ABOUT PHYSIOLOGICAL BASICS OF LEARNING

Danijela Bonacin and Dobromir Bonacin

Faculty of Education, University of Travnik, Bosnia & Herzegovina

Preliminary scientific communication

Abstract
The aim of this article is to understand human learning from the aspect of physiology. We conducted comparison of targeted published information which dominantly deals with methodology of learning and physiology of nervous system. Considerations have shown that it is possible to direct attention to several segments which are probably crucial for the understanding of this matter. We must mention the various types of nerve cells, especially glia and granula cells. Paper addresses the problem of learning in biological and physiological premises, offering a global solution in 5 segments: a global genetic plan, construction, storage, infrastructure, evaluation.

Key words: *learning, processes, physiology, neurons, migration, glia, granula, hypocampus-amygdala*

Introduction

Understanding of learning in any area of human life is not an easy process, especially considering the fact that with the existence, actions and progress, throughout history, man developed the ability to make very complex and demanding construction out of everything that is related to him. So, ***everything*** a man deals with and what surrounds him requires attention and concentration, constant search and finding, understanding and comprehension and appliance and progress. This has brought him to the throne of all living beings. The answer to a question "how this happened?" is probably "***because he is the best learner***!", and the learning is carried out through different spheres. A man is gathering information, processes them, analyzes, discovers and stores this knowledge and applies it sooner or later. Archives knowledge and on foundations of cognition goes further through levels of existence. Sociologists would say this is because he functions in community; according to sociologists the reason for that is psychological profile of each individual while searching for "myself" in everything etc. Every scientific domain has its own theory or an attitude about learning. Physiology, on the other hand, should be interested in what is in a man, even though in interaction with outside influence, but primarily in the man himself, are processes and segments of physiological nature that serve to maintain the balance of internal human existence.

About human

Today's man is complex and demanding observed from all sides, but at the same time presents "amazing" machine able to manage himself and everything around him. He didn't become like this either today, yesterday or the day before. He developed through billions of years and today he presents the most sophisticated result of development of intelligent beings. According to available literature, life on Earth was created approx 4, 5 billion years ago.

That was back in time when there was a little land. There was also, almost no oxygen that could be used, and the day lasted less than 15 hours, where meteors were falling often and with considerable volcanic activity of the planet. Different living forms, through millions of years, adjusted to conditions on Earth in a way that allowed adaptable to survive and preserve their species. It is considered that life on Earth started when volcanic activities ejected a lot of gas and created thin atmosphere and steam clouds condensed and created oceans. After many species that existed and extinct, the beginning of Cenozoic era 60 million years ago, signified the beginning of mammal domination, i.e. the situation same as it is today on Earth, when the first humans appear (General Encyclopedia, 1974; Encyclopedia of History, 2005). As presented, today's man (Homo sapiens) is the result of long-term biological revolution. In his development the same principles ruled as in development of any other species. However, human species, in relatively short time, achieved its rapid development, and some species remained unchanged over the eons. In fact, the life on Earth started to develop 4, 5 billion years ago, and we follow human evolution in the last 4 billion years. In this period, in the beginning, life conditions were difficult, the environment was dangerous in different ways, through natural catastrophes (volcano eruptions, earthquakes, floods, meteors), other creatures (dinosaurs, other) to lack of food and water. In the survival struggle, a man developed from Australopithecus africanus who lived 4 million years ago, over Homo habilis (handy man) and Homo erectus (upright man) all the way to Homo sapiens neanderthalensis (Neanderthals) and Homo sapiens sapiens the species we belong to (e.g. Cro-Magnon). Random events recognized, understood and applied cognitions that forced them forward, better tools and weapons, forming larger communities all this impacted development of a man as it is today (Encyclopedia, 1974; Encyc. of history, 2005).

It's necessary to emphasize that a man was, and today is very complex structured being. He is so complex that the science in order to analyze it, has to divide it in the areas of similar content, so called anthropological sets that are subject to different sciences from different aspects with the aim of better understanding (Keros et al., 1986; Mraković, 1994; Bonacin et al., 2008; Bonacin et al., 2010). Certainly, the goal was to understand a man, consequently the results of the research from this spheres, knowledge and cognition derived from them and enabled further progress and easier long existence, which is learning *par excellence*.

Learning

General learning pattern

Each society has its own culture; system of learned forms, opinions, feelings and actions, as well as expressing these forms in material objects characteristically for certain group of people or community. Culture is a complex whole that consists of behavior patterns that people use, shared values, beliefs and rules to define the relationships of people, and people towards the middle and the tools and techniques that were invented by humans to adjust to the environment. Each culture has its own language, standards, customs, habits and laws. All this is founded on the abstract ideas – values about what is good, right and fair. These values are, through education and socialization transferred to next generations during primary (family) and secondary education (school, faculty, etc.) This task belongs to family and education institutions and today even variety of media like TV, internet, etc. (Fanuko, 1995).

