

PHYSICS OF OUR DAYS

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Uncertainties in comparing a human and an android robot

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Contents

Abstract. **It is shown that one of the significant results of human creativity in the 21st century has been the creation of android robots equipped with artificial intelligence. The level of perfection of these robots is becoming so high that it will soon be impossible to establish differences between them and living people by their external features and behavior. This leads to a logical fallacy: to equate humans and android robots, assuming that both have consciousness. Today, scientific research has expanded the understanding of the phenomenon of consciousness, but problems with its definition have not disappeared. The article provides evidence that the application of the term consciousness to android robots is a mistake that can lead to serious consequences.**

Keywords: virtual models, bioevolution, value of information, hormones and emotions, artificial intelligence systems, android robots

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1. Introduction to the problem and statement of the task

1.1 Problems arising in connection with the definition of the term 'human consciousness'

Many attempts have been made to define the term 'human consciousness' from the physics perspective. For example, Karl Pribram formulated the hypothesis of the holographic basis of *consciousness* [1] taking advantage of X Everett's idea concerning the parallel existence of many worlds [2]. This idea was used by M B Menskii, who tried to explain the phenomenon of *consciousness* [3]. Finally, the hypothesis of M I Rabinovich and M K Muezzinolu should be mentioned. In their article (Ref. [4]), these authors proposed a model of emotional and cognitive activity of the brain based on the study of transient processes in phase space. However, the list of researchers who contributed to defining *consciousness* is not exhausted by the three aforementioned studies; in fact, it is very extensive. The term *consciousness* did not lend itself to a meaningful definition that could satisfy both physicists and neuroscientists for three main reasons: two mistakes in the classification of biosystems and the use of the term *consciousness* as applied to different sets of objects.

First, the classification of concepts used in biology is based on a *bottom-up generalization*, i.e., from the particular to the general. This is the transition from concepts with a smaller number of constituent sets and a larger number of their characteristics to concepts with a larger volume of the sets of concepts but a smaller number of their features. The generalization is the extension of the scope of a concept while sacrificing many features in favor of abstraction. For example, generalizations in biology are transitions along the chain: *Individual → Species → Genus → Family → Class → Section → Kingdom → Domain → Life*. The transition occurs with the successive exclusion of a number of features, e.g., starting from *Individual* followed by *Species*, etc. The maximum generalization in this chain is a philosophical category termed *Life* as it is.

Second, there is an operation opposite to generalization; it is the restriction of concepts. It can come from the philosophical maximum top-bottom generalization but according to other characteristics, such as *Life → Consciousness → Sociability → Information → Emotions → Creativity*. At the same time, one should neither confuse *Information* (as an intangible, ideal category) with its Carrier (the material category) nor equate the *Android as a product of human creativity and the Human itself*.

Human *creativity* is a broader concept than its concrete specific products. *Creative* work brings about a variety of findings and discoveries in various fields of human activity, such as painting, music, architecture, literature, and engineering. The creation of android robots is just a special case of *human creativity*. An android robot is an engineering simulation of human features.

Third, *consciousness* of one individual is not identical to that of another. Even identical twins can differ significantly in their views of the outside world. It will be shown further that it is possible to measure the similarity of people's *consciousness* only in relative units. This fact most clearly reveals the uncertainty of the definition of *consciousness* through a comparison of human behavior with that of so-called creative android robots (CARs).

It is estimated that the human brain contains ~100 billion neurons, with even more glial cells and nerve connections. Over the last 20 years, owing to the development of positron emission tomography (PET), electroencephalography (EEG), functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), functional infrared spectroscopy (fNIKS), electromagnetic stimulation of the brain (EMS), transcranial electromagnetic brain scanning (TES), and neurophotonics [5–7], we have learned more about the functioning of the brain than in the previous 300 years of its study [8].

However, there are still no answers to many questions: e.g., is it possible to introduce sets of new skills directly into the human brain, bypassing its receptor systems? Is there a way to perform video recording of the images of memories and dreams arising in the brain? Will people be able to improve their consciousness with the help of genetic engineering or control of biochemical (e.g., hormonal) activity? Can targeted control of brain action by magnetic fields endow an artificial cognitive system with consciousness?

To answer the last question, it is necessary, first of all, to understand from the biophysical standpoint what *human consciousness* is. Ask a psychologist: 'What is consciousness'? Many will answer that it is something akin to 'my self' or 'my soul' or another similar entity. A second question immediately arises: what is the *soul* from the physics point of view? For a materialist, this ends the discussion, the *soul* being an immaterial entity, the existence of which is based on faith and needs to be considered in the theological context.

An Internet search reveals many definitions of the term *consciousness*. Almost 100 of them are currently known. Table 1 contains, by way of example, only 12 definitions.

Table 1. Examples of definitions of human consciousness.

1	The state of a person in sound mind
2	The ability to correctly reflect phenomena of reality
3	The ability to relate oneself to the external world
4	The highest form of mental reflection of reality as a generalized and subjective model of the outside world based on verbal concepts and sensory images that developed in the course of social life
5	The highest level of mental reflection of objective reality and the highest level of self-regulation inherent in the human subject as a social being
6	The state of a person's mental life expressed in subjective feelings related to events of the external world and personal life as well as self-reporting these events
7	The ability to separate one's 'self' from other people and the environment ('not myself') based on the adequate reflection of reality through the communication facilitated by verbal contacts and individual life experience
8	The process of forming a model of the outside world in the brain based on the analysis of many different parameters (temperature, position in space and time, attitude to other people) with a view to achieving certain goals (searching for a sexual partner, food, shelter)
9	A necessary prerequisite for thinking because we distinguish ourselves from the environment only by means of mental activity that generates cognitive functions. Consciousness includes thinking as its integral component
10	Knowledge that can be transferred to other people with the help of words, mathematical symbols, generalizing images, and works of art and literature in order to become the property of all members of the society
11	The state of the inner world of a person able, on the one hand, to arbitrarily introduce into the sphere of consciousness one idea or another that was previously present in his (her) memory, and on the other hand, to analyze his (her) own mental processes. Memory is an integral part of consciousness
12	A means outside of which there is no knowledge, experience, or human

The list of them can be extended ad infinitum. Over 25,000 articles and monographs concerned with this topic have been published over 300 years. Until the mid-20th century, one of the dominant psychological theories was *behaviorism*,[1] which, in general, denied the expediency of introducing the term 'consciousness' into neuroscience for the simple reason that objective knowledge about animals and humans should be based on the study of their behavior rather than come from subjective assessment of the state of their mind, poorly known to researchers.

Why is it not possible to build up a *universal and meaningful model of consciousness* covering all aspects of human activity? There are at least 12 scientific disciplines trying to improve our understanding of this term (Fig. 1).

It should be noted that a human subject undertaking the processing of information always has a goal along with informational emotional coloring of the process of its achievement. Representatives of different cultures have different sets of basic emotions apparent from the person's facial expression, gestures, or altered physiological para-

[1] Behaviorism (from the English *behavior*) suggests that all human actions consist of behavioral reactions that respond to certain stimuli.

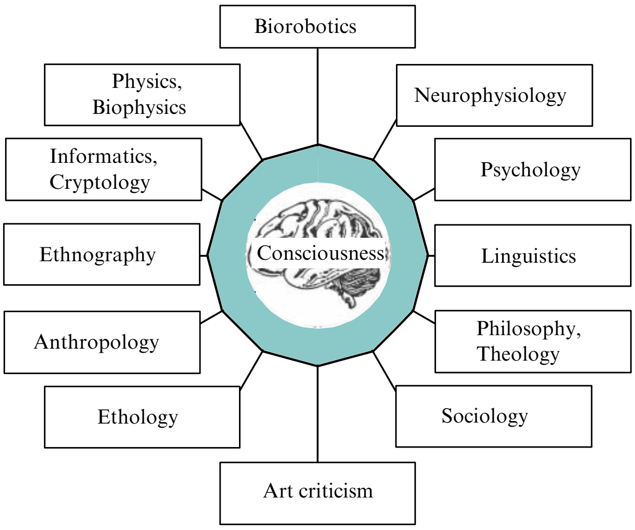

Figure 1. List of sciences contributing to the study of human consciousness.

meters, e.g., the face turning red or white, sweating, or tremors. The basic set of emotions includes fear, anger, disgust, attraction, happiness, sadness, and surprise.

A tree-like list of emotions was proposed at the end of the last century with variations in subsequent publications [9, 10]. Table 2 presents the list of emotions substantially reduced to five.

Attempts to give a meaningful definition to the term *consciousness* have a long history. More than 300 years ago, the mathematician and philosopher Gottfried Wilhelm von Leibniz (1646–1716) tried to offer his own definition of the term. Originally, he was impressed by the ideas of René Descartes but later rejected Descartes's dualism in the 'soul and body' form (i.e., gave up the idea of a binary interpretation of 'consciousness') and came to the idea of pluralism [2] of the variants of consciousness [11].

Based on the continuity of change and development of various living organisms and their natural diversity, Leibniz proposed a dynamic union of a multitude of the so-called monades (i.e., a set of spiritual indivisible 'units') as a model of 'consciousness.' [3] Criticizing Cartesian dualism, he wrote: *If we could inflate the brain to the size of a windmill and examine all its contents then, all the same, we would nowhere find consciousness* [12].

In 1929, the American philosopher Clarence Irving Lewis published a small book called *Mind and the World Order. Outline of the Theory of Knowledge* [13] in which he used the then commonly accepted term *qualia* (from the Latin *qualitas* (sing.) 'properties, qualities') to designate sensory phenomena of any kind. Briefly, *qualia* are the properties of sensory experience on which the model of the external world formed in the brain depends.

For example, some people can hear sounds up to 20 kHz while others have a sound perception bandwidth limited to 14 kHz. Colorblind people do not distinguish colors. For synesthetes, sounds or letters are painted in different colors [14]. It is impossible to explain to a person who has been blind since early childhood the meaning of red or green, since the concept of *color* is absent in his (her) inner world. Such people live in the world of sounds, smells, and various tactile sensations. Naturally, neurophysiologists may doubt that modern physics can describe *qualia and consciousness*, because a variety of perceptions of the external world are likely to turn out to be 'things-in-themselves.' [4] In other words, qualia being virtual models of the external world in the brain of different people can vary significantly and interfere with communication between them.

Other attempts have included, for example, the work of the Russian psychophysiologist P V Simonov (1926–2002) who tried in the mid-20th century to provide a scientific justification for the key concepts of general psychology (consciousness and emotions). He wrote: *Science is based on the principles of presumption of the proven. Everything else belongs to the realm of faith, but one can believe in anything* [15].

However, it is impossible to reliably prove everything; hence, the necessity to use the probabilistic approach to estimating evidence. Simonov assumed that emotion E is a function of the form $E = f[P, (I_P - I_S)]$, where E is the emotion, its quality and sign; P is the strength and the quality of an actual need; $(I_P - I_S)$ is the assessment of the possibility of satisfying a need based on innate and ontogenetic experience; I_P is information about the means necessary to meet the need; and I_S is information about the means that the subject has at the moment. This idea of Simonov's to describe the key basic functions in terms of probability was recognized as quite reasonable and became widespread. Obviously, when the deterministic world becomes stochastic, many uncertainties appear and orientation is described in terms of probability.

Forty years ago (August 1982), the First All-Union Biophysical Congress was held in Moscow. It was attended by more than 2,000 biophysicists and specialists representing related sciences [16]. While preparing for this meeting, we tried to outline the field of action of biophysics as a science. It was emphasized that *biophysical research involves heterogeneous biological objects and a variety of physical phenomena.... Independent sections of biophysics are combined with each other either via common structural levels of the study objects and physical entities or by the elucidation of similar functional features of various processes as well as by virtue of the unified approach to the circle of general problems*.

These conclusions summed up the discussions carried out at that time. They confirmed the status of biophysics as a *systemic science*. The bottom-up hierarchical classification of the structure and functions of living matter still stands and remains relevant (Table 3).

In 2009, I published an article entitled "The 21st century: what is life from the point of view of physics" [17], in which I tried to show how our knowledge has changed over the 65 years after the publication of Erwin Schrödinger's book under almost the same title, *What is life from the point of view of physics?* The article presented 10 features that are usually cited in textbooks on physiology as the main signs of living systems (Table 4).

[2] Pluralism (from the Latin pluralis — multiple) is a philosophical standpoint proclaiming the existence of a few or many principles, forms of being, foundations, forms of knowledge, or behavioral styles, independent and irreducible to each other.

[3] According to Leibniz, all phenomena are produced by the so-called monads (from Greek monados — unit, a simple entity). The monads have no parts and tend to unwrap as they interact during movement while bringing all material substances into a state of interaction.

[4] Immanuel Kant used the term 'thing-in-itself' (German *Ding an sich selbst betrachtet*) in his work on the theory of knowledge (*Critique of Pure Reason*, etc.). He included in this notion warmth, color, taste, space, time, and the like. We feel their presence but can not understand them based on sensory experience.

Table 2. Three-level list of emotions.

No.	Primary emotion	Secondary emotion	Tertiary emotion
1	Love	Attachment	Adoration. Softness. Sympathy. Attraction. Care. Compassion. Sentimentality. Jealousy
		Lust. Sexual desire	Desire. Passion. Infatuation
2	Joy	Cheerfulness	Entertainment. Bliss. Jubilation. Joy. Delight. Pleasure. Happiness. Satisfaction. Ecstasy. Euphoria
		Pursuit	Enthusiasm. Zeal. Excitement. Acute sensations. Excitation
		Satisfaction	Pleasure
		Pride	Triumph
		Optimism	Passionate desire. Hope
		Passion	Admiration. Delight
3	Delight	Surprise	Amazement
4	Anger	Irritability	Aggravation. Excitation. Grouchiness. Cross-matching
		Irritation	Disappointment
		Rage	Disturbance. Hostility. Ferocity. Bitterness. Hatred. Contempt. Resentment. Malice. Vindictiveness. Dislike
		Disgust	Hatred. Contempt
		Envy	Jealousy. Torment
		Sadness	Depression. Darkness. Misfortune. Woe. Sadness. Melancholy
		Disappointment	Anxiety. Discontent
		Shame	Guilt. Regret. Remorse
		Neglect	Alienation. Defeatism. Despondency. Confusion. Homesickness. Humiliation. Uncertainty, Abjection. Isolation. Loneliness. Rejection
5	Fear	Terror	Shock. Anxiety. Fear. Fright. Panic. Hysteria. Humiliation
		Nervousness	Uneasiness. Tense expectation. Anxiety. Concerns

Table 3. Hierarchical structure of living matter (structure and function).

No.	Structural hierarchy	Hierarchy of emerging additional structural functions
1	Quantum and atomic levels	Energy conversion mechanisms
2	Low molecular weight compounds	Mechanisms of environmental influence
3	Macromolecular compounds	Spatial mobility mechanisms
4	Viruses and bacteriophages	Reproduction mechanisms
5	Cell organelles	Process kinetics and biological clock
6	Cells and bacteria	Mechanisms of information perception
7	Tissue	Information processing mechanisms
8	Organs	Pattern recognition mechanisms
9	Organ systems	Resilience mechanisms
10	Organisms	Thinking and memory mechanisms
11	Social systems	Competition mechanisms
12	Humankind	Consciousness mechanisms

At the same time, it was shown that all these signs are also inherent in systems of an inanimate nature. In other words, no *new physics* is required to describe living systems. All their functions can be described in terms of known physical laws. In short, biology does not need the 'things-in-themselves' conception. My article caused a long discussion in journals and on the Internet that lasted for more than 10 years [18]. Only three related terms, *consciousness, meditation* ('changes in the state of consciousness'), and *soul* were dropped from the discussion due to their expressed uncertainty.

Table 4. Characteristics of living matter.

1	Living organisms have an *ordered hierarchical organization*
2	Living organisms are *open systems* that receive energy from the environment and use it to maintain their high orderliness
3	The ability to *respond to external influences* (reception) is a universal property of all living systems
4	The ability to *remember information* about previous states and adapt to changing external conditions
5	The ability to *change and become more complex*
6	The ability to *reproduce*
7	The ability to *self-regulate and heal from injuries*
8	The ability to *exchange substances* with the environment
9	The ability to be *directionally mobile*
10	Living beings exist in a *nonequilibrium state*

It can be speculated that Leibniz's monades as well as Lewis's qualia supplemented with the probabilistic estimates as proposed by P V Simonov can be collected into something that might be called *consciousness* as the highest function of developing living matter.

