Psychiatr. Pol. 2024; 58(3): 433–448
PL ISSN 0033-2674 (PRINT), ISSN 2391-5854 (ONLINE)
www.psychiatriapolska.pl
DOI: https://doi.org/10.12740/PP/174391

The evolutionary and neurobiological attributes of consciousness: an update

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Summary

Consciousness is most frequently defined as a subjective experience of mental processes. The phenomenon of consciousness has always been a subject of great interest in various fields of science, including psychiatry, and the most prominent scientists have engaged in research on it. The studies performed in recent years have brought about novel data on the evolutionary and neurobiological attributes of this phenomenon. In the first part of the article, the evolutionary concepts of consciousness are presented, going back to the beginnings of life on our planet. They are proposed by such illustrious scientists as Joseph LeDoux, Daniel Dennett, António Damásio, and Arthur Reber. Each of them presents the issue of consciousness in the context of evolution slightly differently. However, there are many similarities concerning the development of the nervous system and mental life. The second part discusses the novel research on the cognitive and neurobiological components of consciousness. Among many researchers of this issue, we chose the achievements of two British authors such as Chris Frith and Anil Seth. The neuroanatomical and perceptive aspects of both the level and context of consciousness are provided. Besides presenting the contemporary evolutionary and neurobiological concepts of consciousness, the article aims to bring closer the profiles of the prominent researchers of *neuroscience* mentioned here. This term can be translated into Polish as "neuronauka", although our country's most frequently used name is "neurobiologia."

Key words: consciousness, evolution of consciousness, neurobiology of consciousness

Introduction

Consciousness is most frequently defined as a subjective experience of mental processes. In this sense, it makes a fundamental aspect of the mental realm, and a phenomenon of consciousness has always been a subject of great interest in various fields of science, certainly including psychiatry. The research on this phenomenon often made two preliminary assumptions. The first claimed that *sensu stricto* consciousness

occurs exclusively in humans, and there is no convincing evidence for its presence in organisms on a lower level of the evolutionary ladder. The second contention assumed that given a *par excellence* subjective character of the phenomenon of consciousness, its detailed investigation is extremely difficult or impossible. Some consciousness theorists distinguished so-called hard and easy problems in their research. The first pertains to the mere essence of subjective experience, while the easy one is associated with the brain structures' role and information mechanisms [1]. In the 1990s, the term 'mysterianism' (from the word mystery) was coined for the impossibility of resolving the 'hard' problem, and the followers of such an attitude were called 'mysterians' [2, 3].

In the current article, we refer to these two assumptions based on the concepts and results of studies performed in recent years. In the first part, we make it by presenting the evolutionary concepts of developing consciousness going back to the beginnings of life on our planet. The second part presents the novel research on the neurobiological and cognitive components of consciousness. Both these issues were elaborated on by illustrious contemporary scientists. Besides presenting the contemporary evolutionary and neurobiological concepts of consciousness, the article aims to bring closer the profiles of the prominent researchers of neuroscience mentioned here. This term can be translated into Polish as "neuronauka", although our country's most frequently used name is "neurobiologia".

The evolutionary concepts of consciousness

In 2017–2019, four books appeared, authored by prominent neuroscience researchers, on the evolutionary context of consciousness [4–7]. Three of them were translated into Polish [8–10]. In each book, the issue of the evolutionary aspect of consciousness was presented slightly differently. However, all have some common features, picturing the origin and progress of consciousness in the context of the development of the nervous system and mental processes. The chapter below discusses these four publications and presents the profiles of their authors.

Joseph LeDoux

Joseph LeDoux (born 1949) is an American neurobiologist whose research, since its beginning, concentrated on the processes of emotions, and the brain structure of main focus was the amygdala. In 1996, the results of his experiments were described in the book *The emotional brain* [11], which after several years was published in Polish [12]. Incidentally, the interest in the amygdala was also reflected in the musical activity of Joseph LeDoux because he was a composer and originator of a musical band named "Amygdaloids".

One of the initial discoveries of Joseph LeDoux was the identification of two neuronal information pathways to the amygdala associated with the perception of danger. He showed that one is a 'rapid' subcortical pathway associated with an immediate

behavioural reaction. The other path is slower and associated with the information processing by the prefrontal cortex. This finding allowed for a better understanding of excessive reactions to danger underlying the pathogenesis of anxiety syndromes and post-traumatic stress disorder. Related to this was the research on the reconsolidation of memory traces after a second exposition to a stressful situation, as well as the possibility of their blockade. The research collaborator of Joseph LeDoux on this issue was a Polish psychiatrist from Krakow, Jacek Dębiec, currently working at Michigan University in Ann Arbor [13].