System of any human community functions according to agreed rules and among individuals divided roles, so training such individuals for accepting their sociological roles becomes an important issue (Petrović & Hošek, 1986), and many understandings indicate the necessity to include all important elements of social communities into defining (Rosenstock et al., 1988; Greene, 2007; Morris & Burford, 2007). That value transfer of certain society that is conducted through various institutions, as well as formation of new values according to newly created information and knowledge is administrated by **learning**. Learning is activities by which the body of individual, under influence of surrounding conditions and results of own activity, changes its behavior in order to eliminate the state of initial uncertainty (Hobart, 1950). One part of learning includes motor learning because at the end everything is operationalized in variable environment a man resides, but it is also moving and manipulates the objects (Schmidt, 1975; Mraković, 1994; Guyton & Hall, 2006; Bonacin et al., 2008). That is a process of relatively continuous changes of individuals created during regeneration of new activities that is reflected in his altered behavior (Grgin, 1997). Learning includes receiving, processing and use of information. The skills (habits) and knowledge, is being learned. And indirectly it changes attitude, interests, values, adopt language, social standards, develop skills, social competence (work habits, organization of time, socializing, entertainment), as well as the information that are becoming material for personal and integrative types (logic, mathematics, physics, history, language, literature, linking facts, information, and knowledge of motor ,...) (Pašić, 1987; Nikolić, 1995; Guyton & Hall, 2002).

Processes

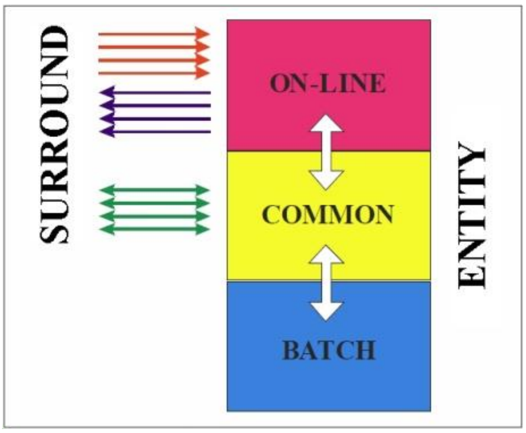

Figure 1. Processes (Bonacin et al., 2006)

Quantity and quality of cognitions increased in proportion with time, space and climate conditions as well as anthropological characteristics of a man, his ability to more artificially develop various tools and weapons, ability to work, adapt regarding the environment and to change it using tools and weapons. New discoveries that he gathered, a man integrated in existing cognition sets, practically directing and maximally using them in clear, specific limited purposes (Katić & Bonacin, 2001), building new models and forming new goals. Since his creation until today a man was learning in the same way. According to a model of three processes (Bonacin & Blažević, 2006) throughout history man was learning in a way of going through three levels. He was present in all three levels at the same time, but depending on the level of knowledge and progress was within these levels in different ratios. Generally, with higher progression, he was more present in the higher level. According to Bonacin & Blažević (2006), the cognition exchange or learning functions like there are three parallel processes and each of them in its development continuum keeps its maximum intensity in certain phase. Those processes are as follows: 1. ***On-line*** , where there is constant exposure of environment influence, information are being collected, they are hard to absorb and threatened with destruction, i.e. in principles they mostly react on stimuli from environment, 2. ***common***, pattern where a man is cooperative with the others it is possible to exchange knowledge with environment, still collecting stimuli from it but also returning, and 3. ***batch***, pattern where he dominantly broadcast information and knowledge i.e. creates but also educates others, but from the environments collects only what he considers important.

It is obvious that in prehistory a man was in on-line pattern 90% of time and situations because of the nature of his surroundings, his knowledge degree, etc. It was relevant for him to *survive* and reproduce and the rest was not so important. For the nature of development and continuous flow of new information and knowledge, the more capable and influential ones according to nature of things converted in common pattern, especially if they cooperated with the others, and the ones who really learned and gathered knowledge converted dominantly into batch pattern

Psychological learning patterns

Generally there is a few basic ways of learning: 1. learning *by cause* – generally award system (positive) and punishment (negative – avoiding and punishment). The example would be with imprinting which occurs for example when newly born baby reacts on mother's heart beats or to ducklings that follow the first thing they see. Hearth beat means protection, warmth, food. Everything else means the absence of that. With exposition learning for example the guinea pig learns to go through labyrinth without impulse, but it has to go somewhere if there is no space/food/water etc. This means its behavior and learning is conditioned by the absence of the mentioned. With habituation the body learns not to react to an impulse that is repeating and is not important. That is how newborn baby accustoms to the surrounding sounds; 2. *Associative learning* - connecting similar information in terms of time and space proximity or contrast. For example newborn baby, after certain time knows when it's time for feeding, changing and connects the space with those things. Other example is mechanic learning in terms which answer goes with which question then repeating the same with appliance of e.g. mnemo-technique; 3. Cognitive learning - with insight and deeper understanding of the task and includes the process of adopting content and structure reorganization includes revealing essential in material, determining fixed points in the matter, grouping of parts of the matter and logical connecting of these points (Andrilović & Čudina, 1988). We can also mention procedural and declarative memory i.e. long term and short term. Those two systems are placed in different part of a brain. Declarative system is learning the facts: words, phrases, date, capitals, phone number, etc. Procedural system is learning skills. The simplest example of procedural learning is bicycle riding. Collecting declarative knowledge generally requires concentration and memorizing. Procedural skills, on the other hand, are learned through work and practice (Ullman, 2005).