1.2 Approaches to creating a model of consciousness

Let us accept as a hypothesis (its validity and limitations will be proven later) that *consciousness S* is a function of at least two simultaneously existing and interacting worlds inside the human body that naturally undergo changes as the body grows (Fig. 2a). They are the world of emotions based on the biochemical (hormonal) milieu E_n and the world of information, based on neural networks I_m. The boundaries of neural clusters define the boundaries of qualia, i.e., areas of sensory perception of the external environment in the cerebral cortex (Fig. 2b). *Consciousness S* is the function of the interaction between the two worlds $\mathrm{E}_n \leftrightarrow I_m$:

$$
\begin{aligned}
S &= F(\mathrm{E}_n \leftrightarrow I_m)\,, \\
\mathrm{E}_n &= f(t, \tau_{\mathrm{E}}, D_{\mathrm{E}}, h_{\mathrm{E}}, J_{\mathrm{E}})\,, \qquad (1)\\
I_m &= f(t, \tau_{\mathrm{I}}, D_{\mathrm{I}}, h_{\mathrm{I}}, J_{\mathrm{I}})\,,
\end{aligned}
$$

where $n = 1, 2, 3 \ldots N$, $m = 1, 2, 3 \ldots M$, t is external astronomical time τ_{E}, τ_{I} is internal time inside each of the worlds in the system, D_{E} and D_{I} are coefficients of diffusion, h_{E} and h_{I} are coefficients of cross-advection [5] J_{E} and J_{I}, respectively.

These two worlds are encompassed by feedback $\mathrm{E}_n \leftrightarrow I_m$ in relation to each other and react to changes in the external environment, thus maintaining the stability of the organism. The upper world (cerebral cortex) can determine, through qualia on the basis of pattern recognition, the interaction of internal processes in the body with processes in the real world; also, it allows distinguishing in the outside world a real person endowed with emotions, thinking, and consciousness from a machine equipped with artificial intelligence. In the framework of the theory of relativity, this process can be interpreted from the standpoint of an external observer [19].

[5] The term advection originates from the Latin *advectio* — delivery. In hydromechanics, the term convection is often used instead of 'advection.' In oceanology, advection is the movement of water masses in a horizontal plane (without mixing), and convection is the vertical movement of water masses with mixing. To describe the operation of the brain, advection is understood as the branching transfer of information between different parts of the brain with the accompanying changes in emotions.

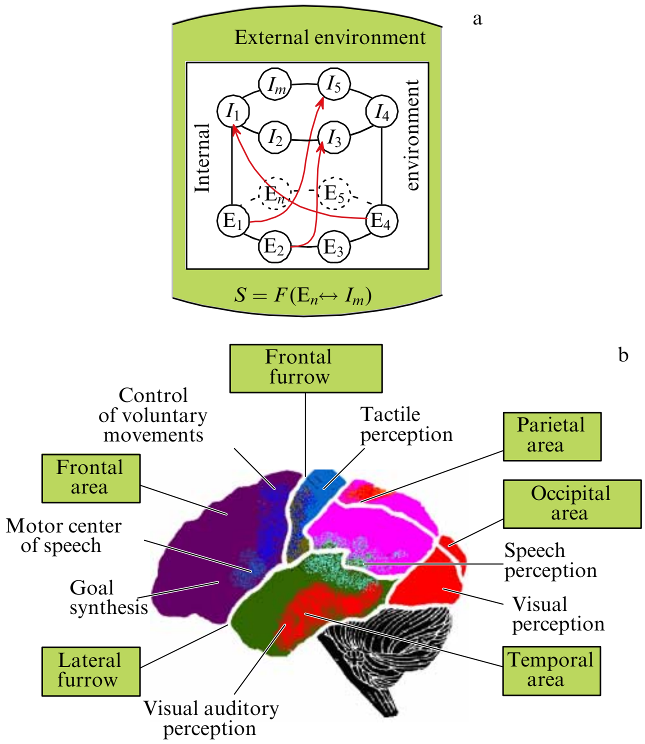

Figure 2. Human *consciousness S* is a function of the interaction between the biochemical world of emotions and the world of information I_m based on neural networks (a); location of qualia zones in the human brain (b). Green boxes indicate spatial location of the functional zones in the neocortex, although their delocalization is conditional because of their mobility and is terminated (advection).

It will be shown below that an essential element of both function E_{n} and function I_m is the diffusion-controlled autowave model with cross-diffusion + cross-advection [20, 21] based on the competition between a set of opposite emotions (e.g., joy ↔ despair) and images recognized during information processing [22].

It can be assumed that the process of formation and development of *consciousness* can be described in terms of the Darwinian concept of evolution of living matter with the analysis of functional behavioral changes, beginning with bacteria to primates and including the appearance of humans. However, such an approach always leads to uncertainty, which makes the definition of consciousness a probabilistic process. Human consciousness differs from the existing systems of artificial intelligence. Moreover, the situation will hardly change as long as artificial systems are created on a different physical and chemical basis.

2. Interweaving of the properties of consciousness in the process of bioevolution

2.1 Zero level of consciousness

All animals possess an intrinsic model of the external world. Historically, the first stage of formation of the *adaptive model* began on the basis of instincts about 3.5 billion years ago and lasted till 2.5 billion years ago, i.e., up to the appearance of the oxygen atmosphere on Earth. With the development of the nervous system some 500 million years ago, the adaptive genetic model was supplemented by a changing model based on learning. Gradually, the model became more complicated under the influence of RNA and DNA mutations, the appearance of and changes to the nervous system, and evolutionary selection. The first human (the hominid Australopithecus) appeared on Earth roughly 3.5 million years ago.[6] Due to their well-developed memory, those ancient people were capable of reversing time forward and backward in their cerebral virtual model without an appreciable loss of information. Nevertheless, they were likely to make mistakes by way of wishful thinking as they built up the model. This accounts for the appearance of prejudices and false hypotheses.

At this first stage of information processing and the emergence of *consciousness*, uncertainty arises, since the past influences formation of the future through the present. However, such influence can not be determined a priori with high accuracy. The prediction horizon in nonlinear systems is always limited [23]. It can be noted, paraphrasing a classic, that "*we can not know how a change will respond*." The notion of information, estimation of its value, and emotional coloring will be considered in the next section.

However, the bottom-up tracing of the first stages in the birth of *consciousness* suggests that classification of the levels of its development should be started from plants and bacteria rather than animals. This level of *consciousness* is called *zero level* [24]. Only in some respects are plants similar to animals, mollusks to reptiles, reptiles to mammals, and so on up to humans. At different stages of evolution, confusion of the emotional and informational worlds took place.

Most plants are weakly mobile. They conquer space by means of reproduction, i.e., seed transfer or expansion of their root system. Also, they strongly depend on the change of seasons. This mode of existence can be described in terms of spatial displacement, i.e., *advection*. As far as adaptation is concerned, plants respond to a limited set of parameters, such as fluctuations in solar radiation, air temperature, humidity, atmospheric pressure, wind, illumination, and mineral and organic composition of the soil. Nevertheless, plants can exchange information with one another using volatile organic substances. Moreover, they appear to react to danger from insect pests and display adequate defensive mechanisms. They also respond in various ways to odorous substances. However, these behavioral traits cannot be regarded as true emotions that are inherent by definition in organisms having interacting nervous and hormonal systems. Plants do not have a nervous system.

There are carnivorous plants, exemplified by the *Venus flytrap* (*Dionaea muscipula*) that have special receptors to deceive insects and arthropods (ants, spiders, grasshoppers, other flying species) which they attract with pleasant smells in order to eventually turn them into victims and ingest them as food [25]. Such a foraging strategy partially blurs the boundary between the worlds of plants and animals (Fig. 3).

As far as bacteria are concerned, they do not have a nervous system either. They search for food and form colonies due to mobility, orienting themselves in space by virtue of a taxis, choosing the direction of movement towards a food source (attractant) or from sources of danger (repellent) by determining the concentration gradient of attractants and repellents. To determine the change in the trajectory of its movement, the bacterium has to 'calculate' the concentration gradient and recognize the direction towards the attractant or away from the repellent, i.e., it must have memory for at least one step of its movement. The individual speed of traveling bacteria depends both on their specific mobility and on the physical properties of the medium (viscosity, temperature, mobility of the medium itself, concentration of repellents and attractants) [26].

It was shown that, during the organization of colonies, moving bacterial waves can produce macroejections consisting of bacteria which, while moving, were split off the main bacterial population wave. In this way, bacterial colonies with outgrowths are formed, this process being a variant of advection (Fig. 4).

All these effects are available by modeling and simulation with the introduction of nonlinear diffusion, which ensures transition from ring waves (leading centers) to branching structures [27, 28]. For different forms of growth of bacterial colonies, specifically for *E. coli JM103*, the following propagation velocities of bacterial waves were reported: the main wave had a speed of 4–9 mm h^{-1}, its slowing caused a drop in the ejection rate to 0.5–1 mm h^{-1}, branching development occurred at 0.1–2 mm h^{-1}. It can be conjectured that at a sufficiently low propagation speed of a bacterial wave, fluctuations in the number of bacteria at the leading edge can disfigure it and give rise to clusters. To verify this assumption, we undertook in our laboratory (more than 20 years ago) an experimental study on the propagation dynamics of various sections of the leading front in a growing bacterial colony (*E. coli JM103*). The resulting macroejections apparent at $t = 0$ began to grow and were able to leave the maternal colony within the next 10–50 min. As a result, the boundary of the maternal population became uneven and 'outgrowths' formed from which 'branches' emerged for 50 min. The stages of formation of leading edge instability in a bacterial population wave are shown in Fig. 5.

Moreover, the study showed that individual bacteria can bud off the maternal population if the viscosity of the medium is rather low. Along with the necessity to have as large an area as possible for traveling, reproduction, and the extension of the ecological niche, living organisms show a tendency to accelerate their spatial distribution. However, slowing occurs too if the surrounding area in question is difficult or impossible because it has insurmountable boundaries or is already occupied by competing neighbors. In this case, the population density increases and bacterial clusters with demarcation boundaries form. Such a situation is typical not only of bacteria alone [29].

It is exemplified by the formation of neural networks. The movement of neurons can be observed under a microscope in an *in vitro* culture of nerve cells on the surface of a nutrient medium in a Petri dish during the artificial formation of a neural network. A neuron forming connections (axons and dendrites) sometime moves to the farthest cluster of similar cells rather that to the nearest one. In other words, neurons, similar to bacteria, exhibit a taxis, i.e., tend toward the most attractive neuronal clusters. The mechanism of such attraction remains to be elucidated (Fig. 6).

Various changes in the direction of movement contribute to the formation, growth, and improvement of not only bacterial colonies but also various networks

[6] Discussions about the time of appearance of primates and hominids still continue.

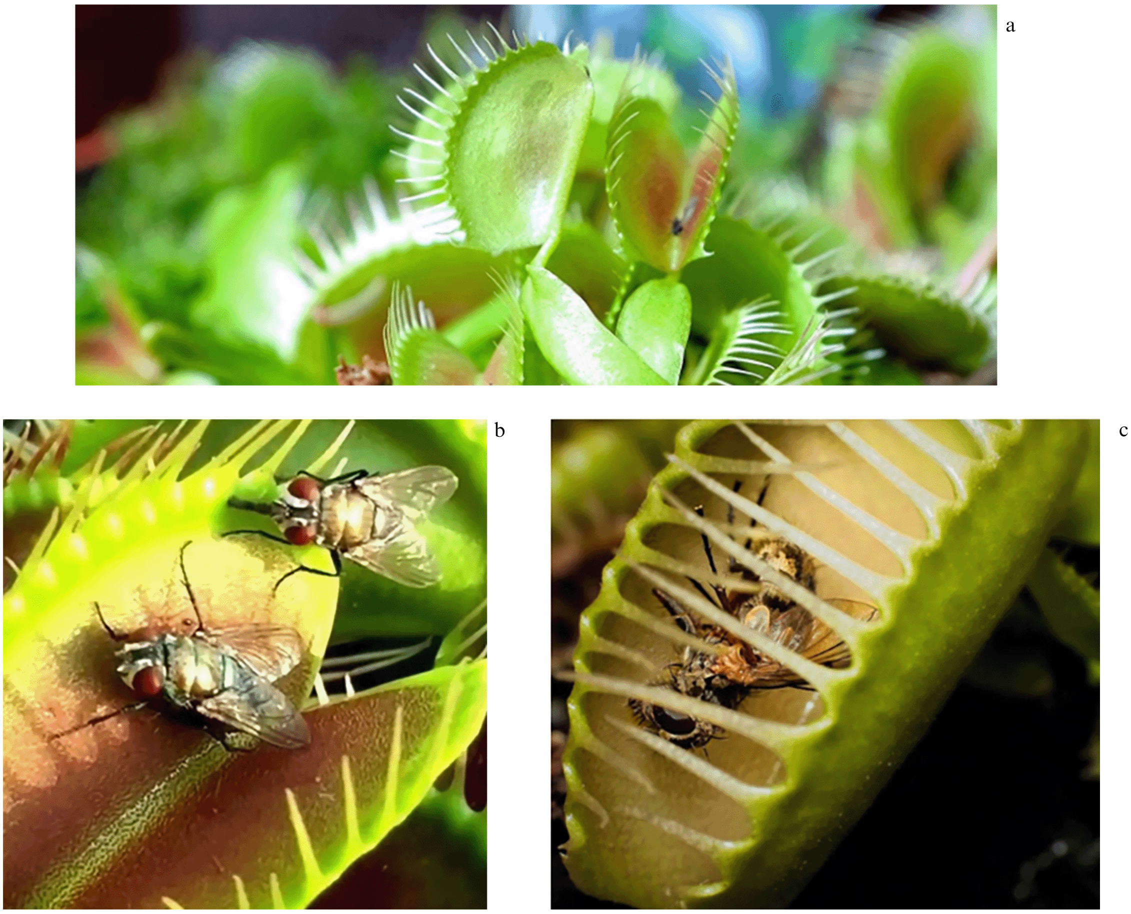

Figure 3. Venus flytrap carnivorous plant captures its victims with the help of a specialized trapping apparatus formed from the marginal parts of the leaves (a). Closing of the trap is initiated by fine sensitive hairs on the inner surface of the leaves. To close the trap, it is necessary to exert a mechanical (b) impact on at least two hairs on the leaf with an interval of no more than 20 seconds. Such selectivity protects against accidental slamming in response to falling random objects, such as raindrops or dust. Closing of the trap and digestion of the prey begin after at least five stimulations of the sensitive hairs inside the trap (c).

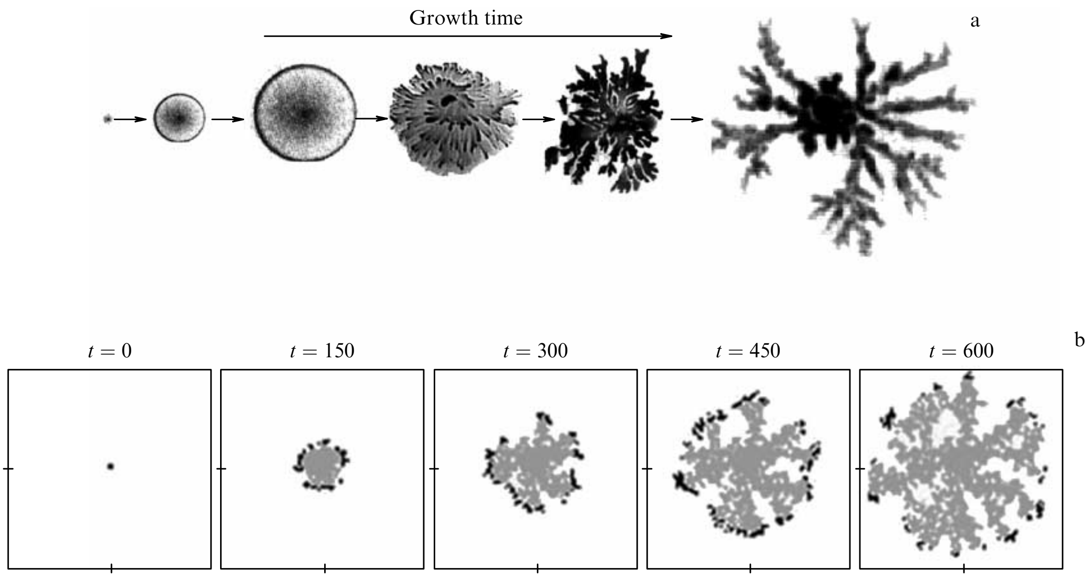

Figure 4. Metamorphoses of the growth of a bacterial colony (*E. coli JM103*) in time: (a) experimentally observed change in the development of the colony structure; (b) model of dynamics of the formation of a branching structure in a model numerical experiment based on a 'cellular automaton' computer model, where t is time in conventional units [26].