In the 21st century, LeDoux continues and elaborates on the concepts of neuronal circuits associated with anxiety and fear in the context of the organism's response to danger. They were reflected in his next book *Anxious. using the brain to understand and treat fear and anxiety* published in 2015 [14] (it appeared in Poland under the title *Lęk. Neuronauka na tropie źródeł lęku i strachu* [15]), and in the article with Daniel Pine, published in 2016 [16]. The main message states that the activity of brain circuits associated with anxiety is not identical to an experience of emotion. LeDoux proposes two systems associated with fear and anxiety. The first is associated with a generation of conscious emotions and mostly pertains to the cortical structures. Whereas the second system acts mostly subconsciously and controls the behavioural reactions to danger. In this process, the main role is played by subcortical structures (amygdala), sometimes linked to the cortical regions. Given contemporary neuroimaging possibilities, such a two-system concept can be significant for the treatment of anxiety conditions. When significant amygdala hyperactivity is shown, pharmacotherapy would be the treatment of choice. On the other hand, in the case of disturbances in cortical structures, psychotherapy would be recommended, aiming at learning to regulate emotional experience. By the way, LeDoux touches on the issue of a 'conscious' perception of emotion. According to him, the brain circuits associated with anxiety and the immediate reaction to danger are common for humans and other mammals. In contrast, the conscious perception of emotions is characteristic mainly of our species.

In the book *The deep history of ourselves. The four-billion-year story of how we got conscious brain*, LeDoux, in an extremely didactic and accessible way, provides the most current data on the development of the evolutionary tree from the single-celled organism until the *Homo sapiens* [8]. Presenting his view on the genesis and development of mental life, he postulates that it became an expansion of so-called survival behaviour, the elements of which already exist in the single-celled prokaryotic organisms such as bacteria and archeons (the single-celled organisms living in extreme conditions). The concept was recently elaborated in an article published in 2022 [17].

According to LeDoux, the ability of the organisms to survive was substantially improved by the nervous system coming into being and its further evolution in multicellular animals. He reckons that the creation of neurons had been followed through little changes, in the course of a passage from such non-tissue animals as sponges, to cnidarians, and the process took place between 800 and 500 million years ago. These cells were produced due to a need for communication between sensory and motor ele-

ments. The ability of the nervous system to learn in the process of evolution brought about a possibility of diversification of body structure and reaching new environmental niches. The development of the nervous system resulted in three double main parts of the brain in the vertebrates: (1) the forebrain (prosencephalon) is responsible for cognitive and motor functions, perception, learning, and memory; (2) the midbrain (mesencephalon) governs sensorimotor reflexes, sleep and waking; and (3) the hindbrain (rhombencephalon) is accountable for visceral reflexes. In the further part of the book, LeDoux dishes up a synthesis of knowledge on the evolution of the brain formulated in the 1950s by Paul McLean as a concept of the triune brain. According to this theory, the forebrain of mammals consists of three superimposed brains: reptile brain, paleomammalian brain (limbic system), and neomammalian brain. The most advanced in the process of evolution is the cerebral cortex, and the human version of it possesses the unique features responsible for the exceptional cognitive abilities of the *Homo sapiens*. They are associated with the development of language, mentalizing and reflexive autonoetic consciousness.

About the issue of consciousness, LeDoux gave a title for chapter 51 of the book as *Being there*, which could refer to the book of Akil Seth *Being you* discussed in the further part of the article [18]. LeDoux defines a conscious experience as viewing the present time through the lens of memory which shapes a perceptual set. According to the higher-order theory (HOT), consciousness acquires several levels. The higher level, so-called autonoetic consciousness, is intrinsic to contemporary humans and is associated with the dorsal prefrontal cortex and frontal pole. This kind of consciousness also includes emotional experiences resulting from the processing of lower-level's elements, associated with subcortical structures, e.g., the amygdala. Some features of the lower level's consciousness can occur in other vertebrates such as mammals or birds.

In 2011, Joseph LeDoux was in Krakow, lecturing at the conference organised by the Copernicus Centre. His concepts on the pathogenesis of anxiety syndromes and their relevance to the pharmacotherapy and psychotherapy have recently been reflected in Polish psychiatric literature [19, 20].

Daniel Dennett

Daniel Dennett (1942–2024) was a professor of philosophy, recently working at Tufts University in Boston. The issue of consciousness has been a dominant topic of his 60-year scientific research. His doctoral thesis, defended in 1965 at Oxford University was published as a book *Content and Consciousness*.

The Polish reader has been fairly familiar with Dennett's publications. His nine books were translated into Polish, including four, mainly concerning the phenomenon of consciousness. They are *Natura umysłów*. *Jak zrozumieć świadomość* [21] (*Kinds of minds. Toward an understanding of consciousness* [22]), *Słodkie sny. Filozoficzne przeszkody na drodze do nauki o świadomości* [23] (*Sweet dreams. Philosophical obstacles to a science of consciousness* [24]), *Świadomość* [25] (*Consciousness explained*

[26]), and *Od bakterii do Bacha. O ewolucji umysłów* [9] (*From bacteria to Bach and back. The evolution of minds* [5]), which will be further analysed in more detail.

Dennett often uses computer terminology, naming the brain 'hardware', on which 'software' is installed, the latter encompassing language and memes. Hardware resulted from biological evolution, and software – from cultural one. Consciousness plays the virtual machine shaping these processes in the brain. Dennett's model of consciousness is called the Multiple Drafts Model. According to this, consciousness is a variable stream transitioning from one draft to another. Several streams are governing different functions of consciousness. The typically human stream is the one related to language and memes..

