tr>
<tr>
<td>1642–1727</td>
<td>David Hartley</td>
<td>Neural messages are the vibration of the substance in the nerves</td>
</tr>
<tr>
<td>1705–1757</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Theories of specificity**

The essence of the theory lies in the fact that each somato-sensory mode (somatosensory modality) is dedicated to a specific way of transmission. A specific receptor that is sensitive to a particular stimulus is connected to a primary sensory nerve fiber. For example, mechanical stimuli are detected by low threshold mech-
anoreceptors, and the primary sensory nerve fiber transmits the impulse to the second neuron, and it is “mechanoreceptive”, in the spinal cord or the cerebral trunk. The secondary “mechanoreceptive” neurons, in turn, project to the cortical structural receptors. Similarly, noxious stimuli will be projected to “higher pain centers” through nociceptive fibers (Dubner et al., 1976).

Table 2. The most important findings on nociception and pain (According to Edward R. Perl [7], with adaptation)

<table>
<thead>
<tr>
<th>Year</th>
<th>Scientist</th>
<th>The essence of the discovery or concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1811</td>
<td>Bell C.</td>
<td>The medial dorsal and ventral pathways have different function, the ventral ones being responsible for muscle contraction. Sensory nerves have specialized functions to detect and transmit a particular stimulus</td>
</tr>
<tr>
<td>1822</td>
<td>Magendie F.</td>
<td>Dorsal medullary transmit sensitive messages</td>
</tr>
<tr>
<td>1840</td>
<td>Müller J.</td>
<td>He developed Bell’s idea. Related neurons have specific (specialized) functions</td>
</tr>
<tr>
<td>1848–1849</td>
<td>Dubois-Reimond E.</td>
<td>Identifying the potential for action in the nerve, which is electrochemical in nature (inspired by Müller’s ideas). Nerve impulses transmit to the brain some of the information about the nature of the stimulus</td>
</tr>
<tr>
<td>1858</td>
<td>Schiff J.</td>
<td>Magendie’s student. Medullary lesions induce different reactions to the application of painless peripheral stimuli. Pain is a specific sensitivity. Spinal lesion produces loss of tactile sensitivity to painfulness</td>
</tr>
<tr>
<td>1860</td>
<td>Brown-Séquard C.</td>
<td>Has demonstrated dissociation of painful sensation from tactile sensitivity in experimental spinal lesions. He found loss of contralateral pain distally and distally from transverse medial hemispheres</td>
</tr>
<tr>
<td>1874</td>
<td>Erb W.</td>
<td>Issues the theory of intensity for pain. Strong stimulation of other sensory ways is painful. The intensity determines the response</td>
</tr>
<tr>
<td>1878</td>
<td>Gowers W.</td>
<td>Describes the dissociation of painful sensation from tactile sensation into bone marrow lesions in humans</td>
</tr>
<tr>
<td>1884</td>
<td>Blix M., Goldscheider A.</td>
<td>Skin sensitivity is discontinuous. They described the mosaic of nociceptive and sensory (pressure, warm, cold) receptor fields. The last – the follower of Erb’s theory of intensity</td>
</tr>
<tr>
<td>1890</td>
<td>Edinger L.</td>
<td>Identified the cross-linking of the related (spinotomalac) tract in the spinal cord. The dorsal medial paths consist of the middle beam, made up of large diameter and lateral fibers (thin fibers)</td>
</tr>
<tr>
<td>1891</td>
<td>Waldeyer W.</td>
<td>The brain is not a syncytium, but consists of distinct cells. Synapses are functional connections between cells</td>
</tr>
<tr>
<td>1896</td>
<td>Von Frey M.</td>
<td>Described circumstantial correlations between the number of skin sensory receptors and structured nerve endings. Ultimate demonstration that pain is an independent sensory way</td>
</tr>
<tr>
<td>1905</td>
<td>Head H.</td>
<td>Describes somatic (epicritic, discriminative) and protopathic (diffuse) sensory innervation, consistent with Edinger L.’s anatomical descriptions</td>
</tr>
<tr>
<td>1906</td>
<td>Sherrington C.</td>
<td>Because pain is usually produced by tissue damage, it has been proposed to introduce the lesion (noxious) stimulant category that is painful regardless of its physical nature. Specialized structures for pain are responsible for nociception. In addition to excitation, inhibition of excitation in neuronal circuits is essential for integrative activity</td>
</tr>
<tr>
<td>1906–1911</td>
<td>Dejerine J., Roussy G., Head H., Holmes G.</td>
<td>Describe the role of the thalamus in pain</td>
</tr>
<tr>
<td>1912</td>
<td>Spiller W., Martin E.</td>
<td>They presented a ventral lateral medullar cordotomy to relieve rebel pain, located on the opposite side of the section</td>
</tr>
<tr>
<td>1915</td>
<td>Ranson S.</td>
<td>Primary afferent primary diameters are protopathic and lead, in part, painful stimuli</td>
</tr>
<tr>
<td>1924–1928</td>
<td>Erlanger J., Gassner H., Bishop G.</td>
<td>Describe the complexity of the peripheral nerve potential and its relationship to the diameter of the nerve fiber. Nerve fibers with different driving speed are involved in pain</td>
</tr>
</tbody>
</table>