Learning in human development

Dominant somatic (in principle on-line): Somatic learning presents storage of information and resources for the needs of mostly somatic (body) functions and motion (motor programs in sensor areas, adrenal reactions, potential activation, etc). It was important in order to dislocate in space, food gathering etc. This is primarily referring to **implementation.** A man is learning different repertoires of behavior (verbal and motor) as well as criteria form (Andrilović & Čudina, 1988). In principle – „the body is learning". *Dominant differential (in principle common)*: Differential learning is remembering information with new goals and includes specialization (targeted activity) with dominant role of **knowledge**. Implementing is still present, but knowledge become dominant regarding to higher level and cortical functions are being developed for this purpose. We talk about targeted and largely conscious work. A man is directly learning skills (habits), knowledge, and indirectly with learning changing attitudes, interests, values, he adopts language, social standards, develops abilities, and socially acceptable expression of emotions, etc. (Grgin, 1997). In physiological sense, reverberative circles dominate and networks of these circles with probably determined number of glia cells and neuron granule cells. *Dominant managing (in principle batch)*: Managing learning means dominant cortical cognition functions in order to **manage**. Social competencies are being learned like work habits, time organization, socializing, entertainment, different disciplines etc.

Characteristics of this learning are planning, long term thinking etc, and all complex structures of CNS are activated. In this area learning occurs for the purpose of creating where opening of new areas and levels dominates because there is requirement for new solutions. For this purpose archived various and different structured knowledge is needed, its availability and possibility of its application (Bonacin Da., 2008). If we look back in the past of humanity we will see that his development starts with plain performance (running, catching, fight, reproduction) over specialization into hunters, magicians, collectors etc, to managing in the form of created systems with management control. Throughout all this time people function through on-line, common, and batch system of information exchange, and how much they are in which pattern tells us about how much knowledge they gained and how that influenced their ways of thinking and their needs (Bonacin & Blažević, 2006).

Physiological basics of learning

Anatomic basics of brain

A man's "apparatus for thinking and management" in other words brain, in adult man has a mass in range from 1200 to 2000 g, and surface of 2500 cm^2 with curved numerous protrusions (gyrus) and channels (sulcus). It has a shape of two hemispheres divided with sagital crack. Hemispheres are interconnected with commeasures that link with nerve fiber centers of left and right hemisphere. Within certain areas in brain there are centers for reception of stimuli from the body and head (vision, hearing, smell, touch, pressure, pain, etc.).

Bioelectrical potentials created in receptors are transferred by ascending (afferent) nerve routes (nerves) to specialized regions of the brain (visual, auditory, olfactory, etc.). Here, received bioelectrical potentials of certain frequentation and rate are sensed as original sense of a certain intensity and duration. According to different sources, the brain consists of cells and there is up to 100 billion. The largest part of all neurons is located in the cortex of the cerebrum. Cerebrum serves as some kind of receiver for all stimuli from surroundings and interior of the body. Bioelectrical potentials are directed into individual interpretative regions where they are being interpreted into a real sense (Judaš & Kostović, 1997).

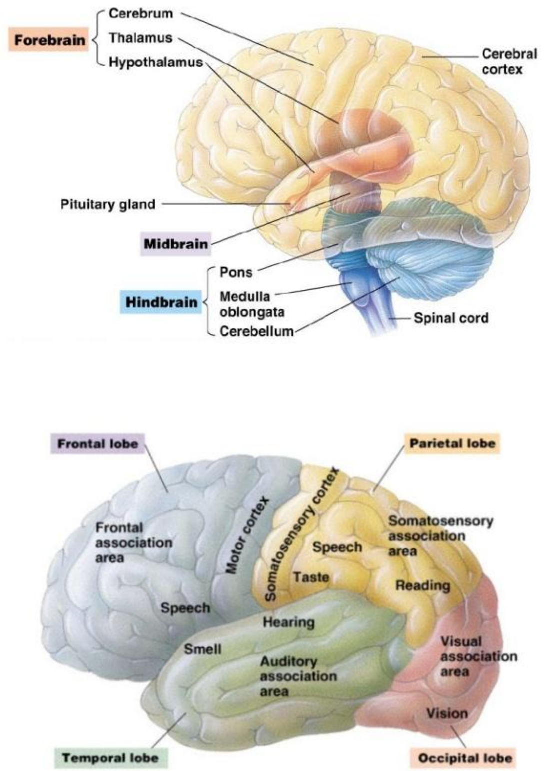

Figure 2. Human brain structure and functions

Table 1. Chick embryo primary brain vesicles and derivatives (Sadler, 2000; Smit, 2006)