(neural or circulatory). A wave in an excitable system with nonlinear cross diffusion changes its diffusion coefficient over space under the influence of moving neighbor waves.

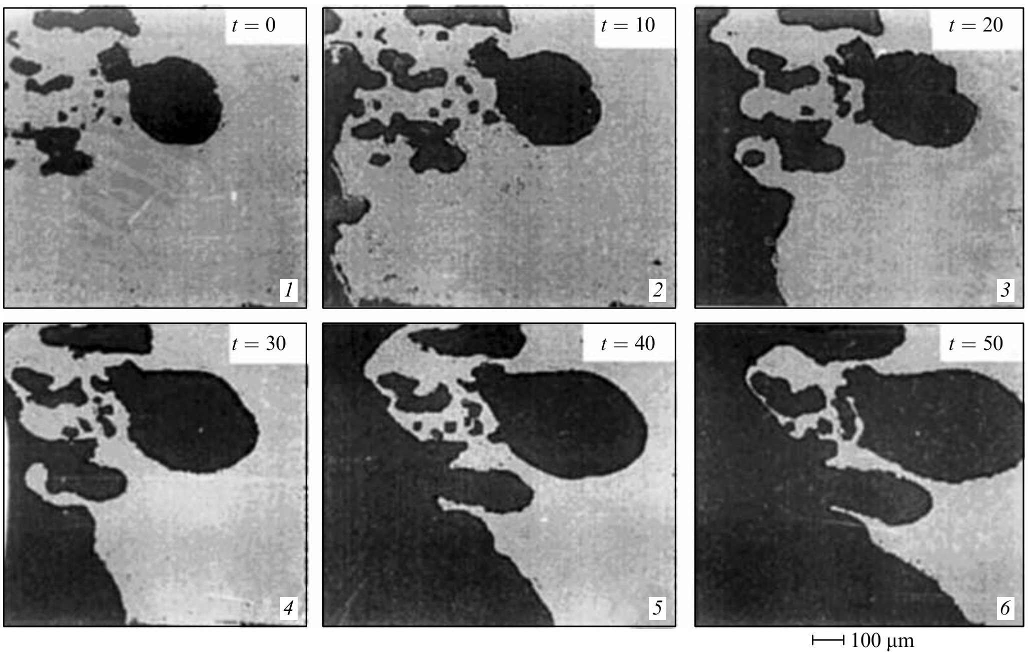

Figure 5. Filmogram of six frames illustrating growth dynamics of the leading front of a bacterial population with macroejections at the leading front of the 'maternal' population. Time t is given in minutes, spatial scale in μm.

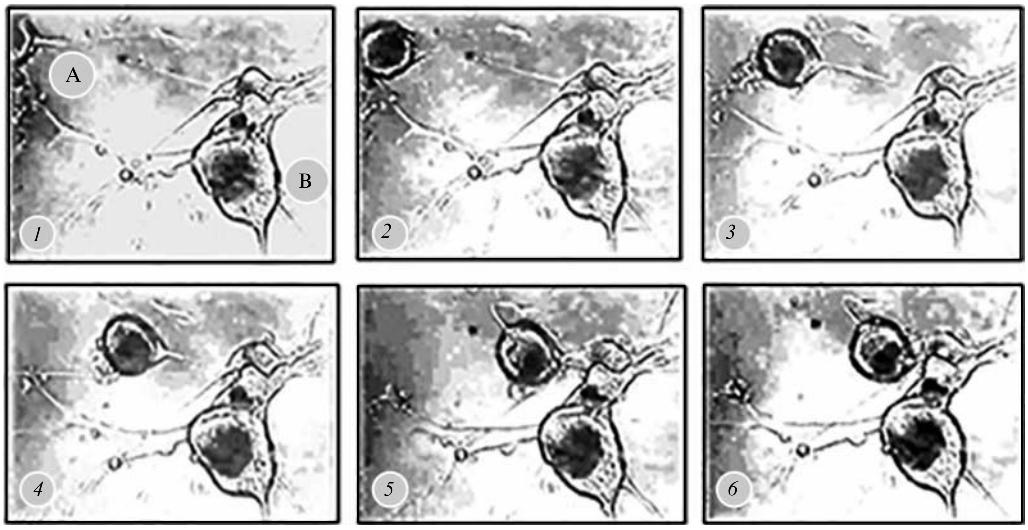

Figure 6. Filmogram of a sequence of frames showing the formation of neural clusters in a petri dish. Neuron A (upper-left corner of frame *1*) moves with a pulsating speed towards the previously formed group of neurons B apparently having a taxis that indicates the direction of movement.

The spatial propagation of an observed wave (in this case, the bacterial or neuronal population wave) described by one of the variables u is associated with the diffusion of another wave described by variable v. The second wave is a deceleration wave (bremsstrahlung). The equations leading to cross activation of motion have the form [30, 31]

$$\frac{\partial u}{\partial t} = \left[u(1-u)(u-a) - v + D_1 \frac{\partial^2 u}{\partial x^2}\right] + h_1 \frac{\partial}{\partial x}\left(Q_1(u,v)\frac{\partial v}{\partial x}\right),$$

$$\frac{\partial v}{\partial t} = \left[\varepsilon(u-v) + D_2 \frac{\partial^2 v}{\partial x^2}\right] - h_2 \frac{\partial}{\partial x}\left(Q_2(u,v)\frac{\partial u}{\partial x}\right), \qquad (2)$$

where u is the accelerator (activator) of motion, v is the inhibitor of motion, a is the excitation threshold, ε is the ratio of acceleration and inhibition time scales, $D_{1,2}$, $h_{1,2}$ are coefficients of self-diffusion and cross diffusion, and $Q_{1,2}(u,v)$ is the cross-interaction parameter. At $h_1 = h_2 = 0$, mathematical model (2) is an ordinary 'reaction–diffusion' autowave with the diffusion coefficients $D_1 \geqslant 0$, $D_2 \leqslant 0$ (at least one $D_i \neq 0$). When at least one of the coefficients $h_i \neq 0$ with any sign, the system becomes cross diffusional. It follows from Eqns (2) that in this concrete case the cross diffusion terms h_1 and h_2 have opposite signs, i.e., cross diffusion demonstrates repulsive rather than attractive competition. A system with parameters (u,v) depending only on time looks like two coupled oscillators, deviations of which are described by expressions $[u(1-u)(u-a)-v]$ and $[\varepsilon(u-v)]$. They characterize the feedback between the acceleration/deceleration functions. In this case, the description of u (acceleration) has roots $u_1 = u_2 = v$ and $u_3 = (u-v)$, where u_3 can take any value.

Cross-diffusion processes lead to spontaneous formation and development of complex ordered dynamic structures. Self-organization of such systems may give rise to *emergence*, i.e., the appearance (due to feedback) of new properties which none of the interacting parts separately possess; hence, the difficulty of accurately predicting the development of the structure. In equations (2), the appearance of new properties depends on the value of the cross-diffusion coefficients in the terms

$$\left[+h_1 \frac{\partial}{\partial x}\left(Q_1(u,v)\frac{\partial v}{\partial x}\right)\right],$$

$$\left[-h_2 \frac{\partial}{\partial x}\left(Q_2(u,v)\frac{\partial u}{\partial x}\right)\right].$$

However, model (2) gives no indication that moving waves can be split into branches necessary for the formation of networks. This requires complicating equations (2) and supplementing them with cross advection. In our recent publication, we reported dynamics of autowaves that simultaneously exhibit both cross diffusion and cross advection [21].

The processes of cross diffusion and cross advection are related, but each of them is characterized by its own variable. The model with cross diffusion and cross advection during wave front collisions was considered earlier in Ref. [20]. The system of equations for the combinations of cross diffusion with cross advection has the form

$$\frac{\partial u}{\partial t} = u(1-u)(u-a) - v + D\frac{\partial^2 u}{\partial x^2} + h_1\frac{\partial^2 v}{\partial x^2} + J_1\frac{\partial v}{\partial x},$$
$$\frac{\partial v}{\partial t} = \varepsilon(u-v) + D\frac{\partial^2 v}{\partial x^2} - h_2\frac{\partial^2 u}{\partial x^2} - J_2\frac{\partial u}{\partial x}. \quad (3)$$

Expression (3) differs from expression (2) in that additional terms with the coefficients $+J_1$ and $-J_2$ are introduced to determine the magnitude of cross advection. In this case, another process occurs that shifts the equilibrium point to the two aforementioned ones, i.e., acceleration (activation) and deceleration (inhibition). In this case, along with mutual control of 'acceleration ↔ deceleration,' there is an additional control of 'changing the direction of movement of part of the wave.' Figures 7 and 8, below, compare changes in wave velocity, first only during cross diffusion (Fig. 7), then only during cross advection (Fig. 8), as a function of their coefficients h and J.

Cross diffusion controls the second derivative with respect to space by lowering the acceleration of the diffusive motion while cross advection decreases cross velocity, i.e., it is the first derivative with respect to the movement in space. Consequently, there are two ways of space control inside the loop. In this case, one control is diffusional, the second is directional.

We have considered a special case where $h_1 = h_2$, $J_1 = J_2$, and $\varepsilon = 1$, i.e., when there is no discrepancy between time scales in the external environment and in the internal process. For an analytical solution to the system, one can apply the piecewise linear McKean approximation [32, 33], where cubic nonlinearity in the activator equation is substituted by the Heaviside function $H(u-a)$. As a result, model (3) is converted to (4), convenient for calculations and described

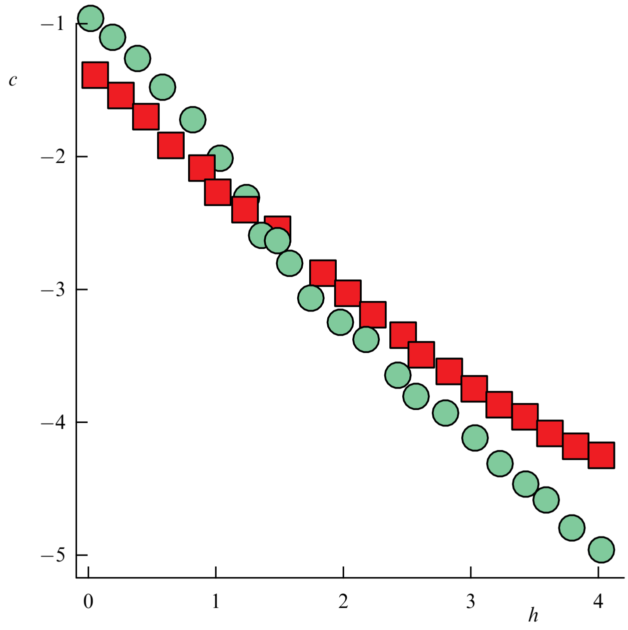

Figure 7. Wave speed c as a function of the cross-diffusion coefficient: $c = c(h)$. Values of the excitation threshold and ratio of time scales of self-diffusion and cross-advection coefficients are fixed and equal to $a = 1/4$, $\varepsilon = 1$, $D = 1$, and $J = 1$. Results of analytical calculations are marked by green dots, results of simulation modeling, by red squares.

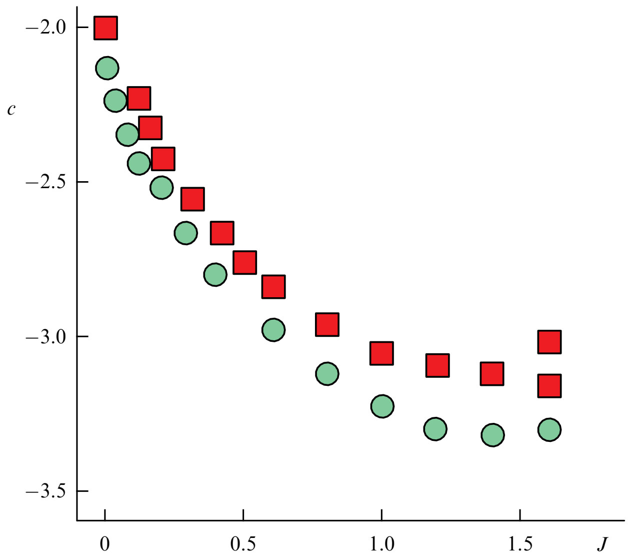

Figure 8. Wave speed c as a function of the transverse advection coefficient: $c = c(J)$. Values of the excitation threshold and ratio of time scales of self-diffusion and cross-diffusion coefficients are fixed and equal to $a = 1/4$, $\varepsilon = 1$, $D = 1$, and $h = 2$, respectively. Results of analytical calculations are marked by green dots, results of simulation modeling, by red squares.

by the expressions

$$\frac{\partial u}{\partial t} = -u - v + H(u-a) + D\frac{\partial^2 u}{\partial x^2} + h\frac{\partial^2 v}{\partial x^2} + J\frac{\partial v}{\partial x},$$
$$\frac{\partial v}{\partial t} = \varepsilon(u-v) + D\frac{\partial^2 v}{\partial x^2} - h\frac{\partial^2 u}{\partial x^2} - J\frac{\partial u}{\partial x}. \quad (4)$$

Simulation modeling in the framework of this model reveals nonobvious modes of behavior, since the change in velocity

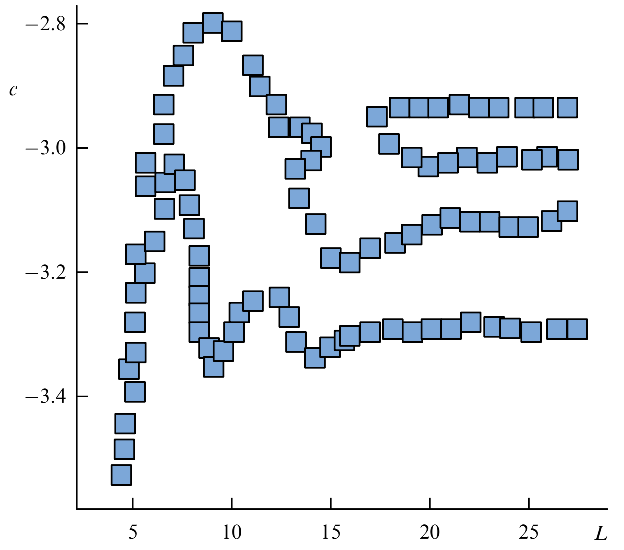

Figure 9. Velocity of a wave train as a function of step interval L, $c = c(L)$, with strong transverse advection when cross advection coefficient $J > 1$. In the calculation, it is fixed at the level $J = 1.6$. The remaining parameters are $a = 1/4$, $\varepsilon = 1$, $D = 1$, and $h = 2$. Oscillatory and discontinuous flows in the form of a *pitchfork with two branches* are shown.

here depends not only on diffusion but also on the size of directed steps in space. Feedback changes the shape of ejections and their portraits. Figure 9 presents an example of a change in the speed of trains under the combined action of cross diffusion and cross advection.

In this case, the form of the phase relations 'acceleration ↔ deceleration (u, v)' changes too [21]. Unlike human cells, bacteria are almost immortal. For example, the *E. coli* bacterium divides approximately every 20 minutes and can continue to divide till it encounters a lack of nutrition, extreme heat or cold, harsh radiation, or harmful chemicals. Many bacteria die under extreme conditions while others undergo sporification to wait for the resumption of normal conditions for reproduction.

Zero gradation (the absence of even primitive signs of *consciousness*) includes not only plants and bacteria but also viruses, fungi, and many insects species, i.e., all organisms whose lifestyle depends solely on innate instincts.