Here, some space can be dedicated to the concept of 'meme' as the least unit of cultural information, having the ability to replicate. The term comes from Greek, where *memesis* means 'imitation'. The concept was introduced by Richard Dawkins in the book *The selfish gene* as an example of a replicator different from a gene [27]. According to Dennett, memes as notions expressed by words, have been significant in shaping cultural evolution. They have been subject to the action of natural selection without the necessity of increasing reproductory success. The current popular perception of the meme as a drawing with text elements, frequently of a humorous character, is very remote from its initial definition.

The book *From bacteria to Bach and back* summarises Dennett's views on the evolutionary context of consciousness. Two mainstreams can be distinguished here. The first is about developing the elements of consciousness during evolution, and the second describes the 'language' genesis of consciousness in humans. Discussing the development of consciousness during the evolution, beginning from bacteria, Dennett reckons that so-called mental life has come into existence due to the affordances, which denoted the possibilities of coping with the ambient world. The term 'affordances' was introduced into psychology by James Gibson in 1977 [28]. Using affordances, the organisms have developed many adaptive abilities that have been consolidated during evolution. However, Dennett points out that 'to know' does not mean 'to understand'. Initially, the organisms are not aware of the abilities which enable them the effective functioning. The process of 'understanding' is progressing gradually, with the participation of the nervous system, making the inception of consciousness. However, the final formation of consciousness in humans is achieved owing to language development. According to Dennett, consciousness is a hidden verbal behaviour. The mind can be defined as a cognitive activity of the brain and body, augmented and driven by the language, whereas the consciousness is an experience of speaking and its content. This concept has been frequently undermined by the observations showing that a loss of speech does not result in a loss of consciousness.

In the context of the role of language and its evolution in the development of consciousness, Dennett mentioned the concept of an Americal psychologist, Julian Jaynes (1920–1997), formulated in a 1976 book titled *The origin of consciousness in the breakdown of the bicameral mind* [29]. Despite the theory not being confirmed in

the following years, it can be of interest to psychiatrists given its psychopathological and evolutionary aspects. Therefore is worthy of providing it several sentences here. According to Jaynes, consciousness developed not until 3,000 years ago, when the dominance of auditory hallucination wore off. Up to this time, there had been a bicameral mind. The first chamber was an unconscious observer of reality and a passive performer of activities dictated by the second chamber. The latter was an illusory speaker, giving orders for planned aims and deeds (e.g., as the voice of god). According to Jaynes, the auditory (verbal) hallucinations in the form of commands were natural during the preceding stage of language development. A receiving listener would identify them as coming from a leader of the group, master, or god. Such hallucinations played a communicative role, bonding human groups with several dozen or more individuals. As a result of civilization turbulences in the second century B.C., such a form of communication vanished, and the processes of conscious perception and decision-making developed. Reactivation of this psychopathological phenomenon can occur nowadays in many psychiatric conditions, mainly schizophrenia.

António Damásio

António Damásio (born 1944) is a neurobiologist of Portuguese origin, currently working at the University of Southern California as a professor of psychology, philosophy and neurology. Previously, he had been a chairman of the Department of Neurology at the University of Iowa for twenty years. Like former authors, most of António Damásio's books were translated into Polish. Probably, the most popular became *Błąd Kartezjusza. Emocje, rozum i ludzki mózg* [30] (*Descartes' error. Emotion, reason, and the human brain* [31]), where Damásio firmly turned down Descartes' dualism of the soul and body. The Polish reader may also know his publications, significantly concerning consciousness, such as *W poszukiwaniu Spinozy* [32], (*Looking for Spinoza* [33]), *Tajemnica świadomości. Jak ciało i emocje współtworzą świadomość* [34] (*The feeling of what happens* [35]) and *Jak umysł zyskał jaźń* [36] (*Self comes to mind. Constructing the conscious brain* [37]).

Damásio reckons that the integral unity of the brain and body pertains to experiencing all mental processes that are particularly manifested for emotional functions. According to him, 'feelings' are mental experiences of the body state [38]. This concept refers to the first neurophysiological theory of emotions, formulated in the 19th century by the Danish scientist Carl Lange (1834–1900) and an American psychologist, William James (1842–1910), known as the James-Lange theory. The theory claims that the perception of emotional states is an experience of 'peripheral' somatic changes occurring in response to stimuli of emotional valence. Damásio points mostly to William James, whereas the review of the contributions of Carl Lange, the great scientist and physician, who also introduced lithium carbonate for the treatment and prevention of periodic depression, made a topic of the article of one of this paper's co-author [39].

Among many original Damásio's neurobiological concepts, the most popular seems to be the theory of the so-called somatic marker. It depicts how emotions and their biological substrate, both in the central nervous system and the whole body participate in the process of decision-making. Because the gastrointestinal tract is substantial in this process, the theory alludes to the phenomenon of 'gut feeling', which may mean something like premonition or intuition [40]. The concept of the influence of the gastrointestinal tract on cognitive and emotional functions was already widely discussed in the 19th century [41]. In recent years, the term has been travestied for defining the role of the gut microbiome in mental functions [42]. Irish researchers reckon that in the course of evolution, the expansion of the gut microbiome in mammals, including humans, has played a significant role in the development of cognitive functions, social interactions and coping with external stress. According to them, the gut microbiome is an element of behavioural regulating system called the collective unconscious [43].