Brain	Primary vesicles	Secondary vesicles	Derivatives
Forebrain	Prosencephalon	Telencephalon	Cerebral hemispheres
		Diencephalon	Thalami
Midbrain	Mesencephalon	Mesencephalon	Midbrain - Cerebral aqueduct
Hindbrain	Rhombencephalon	Metencephalon	Pons
			Cerebellum
		Myelencephalon	Medulla oblongata

Brain forms memory (remembers) by storing information (learning), and is able to "currently" read the stored information, i.e. to use the knowledge gained, and can manage a variety of motor functions. The brain is used for speaking and writing. It develops logical judgments and intelligence. It thinks abstract and real, determines consciousness, behavior, experience, temperament and personality of a man. The brain determines our attention, alertness, and is responsible for sleeping, dreams, alertness, etc.

Lower centres located in hypothalamus and thalamus, reticular formation etc, are supervising the state of alertness, modulation of motor functions, moderators of autonomy and reflex reactions, coordinators of balance maintenance and vital functions like breeding, heart beats, adjustment of blood pressure, maintaining body temperature, digestion organ's activity etc. (Judaš & Kostović, 1997; Guyton & Hall, 2002).

Functions of neurons

Human body is complicated structured system and the main unit is the **cell.** There are different cells adjusted to some functions in the body. The main physiological characteristic of nerve cell is excitability, i.e. ability to respond to stimuli and interpret stimuli into nerve impulses and conduction or ability to transmit impulses. Basic cells to transfer information through body are nerve cells and they make the most important body system – nervous system responsible for integration and management. Nervous system is basically acting like cybernetic (integration) system. It is characterized by receiving, transferring, storing, reading and interpreting of information as well as reaction to received stimuli or performing thinking activities. Nervous system consists of central and peripheral part. Central part is the brain (cerebrum, cerebellum and medulla oblongata) medulla spinals, and they are located in the scull and spinal canal. Peripheral system is made of nerves that connect body parts and central nervous system in both directions (12 pairs of brain and 34 pairs of spinal). Nervous system, according to structure, location and the role, can be divided in sensory (receptive), actuating or motor, willing (medulla spinalis), and autonomous (vegetative – sympathetic and parasympathetic).

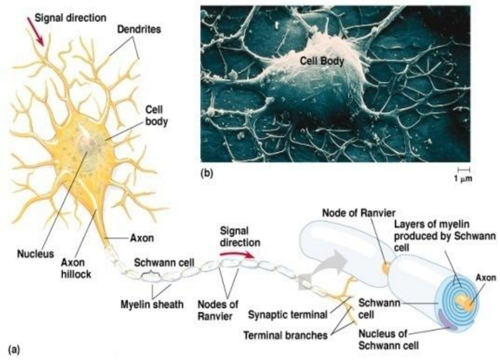

Figure 3. Neuron scheme (Wessley Longman, 1999)

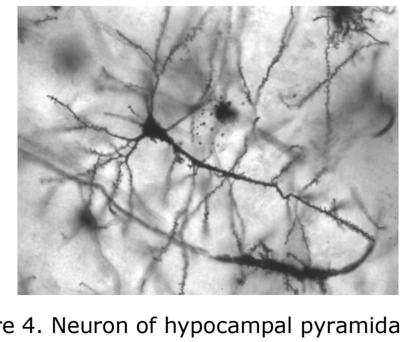

Figure 4. Neuron of hypocampal pyramidal tract (Wikipedia, 2010)

Entire nervous system was made of nerve cells – neurons. Neuron is made of cell body (soma) and in the extension there are a number of shorter nerve fibers (dendrites) and one long nerve fiber (axon or neurit). Dendrites are usually well-branched like a tree crown. Similarly is branched end part of axon that looks like plant rooth. Nerve cells are interconnected by nervous connections (synapses) and dendrites and axons. Specificity for nerve cells is inability of the division after the end of embryo development for the loss of centrosome (right before the birth). Regardless is it motor or sensory, big or small, each is electrical and chemically active. They cooperate in regulation nervous system general condition similar to individuals in society during decision making. If the nerve cells are uniting with their nerve fibers into the line they become **nerve**. In the brain, nerve cells are connecting in principle each cell with each cell, which doesn't have to be conducted till the end. Many branches of synaptic axons connect to multiple dendrites of neighboring neurons. This interconnection of neurons is called networking. Networked group of neurons that form a functional unit called - **neural circuit**. More interconnected neurons in the neural structure, the better function of that part of the brain. Functional classification of neurons divides neurons in the part of the neuron that receives information (dendrite) integrates them (soma) and the part that transmits them (Axon). This transmission we call polarization, since information is being transmitted only in one direction in neuron, and for re-transmission repolarisation is being achieved. Information is transmitted with impulses chemical signals that use neurotransmitters to get to axons. This chemical signals that dendrites received from axons are transforming into electrical signals that are summed or subtracted from electrical signals of other synapses where the decision is made whether the signal will be transmitted. Among nerve cells, some developed into specialized receptive (sensory, sensory, receptor) cells so they could receive specific type of stimuli like touch, pressure, heat, cold, taste, smell, sound, light, color, etc. Sensory neuron receives direct stimulus only on their receptive fields, which are mostly fiber dendrites or only body neurons. At the site of stimulation a number of osmotic and electrical changes will occur. For each such activity fuel is necessary. That is why there are "power plants" (mitochondrion) in the cell that enables its function.