2.2 New stage of development: complication of movement and healing from injuries

Among the inhabitants of the seas, benthic cephalopods, which appeared approximately 500 million years ago, have always caused astonishment. For example, the common octopus has the most developed brain among invertebrates in which the neocortex begins to form [34]. The nervous system of the octopus consists of 500 million neurons (for comparison, rats and cats have 200 and 700 million, respectively). Of course, it is an insignificant number compared with the roughly 20 billion neurons in the human cerebral cortex alone. The octopus's neurons are not only concentrated in the middle of the body around the stomach but are also scattered throughout its remaining parts and form complex connections with other internal structures. A large number of neurons are located in limb ganglia. In a word, the brain of an octopus is distributed throughout its body.

The octopus's life-regulation system is a specialized set of regionally distributed mobility control mechanisms. The octopus viewed as a whole is actually a 'jelly brain,' malleable and viscous (Fig. 10).

Each octopus tentacle functions under autonomous self-control. Taken together, the tentacles can move in three-dimensional space creating different combinations of directions for body movement. At the same time, the number of degrees of freedom for motion increases sharply and is equal to the number of permutations P_n, where $n = 8$:

$$P_n = 8! = 1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8 \approx 4 \times 10^4 \,. \quad (5)$$

This number of degrees of freedom is supplemented by a set of independent contractions of each tentacle muscle. If the environmental conditions change at the rate

$$v_{\text{en.co.}} = a_{\text{en.co.}} t_{\text{en.co.}} \quad (6)$$

where $a_{\text{en.co.}}$ is the acceleration of environmental changes and $t_{\text{en.co.}}$ is environmental time, then each moving tentacle can compensate or use a change in the environment. In other words, an octopus with the goal of movement in three-dimensional space moves towards it. In addition, an octopus can remain motionless relative to the bottom without using its suckers even when water flows are being displaced. It just hovers in the water column like a helicopter or just moves over a wide range of speeds. To enable the octopus to behave like this, the condition $v_{\text{en.co.}} = v_{\text{oc.}}$ must be satisfied, corresponding to the proportion

$$\frac{t_{\text{en.co.}}}{t_{\text{oc.}}} = \frac{a_{\text{oc.}}}{a_{\text{en.co.}}} \,, \quad (7)$$

where $t_{\text{oc.}}$ and $a_{\text{oc.}}$ are internal time and acceleration of contraction and expansion of each tentacle, respectively. Moreover, the common octopus has two rows of suckers on each tentacle with 120 of them in each row. All in all, the octopus has 1920 suckers. In order for each sucker to be able to locally regulate its position, it must have six degrees of freedom, i.e., two antagonist muscles per axis (x, y, z) and two muscles that regulate the force of clinging to an outside object and relaxation of suction, i.e., a total of eight muscles. This gives an additional 15,360 adjustable degrees of freedom.

Furthermore, on each tentacle, there are up to ten thousand taste buds that determine whether the object grasped by the octopus is edible or inedible. Therefore, to the degrees of freedom for movement (40,320 + 15,360), another 80,000 adjustable reception systems are added. Altogether, this makes up 135,680 degrees of freedom for the octopus.

Along with this, the octopus has three pumps inside the body which can be called hearts: one drives blood throughout the body, and the other two push fluid through the gills. The blood of an octopus is blue because the carrier of oxygen is copper rather than iron as in human hemoglobin [36]. On a hard surface (including a sheer one), the octopus crawls using its suction cups. It can also swim forward or backward using its tentacles and setting itself in motion by a kind of water jet that takes water into its cavity and forcibly pushes it in the direction opposite to the movement through a funnel that plays the role of a nozzle [37].

Therefore, the octopus is an underwater multi-copter, i.e., an aircraft in the aquatic environment built by evolutionary selection according to a helicopter design with eight tentacle rotors that can take any angle of inclination, compress, and relax. Also, it has an additional jet thrust in the form of gill

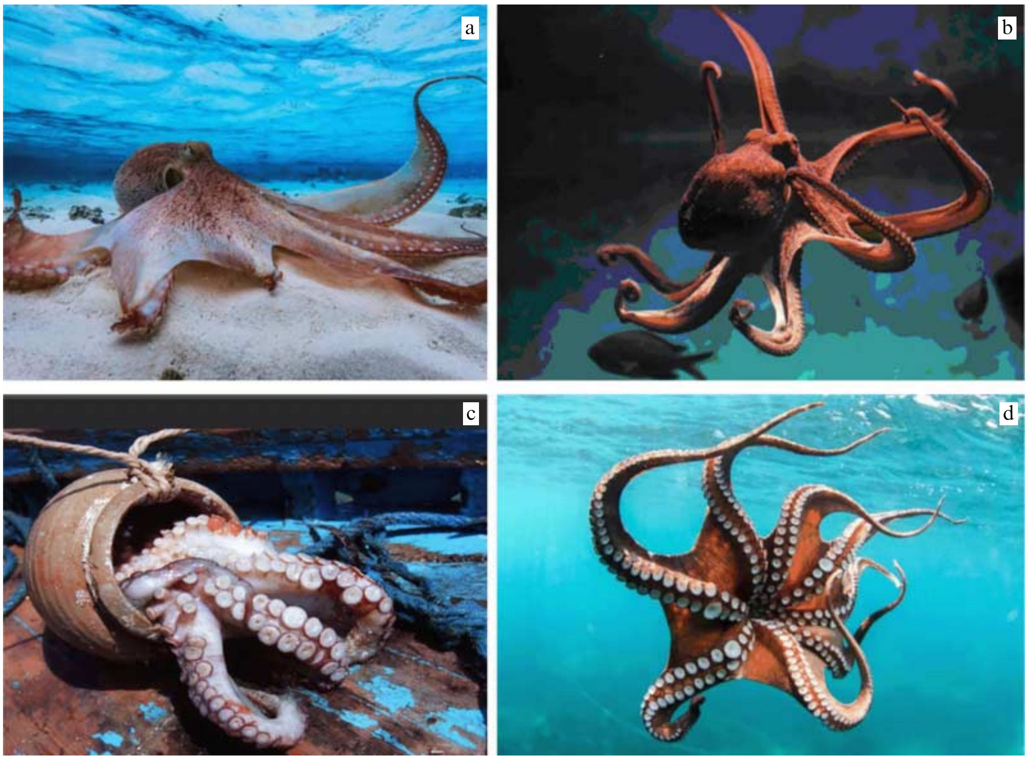

Figure 10. Movement regulation system of an octopus is a special system of regional self-government by a nonskeletal body: (a) a sprawling octopus; (b) a walking octopus; (c) a hiding octopus; (d) a floating octopus [35].

openings. In total, it has > 135 thousand degrees of freedom, the choice of which it can control with the help of motor neurons. Due to the absence of a rigid skeleton, the body of an octopus can change shape. Compactly squeezing the body, i.e., significantly reducing its volume, the octopus, depending on the task that has arisen, adapts to changes in the external space. Octopuses are trainable, have a developed memory, distinguish geometric shapes, recognize people, and get used to those who feed them. If you spend enough time with an octopus, it becomes tame. However, discussions continue about the level of intelligence of octopuses. According to recent research at the University of San Francisco, octopuses can experience psychological pain (resent their handlers) in much the same way as mammals do [38].

Cephalopods are older than the first reptiles. Reptiles appeared, most likely, about 420–310 million years ago. Therefore, octopuses can be put on a level of intelligence above plants, bacteria, and even reptiles. However, Paul McLean, in his evolutionary classification of brain development [39], did not pay much attention to this fact. Nevertheless, formation of a developed nervous system in octopuses indicates that this feature, which was later called intelligence, appeared on their family tree more than 500 million years ago.

In addition, the octopus has a special way of protection. The animal discards its limbs to save its life. Caught by an enemy, the octopus cuts the tentacle off from the body by a strong contraction of the muscle. The severed tentacle for a long time (as long as it has enough internal energy reserves) continues to move and respond to tactile stimuli, which serves as a distraction for the predator that attacked the octopus. This method of protection can be considered a special advection mechanism, but a whole animal can not be restored from a severed tentacle.

The order of intestinal flatworms includes the genus Planaria. The length of these organisms varies from 1–2 cm or more. They can perfectly regenerate, restoring their body after dissection. From each cut half of it, new planarians appear [40]. In other words, there is a similarity between planarians and bacteria that reproduce by fission. Mammals, including humans, are also capable of regeneration but only by replacing dead cells.

The human body contains three groups of different cells:

(1) Irreversibly differentiated cells specialized to perform certain function (neurons, muscle fibers, blood cells — erythrocytes, leukocytes, and platelets). They can not be forced to divide.

(2) Reversibly postmitotic cells. They are also specialized but retain the ability to divide under certain conditions (for example, liver and kidney cells).

(3) Finally, stem cells — nonspecialized cells that easily enter into the process of division with subsequent specialization. What is eventually formed from them depends on the environment or regulatory systems of the body (basal cells of the epidermis, intestines, blood cells).

Science has not yet learned how to make the human body grow a completely lost limb (arm or leg) as a crab or salamander does. It is possible to partially restore the skin and liver of a patient or to mend bones; it is even possible, in childhood, to grow a lost terminal phalanx of the finger given that the rest of the nail remains active and growth appears, but it is impossible to grow a hand where one has been amputated. To do this, it is necessary to regenerate the circulatory and nervous networks, and bone and muscle tissues, and force many stem cells to specialize directionally. Regeneration is controlled by many genes. If we understand how to activate them simultaneously, we shall possibly be able to solve the problem of limb regeneration in humans. For the time being, it remains a fantasy.

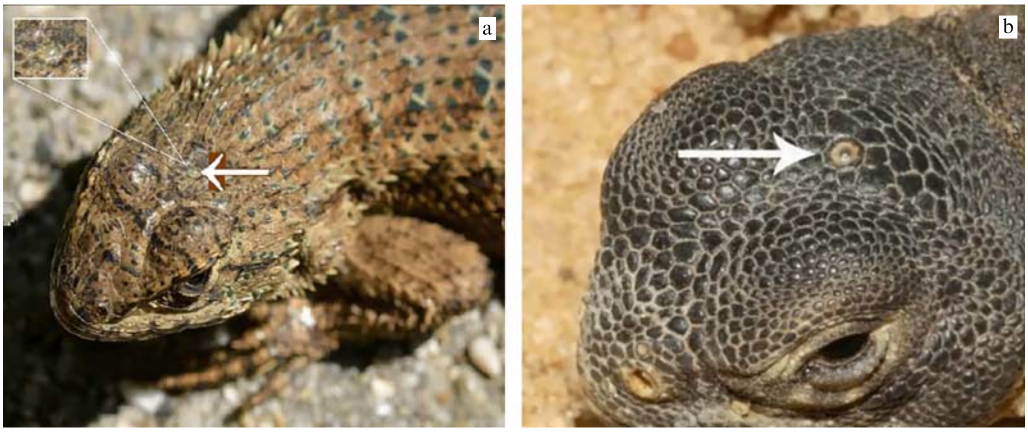

Figure 11. 'Third unpaired eye' on the head of various reptilian species is shown by arrows.

2.3 Appearance of biorhythms — the 'biological clock'

Now, let us turn to reptiles. Michio Kaku [41], influenced by the idea of Paul McLean [39], included reptiles in the first gradation of the development of *consciousness*, Reptilians represent a class of living organisms that lay eggs for reproduction. These are modern turtles, crocodiles, and beak-headed and scaly animals. It is possible that reptiles and birds had a common ancestor [42]. A special place in the study of reptiles is occupied by their so-called 'third unpaired eye' (Fig. 11),which is absent in both cephalopods and mammals [43].

This unpaired photosensitive organ is present not only in reptiles and amphibians but also in jawless (lampreys, hagfish) and some other primitive fishes (acanthodians, armored, bony, ray-finned, lobe-finned). This 'eye' perceives the intensity of light, but does not give an image. It works like an endocrine gland, participating in the regulation of daily and seasonal rhythms and in the thermoregulation of the body. Some amphibians and reptiles need it for normal orientation in a lighted or darkened environment. In doing so, they use changes in the direction of illumination and/or sunlight polarization [44].

So, genetic variability and evolutionary selection have found ways to adapt organisms to varying rhythms in the external environment: the daily (circadian) rhythms of Earth and the seasonal rhythms of its revolution around the Sun. The chemical language of communication between the internal organs of the living organism, i.e., the language of hormonal regulation, provided this adaptability.

However, these rhythms are also inherent in plants, for example, the sunflower, a species of the aster family. Its Russian name originates from the fact that it shows a higher degree of heliotropism than do other plants. The sunflower more readily turns its opened inflorescences towards the Sun, tracking its movement across the sky. This is a special case of phototropism. Many other plants possess the property of positive phototropism manifested as the bending of the stem and leaves towards a light source. Moreover, there is a 'flower clock' allowing time to be measured by plants quite accurately in the summertime. At about 5 o'clock in the morning, rosehip and poppy buds bloom, at 10 o'clock, coltsfoot flowers do so, at 8 o'clock in the evening, the aroma of fragrant tobacco can be smelled in the air, and an hour later, night violets begin to smell fragrant [45]. Along with positive heliotropism, there is also negative heliotropism, when the stem tends to bend so as to remain in the shade. This is how the ivy stem behaves. Thus, when classifying, it is impossible to draw a boundary in the form of clear dividing lines across the entire variety of features of living objects. These will be overlapping, entangled distributions within which essential separating features of the species may exist or disappear.

2.4 From the 'third eye' to the change in biochemical synthesis

The historical connection to the 'third eye' of cold-blooded reptiles can be seen in mammals in the form of glands that synthesize hormones, although mammals have lost the 'third eye' which was directly sensitive to light. It was replaced by the epiphysis [7] and turned into an endocrine gland producing hormones. In humans, melatonin (it has many functions concerned primarily with sleep cycle control) begins to increase at about 9 p.m. and returns to daytime levels around 7–8 a.m. It also leads to the formation of neural networks in the brain. The 'biological clock' is a concept referring to the sense of time and the creation of internal inherent daily rhythms [46].

It has long been noticed that the posterior and central parts of the human brain, including the brainstem, cerebellum, and subcortical ganglia, are almost identical to the structure of the reptilian brain. These structures are sometimes referred to as the 'reptilian brain.' They are ancient brain structures that control bodily functions such as balance, breathing, digestion, heartbeat, and maintaining blood pressure. Their work occurs automatically, is not realized by a person, and does not require the participation of thinking or training. In addition, the biorhythm controls, through hormones, behavioral phenomena such as fighting, hunting, mating, and territoriality, which are necessary for survival and reproduction of their own kind. This was the reason for Paul Donald McLean to consider brain evolution from the standpoint of Darwin's theory with reference to the reptilian brain as the first level of *consciousness* [39]. However, such an approach proved erroneous.

Long before the American MacLean, there was the German researcher Ernst Heinrich Haeckel. However, this approach, as shown by further studies, turned out to be erroneous. Heinrich Haeckel put forward a more universal hypothesis. In 1874, he published the book *Anthropogenie* or *Entwickelungsgeschichte des Menschen* (*Anthropogeny* or *The*

[7] The *epiphysis*, or the pineal gland, is a glandular structure up to 12 mm long and up to 8 mm wide. It is located in the brain between the hemispheres immediately behind the third ventricle above the posterior part of the midbrain, in close proximity to the Sylvian aqueduct — a canal connecting the cavities of ventricles III and IV.

History of Human Development), translated into Russian in 1919). That was the first study in the history of science in which the problems of human evolution were discussed from different angles. He formulated the so-called *biogenetic hypothesis*. The essence of his hypothesis was that each living being repeats in its individual development (in embryogenesis) the historical evolutionary forms of its family and species (in phylogenesis). However, in the 20th century, this hypothesis was refuted.

The reason was that the architectonics of developing organisms, which anatomists describe, take into account only spatial changes and ignore the time of transition from one form to another. In order for a species to exist in nature, three conditions must be satisfied:

(1) it must meet the conditions of the external environment (i.e., have a niche in space for its existence containing a supply of energy);

(2) it must reach puberty within a specific time interval in order to reproduce (i.e., replenish the loss of dead relatives in time);

(3) because of the space limit in any niche, reproduction and mortality rates must be balanced, i.e., it is necessary to maintain a balance of mortality (life expectancy) and fertility (the duration of embryonic development) and of the development in ontogenesis (i.e., the time period before the beginning of independent life and reproduction).