Gate control theory
Proposed in 1965 by Ronald Melzack and Patrick Wall, the theory provides a physiological explanation of the findings made in the psychology of pain perception. She “reconciled” the theories of specificity and patterns, revolutionized research into nociception and pain.
The essence of the theory is that the painless impulses transmitted through thicker, myelinated (Aβ) fibers will close the “gate” of painful impulses (transmitted through the myelinated Aδ and unmyelinated fibers, type C), thus preventing them from reaching the central nervous system. Inhibition is presynaptic and involves interneurons in the structure (Fig. 2). Although the conceptual structure of the neural circuit is simple schematized, it is much more complex, both as a network and biochemical composition.

Contemporary theories

The theory of neuromatrix

According to Ronald Melzack (2005) [citation]: “The neuromatrix theory of pain proposes that pain is a multidimensional experience produced by characteristic “neurosignature” patterns of nerve impulses generated by a widely distributed neural network – the “body-self neuromatrix” – in the brain. These neurosignature patterns may be triggered by sensory inputs, but they may also be generated independently of them. Acute pains evoked by brief noxious inputs have been meticulously investigated by neuroscientists, and their sensory transmission mechanisms are generally well understood. In contrast, chronic pain syndromes, which are often characterized by severe pain associated with little or no discernable injury or pathology, remain a mystery. Furthermore, chronic psychological or physical stress is often associated with chronic pain, but the relationship is poorly understood. The neuromatrix theory of pain provides a new conceptual framework to examine these problems. It proposes that the output patterns of the body-self neuromatrix activate perceptual, homeostatic, and behavioral programs after injury, pathology, or chronic stress. Pain, then, is produced by the output of a widely
distributed neural network in the brain rather than directly by sensory input evoked by injury, inflammation, or other pathology. The neuromatrix, which is genetically determined and modified by sensory experience, is the primary mechanism that generates the neural pattern that produces pain. Its output pattern is determined by multiple influences, of which the somatic sensory input is only a part, that converge on the neuromatrix’ [4, 5].

What beyond neuromatrix?
As it observed, most of the pain theories are not “global” but “localized” to body structures or functions: receptors (intensity and specificity), coding of information (neural patterns), dorsal medulla (portion control theory), central nervous system (neuromatrix theory). Other important elements are the figures of a puzzle – beliefs, memory, previous experiences, stress, central and peripheral sensitization, downward modulation, cortical plasticity and retography, neuroimmuno-humoral mechanisms etc. (Fig. 3).

The human body is whole. Any structure and function at any scale can be studied and presented individually, separately. In reality, however, “everything is connected to everything”, functioning as a whole. In this way, each pain theory has its place, reflecting an element in the puzzle. Could a new theory of pain go beyond the neuromatrix scale, so that the puzzle is the final picture? What would be after neuromatrix? Which elements could complement it?

Here we can mention nonperceptual influences on neuromatrix, its interaction with other body analyzers (seeing, hearing, smell, taste, touch). Recent studies have found the connections between the olfactory analyzer and the visual eye with neuromatrix pain. Applications, which will clarify these issues, are of the future [8, 9, 10].

Brain matrix and the missing element of pain: gut microbiota
From a certain point of view, humans can be considered superorganisms, which are composed of the human and the microbial component. With the help of contemporary biotechnology and information technologies, it has been found that microbial communities within the human body can alter their lifestyle, behavior, influence the perception of pain or induce/favor the occurrence of many diseases (Fig. 4).