The book *Strange order of things* is among Damásio's publications, the most conspicuous for discussing the development of the nervous system and consciousness in the context of evolution [10]. According to Damásio, the leitmotiv for the life phenomenon is living organisms striving for homeostatic regulation. Similar to previous researchers, Damásio gives much attention to bacteria as the earliest living organisms and, nowadays, the most numerous and diversified inhabitants of the Earth. Furthermore, each human organism has ten times more bacterial cells (residing mostly in the intestines), than its own cells. Damásio reckons that bacteria can 'detect' the environment which property can make an inception of the consciousness.

In the opinion of Damásio, a homeostatic imperative was instrumental for emerging the multicellular organisms and sparking off a nervous system about 500 million years ago. An original Damásio's view claims that in the process of evolution, the visceral nervous system was the first brain, preceding the central nervous network. This view can relate to his concept of the somatic marker, pointing to the role of the gastrointestinal complex in mental processes. Discussing the process of evolution, Damásio thinks that between the cell sentience and completed mental processes, the intermediate level consists of the most basic mental processes, i.e., feelings. They constitute an internal state of the organism in which consciousness exists. The two main features of consciousness: subjectivity and integration of experiences, are created in many regions of the brain in cooperation with the actual body. In the context of evolution, we experience mental processes as feelings because they are advantageous for an organism and help produce the most homeostatic behaviours.

Arthur Reber

Arthur Reber (born 1940) is an American cognitive psychologist. His most significant contribution to psychology was introducing the concept of 'implicit learning', a kind of learning without conscious realization of either the process of acquiring knowledge or the context of learning. Reber was also researching paranormal phe-

nomena trying to prove that they do not exist. He was also a theorist and commentator of gambling, especially of poker.

Reber's book *The first minds. Caterpillars, karyotes and consciousness* is dedicated to the evolutionary concept of consciousness [7]. The author admits that one of the incentives to write it was an observation of a caterpillar's behaviour. In the book, Reber proposes a model of the Cellular Basis of Consciousness (CBC). He reckons that the ability of perception (sentience) makes a fundamental property of life; therefore, the phenomena of life and consciousness are mostly overlapped. In the context of evolution, the development and conservation of appropriate features should meet the following criteria: (1) (reproductive?) success in species having it; 2) conservation: in a moment of inception, there is a consolidation and the basis for the features produced in further period; (3) stability – the adaptative functions created in an earlier period show less variability compared to those produced later; and (4) universality – prevalence in various species. All these criteria are met by the phenomenon of 'sentience' occurring already in prokaryotes (bacteria). Since it is: (1) as successful as other features in evolutionary biology; (2) conserved and occurring in all organisms emerging later; (3) stable and makes a basis for subsequent versions of perception and consciousness developed later; and (4) reflecting the universality of perceptual, sensory, memory, and motor functions as well as self-representation, occurring in all animal kingdom.

The CBC constitutes an original approach to the 'hard' problem of consciousness. Instead of the search for how the brain produces a mind, consciousness is perceived as an integral property of living organisms. Reber postulates using the modern methods of molecular genetics and bioinformatics to identify the DNA sequences responsible for the sentience in bacteria, which should be further present in the whole animal kingdom. A significant evolutionary step was the organisation of this process in multicellular organisms, developing after nearly two milliards of prokaryotes' and single-cell organisms' existence, about 900 million years ago. The application of molecular genetics and bioinformatics can also concur to better recognition of the biological basis of sentience on a primary level and its further evolution until consciousness in humans.

Neurobiological and cognitive concepts of consciousness

The views and achievements of two eminent British scientists such as Chris Frith and Anil Seth will be discussed, among many researchers on neurobiological and cognitive correlates of consciousness. Similar to the previous chapter, their profiles will also be presented.

Chris Frith

Chris Frith (born 1942) is a British cognitive neuropsychologist currently affiliated with the University College of London and the Aarhus University in Denmark. For psychiatrists, he is noted due to his research on schizophrenia. The most popular be-

came his pathogenetic hypothesis of schizophrenia, known as the disconnection theory, referring to the term schizophrenia, formulated by Eugen Bleuler. It postulates that in schizophrenia, there is a disturbance in the integration of brain circuits, predominantly in the prefrontal cortex and frontal lobe [44]. This phenomenon can make the basis for the mechanism of psychotic symptoms, but also for mental incongruence, characteristic of the deficit symptoms [45]. Many elements of the disconnection hypothesis have been confirmed by contemporary neurobiological and neuroimaging studies [46].