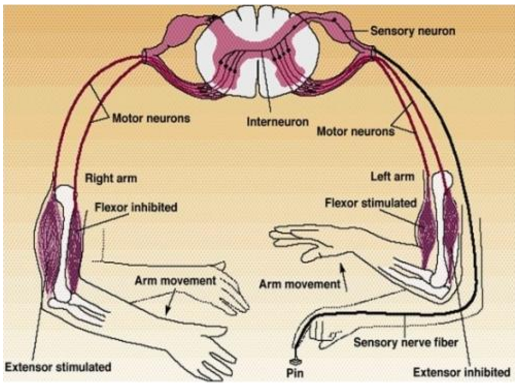

Figure 5. Reflex reaction

Majority of synapses on neurons of cortex are located on dendrite spikes, which peek like little microphones looking for week signals. The communication between neurons is placed in so called **synaptic transfer** and it consists of chemical processed. When dendrite receives some of chemical emissary – neurotransmitter, which crossed small crack that divides axon from dendrites, in dendrite spikes small electricity, is created. This electricity that enters the cell is called **excitation**, but could also be power that is coming out of cell, called **inhibition**. All this positive and negative power is gathered in dendrites and entering cell body. If the sum of these powers is not too big, they will disappear rapidly and nothing will happen. But, if the sum of powers exceeds certain value, then the message will be sent to different neuron as action potential enabled after refractory period (necessary for recovery). Neuron is, therefore, like small electro calculator – constantly summing and subtract messages received from other neurons. Some synapses cause excitation, some inhibition. Regarding network where neurons are incorporated, these signals will be the basis of sensory, thoughts and motion. Some neurons transmit impulse rapidly. This happens because big parts of axons are wrapped with small isolated blanket – myelin sheet, which is an outgrowth of glia cell membrane. Action potential along myelin axons has speed of 100 m per second! A feature of the action potential is everything or nothing, it will appear or it will not. Action potentials differ not according to their size, but frequency. This is the only way that the strength or duration of particular stimulus can encode in the individual neuron, is changing the frequency of action potentials. The most efficient axons can transmit the action potential frequency of 1,000 times per second (Guyton & Hall, 2002).

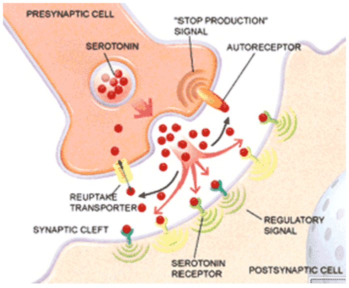

Figure 6. Logical synaptic link (Wikipedia, 2010)

Reverberation circles

Reverberation is generally the persistence of information in a particular space after the original information source is removed (Guyton & Hall, 2002; Ribeiro et al., 2004). In nervous system, such circles are able, in electrical level, to memorize certain information in shorter duration in a way to close the loop that keeps excitation in the set of regulated neurons. We practically speak of oscilatory sets that maintain continuous information active (Freeman, 1963; Pelionizs & Llinas, 1985; Freeman, 1992). However, not even existing number of neurons and neural connections in man wouldn't be sufficient to permanent memorizing.

That is since the amount of information that a man is familiar with, is large that reverberative circles would be constantly active, and since neuron functions in a way “all or nothing” then such circle would be specialized only for certain information, which would cause the system to lose its functionality. That is why the role of these circles is the key role in memorizing information that could, but not necessarily will become permanently recorded which releases activity for other information. This also means that reverberative circles do not contain information, but they are stored somewhere else, and the circle is just their temporary detention before saving, activating, or invocation of previously memorized material. Since neurons in the circle are making multiple connections, it is clear that virtually almost the same circle can, with different acquisition of various signals at synapses, recall different information, which entirely realizes his role.