As noted above, it is known from experiment that in many cases the movement of cells and whole organisms depends on both their number and age. In [47, 48], we considered cases of diffusion mobility of a population of reproducing organisms, when their mobility was linked to the age cycle. The model with the 'biological clock' was obtained by adding a diffusion term to the equation for the dynamics of changes in the age composition of the population, which varies depending on the population density:

$$\frac{\partial n}{\partial t} + \frac{\partial n}{\partial \tau} = -m(\tau)n + \operatorname{div}\big[D \operatorname{grad}(n)\big]\,, \qquad (8)$$

where t is external time, τ is internal time (age), x, y are the spatial variables, $n(t, \tau, x, y)$ is the age-related population density, $m(\tau)$ is the mortality rate coefficient, and D is the spatial diffusion coefficients of individual beings. Here, $D = \text{const}$, and $n(t, \tau, x, y) = \text{vary}$. Equation (8) must satisfy the following initial and boundary conditions:

$$n(t, 0, x, y) = \int_{-\infty}^{\infty} b(\tau) n(t, \tau, x, y)\,\mathrm{d}\tau\,, \qquad (9)$$

$$n(0, \tau, x, y) = \varphi(\tau, x, y)\,, \qquad (10)$$

where $b(\tau)$ is the birth rate in the population, and $\varphi(\tau, x, y)$ is the initial spatial distribution of the population by age. Let us consider the development of a population that was initially local and synchronous.

$$\varphi(\tau, x, y) = N_0 \delta(x, y) \delta(\tau - \tau_0)\,, \qquad (11)$$

where N_0 is the initial population size, and δ is the delta function. Activation of their movement occurs within a certain interval of ages, i.e., in a certain phase of their age-related sexual development. This leads to a spatially heterogeneous distribution of the population. The development of an initially synchronous population in space on the assumption that the movement of individuals can occur when their total density at a given point exceeds a certain critical value $N_{\rm cr}$ and the age of individuals does not exceed $\tau_{\rm cr}$. In this case,

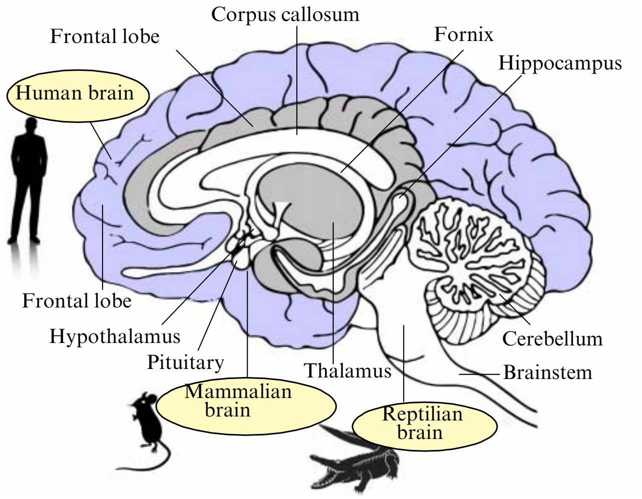

Figure 12. Evolutionary change in structure of the brain (vertical section) along the chain reptiles → mammals → humans.

$R = \operatorname{div}[D \operatorname{grad}(n)]$ takes the form

$$R = \theta(N - N_{\rm kr})\theta(\tau_{\rm cr} - \tau)\,,$$

where

$$N = \int_0^{\infty} n(\tau, x, y)\,\mathrm{d}\tau\,; \qquad (12)$$

here, θ is the Heaviside step function. This model and numerical experiment explain the mechanism of spatially inhomogeneous changes characteristic of a number of populations and demographic problems when population waves are generated. The idea of the model is simple: $R = f(N, \tau)$. The function f has two competing thresholds: $N_{\rm cr}$ and $\tau_{\rm cr}$. As the population size increases due to reproduction, it hits a certain threshold, and individuals start moving in space (x, y) and population density rapidly decreases over time $(\tau - \tau_{\rm cr})$; then, the process repeats. Thus, in evolutionary biology, the factor of internal time (along with astronomical external time) becomes one of the most important factors in regulating processes. It will be shown below that a similar process takes place at the cellular level too. It results in the formation of neuronal networks in the brain.

In short, every next step of development proceeds from the previously achieved level, if this result meets the conditions of the external environment. Therefore, Paul McLean's idea that the new cortex of our brain formed spontaneously as a new organ rather than arose in the course of evolution from pre-existing structures is highly questionable. Brain evolution, like evolution of all living matter, occurs as a process of gradual growth and topological variability of parts. New brain structures grow on the basis of already existing old ones. What arises grows out of what exists [49]. Instead of a structure, a new functional quality may arise abruptly, since clusters of neural networks are formed as the population size increases with a scattering of ages inside it (Fig. 12).

Clustering leads to the appearance of new brain functions. Some evolution theorists hold that the prolongation of the early periods of human life was a specific feature of its evolution in comparison with that of other species of the primate family, namely:

• prolongation of childhood, delay in the onset of puberty, and general increase in life expectancy;

• retarded limb development (large head, flat face, and relatively short arms);

• reduction of the hair surface, etc.

In other words, progress is associated with the inhibition of development. However, all these signs are external. An analysis of the anatomy of the limbic system, the cerebellum, and the brainstem of humans shows that, in spite of its similarity, the anatomy of the analogous structures in the reptilian brain differ significantly as regards mechanisms of operation due to the influence of the new cortex that has developed on its surface [50].

2.5 *Homo sapiens* is the leader in the fight for survival

Obviously, humans, like all animals, are not perfect in many ways. We are inferior to other mammals in the speed of movement, muscle strength, and life expectancy. The world speed record for a human in running a hundred meters is 0.373 times that of a cheetah. Dolphins swim 6 times faster than humans. Dolphins, cheetahs, and kangaroos can jump 3, more than 2, and 1.5 times higher, respectively, than humans. The Guinness Book of Records holds a human record for lifting a truck weighing 2400 kg, which exceeded the weight of the athlete by approximately 12 times. However, world records here belong not to mammals but to insects. Apparently, the strongest beetle is the rhinoceros beetle, which is able to carry a load of 850 times its body weight. An ant is able to carry a load that is 50 times its own weight. In terms of life expectancy, human beings are not the champions either. Here are data on the life expectancy of two well-known centenarians, whose age registration is beyond doubt. The French woman Jeanne Calment died on August 4, 1997 at the age of 122 years and 164 days, while the Japanese Jiroemonu Kimura lived 116 years and 54 days. As for the longest living mammals, the bowhead whale wins: its record is 211 years. Among reptiles, the Galápagos tortoise (*Geochelone nigra*) is over 170 years old and the giant tortoise (*Geochelone gigantea*) is 150 years old.

Comparisons can continue. However, the main thing is not that *Homo sapiens* lost in this competition, but that it actually won thrice thanks to the development of a new cerebral cortex and a biochemical hormonal system. The first win is the development of *consciousness*. The second one is universality of actions, i.e., a human subject can do a lot at a fairly good level. His (her) body, face, and limbs have many degrees of freedom for movement, their number exceeding not only that in an octopus but also in mammals. Third, the main difference is *Homo sapiens* has a new type of social communication, including a sound language, which allowed people to introduce abstract concepts, think by analogy, create generalizations, and develop external sources of memory (writing, painting, architecture, up to the Internet). This greatly facilitated the development of various technologies that gave them an advantage in populating the entire space of our planet.

3. Integral information theory + emotional coloring

3.1 Human assessment of the value of incoming information

Our brain works with information. It is not only the value of *information that is important*, but also its *emotional coloring*. Any information can be transmitted only with the help of a material carrier. However, the laws of information conversion and the laws of its emotional coloring differ from the laws of motion of the material bodies that carry it. Substituting one for the other can lead to misunderstanding.

What is *information* in terms of physics? This question is not so easy to answer, since the term *information*, like the term consciousness, has many interpretations, some being almost identical with the term *consciousness*. For example, D S Chernavsky, in his book and in the article "The problem of the origin of life and thinking from the point of view of modern physics" [22, 51], mentions with reference to books [52, 53] 16 definitions of the term *information* (Table 5).

The generator of messages and the method of their transmission can be not only another person, but also any element of the external environment. In the general case, the change in the probability p_i is in the interval $1 \geqslant p_i \geqslant 0$. When choosing it from n possible options presented in a binary code, information I is usually expressed, since the time of K Shannon, by formula [54] as

$$I = \sum_{i=1}^{n} p_i \log_2 p_i \,, \tag{13}$$

where n is the number of information levels in the interval $i = 1, 2 \ldots n$.

The perception of information is a probabilistic process.

The statement that the interaction in the transfer of information between an object and a subject forms a cycle (object $\leftrightarrow$ subject) must be supplemented with four additional requirements for the participants in this cycle.

First, the person receiving the information must have the tools to decrypt the received message. Thesauruses (from the Greek θησαυρός — 'treasure'), i.e., the stock of knowledge and lexical units (words, phrases) must meet the requirements of communication between the object and the subject. Otherwise, the information will be inaccessible to the subject and the cycle will disappear.

Second, the information should be supplemented with a sign of *informational value, which is associated with human emotions*. For this, it is necessary that the goals of the subject and the object be complementary with respect to the received and transmitted information.

Third, as noted above, *information* can not be transmitted without a material carrier. In this case, some of the information may be lost during its transmission.

Fourth, the *value of information* differs from the *price of the action* used to transfer material media. It has a different dimension and a different meaning.

The first of these provisions is obvious, the rest will be briefly explained. Let us first consider the concept of the *value of information*. Information from the position of the subject is some information transmitted to him, which brings him closer to solving a problem that has arisen before him. The coloring of the perception of the external world in humans is based on emotions. At the same time, opposite emotions, for example, love and anger (Table 2), can lead to opposite actions. Love can give rise to jealousy, suspicion, and then anger (an example is William Shakespeare's tragedy 'Othello,' which is on the list of the most significant works of world literature that describe the manifestation of people's emotions).

However, the value of information depends not only on the purpose of the subject (receiving information), but often also on the purpose of the object (transmitting information). If the purpose of the object is to interfere with the solution to

Table 5. Definitions of the term information.

1	Knowledge transmitted by someone else or acquired through one's own experience
2	Information contained in a given message and considered an object of transmission, storage, and processing
3	That which has the function of a signal
4	The content of the information received from the external world in the process of our adaptation to it and adaptation of our feelings
5	One of the properties of phenomena, objects, processes of objective reality, and human-made control machines consists in the ability to perceive the internal state and the impact of the environment, as well as the ability to save these data for a certain time in order to transfer them to other partners
6	The objective content of a connection between interacting material objects manifested in a change in the states of these objects
7	Communicative way of creating order out of disorder or at least increasing the degree of ordering that existed before the message was received
8	Current data on variables in a certain field of activity, systematized information regarding the main causal relationships that are contained in knowledge as concepts of a more general class, in relation to which information is subordinate
9	Knowledge of some special event, incident, or the like
10	Data about the outside world that we receive both through a direct impact on our sense organs by surrounding objects and phenomena and indirectly through books, newspapers, stories from other people about some special event, incidents, or the like
11	In transmission problems, 'information' refers to any communication or transmission of information about something that was not previously known
12	Information in the most general case is a variety of data that one person has about another. From the perspective of the theory of reflection, information can be represented as a reflection of the diversity that the reflecting object has in comparison with the reflected one
13	Reflection in the minds of people of objective causal relationships in the real surrounding world
14	The content of reflection processes
15	Information is not identical to reflection, it is only its invariant part that submits itself to definition, objective interpretation, and transmission
16	Information is a philosophical category, considered along with such concepts as space, time, and matter. In the most general form, information may be represented as a message, i.e., a sort of communication between the source, which transmits the information, and the recepient, which receives it.

the problem by the subject, then the information transmitted to the subject can be false. Recall the Venus flytrap plant (Fig. 3). Its purpose is to deceive the insect, attract it with a smell, and eat it. If the subject does not have the ability to distinguish lies from truth, then false information will move it away on the time axis from solving its own problem, sometimes leading to tragic consequences. Thus, the *value of information* in terms of the probability p can be expressed in the form of three limiting situations.

Information is important for a subject when it has a task that needs to be solved, or a goal arises that needs to be achieved. A person cannot achieve a goal that they do not clearly see. But if they make attempt after attempt, then, in the end, its achievement becomes possible. In this case, there are two different types of information: a priori with probability p (i.e., information available before the start of the emerging goal) and a posteriori with probability P, which leads to the solution to the problem that has arisen (Fig. 13).

A posteriori information at $P_1 = 1$ is of special value, since it allows the problem to immediately be solved. When $P_2 = 0$, the information is neutral, not related to the solution to the problem. When $P_3 = -1$, the information is false, disguised as valuable information. However, if the subject has the ability to recognize and distinguish according to some signs lies from the truth, then it can, having started solving the problem, turn false information into valuable information. By doing the opposite, it can, contrary to the desire of the object, make the transition

$$\text{from} \quad P_3 = -1 \text{ to } P_1 = +1\,. \tag{14}$$

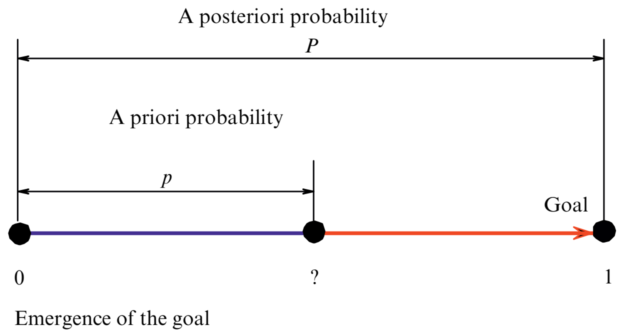

Figure 13. A priori p and a posteriori P information. Missing probability Δp to achieve the goal: $\Delta p = P - p = 1 - p$.

In the case of a subject's *successful* solution to the problem, the path of its solution is remembered, turning into a long-term *memory* of the subject's. This is how learning happens. Filling our memory is the main part of the mechanism of formation of *consciousness* [55, 56].

The *value of information* is related to the volume of the set from which options for information are selected, coming from the object to the subject. The perceived information is always limited by the bandwidth (qualia are the 'windows' of its perception), and the information volume is our ability to store information, i.e., our memory, which is also limited. It seems that the approximate memory capacity of the human brain is about 1000 terabytes [57].

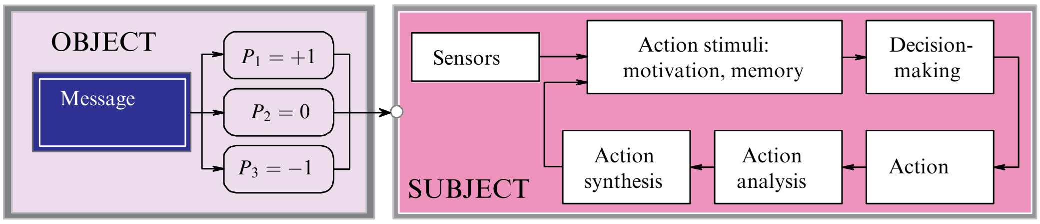

Figure 14. Information interaction between an object and subject. In general, the behavioral action of the subject is characterized by purposefulness and active action. Object transmits various pieces of information that change probabilities P_1, P_2, and P_3. Required probability Δp is determined in the 'decision-making' block.

Figure 14 shows a diagram of information interaction between object and subject.

Our brain has two possible ways of information flow [58]. The first is a short and *unconscious path*: *sensors → action stimuli → decision making → action*. It is sometimes called intuition. [8] The second, a longer path, comes into play when, for some reason, when making a decision, there are conscious doubts about the implementation of the required action, i.e., it is necessary to analyze the possible consequences of the decision being made. The assessment of the consequences follows the feedback chain: *action → action analysis → action synthesis → action stimuli → decision making → changing the action or abandoning it*.

As noted above, when determining the *value of information*, one usually operates with two of its values: a posteriori probability P and a priori probability p. The a priori probability p is our confidence that a solution to the problem exists. The a posteriori probability P is the changing probability after reception of additional information. It can be either greater or less than the a priori information p. Earlier, in Ref. [59], we considered the use of the above two probabilities in the analysis of the Bayes formula.

The ideal Bayesian observer, unlike 'Maxwell's demon,' 'feeds' not only on energy but also on the time spent to perceive and memorize information (catchphrase: *repetition is the mother of learning*).