Frith has also been extensively dealing with the issues of consciousness. In 2007, he published a book *Making up the mind. How the brain creates our mental world* [47], which in 2011 gained the Polish version entitled *Od mózgu do umysłu. Jak powstaje nasz wewnętrzny świat* [48]. Frith's views on the neuroanatomical basis of consciousness were explicated in an article published in 2019 [49]. According to him, a definition of 'being conscious' means "having subjective experiences". In the phenomenon of consciousness, two aspects can be distinguished: the level of consciousness and the content of consciousness, associated with the activity of specific brain structures. Within the level of consciousness, a 'vegetative' state can be discerned, where sleep-waking cycles are present, however, there is no reaction to stimuli and no signs of intentional behaviour. At a minimal level of consciousness, an individual shows a reaction to stimuli and follows simple orders. In both these conditions, brain metabolism is reduced by nearly half, especially in the frontal and parietal cortex. In Frith's opinion, for the level of consciousness, significant are cerebral circuits, connecting thalamic interlaminar nuclei with the prefrontal cortex and anterior cingulate cortex. He supports the integrated information theory (IIT). The IIT postulates a specific kind of integration of information from multiple brain regions, which regulates the level of consciousness. E.g., psychoactive substances can change the level. As a result, altered states of consciousness arise, with such phenomena as experience of unity, disembodiment, or complex imagery.

As to the content of consciousness, Frith draws from research showing that the specific brain structures, so-called essential nodes can be established for the perception of various contents,. For example, for a perception of faces, there is the fusiform face area (FFA); for an experience of touch – the primary somatosensory cortex; for interceptive stimuli – the anterior part of the insula; and for motor experiences – the pre-supplementary motor area. Whereas, for 'conscious' perception, communication between these 'nodes' and the frontal and parietal cortex is necessary.

Similar to Reber, Frith thinks that 'sentience', as an awareness of an object, occurs in many organisms. It probably originated 500 million years ago during the formation of the nervous system and the possibility of associative learning associated with relation to the environment. Such a property became a feature of all organisms that further developed because its presence and evolution allowed to implement the new tasks associated with survival or better fulfilling the old ones. Whereas, the typical human quality is the so-called metacognition, which includes thinking about an object and sharing experiences with others. In a psychopathological context, such symptoms

of schizophrenia as psychosis or lack of insight are regarded by Frith as disturbances of 'metacognition'.

The leading role in the phenomenon of metacognition, characteristic of humans, is probably played by the brain structures which displayed the most extensive expansion in *Homo sapiens*. They undoubtedly include the prefrontal cortex and fronto-polar cortex (FPC). Whereas in recent years, it was found that the precuneus, located on the medial surface of the brain hemispheres and qualified as a part of the parietal cortex, showed significant expansion not only compared to chimpanzees but also to *Homo neanderthalensis* [50].

The neuroanatomical basis of consciousness is also presented by António Damásio in his book *Feeling and knowing. Making mind conscious* [52], (*Odczuwanie i poznawanie. Jak powstają świadome umysły* [51]). It shows similarities and differences with the picture depicted by Frith. According to Damásio, among cortical structures, the most important for the conscious mind are the rear and side areas of the cerebral cortex. These regions interact with the insular cortex, cingulate cortex, peripheral part of the interoceptive system, and some brain stem nuclei. Damásio's view arguing that the frontal and prefrontal cortex are not significant for the conscious mind, may be surprising.

Modern methodology of neuroanatomical research on consciousness employs mostly neuroimaging studies. They aim for the assessment of so-called self-referential processing (SRP) that is self-feeling. There are two kinds of SRP. The first is associated with the mind and verbalized in the process of introspection. Whereas the second one is associated with the body and manifested by somatic experiences as interoception. These studies evaluate both brain structures and their connectivity. The most frequently listed in this respect are the ventrodorsal prefrontal cortex, entorhinal cortex, frontoparietal control network, anterior cingulate, and insula [53].

Anil Seth

Anil Seth (born 1972), the youngest of the scientists discussed here, is a British cognitive psychologist of Hindu origin, currently a Professor of Cognitive and Computational Neuroscience at the University of Sussex. His views on the issue of consciousness were presented in the already-mentioned book *Being you. A new science of consciousness*, published in 2021 [18]. The book's main message is that the perception of the surroundings and the self is an active product of the brain activity. The brain constitutes a prediction machine, whereas the final perception makes the best guess of perceiving and processing stimuli. In the context of brain activity, such perception can be described as 'controlled hallucinations'. As early as 2013, Seth put forward a concept that this fact concerns both exteroceptive and interoceptive stimuli [54].

This kind of activity also pertains to the integrated perception of own person, which can be called self or consciousness. According to Seth, consciousness can be regarded as a collection of perceptions (controlled hallucinations) concurring with the

'embodied selfhood' or 'being a body'. He proposes to distinguish within such domain the 'perspectival self', 'volitional self', 'narrative self', and 'social self'.

In an article published in 2022 [55], Seth discusses currently prevalent theories of consciousness. Besides those mentioned in this paper, such as the HOT and IIT, he distinguishes the theories such as global workspace, re-entry and predictive processing. He points out the differences between these theories in explaining various aspects of consciousness, suggesting also the appropriateness of their further specification and the elaboration of 'measurements'.