The human intestine hosts, under anaerobic conditions, over 100 trillion microorganisms, which are representative of over 1,000 distinct species. Recently, there was a bidirectional link between the intestine and the brain, where the microbiomatrix composition can influence behavior and cognition, and the nervous system in turn – the microbial composition of the intestine. Bacterial metabolites (up to 99% undetected), vagus nerve, immune system, hypothalamic-pituitary-adrenal axis

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**Fig. 2. Gate control theory of pain**

**Fig. 3. The Puzzle of Pain: each element with its own picture (According to: Ben Cormack, 2017)**
are involved in generating various pathological conditions: depression, anxiety, irritable bowel syndrome, neurodevelopmental disorders (autism, Parkinson’s disease, Alzheimer’s disease).

Bacterial metabolites, in particular, of the bioactive lipid class (N-acylethanolamine [NAE] class – N-arachidonylethanolamine [AEA], palmitoylethanolamid [PEA], oleoylethanolamide [OEA], short chain fatty acids, such as butyrate[short chain fatty acids, SCFAs]) are able to modulate peripheral and central pathological processes. The role of these substances has already been demonstrated in the generation and maintenance of inflammation, neuroinflammation, acute and chronic pain, obesity, central nervous system disorders [6].

And this new direction of study will, as far as we can see, significantly complement our knowledge of ourselves, including those related to nociception and pain.

**Instead of conclusions**

Even the most contemporary theories of pain were based on the knowledge gained from older theories. In turn, they will be the platform for generating new knowledges to formulate the next generation of pain theories.

*“This is not the end… It is perhaps the end of the beginning”*  
Whinston Churchill (1874–1965)  
Speech at the Mansion House, 10 November 1942.

**References**

Проблемна стаття / Problem article

Теорії болю: до Декарта і після нейроматрикса: яка їхня роль в розвитку майбутніх парадигм?
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Резюме. Стаття є синтезом літератури щодо античних, середньовічних і сучасних теорій болю. Якщо коротко, описано найважливіші теорії ноксепції та болю. У хронологічному порядку представлено відкриття фізіології, анатомії, гістології та інших методів діагностики болю. Обговорюється роль теорій минулих століть і їх впливу на розробку нових. Бул о сформульовано гіпотезу щодо розвитку теорії нейроматрикса, враховуючи появу нових даних про вплив людської мікробіоти на появу і перцепцію болю або інших супутніх патологій із психологічним або болевим компонентом.

Ключові слова: історія медицини, теорії болю, нейроматрикс, людська мікробіота.


Теорії болю: до Декарта і після нейроматрикса: яка їхня роль в розвитку майбутніх парадигм?
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Резюме. Статья является синтезом литературы относительно античных, средневековых и современных теорий боли. Вкратце, описаны наиболее важные теории о ноксепции и боли. В хронологическом порядке представлены открытия физиологии, анатомии, гистологии и других методов диагностики боли. Обсуждается роль теорий прошлых веков и их влияния на разработку новых. Была сформулирована гипотеза относительно развития теории нейроматрикса, учитывая появление новых данных о влиянии человеческой микробиоты на появление и перцепцию боли или других сопутствующих патологий с психологическим или болевым компонентом.

Ключевые слова: история медицины, теории боли, нейроматрикс, человеческая микробиота.

Травмы позвоночника остаются серьёзной проблемой для всего человечества. Они не только причиняют боль, но и существенно ограничивают социальную активность пострадавших. Для коррекции и стабилизации позвоночника разрабатываются новые виды малоинвазивных оперативных вмешательств. Одним из перспективных направлений в этой области является баллонная кифопластика. Суть метода состоит в проксимальном введении и тело пораженного позвонка специального баллона. Баллон вводится в спинном участке, а затем в него под давлением нагнетается жидкость. Баллон расправляется в теле позвонка, обеспечивая положение посттравматической компрессии. Затем баллон извлекают, а форма и положение костных элементов остаётся неизменным. Костный цемент на основе метакрилатов полимеризуется в процессе операции, что обеспечивает стабильность. К преимуществам данного метода относится малоинвазивность, быстрый клинический эффект, использование экологичных деструктивов, а также возможность проведения вмешательства в амбулаторном порядке. Книга будет интересна для ортопедов-хирургов, нейрохирургов и студентов-медиков.


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