The *value of information* can be characterized using different expressions, for example, according to Bongard–Kharkevich [57, 60]. If the value of information is denoted by the letter V, its measure is V_1 in terms of the probability of achieving the goal can be expressed as

$$V_1 = \log_2 \left(\frac{P}{p} \right) , \tag{15}$$

where p is the prior probability of achieving the goal, and P is the posterior probability. However, expression (15) does not take into account that the information received by the subject may turn out to be an unrecognized lie. Therefore, V I Korogodin proposed another expression V_2 to assess the value of information [61]:

$$V_2 = \frac{P - p}{1 - p} . \tag{16}$$

If $p > P$, then the value of information becomes negative, since it is based on false information, and P is within $1 \geqslant P \geqslant 0$. It is clear from expression (16) that, if the information is false, then $p > P$ and $V_2 < 0$, i.e., the value of information has a negative sign. The value indicator itself varies in the range $V_{\max} > V_2 > -\infty$. If $p = P$, then $V_2 = 0$, i.e., the value of new incoming information is reset to zero, since no new information is required and the problem is solved. According to the theory of information, if information I is measured in bits and all observed points (pixels) serve as information carriers, then, in the general case, the amount of information corresponds to

$$I = m \log_a N , \tag{17}$$

where N is the number of informative points (pixels), and m is the transition modulus linking information units, i.e., the alphabet used in the formation of information [62]. In this case, the logarithm $\log_a N$ makes sense when $a > 0$ but not when $a = 1$, $N > 0$. For example, if $m = 1$, $N = 256$, and $a = 2$, then $I = 8$, since $2^8 = 256$. This example corresponds to the measurement of information in binary units 0 and 1, i.e., in bits when base $a = 2$. If a different alphabet is chosen, such as bytes, then the base is $b = 8$:

$$I = m_1 \log_b N . \tag{18}$$

If in expression (17), m is equal to 1, then in expression (18), if information I is measured in bits, the transition modulus m_1 is determined by the expression

$$m_1 = \frac{1}{\log_a N} = \frac{1}{\log_2 256} = \frac{1}{8} , \tag{19}$$

where $a = 2$, and $b = N$. Thus, 1 byte contains 8 units of information expressed in bits. Also, there may be other records of information, e.g., using decimal or natural logarithms.

Consider a third situation. To begin with, let us make a remark, neglecting which can lead to misunderstanding. Problems arise due to differences in the concepts of '*information volume of the external environment*,' from which a subject draws information, and '*information volume of the subject's memory*,' which may contain the previously accumulated a priori information useful for solving new emerging problems. Let us assume that the external environment is a large area filled with information — encompassing a small area (the subject). The small area contains the previously stored information. However, this information is not enough for the subject to solve the new problem that has arisen. To solve it, one must replenish the information stock obtained from the external environment. Human sensory systems are 'windows' (qualia) allowing information to be pumped from

[8] *Intuition is the unconscious ability* of a human to penetrate the meaning of events and quickly draw the right conclusion, although one can not logically explain why he (she) took this or that decision. The answer usually reduces to 'I like it' or 'I don't like it.'

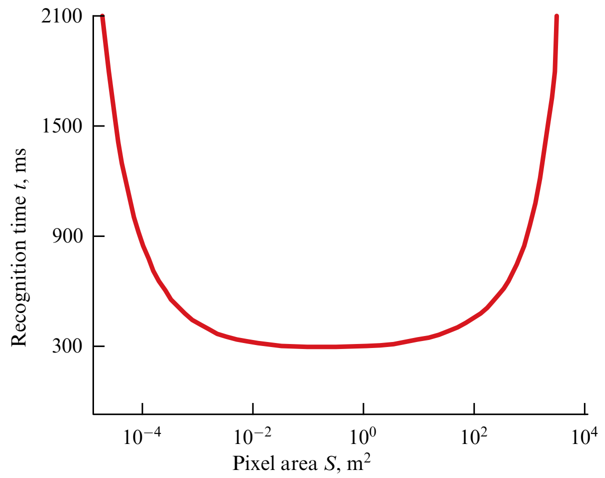

Figure 15. Dependence of the time of visual recognition of an image on the logarithm of information pixel area measured in meters.

the external environment. The physical dimensions of each 'window' are limited both from above and from below. In the set theory, the upper limit of the information coming from the environment through each 'window' is usually denoted by 'sup' (the supremum of information) and the lower bound is denoted by 'inf' (infimum of information).

However, there is no exact border of the 'windows' (qualia) for a person. The boundary is floating, since humans have invented many devices during the period of their existence that have expanded the spatio-temporal range of their receptors (telescopes, binoculars, microscopes, radars, particle accelerators, sound amplifiers, etc.), and many ways of storing information. Consequently, the dimensions of the 'window frame' are not constants: they are individual and depend not only on the genetics, profession, and age (experience) of an individual but also on the equipment with devices and information navigators, i.e., on the initial conditions of information interaction between the subject and the external environment (object) taking place at a given stage of technological development.

A short remark on material carriers of information is in order. Clearly, they can be of any form and size. Ones that are too small (microworld) or too large (astroworld) make it difficult to perceive and recognize information, since they require adaptation of the resolution of our qualia. For example, if only the channel of visual reception works and the subject-expert is interested in the integrity of an artist's painting (as a source of information), then it is necessary to arm oneself with a magnifying glass and examine the microcracks of the paint applied to the canvas. If the task is to assess the peculiarities of the artist's skill, for example, assessing the method of applying strokes of paint to canvas, then a magnifying glass is not needed. The resolution of our eyes is enough if you get closer to the picture. If the task is to evaluate the plot of the picture, then it is necessary to move a distance in order to cover the entire canvas of the image with a single glance. So, the scale can both make it difficult and facilitate the solution to the task. In this case, for the minimum time spent in pattern recognition, the optimal scale of the external image is such that its projection on the retina of our eye occupies a significant area. Figure 15 shows the average dependence of the image recognition time on the pixel area of the information carrier.

3.2 Memory availability and reduced value of incoming information

Using expression (15), we combine the contents of the *memory with the value of the information*. Suppose the subject has achieved the goal, the problem that has arisen has been solved. This means that the a posteriori probability became equal to $P = 1$. In the process of solving the problem, it was found out that, for its solution, it was necessary to make n attempts with a change in the solution paths. Only one path turned out to be successful and led to the solution to the problem. Therefore, when setting the problem, the a priori information was equal to

$$p = \frac{1}{n-1}\,, \tag{20}$$

where n is the total number of analyzed paths used in the search for the solution to the problem. If $n \to \infty$, it is unlikely that such a problem will be solved in a finite time. Only luck will allow finding by chance the only variant of the path leading to the solution. Suppose that our memory M or other external sources of memory available to us contain information that $(n-1)$ paths explored earlier did not lead to success, and only a single path proved promising. Assume also that our memory contains information about $(n-1)$ unpromising paths, i.e.,

$$M = n - 1\,,$$

and posterior probability $P = \dfrac{1}{M+1}\,.$ (21)

Taking into account expressions (15), (20), and (21), it is possible to write the value in terms of this memory:

$$V_1 = \log_2\left(\frac{P}{p}\right) = \log_2\left[\frac{n-1}{M+1}\right] = \log_2\left(1 - \frac{1}{M+1}\right). \tag{22}$$

It follows from expression (22) that, if memory $M + 1) \to \infty$, then $V_1 \to 0$:

$$\text{Lim}\; V_1 \to \log_2 1 = 0 \;\text{at}\; (M+1) \to \infty\,. \tag{23}$$

This means that the value V_1 of the information received from the external environment necessary to solve the problem decreases with an increasing amount of useful information previously accumulated in the brain. This conclusion is obvious, but it does not mean that a large amount of memory always allows one to quickly adapt to a change in the external environment. Although memory is accumulated experience, its memorization must meet a number of conditions.

3.3 Comparison of computer and human memory

A system with very large memory is not always a good system. It can be extremely conservative. It is a hard job to look for something you need in a poorly organized memory. For example, the Internet with address memory greatly facilitates solving problems, but little by little it turns into a wastebasket, because one has to recognize whether one obtains true or false information; this requires time and energy.

Conventional computer memory is locally addressable, i.e., the address is presented and the information recorded at this address is retrieved. It is encoded in a certain way in the form of a pattern and is located in a certain cell in the computer's memory. The process of memory operations is divided into two operations separated in time: writing and reading. If memory is limited, then there is a forgetting option (*deleting unnecessary information*).

Human memory is structured differently. Since information operations are described in terms of probability, the code consists of three distinct states: *Yes, Maybe, and No*. In addition, these operations take place under the control of a separate specialized device, a memory controller, which recognizes the importance of information, evaluates its quality, and gives it an emotional coloring. One of these controllers is the hippocampus (a subcortical structure of the brain). In other words, memory is inextricably linked to thinking — pattern recognition and evaluation of emerging situations. Thus, human memory is a dynamic and, consequently, energy-consuming process. Events and phenomena are quickly forgotten, if not repeated, which confirms the dynamism of memory. Information is retained in a certain way, but, in the absence of demand, it fades away, i.e., is superseded by other information. In an hour, about half of everything that has entered the memory is forgotten, and after six months, all information may disappear.

It is important to note that human memory is associative, i.e., one memory can generate a large area associated with it. One faint phenomenon (for example, the smell of a flower, a visual image, or a musical chord) reminds us of another, and this other of a third. If time is not limited, our thoughts will move from pattern to pattern along the chain of neural clusters. For example, a few beats of music or specific smells can trigger a whole gamut of sensory memories, including sights, sounds, images of familiar people, and events from our past. Conventional computer memory is, as a rule, locally addressable,[9] while human memory has a hierarchical structure using several layers of patterns to write and read information. Layers of patterns have different spatio-temporal characteristics of recording, storing, searching for, and forgetting information and are interconnected. But the main difference between human memory and the memory of machines is that the brain works not with sets of symbols but with the meanings contained in their sets.

The amplitude-frequency spectrum of an EEG with which our brain works demonstrates the contribution to the total amount of each harmonic component that came through one or more receptor channels (vision, hearing, touch, etc.). When a child learns to recognize a *cat*, it initially perceives a set of its essential features, such as the size, the presence of a tail, whiskers, movement on four legs (perceived by vision), the sounds of 'meow' (perceived by hearing), soft fur, or direct contact with the human body (perceived by tactile reception). To the eye, the process looks like this. The ganglionic system of a receptor transfers each feature in the form of a *harmonic* component $S_{i\,\mathrm{from}}(\omega_x, \omega_y)$ from the image projection plane on the retina to the image wave representation plane in the cerebral cortex. Visual information mainly enters the occipital part of the human cerebral cortex.

With the accumulation of experience starting from childhood, its own weight factor $F_i(\omega_x, \omega_y)$ is formed for each harmonic [64]. Using a set of such multipliers, it is possible to transform the wave image $F_i(\omega_x, \omega_y)\, S_{i\,\mathrm{from}}(\omega_x, \omega_y)$. The set $\{F_i(\omega_x, \omega_y), S_{i\,\mathrm{from}}(\omega_x, \omega_y)\}$ consisting of a set of image features presented in the language of autowaves provides the basis for completing the image recognition operation that occurs in the frontal cortex of the brain [65, 66]. So, receptor (sensory) systems, i.e., qualia, have tools that connect the outside world with the inner world of a person by recoding the received message. Since any information transformation process can introduce errors, the result often contains some uncertainty. In this case, the posterior probability will be less than one.

It will be shown below that the emotional coloring of information is associated with the biochemical, primarily hormonal, background.

3.4 Hormones and emotions — the chemical language of communication

Hormones (Anc. Greek. Ὀρμάω — I move, I induce) are biologically active chemical substances produced in some cells and binding to the receptors of other (target) cells. They regulate metabolism and the speed of information processing. As of today, ≈ 150 hormonal compounds and peptides showing biological activity have been discovered in humans. Given the chemical structure of thought regulators, they can be divided into the following groups:

• Steroid compounds synthesized from a cholesterol precursor. They are formed in the adrenal cortex or in the gonads of men and women.

• Protein and peptide hormones, including hypothalamic and pituitary agents, as well as pancreatic hormones.

• Finally, compounds that are derivatives of amino acids are formed in the pineal gland, adrenal glands, neurons, and thyroid gland.

In higher animals, including humans, hormonal regulation is coupled to nervous regulation. Taken together, they make up a united regulatory system. It was mentioned in a preceding paragraph that hormonal regulation, e.g., in reptilians, is evolutionarily the oldest. Hormones are transported inside the body in mobile fluids (blood, lymph, tissue fluid). Some hormones associated with emotions are listed in Table 6.

Of particular note are neurotransmitters — biologically active chemicals through which an electrochemical impulse is transmitted from one nerve cell to another through the synaptic gap between neurons, as well as from neurons to muscle tissue or gland cells. A nerve impulse entering the presynaptic ending releases neurotransmitter vesicles into the synaptic cleft.

Neurotransmitter molecules interact with specific receptor proteins of the cell membrane, initiating a chain of biochemical reactions that cause a change in the transmembrane ion current, which leads to membrane depolarization and the emergence of an action potential in the next neuron. In this way, neurons 'talk' among themselves in addition to electrical impulses in the language of neurotransmitters. It may seem that such bilingualism should greatly slow down the process of their communication.

However, it is not so. The width of the gap l which separates pre- and postsynaptic membranes is $l \leqslant 0.1$ μm. Therefore, a hormone vesicle has to travel a very small distance to bind to receptors on the postsynaptic membrane. Although diffusion is a slow process (this short path taking no more than 1–2 ms), excitation of the next neuron occurs with a slight delay. After the excitation is performed, neurotransmitters are inactivated by special enzymes. The neuron is again ready to perceive a new chemical signal.

[9] However, *associative memory* can be realized in the form of machine memory by using a program application for a fast search, e.g., 'memory addressed based on the content of a key word' [63].

Table 6. Certain hormones associated with emotions.

No.	Hormone	Emotion
1	Endorphin	'Hormone of pleasure and love,' inspires state of calm and serenity, reduces pain
2	Noradrenalin	Promotes mood and positive perception of reality. Low levels cause depression and melancholy
3	Oxytocin	Has strong positive effect on the formation of maternal instinct in women (tenderness, fidelity, and reliability)
4	Serotonin	Mood hormone, a neurotransmitter, i.e., one of the chemical transmitters of impulses between nerve cells in the human brain. Controls susceptibility of brain receptors to stress hormones (adrenaline and norepinephrine). Stimulates areas responsible for cognitive and motor activity, mood, muscle tone, self-control, or emotional stability. Deficit of serotonin impairs mood and causes depression
5	Dopamine	Helps to adapt to a new environment, controls the ability to learn, supports the desire for everything new, helps to achieve a goal, gives confidence. Lack of dopamine leads to indecision and self-doubt. However, if a person has a predisposition to alcohol and drugs, this hormone helps to consolidate such addictions
6	Melatonin	Regulator of main biorhythms, sleep cycle, rest, and work, promotes removal of metabolic 'slag' from the brain, helps to restore the body's energy supply and the accumulation of fat as an energy depot
7	Estradiol	Female hormone, regulates menstrual cycles, causes secondary sexual characteristics in girls
8	Vasopressin	Synthesized during stress associated with analyzing certain situations, thinking, the formulation and choice of goals, the search for a sexual partner
9	Thyroxine	Has strong effect on increasing irritability (nervous state), but helps to cope with stress
10	Adrenalin	Increases aggressiveness, its lack leads to passivity in overcoming life's difficulties
11	Testosterone	'Hormone of aggression,' affects not only mood but also health
12	Acetylcholine	'Hormone of disgust,' affects intellectual and motor activity, at low concentrations lowers the excitation threshold of neurons, at high concentrations inhibits excitation and impairs decision-making

Thus, a human subject, unlike modern artificial creative systems, has two connected languages of communication between cells and organs: a fast one — electrical — and a slower biochemical one, including hormones. In this case, we are interested in derivative hormones of the amino acid group that work in the human brain.

Apparently, hormones make up a vocabulary that shapes emotions. They have high biological activity. Some of the chemical compounds, due to their specificity, have a subtle regulatory effect at very low concentrations (10^{-8}–10^{-15} mol liter^{-1}). Their specificity is explained by the presence of selectivity in the interaction of receptors with these molecules [67].