Until now, the neuropsychological research, among others based on the observations of psychological functioning after lesions of a particular cerebral region, greatly contributed to the identification of both conscious and unconscious elements of sensory information processing and memory processes. In neuropsychological understanding, consciousness is best seen as an expression of global organization of the central nervous system. An indication of this is a preservation of consciousness after damage of large portions of the brain (including those thought to be associated with consciousness), as a result of brain reorganisation. This is mostly compatible with the integrated information theory (IIT) of consciousness [56]. Neuropsychological methods used by Seth are mostly dedicated to studying the processes of perception, both exteroception and interoception. There were exactly the results of this research which brought about his concept of perception as 'a best guess' and 'controlled hallucinations'.

Summing-up

In recent years, consciousness research has made some progress. The four apostles of the evolution of consciousness (LeDoux, Dennett, Damásio and Reber), agree that the beginning of this phenomenon can be recognised in the first single-cell prokaryotes. The evolution and development of consciousness progressed concomitantly with the evolution of mechanisms that were essential for the life of animal organisms. These mechanisms were called differently, e.g., survival, affordances, or homeostasis. Nevertheless, all the researchers reckon that the highest level of consciousness, known as autonoetic or 'metacognition', encompassing the thinking of objects and sharing experiences with others, makes a characteristic feature of *Homo sapiens*. The four mentioned books described the evolution of the nervous system and emerging new neurobehavioral functions, with consciousness as a crowning achievement. Each author pointed out the role of consciousness as an integrative mental function, evolutionally advantageous, allowing for the adaptation to a great variety of ecological and cultural milieux.

Apart from the four great scientists, an evolutionary concept of consciousness elaborated by an American psychologist, Michael Graziano, may be mentioned. Graziano is a professor of psychology at the University of Princeton. He provided his theory in the book: *Rethinking consciousness. A scientific theory of subjective experience* published in 2019 [57] and in his recent article in the *Proceedings of the New York*

Academy of Sciences journal [58]. Graziano discusses consciousness in the Attention Schema Theory (AST) context. He reckons that the simplest components of attention, i.e., competition between signals, had already been present during the emergence of the nervous system. The evolution of the selectivity of attention brought about the possibility of the modelling of attention both own and in the other individuals. This ability has reached the highest level in humans, as so-called the theory of mind. The brain structures associated with such activity include the superior temporal sulcus (STS) and temporoparietal junction (TPJ).

However, information should be provided here that as early as almost fifty years ago, a precursor of the evolutionary concepts of consciousness became Hoimar von Ditfurth (1921–1989), a professor of psychiatry and neurology at the University of Heidelberg and a great populariser of science. He provided it in the book *Der Geist fiel nicht vom Himmel*" [59], which was introduced to a Polish reader in 1981 and titled *Duch nie spadł z nieba* [60]. Many aspects presented by contemporary theorists of the evolution of consciousness can be found here, such as invoking bacteria (the chapter: *Single-cell organisms as a probe of the brain*), integrating mental and bodily processes in the brain, and hierarchical systems of mental functions. The book was never translated into English, which may explain its low perception among contemporary American and British authors.

It can be noticed that none of the mentioned publications pays major attention to the shaping of consciousness in the course of ontogenetic development. Yet, it can be suggested that for a better understanding of consciousness, it would be necessary to have both a knowledge of its evolutionary history and its gradual emerging in childhood. As a Canadian developmental psychologist, Paul Bloom, observes, since early infancy, the representatives of our species distinguish the inanimate objects from the subjects capable of autonomous action, determined by aims and motives. This phenomenon is important both for shaping self-consciousness and producing a dualistic kind of thinking. In this, a subjective experience of mental and emotional processes and a perception are not accompanied by an experience of physicochemical changes occurring in the brain. Therefore, the beginning of his book's title reads *Descartes' baby* [61].

In recent years, updated information has been obtained as to the cognitive and neurobiological (mostly neuroanatomical) aspects of consciousness. Among the cognitive theories, that of Akil Seth comes to the forefront. As a mechanism of perception, it postulates so-called controlled hallucinations and as a mechanism of consciousness – their integration [18]. It can be mentioned that von Ditfurth also regarded a surrounding reality as a production of the brain, constituting a kind of hypothesis about the world or a project for reality [59].

The contemporary neuroanatomical concepts of consciousness claim that for the processing of consciousness phenomenon, integrating brain circuits with some peripheral elements is necessary, which gives a subjective experience both for the environment and the body. It seems that among the cortical structures, the most important are their

rear and side parts (temporal and parietal lobes), and the majority of researchers also point to the prefrontal cortex.

The studies on consciousness have contributed to a novel view of some brain structures. One of them is the insula, located in the lateral sulcus of the brain (the Sylvian sulcus). The anterior part of the insula is probably responsible for the integration of interoceptive stimuli, making a significant element of the subjective experience of a physical 'self' and emotions. It is worth mentioning that this structure was discovered by a German physician, Johan Christian Reil (1759–1813), who was the first to introduce the term 'psychiatry' into medicine [62]. The role of the precuneus, constituting a part of the parietal lobe, in the process of consciousness, has been strengthened by the fact that this structure is expanded in *Homo sapiens* not only compared to chimpanzees but also to *Homo neanderthalensis* [50]

A century ago, philosopher Henri Bergson assumed that living organisms so greatly differ from inanimate matter that for understanding of their functioning, the reference to a notion of a vital force (French: *elan vital*) is necessary. Nowadays, due to the explanation of the genetic mechanisms, divisions, and differentiations of the cells as well as homeostatic regulation, life is regarded as a collection of many precisely attuned processes. Almost nobody explains life by the mysterious supernatural forces or suggests its unknowable nature. With the development of neurobiology, the same case will probably pertain to consciousness. It will not be regarded as a homogenous mysterious phenomenon but rather as an assembly of self-steering, complementary algorithms. However, some hindrances to this in humans may be a dualistic mindset, which progresses during the development and can consolidate the belief of the distinction between the mental/conscious and material world.