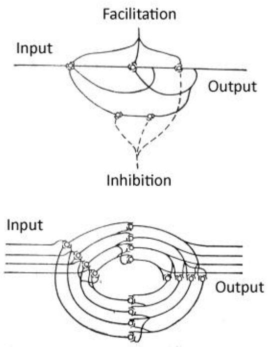

Figure 7. Two simple reverberation loops (Guyton & Hall, 2002)

Tissue of CNS system

Medulla spinalis contains gray matter located around central canal (canalis centralis). On cross section it has the shape of a butterfly or the letter ‘H’. Gray matter contains nerve cell body and cell glia. Central canal in the center is covered with ependimic stations as epithel. Marginally from gray there is white nerve matter. It is built of nerve fibers surrounded by the myelin sheath. White matter does not contain nerve pericarions and there are fewer veins in than in the gray matter. Cortex cerebellum (cortex cerebelli) consists of three layers: Stratum molecular (molecular layer) is a on the surface, a first layer in which a small number of basket looking and star-cells, Stratum gangliosum (layer Purkinje cells) is a second layer consisting of one row of large pearshaped Purkinje cells, and Stratum granulosum (granular layer) is the third layer, and its granulated appearance is the result of complex dense cores of granular cells. In the granular layer could be identified eosinophilic parenchyma islands (glomeruli cerebelaria), which consists of a number of nerve fibers and their mutual synapses. Cortex cerebellum shows regional differences. Most of the cortex seizes neocortex (izocortex) which is composed of six layers: Lamina molecularis is surface layer where there is only few nerve and gill cells, Lamina granularis external is the second layer which mainly consists of small roundish (granular) nerve cells, Lamina pyramidalis external is the third layer with pyramidal cells that characterize cortex cerebellum, Lamina granulates internal is the forth layer with a lot of roundish cells, Lamina pyramidalis internal is the fifth layer which contains large (Betz) pyramidal cells, Lamina multiformis is the deepest layer of cortex cerebellum where we find rarely arranged irregularly shaped neurons. Pyramidal layers are better developed in the area of motor cortex, and there are the biggest pyramidal cells (Betz cells), that can reach the size of up to 120 micrometers. In contrast granular layers are better developed in the sensory areas. The layers of cortex that pass one to another without sharp boundaries as well as lamina mulitformis slightly exceeds into white matter. Spinal ganglia (ganglion Spinale) are made from bodies of pseudounipolar nerve cells. Their pericarions are roundish and pear shaped, surrounded with the layer of densely distributed satellite cells called amficites. Nerve fibers in spinal ganglia are mostly mineralized (app. 70 %). Ganglia are surrounded with connective shell where thin binding fences along with blood veins penetrate into their interior. Vegetative ganglia (ganglion vegetativum) can be sympathetic and parasympathetic, are constructed from bodies of multipolar nerve cells. Their pericarions are different according to their size and form. Pericarion vegetative ganglia of nerve cells are carried out by amficites, but in far smaller numbers than is the case in the spinal ganglia. Pericarione nerve cells of vegetative ganglia amficita wrapped, but in far smaller numbers than is the case in the spinal ganglia. The fibers are mostly unmyelinated.

Brain 'maturation'

Brain maturation is a genetic process but epigenetic influence supervenes not only from embryos but from the external environment. Internal influence includes factors like surface interaction between cells and hormonal blood changes. External influence includes factors like nourishment and sensory experience. Interaction of this factors controls proper differentiation of neural cells and creation of neural links. This process takes place as a series of specific steps that are precisely timed and determined by temporal sequence that is relatively determined and characteristic for particular neural structure. Prenatal development is basically divided in few phases: stage of germination, embryonic and fetus stages. *Development in embryonic phase runs very fast.* Even though embryonic has only few inches, one month after conception it is 10 000 times bigger than zygote from which it developed while in the last 7 months of pregnancy i.e. fatal phase primarily purification of primitive systems that are already in the place is being conducted. *The growth of the brain doesn’t end with birth.* Since the seventh month of prenatal development to the child’s birth, brain gains more them one milligram per minute. At birth, the newborn baby’s brain has 25% of total weight of an adult, but by the second birthday the ratio increases to 75%. When we look at it like that, it is not surprising that the last two months of prenatal birth are determined as phase of extreme growth of human brain.