3.5 Hormonal mixtures with different concentrations of constituents

In 1949, Claude Shannon published "Communication theory of secret systems" [68], where he formulated five criteria for the protection of classified information. The fifth paragraph of the wording in this article was: *when encoding a message, it is necessary to mix the correct message* (*information*) *with many incorrect ones* (*misinformation*)*, which will lead to a large expansion of the message. At the receiving end, a key* (*decoder*) *is needed, which would determine what part of the message is information*. This formulation is understandable and banal, but its essence lies in the fact that it arose from Shannon's comparison of artificial machine languages (for example, Morse code with a *deterministic structure*) with the natural languages of communication of people with a complex cultural and linguistic context.

If real human languages are used, then an extended version of the transmission of encrypted information through one channel is possible when information intended for other users is also provided as disinformation. In this case, *different mixed information* intended for *different* clients is transmitted simultaneously over one channel. Information intended for the first client has its own attribute '*a*.' Information intended for the second client has its own attribute '*b*.' Information intended for the third client has its own attribute '*c*,' and so on. The first client at the receiving end of the communication channel has its own specific decoder for information sign *a*, the second client, for the attribute of information *b*, the third client, for the attribute of information *c*. Since the information in the channel is mixed, for an outside observer it looks like meaningless chaos (crowd noise), but this chaos is deterministic, since it generally carries meaningful information, but intended for different clients.

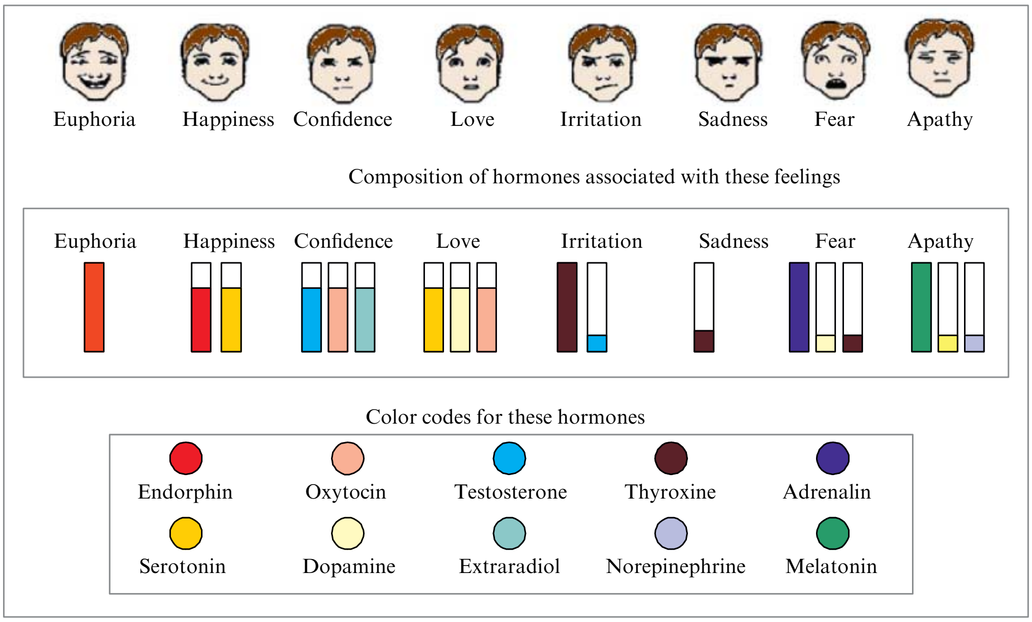

Figure 16. Examples of human facial expressions associated with various combinations of hormones.

The biochemical language, including hormones, has been used in living systems for many millions of years. Hormones are produced in specialized glands and cells, communication channels are those of blood supply or channels of intercellular fluid, decoders are specific receptors *a, b, c*... that decipher the information delivered in the form of carrier molecules. Depending on the set of receptors and their selective ability, mixed information is distributed among its receptors and causes different feelings in the individual, which affect the body and muscle tone, including facial muscles. A person's face becomes an essential tool of communication. An infant learns this language before it learns the spoken language.

As soon as 9 minutes after birth, a baby seems interested in the faces of the surrounding people; by day12, it is able to imitate facial expressions. This ability of a child develops the ability to recognize faces by mimicking. Due to the presence of individual basic emotions, each child more accurately evaluates people close to them from their facial expressions.

The facial expressions of each person have not only genetically but also culturally conditioned traits formed under the influence of upbringing. They influence our perception and interpretation of emotions. The external language of facial expressions and gestures is a manifestation of the internal biochemical language in its interaction with the language of the nervous system (Fig. 16).

Some national communities of people readily display emotions. In Europe, they are, as a rule, inhabitants of the Mediterranean coast. Others, on the contrary, have faces with a 'permanent smile on duty,' e.g., in England. Such a smile masks emotionality. In other communities, it is generally accepted that the manifestation of the expression of emotions should be managed depending on the circumstances. The rules of expressing human emotions that are specific to a given culture are learned by a child in childhood, in the process of observing the facial expressions of adults. For example, in Japan, it is customary to hide one's negative state in order to maintain overall harmony. However, at the same time, the eyes can give out an artificial facial expression — a smile on the face and sad eyes. In Russia and the United States, restrictions on the display of emotions are less pronounced.

4. Is it possible to distinguish between an android robot and a real human subject?

4.1 Android robots and the language of emotions of the 'human face'

We shall understand by the term '*android robot*' an electromechanical machine with artificial intelligence, outwardly resembling a human body with arms and legs, and with a human-like face, although sometimes this version of the robot is based on an image of a real person with a chip implanted in the brain that controls behavior. This as yet uncreated variant of the robot is known as a 'zombie.'

The design and use of an *android robot* can be intended for both functional purposes (interaction with real people as tour guides, nursing home attendants, office secretaries, etc.) and experimental purposes (learning bipedal locomotion, learning language, facial expressions and gestures) [59].

Creating such robots is a complex engineering challenge. In many countries, work is currently underway in this field. As an example, I present a list of the most famous android robots created over the past 10 years (Table 7), although this list does not exhaust all the latest developments in this field. The list is growing rapidly.

Let us consider the latest robot. The android robot Ameka (Atesa) was displayed at the CES exhibition [10] held in Las Vegas in early 2022. Ameka was immediately called the most human-like robot due to its very realistic facial expressions. At the moment, this robot can control the lips, wrinkle the nose, control the eyelids by opening/closing the eyes, and wink. Ameca's facial expressions are not related to hormones and are purely electromechanical imitation. Under

[10] The Consumer Electronics Show (CES®) is an important event in the West that serves to demonstrate promising technologies and breakthrough projects.

Table 7. Design and creation of android robots.

Year	Name	Creator and capabilities of the robot
2012	COMAN	Advanced Robotics Department of the Italian Institute of Technology. First version of the human robot was COMPLITANT (COMAN), designed for walking and balancing over rough terrain [69]
2012	NimbRo	Group of autonomous intelligent systems of the University of Bonn (Germany): Humanoid TeenSize NimbRo-OP platform [70]
2013	TORO	German Aerospace Center (DLR) — humanoid robot TORO (torque controlled humanoid robot) [71]
2013	SCHAFT	On December 20–21, 2013, the DARPA Robotics Challenge presented 16 humanoid robots in a fight for a cash prize of two million US dollars. Lead team SCHAFT scored 27 points out of 30 and was bought by Google [72]
2013	REEM-C	PAL Robotics launched REEM-C, the first bipedal humanoid robot designed as a robotics research platform based 100% on the ROS platform [73]
2013	Poppy	First open source humanoid robot printed on a ZP printer with legs designed for bipedal locomotion. Developed by the TsvetkovINRIA Department [74]
2014	Manav	India's first ZP-printed humanoid robot was developed in the laboratory of A-SET Training and Research Institute by Diwakar Vaish (Head of Robotics and Research, A-SET Training and Research Institute) [75]
2014	Pepper robot	After acquisition by Aldebaran, Soft Bank Robotics has produced commercial public robots [76]
2014	Nadine	Female humanoid social robot developed in China at Nanyang Technological University in Singapore with a face similar to its director, Professor Nadi Magnenat Talmann. Nadine is a socially intelligent robot that responds to greetings, establishes eye contact, and remembers all conversations it has had with visitors [77, 78]
2016	Sophia	Humanoid robot designed by the Hong Kong company Hanson Robotics in the image of Audrey Hepburn. Sophia has artificial intelligence, visual data processing, and facial recognition [79]
2016	OceanOne	Developed by Stanford University (USA) under the direction of Usama Khatib, OceanOne completed its first mission by diving in a treasure hunt in a sunken ship off the coast of France to a depth of 100 meters. Robot is controlled remotely, has tactile sensors and artificial intelligence in its hands [80]
2017	TALOS	PAL Robotics created an all-electric humanoid robot with torque sensors in its arm joints. TALOS robot has Ether-CAT communication technology and can also manipulate a payload of up to 6 kg in each of its grippers [81]
2018	Rashmi Robot	Randjit Srivastav (India) created a multilingual realistic humanoid robot with the ability to interpret the emotions observed on people's faces [82]
2020	Vyommitra	The Indian Space Agency is developing a humanoid robot with a female face as a crew member to work on board the orbital crewed Gaganyaan spacecraft [83]
2020	Epi	In Sweden, Lundsky's Cognitive Science Robotics Group developed the humanoid robot Epi. It is intended for use in robotics development experiments. Its control is based on the Ikaros system platform and is focused on the study of cognitive development [84]
2022	Robot Shalu	Homemade Indian multilingual humanoid robot with artificial intelligence made from old technical parts (waste) by schoolchildren, can speak 9 Indian and 38 foreign languages (a total of 47 languages). Developed by Dinesh Kunwar Patel, computer science teacher, Kendriya Vidyalaya, Mumbai (India). Robot Shalu can recognize and remember a person, identify many objects, solve mathematical problems, write horoscopes and weather forecasts, teach in the classroom, and conduct quizzes [85]
2022	Ameca	Android robot (Engineered Arts). At the time of its creation, it was considered the most successful in terms of imitating human emotions. Robot can copy human facial expressions and speech, conduct a meaningful dialogue. It stands on its feet but is not yet able to walk, works well using its hands [86]

the silicone cover of Ameka's face, many controllable mini-motors are installed, with the help of which the silicone skin of her face is deformed, imitating the facial expressions of a real person: joy, sadness, and other basic emotions. In addition, this robot can gesticulate with its hands, recognize objects around it, and communicate with visitors (Fig. 17).

Ameca itself told visitors at the exhibition that it was created to test interactions among people based on the use of language, facial expressions, and gestures. However, it still does not know how to use the entire arsenal of voice modulation. Meanwhile, communication with people is known to largely depend on articulation and changes in the volume of the voice.

Representatives of Engineered Arts have been creating robots with which it is possible to communicate as with real people for more than 15 years. ''The human face is a communication interface with a very high rate of generation of visual information due to mobility of its features.''

4.2 Human or robot? Special problem of pattern recognition

It is clear that our identity is formed not only by the face but also by gait, appearance, gestures, the timbre of the voice, and the ability to listen to the interlocutor, as well as the content of the conversation. Supplying androids with the entire arsenal of the listed means and reactions is a difficult but technically feasible task. Moreover, it is possible to simulate the transfer of emotions from human to android and from android to human based on imitation.

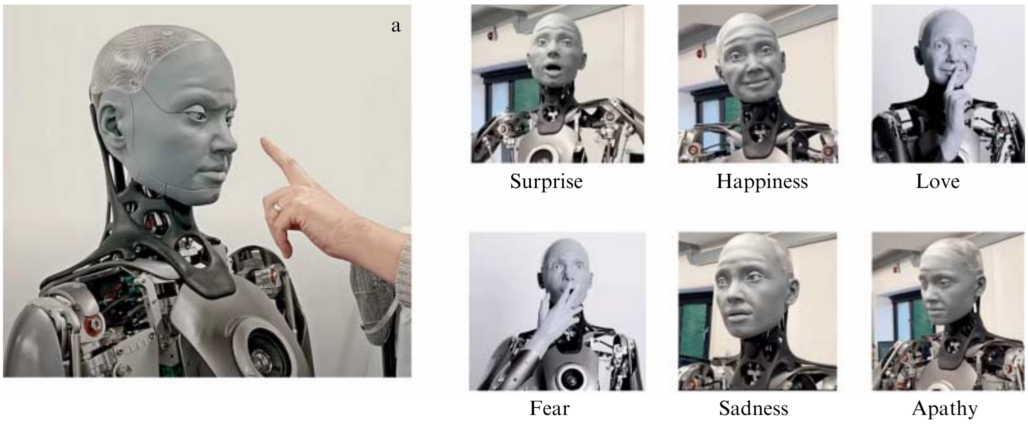

Figure 17. Robot Ameka (a) and changes in its face imitating human facial expressions (b) [84].

Experiments show that the emotional component in our relationship with robots is of great importance. If an android has a natural human voice, we cannot avoid feeling that before us is not a robot but a human, even if the robot does not always answer our questions logically. The effect of the presence of the interlocutor is important. However, when the robot is not very human-like, i.e., it is noticeably different, then an unpleasant feeling arises. If this threshold is passed (the unnatural appearance and movements are eliminated), then the robot begins to be perceived as a person. To cross the border of hostility, it is necessary to achieve not only a physical similarity but also the intellectual ability to conduct a reasonable conversation. A popular expression is ''they are greeted by clothes, but they are escorted by the mind.''

In 1978, the Japanese scientist Masahiro Mori conducted a survey among people interacting with different robots, while exploring their emotional reaction to the appearance of robots. At first, the results were predictable: the more human-like the robot, the prettier it seems — but only up to a point. The most humanoid robots unexpectedly turned out to be unpleasant to people due to minor inconsistencies in the appearance of a person, causing a feeling of discomfort and fear. The unexpected drop in the 'emotions' chart has been called the 'Sinister Valley' (Fig. 18). Masahiro Mori found that animation enhances both positive and negative perceptions [87].

Note that the development of digital information technologies changes people's perception. As a result, discussions periodically arise on the topic: is it possible to apply such concepts as thinking to robots? The argument of artificial intelligence supporters is simple. Computers do not deal with phenomena themselves, but with their models in the form of programs that implement algorithms. The same model can describe different natural phenomena. In this sense, the program is universal and, in principle, it would seem that it can reproduce any work of the brain with high accuracy. Information technology developers have expressed the opinion that, from this point of view, all existing limitations are based on those simplifications that are inevitable today, but the time will come when more advanced programs will get rid of such limitations and thereby qualitatively change the intellectual abilities of computer technology.

The assessment of program excellence is based on the results of an experiment based on the operational method. Its main provisions were formulated long ago. In the middle of the 20th century, U R Ashby defined four components of the operational method [88]:

(1) it must be defined in the form of a working method;

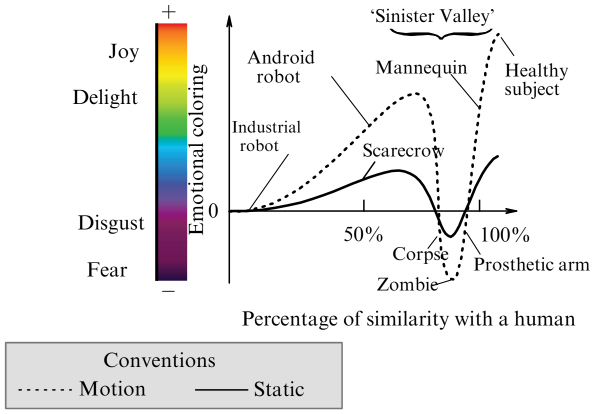

Figure 18. 'Sinister Valley' of Masahiro Mori.

(2) it should be applicable to the study of all material 'machines' — both animate and inanimate;

(3) a method of obtaining information from the 'machine' must be available for reproduction and demonstration;

(4) the 'machine' itself must serve as the source of information — no other source is allowed.

More than 70 years ago, Alan Turing proposed a test [89] which he planned to use to answer the question: 'Does a machine think?' Later, John Searle proved the Turing test to be invalid [90]. With the help of an invented thought experiment, Searle showed that the use of a program (even a perfect one) by some device does not testify to its reasonableness and the presence of *consciousness*. The emergence of *thinking and consciousness* (as shown above) is the result of a long evolution of living organic systems. Therefore, no activity of analyzing systems that operate on a material basis with a set of artificially created reactions should be referred to using the term *consciousness*.