The recent years can also be regarded as a time of some acceleration in consciousness research. It seems that this will be proceeding and in not so distant future we will be closer to the elucidation of this phenomenon. The books and articles mentioned in this paper substantiated *par excellence* neurobiological comprehension of consciousness. However, it needs to be clarified whether our inherited dualistic mindset could be overcome, and consciousness can be regarded as a materialistic issue.

References

1. Chalmers D. *Facing up to the problem of consciousness*. J. Conscious. Stud. 1995; 2(3): 200–219.
2. McGinn C. *Can we solve the mind-body problem?* Mind 1989; 98(391): 349–366.
3. Flanagan OJ. *Consciousness reconsidered*. Cambridge, Mass.: Bradford Books, MIT Press; 1992.
4. LeDoux J. *The deep history of ourselves. the four-billion-year story of how we got conscious brain*. New York, NY: Viking; 2019.
5. Dennett DC. *From bacteria to Bach and back. The evolution of minds*. New York, NY: W. W. Norton & Company; 2017.

6. Damasio A. *Strange order of things. Life, feeling, and the making of cultures*. New York, NY: Vintage Books; 2018.
7. Reber AS. *The first minds. Catepillars, karyotes, and consciousness*. New York, NY; 2019.
8. LeDoux J. *Historia naszej świadomości. Jak po czterech miliardach lat ewolucji powstał świadomy mózg*. Krakow: Copernicus Center Press; 2020.
9. Dennett DC. *Od bakterii do Bacha. O ewolucji umysłów*. Krakow: Copernicus Center Press; 2017.
10. Damasio A. *Dziwny porządek rzeczy. Życie, uczucia i tworzenie kultury*. Poznan: Rebis Publishing House; 2018.
11. LeDoux JE. *The emotional brain*. New York, NY: Simon & Schuster; 1996.
12. LeDoux J. *Mózg emocjonalny. Tajemnicze podstawy życia emocjonalnego*. Warsaw: Media Rodzina; 2001.
13. Debiec J, LeDoux JE. *Noradrenergic signaling in the amygdala contributes to the reconsolidation of fear memory: Treatment implications for PTSD*. Ann. N. Y. Acad. Sci. 2006; 1071: 521–524.
14. LeDoux J. *Anxious. Using the brain to understand and treat fear and anxiety*. New York, NY: Viking; 2015.
15. LeDoux J. *Lęk. Neuronauka na tropie źródeł lęku i strachu*. Krakow: Copernicus Center Press; 2017.
16. LeDoux JE, Pine DS. *Using neuroscience to help understand fear and anxiety: A two-system framework*. Am. J. Psychiatry 2016; 173(11): 1083–1093.
17. LeDoux JE. *As soon as there was life, there was danger: The deep history of survival behaviours and the shallower history of consciousness*. Philos. Trans. R. Soc. Lond. B Biol. Sci. 2022; 377(1844): 20210292.
18. Seth A. *Being you. A new science of consciousness*. London: Faber & Faber Ltd; 2021.
19. Chojak A. *Recent findings in the pathogenesis and treatment of fear and anxiety*. Neuropsychiatr. Neuropsychol. 2022; 17(3–4): 132–139.
20. Murawiec S, Danel J. *The pathogenesis of anxiety syndromes in the concepts of Jaak Panksepp and Joseph LeDoux* (*Patogeneza zespołów lękowych w koncepcjach Jaaka Panksepa i Josepha LeDoux*). Pharmacother. Psychiatr. Neurol. 2023; 39(1): 65–78.
21. Dennett D. *Natura umysłów: jak zrozumieć świadomość*. Warsaw: CIS; 1997.
22. Dennett D. *Kinds of minds. Toward an understanding of consciousness*. New York, NY: Basic Books; 1997.
23. Dennett D. *Słodkie sny. Filozoficzne przeszkody na drodze do nauki o świadomości*. Warsaw: Prószyński i S-ka; 2007.
24. Dennett D. *Sweet dreams. Philosophical obstacles to a science of consciousness*. Denver, CO: Bradford Books; 2006.
25. Dennett D. *Świadomość*. Krakow: Copernicus Center Press; 2016.
26. Dennett D. *Consciousness explained*. Boston: Little, Brown & Co.; 1991.
27. Dawkins R. *Samolubny gen*. Warsaw: Prószyński i S-ka; 1998.
28. Osiurak F, Rossetti Y, Badets A. Neurosci. Biobehav. Rev. *What is an affordance? 40 years later*. 2017; 77: 403–417.
29. Jaynes J. *The origin of consciousness in the breakdown of the bicameral mind*. Boston: Houghton Mifflin Company; 1976.