Human brain and nervous system consist of large number of specialized cells which are included in transmission of electrical and chemical signals through even larger number of connecting spaces between cells (Gross, 2006). There are different kinds of cells in nervous system: long neurons, glia cells and granules. Neurons are basic units for processing/transmission of information in the brain and nervous system and they are being formed at the end of the second third of pregnancy. *Glia cells are much more numerous then neurons and they are produced during lifetime.* They are probably not essential for neural transmission... It is considered they have other roles. *Glia cells are feeding neurons and ensure the solidness of a brain as supporting elements.* Some types of glia cells are producing soft matter called myelin that creates cover around majority of axons. Myelinization functions as isolator that speeds transfer of neural signal. Other kinds of glia cells have a role to feed, remove the remains of dying cells or injuries, or can participate in creating of blood-brain barrier, in migration of neurons toward cortical layers and elsewhere (Pašić, 1987) or in axon outgrow. According to number of cells, there is 10 times more glia cells then neurons, and ¾ of all neurons are granules. Initial creation of neurons and their migration to the right place in the brain are events that are almost completely take place before birth. There are two types of neural changes after birth: f*ormative* and *regressive.* Formative changes include proliferation, migration and differentiation of nerve cells, myelinization of neural routes, and increasing neurons connections between neurons. Regressive changes include neuron elimination and removing synaptic connections. It is interesting that a child after birth has more neurons and neural connections then in adult age. Mentioned changes in nervous system can enclose important pressure on development of motor skills, language and cognitive abilities. Creation of nerve cells begins inside the neural tube. From the hole of neural tube ventricular system CNS is being developed. Internal wall of neural tube creates all neurons and glia cells of nervous system. However, the creation of the cells is not equal along that neural tube. Different areas spread differently in order to create differently specialized structure of mature nervous system. Characteristic of nerve cells is that they migrate from the place of creation (in ventricular zones) until their final destination. Generally, we could say there are two ways of nerve cell's migration to their final destination. In some parts of developing nervous system, migration takes the form of passive migration. This means that after leaving the zone of creation, the cells are initially travelling small relations, but then from original location they are being transferred because of newly created cells. So the cells that originate earlier at the end become distant from the zone of creation, then the cells that originate later. The areas of nervous system that show the inside to outside spatiotemporal gradient include thalamic areas and many parts of brain stem and spinal cord. Still in many cases neuron actively contributes its migration from the zone of creation. When this occurs, later created neurons can pass through neurons created earlier and create a sample inside to outside that can be found in most parts of cerebral cortex. In order to analyze the brain growth it is important to know how migrating neurons travel to their final destination. Shortly after the formation of the neural tube many neural cells begin to generate. Although, certain cell group, radial glia cells, continue to maintain contact with both surfaces of neural tube. In cortex of a primate, many neurons are using radial cells to navigate from zone of creation to get to their final destination. Noticing this, Rakić in 1988 suggested hypothesis about glia cells, assuming that the zone of creation is already segmented into different units. He assumes that each unit creates neurons that are using the routs of glia cells, in order to get to some destination. In that fiber a series of individual units for creation is creating primary map of mature brain specialized areas. It is being assumed that radial cells are presenting the basis for columnar division of cortex. This division (separation) or mature cortex is an important indication of its functional organization. For example, the researching of visual cortex indicated when we vertically insert microelectrodes, all cells respond in the same way to visual orientation stimuli. When we move microelectrodes into neighbor area, cells react in the same way, but this time to differently oriented stimuli. Similar modular organization was discovered in other brain areas. For now it's important to mention that radial glia cells cannot explain the whole story, since many neurons migrate into areas of nervous system where no radial glia cells were discovered. Once a cell reaches its final destination, sometimes even before that, it enters the phase of differentiation. During this phase on the cell of growth, axon that ends as a bulge called conical growth navigates alone towards certain target. Even though mechanism of such route discovery is not completely explained it considers chemoafinity as one important factor. For example, it can be demonstrated that conical growth orients toward the target that transude protein known as factor of nerve growth, based on that we assume that conical growth can sense and follow chemical traces over large distances. Several hours after they reach their destination, conical growths are transforming into nervous terminal that gradually forms complete synapse. Formation of synapse is complex process which begins with immobilization of conical growth on its target. Then the receptor molecules accumulate under the terminal while the density of receptors above synaptic place is significantly reducing. When receptor molecules are stabilized under the growing terminal, other axons can arrive and connect to the same target. The one that arrives first is not necessarily the one that will endure. In another words, some synapses will be eliminated even majority of contacts continues to grow. Important function of selective elimination is not only fine tuning of synaptic connections but also adjustment and even elimination of neural routes. There is interesting phylogenetic trend in synaptogenetics of cerebral cortex.