It may seem that this semantic dispute is meaningless, since it carries a load of vague and ambiguous terms that are used for many purposes. It is important, however, that the substantive part of the disagreements is concerned with a more general problem related to the strategy of knowledge of the surrounding world. When a lecturer uses the Zoom Video Communications program, allowing remote connections to many listeners using video telephony, communicating with the audience at a distance, and answering questions, few of the participants would grow suspicious because the video monitor is not a person but a robot. However, today, the situation has changed. There can also be a robot on the monitor, as was proven experimentally.

Figure 19. Professor Hiroshi Ishiguro (right) and his android robot counterpart (left).

For example, the Japanese engineer, Professor Hiroshi Ishiguro, affiliated with the University of Osaka since 2003, is known as the creator of a series of humanoid robots. One of his products, the 180-cm-tall Geminoid Hi, mimics its creator and replaces him as a lecturer. This is a remote-controlled robot, under the silicone skin of which there is a plastic skull, a metal frame, and a body made of polyurethane foam, tactile sensors, and pneumatic actuators. It has several modifications [91] (Fig. 19).

Hiroshi Ishiguro defines the goal of replacing himself with the created robot double as follows: *First of all, this is an attempt to understand with the help of an android who is a person. The use of the Geminoid allows the inventor to be present wherever he wishes. It is also possible to raise the philosophical question*: *what is human presence*? *Where is the boundary between the mind and the body*? *That's my goal, that's why I'm studying human telepresence in the shell of an android robot*.

The creation of android robots has rekindled the old pointless discussion about robot *consciousness*.The old hypothesis about the existence of consciousness not only in humans but also in robots has come to the fore again. Some neurophysiologists maintain that *consciousness* is not an objective reality but a subjective phenomenon and that the soul and consciousness are just mutually functioning parts of the cortex and subcortex of the human brain (see Fig. 2). Behaviorists insist that consciousness does not exist and is a mere illusion in which people believe.

When someone claims to have consciousness, behaviorists object that a self-learning supercomputer could say the same. Consciousness is a subjective phenomenon and cannot be demonstrated to other people. Therefore, to recognize the existence of consciousness or not depends on an agreement between people. I believe that you are not a supercomputer, and you think that I am not human but a supercomputer. It's just our faith.

In conclusion, it should be noted that there are many neurocomputer structures that imitate the thinking of different sensory modalities [92–94]. One can try to apply a relativistic theory to modeling consciousness based on the relativity of judgments in relation to 'machines' that are similar or not similar to humans that exist in society. Recently, such an attempt was made by the physicists Nir Lahav from the University of Bar-Ilan (Israel) and Zechariah Nimeh from the University of Memphis (USA), who published an article entitled "The Theory of Relativity of Consciousness" [19]. In the article, they noted: *The phenomenon of consciousness is not a private or invented concept, it is simply relativistic. In the frame of reference of the cognitive system, consciousness will be observable from the point of view of one observer, but not observable by another, who will claim that it is illusion. In another cognitive system, the situation may be reversed. Neither of the positions of these two observers can be considered privileged...* . So, the complexity of defining the term 'consciousness' based on different approaches is due to the fact that each experimenter using a particular research method faces a specific set of uncertainties that make it difficult to solve the problem as a whole. This situation is similar to the well-known ancient Indian parable, The Blind Men and the Elephant [95], which illustrates the misperceptions of the blindmen, who feel different parts of the elephant and do not understand what this creature looks like. Their statements are erroneous because they are based on the fragmentary availability of information sources.

5. Conclusions

1. *Consciousness* cannot be unambiguously defined for all people since the *consciousness* of one person is not identical to that of another; hence, a variety of definitions of the term *consciousness*. It is possible to evaluate the similarity of *consciousness* only in relative units by comparing its similar carriers.

2. Finding a difference depends on what signs of difference one takes as the basis for recognition and classification. Errors in the choice of features used in classification lead to paradoxes, so the answer to the question, can a machine have consciousness?, depends on agreement among researchers, since different groups of them put their own meaning into this term.

3. A person works with three characteristics of information: *syntactic, semantic, and pragmatic. The syntactic* one is related to the technical problems of storing and transmitting information, the *semantic* one concerns the sense and the meaning of the truth of messages, and the *pragmatic* one is the influence of information on the behavior of systems that perceive it. For a robot, the *semantic and pragmatic characteristics are reduced, whereas the objective function is set by the programmer*.

4. According to the long-known negentropic principle, information is negentropy [96]. The ability of thinking people to create new information while adapting to the external environment, to share the knowledge gained with other people, increases the stability of existence of both the individual and the remaining people taken as a whole.

It may seem that these four points of the conclusion could close the topic. However, the rapid development of digital technologies, artificial intelligence, and robotics brings humankind into a very uncertain and therefore dangerous phase of its development.

6. Postscript

New technologies constantly created by us change the outside world, which changes us ourselves. We already live in the era of a giant collision of real and virtual worlds. The emerging situation can be called *informational psychosis*, in which the thresholds between the worlds in the head of many representatives of the human population began to disappear. It may compromise the stability of society. At one time, a creature from the animal world stood out in that it created new information carriers with large characteristic lifetimes, far beyond the life of one generation of people (writing, art, replicating information by multiplying texts, and, finally, creating new types of long-term memory in the era of computerization and the Internet). All this contributed to the development of information technologies and the technological acceleration of the development of human society. However, at present, the widespread use of artificial intelligence (AI), based on statistical machine learning, has already begun to cause problems. I will limit myself to two examples.

The well-known American linguist, philosopher, and professor at the Massachusetts Institute of Technology, Avram Noam Chomsky,[11] believes, based on his many years of experience, that the development of AI has gone the wrong way and is even dangerous for humankind. Although the statistical approach may be of practical value, e.g., for useful search work, and facilitates the processing of large amounts of data given the availability of fast computers, such an approach is inadequate from the scientific point of view or, putting it more harshly, superficial.

Chomsky has repeatedly shared with readers his opinion about chat bots implemented in the form of computer programs ChatGPT, OpenAI, and Bing AL. To recall, a *chatbot* is a virtual interlocutor created by a computer program. The chatbot follows a human user on the Internet, collects and analyzes their requests and correspondence, then, based on a statistical analysis of these data, forms a psychological portrait of the client and, as it were, seeks to overcome the person's problems.

By automatically communicating with the client, the *chatbot*, using either text or the voice, conducts a dialogue with the client in order to provide them with up-to-date information or a finished product in a short time. Chomsky notes that the widespread use of such AI programs creates the illusion of their super-usefulness, since they supposedly can compete with the human mind. However, *chatbots* operate in the virtual world of the Internet, based on statistical probability, and not in the real world of knowledge and understanding of ongoing events in people's lives. For my part, I note that *chatbots* based only on statistics can equally assert that Earth is round or flat. Moreover, they may conclude that the artificial spread of suicide or the growth of sexual minorities (LGTB communities) in human society is useful, as it limits population growth, or that the classical family (husband, wife, and their children) is archaic, etc. The *chatbot* advice is superficial and therefore dubious. Such mistakes coming from communication with chatbots lead to deception of people and, at best, end up in court. From the standpoint of a lawyer, who owns the rights to works created by neural networks, or who should be responsible for damage caused by AI? Can AI be the copyright holder of something it creates on its own? The courts are not yet ready to consider such cases, since there is no legislative basis. The desire of companies creating AI programs to collect large amounts of data is understandable, but it is not clear what theory this data can fit into. The Russian proverb, *they hear the ringing, but do not know where it is*, well reflects the result of the work of such programs.

Such discussions raise the age-old philosophical question of science: how is a true scientific theory made? How is success defined in science? Science is created by the mind and consciousness of people. The human mind, unlike *chatbots*, works with small amounts of information and does not seek to rely on rough correlations and probabilistic estimates, but is looking, first of all, for an explanation of events and a forecast of negative consequences. Conclusion: *Chatbots simply trade probabilities that also change over time*.

On March 29, 2023, the nonprofit organization Future of Life published an open letter on its website. In this letter, the head of SpaceX, the owner of several other companies, and billionaire, Elon Reeve Musk, Apple co-founder Stephen Gary Wozniak, the entrepreneur and politician Andrew Yang, and a thousand other AI researchers called to 'immediately pause' training AI systems 'more powerful than GPT-4.' The main part of their letter is as follows: *Artificial intelligence systems that compete with humans can pose a serious danger to society and humanity, advanced AI can trigger profound changes in the history of life on Earth, and should be developed and managed with commensurate care and limitations. Unfortunately, this level of planning and management does not exist, in recent months the artificial intelligence laboratories have been in an uncontrollable race to develop and deploy ever more powerful 'digital minds.' Nobody, even their creators, can understand how these systems work, and, therefore, have no reliable methods for their control. Modern artificial intelligence systems are becoming sources of negative propaganda and fakes, violating stability of society in solving important problems facing humanity. We must ask ourselves: should we allow machines to flood our information channels with absurd information? Should we automate all jobs, including those that are potentially being replaced by AI? Should we develop 'nonhuman minds' that may ultimately surpass us in both speed and cunning? Should we risk losing control over the development of our civilization? Powerful artificial intelligence systems should only be developed when we are confident that their use will be positive and the risks manageable. This confidence should be well founded and developed as part of the improvement of control over the operation of such systems. A recent statement from OpenAI regarding Artificial General Intelligence states that 'at some point it may be important to obtain an independent assessment before proceeding to train future systems, and for the most advanced efforts, agree to limit the growth rate of the calculations used to create new models.' We agree with this limitation. This moment has already arrived. Therefore, we call on all AI labs to immediately suspend training on AI systems more powerful than GPT-4 for at least six months. This pause should be universal and controllable, and involve all key participants If such a pause cannot be established quickly, then Governments should intervene and impose a moratorium by directive. AI Labs and independent experts should use this pause to jointly develop and implement a set of common security protocols for advanced AI design and development that will be overseen by independent external experts. These protocols should ensure that the AI systems that are developed are completely secure. This does not mean a stop to the development of AI in general, but simply a step back from a dangerous race with unpredictable consequences. AI research and development must be refocused on making powerful modern AI systems more accurate yet safe, interpretable, transparent, reliable and trustworthy. In parallel, AI developers must work with policymakers to greatly accelerate the development of robust AI control systems. These efforts should, at a minimum, include new and capable AI regulators, oversight, and oversight of high-performance AI systems. In this case,*

[11] A N Chomsky (born in 1928) greatly contributed to the classification of formal languages, known as the *Chomsky hierarchy*, which facilitated the development of the cognitive sciences.

humanity will be able to enjoy a prosperous future with AI. At one time, society suspended the use of other technologies with potentially catastrophic consequences. We can apply this measure here as well.

It is difficult to understand from the text of the above address which is more the point — concern for the fate of humankind or the desire to slow down competitors in the struggle for a new information market.

Today, the one-sided tendency in the development of part of the younger generation on the basis of computer games is becoming more and more noticeable, which leads to the displacement of reality from their consciousness. These youth, as they grow up, breed a trusting clientele of *chatbots*, which really begins to lead to unpredictable consequences. The virtual world in the brain of a child brought up in a virtual computer world lives according to laws that often do not coincide with those of the real world. This discrepancy is fraught with a violation of stability of their psyche (the effect of cyberpunkism) and may lead in the future and is already leading to a change in a significant part of *Homo sapiens*.

However, it is safe to say that the development of AI systems and chatbot programs cannot be stopped. Large laboratories will either stop publishing what they are doing, or, if prohibited by law in a given country, will either take their developments to other countries or prove that their work is exclusively beneficial for all humankind. Since the world has already formed a consumer society, in which only money rules, firms will seek and find dozens of ways to get around the bans. The Russian proverb, *Until the roasted rooster pecks*, is a good reflection of the behavior of today's financial elites. It is possible that the *cock will soon peck*. Experts at the *Goldman Sachs Group* (the largest investment bank in the United States) reported that, in the near future, with the development of AI, more than 300 million people may be left without work. In addition, seeking advice from *chatbots* can, among adolescents (the most unstable part of society), lead to an increase in self-sterilization and suicide.

Nevertheless, an optimistic scenario is also possible. Risks have always arisen and existed. Predicting the behavior of complex nonlinear systems is almost impossible. The next generation is likely to be smarter than the current one. This situation is common in the development of humankind and periodically repeats itself. Therefore, there is hope that humanity will cope with new risks. However, this requires the intensive development of education tuned to the development of interdisciplinary sciences and strengthening the promotion of their scientific achievements. Nature is one, and its division into rubrics is conditional [4].

The effectiveness of interdisciplinary sciences should cause optimism among young people, as it will accelerate the clarification that all particular risks, like physical laws, despite their diversity, have some common features. Their assimilation will accelerate humankind's adaptation to innovations. Here, it is appropriate to recall that the most fruitful applications of mathematical formalism are at the boundaries of the rubricators of the sciences. Back in 1944, the famous French mathematician *Jacques Salomon Hadamard* wrote the book *Essai sur la psychologic de l'invention dans le domaine mathématique* (*An investigation into the psychology of the process of invention in the field of mathematics*). As far as I know, it was twice translated into Russian [97]. Its main idea is that, for those who want to discover the hidden, it is important not to be isolated in one area of science but to keep in touch with its other areas. In fact, the mentioned book outlines the idea of a special role of consciousness and thinking in the development of mathematics, although the author does not explicitly indicate this but outlines in an implicit form a new branch of biophysics, which could be called psychophysics.

Nevertheless, one should not exaggerate, let alone absolutize, the significance of certain physical and mathematical ideas or scenarios and their current prognostic value, including the generalized Predator–Prey theory, because, at best, they will have to be modified many more times, and at worst, replaced with something new. This situation is common in the development of science. Since *biophysics* as a science is still based on classical mechanics, which is limited from above by the General Theory of Relativity and from below by quantum mechanics, not only the solution to many practical problems of biomedicine and ecology, but also the movement of the entire front of fundamental science, including the development of AI, depend on their mutual accelerated development [29].

It is necessary to understand not only how our brain works with information carriers but also how it works with the meaning of the information created and transmitted. When summarizing the results of the study, on the one hand, it is necessary to avoid errors generated by the plasticity of the human brain and a large individual variation in people's perception of the meanings of information. My experience shows that this is a very difficult task. The researcher in a study of the brain, in order not to fall into wishful thinking, must take into account the narrow but continuously changing corridor in the study of each individual brain. In other words, the researcher in this case is between Scylla and Charybdis. Many prominent people who have dedicated their lives to the neurosciences have become victims of erroneous interpretations of the results obtained. As an example, I will give a short list of the causes of such errors, consisting of four groups (it is possible that in reality there are many more of them).

1. Errors due to overestimation of the influence of the external environment:

• Reassessment of the importance of special cases dictated by external circumstances.

• Errors due to boundless faith in the infallibility of mathematics.

• Reassessment of the impact of external influence on future events.

2. Errors due to underestimation of the influence of the external environment:

• Underestimation of chances, i.e., the assumption that events are always influenced by previous events.

• Underestimation of the effect of amplifying suggestion, when a lie repeated many times may, by virtue of suggestion, seem to be true.

• Underestimation of the predominance in our memory of a positive perception of past events, arising from changes in our age and the conditions of the past period.

3. Errors associated with the work of the brain on the border of order and chaos.

• Error arising from increased attention to any one aspect of the phenomenon, which limits the range of prediction as a whole.

• The erroneous assumption that one can always control or at least influence the outcome of events.

• Underestimation of the fact that the last event is remembered better and displaces past events from memory.

4. Mistakes due to the rapid change in the influence of the social environment.

• Uncritical attitude to the assessment of events by any prominent person and dependence on this opinion.

• Neglecting the paradoxes that arise due to views shared by the majority of people.

• The erroneous and unconscious assumption that everyone else shares your opinion.

However, there are no reliable recipes for how to avoid such errors yet. Each of us can only hope for the development of our own intuition and our own experience.

I would like to end the article with the words: *it is unlikely that humans, developing information technologies, have driven themselves into a hopeless dead end. A way out on the basis of a compromise will be found in the near future and will serve as a new stage in accelerating the development of humankind with the widespread use of AI as a tool for understanding the world around us and ourselves*.

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