30. Damasio A. *Błąd Kartezjusza. Emocje, rozum i ludzki mózg*. Poznan: Rebis Publishing House; 2002.
31. Damasio. A. *Descartes' error. Emotion, reason, and the human brain*. New York, NY: Putnam; 1994.
32. Damasio A. *W poszukiwaniu Spinozy*. Poznan: Rebis Publishing House; 2005.
33. Damasio A. *Looking for Spinoza*. San Diego: Harcourt; 2003.
34. Damasio A. *Tajemnica świadomości. Jak ciało i emocje współtworzą świadomość*. Poznan: Rebis Publishing House; 2000.
35. Damasio A. *The feeling of what happens*. San Diego: Harcourt; 1999.
36. Damasio A. *Jak umysł zyskał jaźń*. Poznan: Rebis Publishing House; 2011.
37. Damasio A. *Self comes to mind. Constructing the conscious brain*. New York, NY: Pantheon; 2010.
38. Damasio A, Carvalho GB. *The nature of feelings: Evolutionary and neurobiological origins.* Nat. Rev. Neurosci. 2013; 14(2): 143–152.
39. Rybakowski J. *Carl Georg Lange (1834–1900) – prekursor neurobiologicznej teorii emocji i leczenia litem chorób afektywnych*. In: Rzepa T, Domański CW, editors. *Na drogach i bezdrożach historii psychologii*, vol. 5. Lublin: Maria Curie-Skłodowska University Press; 2016. P. 81–91.
40. Damasio AR. *The somatic marker hypothesis and the possible functions of the prefrontal cortex*. Philos. Trans. R. Soc. Lond. B Biol. Sci. 1996; 351(1346): 1413–1420.
41. *Gut feeling and digestive health in Nineteenth-century literature, history and culture*. Mathias M, Moore AM, editors. London: Palgrave Macmillan; 2018.
42. Fasano A, Flaherty S. *Gut feelings. The microbiome and our health*. Cambridge, Mass.: The MIT Press; 2022.
43. Dinan TG, Stiling RM, Stanton C, Cryan JF. *Collective unconscious: How gut microbes shape human behavior*. J. Psychiatr. Res. 2015; 63: 1–9.
44. Friston KJ, Frith CD. *Schizophrenia: A disconnection syndrome?* Clin. Neurosci. 1995; 3(2): 89–97.
45. Frith C. *The neural basis of hallucinations and delusions*. C. R. Biol. 2005; 328(2): 169–175.
46. Friston K, Brown HB, Siemerkus J, Stephan KE. *The disconnection hypothesis (2016)*. Schizophr. Res. 2016; 176(2–3): 83–94.
47. Frith C. *Making up the mind. How the brain creates our mental world*. Hoboken, NJ: Blackwell Publishing; 2007.
48. Frith C. *Od mózgu do umysłu. Jak powstaje nasz wewnętrzny świat*. Warsaw: Univerity of Warsaw Press; 2011.
49. Frith CD. *The neural basis of consciousness*. Psychol. Med. 2021; 51(4): 550–562.
50. Bruner E, Preuss TM, Chen X, Rilling JK. *Evidence for expansion of the precuneus in human evolution*. Brain Struct. Funct. 2017; 222(2): 1053–1060.
51. Damasio A. *Odczuwanie i poznawanie. Jak powstają świadome umysły*. Krakow: Copernicus Center Press; 2022.
52. Damasio A. *Feeling and knowing. Making mind conscious*. New York, NY: Pantheon; 2021.
53. Frewen P, Schroeter ML, Riva G, Cipresso P, Fairfield B, Padulo C et al. *Neuroimaging the consciousness of self: Review, and conceptual-methodological framework*. Neurosci. Biobehav. Rev. 2020; 112: 164–212.
54. Seth AK. *Interoceptive inference, emotion, and the embodied self*. Trends Cogn. Sci. 2013; 17(11): 565–573.

55. Seth AK, Bayne T. *Theories of consciousness*. Nat. Rev. Neurosci. 2022; 23(7): 439–452.
56. Berlucchi G, Marzi CA. *Neuropsychology of consciousness: Some history and a few new trends*. Front. Psychol. 2019; 10: 50.
57. Graziano MSA. *Rethinking consciousness. A scientific theory of subjective experience*. New York, NY: W.W. Norton & Company; 2019.
58. Graziano MSA. *A conceptual framework for consciousness*. Proc. N Y Acad. Sci. 2022; 119(18): e2116933119.
59. Von Ditfurth H. *Der Geist fiel nicht vom Himmel*. Hamburg: Hoffman und Campe; 1976.
60. Von Ditfurth H. *Duch nie spadł z nieba*. Warsaw: State Publishing Institute PIW; 1981.
61. Bloom P. *Descartes' baby. How the science of child development explains what makes us human*. New York, NY: Basic Books; 2004.
62. Rybakowski J. *Człowiek, który odkrył wyspę i stworzył termin „psychiatria"*. Psychiatra 2022: 36(1): 72–75.

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