In rodents there is little evidence of excessive synapses. In the brain of a rat synaptic density reaches maximum that is only by 10% bigger than the value of an adult. In cats, maximal value is 50 % bigger than the value of an adult and in monkeys and man maximal value is bigger than the value of an adult for 75 – 95%. In human visual cortex (area *17*), only 10% out of maximum value can be found around birth. The maximum is reached around the age of 8 months, followed by a decline of 50-60% with maximum in age of 11. Synaptogenetics is different for frontal cortex (middle frontal lobe). Maximum synaptic density is reached around age of 1, and he decline that follows can be evident in the age of 7, while the level of an adult is reached at age of 16. If we notice that human brain contains large initial excess of synaptic connections, that is later purified in order to keep only some connections while other disappear, this results with epigenetic theories of brain development that are being strongly associated with assumptions of selective stabilization. Theory that epigenetic contributes specification of neural networks is offering satisfying explanation for obvious disruption between complexity of brain and simplicity of genomes. For example, functional cognition link between amount of DNA, genetic material and brain complexity is still not established. From a mouse to a man, the level of brain organization and performance is spectacularly increased, while the total amount of DNA in nucleus has no significant changes. In the same way epigenetic theory can offer explanation of huge brain connectivity, coded by limited number of genes. Epigenetic theory, with selective stabilization, ensures existence of critical periods and sensitive phases in body development that correspond to phases of maximal connection where synaptic contacts are still in labile state (Scheibel, 1997). Presence of large number of labile connections can enable anatomic basis for neural plasticity during development. Finally, extended period of synaptogenetics can influence psychopathology. For example, obstruction of synapses elimination evidently is linked to etiology of some diseases, like shizofreny. Ideally, when the conditions in inner body environment (cells) are unchanged or permanent, the body is in the state of homeostasis. The ideal case would be the state of resting, absence of stress of any kind. This obviously proves that homeostasis is variable state. Concern about the state of homeostasis leads biological control system made of receptors, integrating control unit and effects of where the most control systems operates on the principle of negative feedback – what is missing seeks to complement or balance (when thirsty – we drink).

Hypokampus and Amygdale role in learning

Creation in the middle NS - hyppocampus, is one of the oldest, and the research on animals indicated it „behaves" very specific during learning, so, among other things, for example, there is evidence that this is a kind of cognitive map of *spacialization*, i.e. determining the position in space.

That was especially in the past, due to highly variable environmental conditions, is crucial to the motion. Hyppocampus participates in determination of space relations and with defining long term memorization (*potentiating - LTP*) is extremely active. During its activation the phenomenon of transmitter glutamate is particularly emphasized, which is the most abundant transmitter in all vertebrates (found in cell membranes) and is believed to be involved in the process of learning and memorizing, so it is concluded that the glutamate plays one of a key roles.

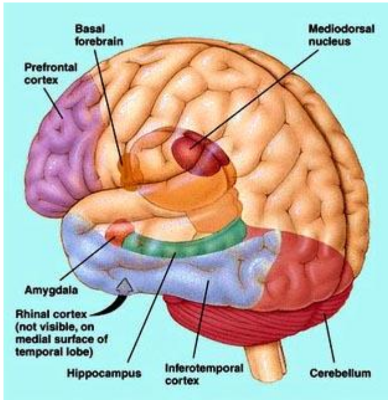

Figure 8. Hippocampus and Amygdale location (Wikipedia, 2010)

Corpus amygdaloideum (Greek: αμυγδαλή) is a name for large set of nuclei located in the top part of dorzomedial temporal lobe and presents the major basal ganglia of limbic system. Amygdale is a structure Amygdale structure in which there is the sensory integration of specific information to provide adequate *emotional significance and context,* and electrical stimulation results in experiences of positive or negative emotion, depending on the core of stimuli. Three large bundles of axons are connecting the amygdale with other brain areas. Efferent axons from amygdale are transferring to various brain areas; septal-preoptical area and hypothalamus, numerous areas of brain stem and cortex as well as to corpus striatum. Afferent fibers mostly arrive from the areas where efferent are projected for their two way connection with limbic, paralimbic, unimodal and heteromodal areas of cortex, as well as with earlier mentioned parts, amygdale participates in regulation of instincts, affective and motivation states, autonomy and endocrine functions. Joseph LeDoux in Centre for Neurology New York University was the first to discover the key role of amygdale in emotional brain. That research indicates that amygdale acts like some kind of cell alert or "neural alarm", and can take control over behaviour even while the prefrontal cortex is still in the phase of selecting adequate reaction. The nerve routes that regulate emotions can avoid cortex. Signals from the eye and ear in the brain first travel to thalamus, and then – switching only in one synapses – to amygdale. Second signal (goes the long way because it has to go through cognitive processing) from thalamus is directed in neocortex, and then to limbic brain that reaction transmits through entire body (Guyton & Hall, 2002).

This shorter way that requires only 12 milliseconds to activate amygdale, can explain how some emotional reactions and memories can appear without the slightest conscious, cognitive contributions. Hippocampus helps with creation of emotional reaction giving the adequate context, analyzing and comparing of incoming signals with the ones stored in memory material (Judaš & Kostović, 1997). When the system of amygdale – hippocampus reacts without returning information from cortex, leads to strong and fast emotional reactions, but at the same time superficial and incorrect since the analysis of situation is conducted with association. The common characteristic of disorder is incorrect direction of instincts at visible targets in the environment. The instinct is not the only thing disordered, but its directing to certain target. If out amygdale would be surgically removed, we would lose the ability to recognize feelings, as well as every other feeling about feelings. We would not be interested for contacts; we wouldn't be able to recognize relatives. Amygdale is considered as storage of emotional memory. A life without amygdale has lost a meaning of everything personal. The most significant of bilateral amygdalectomy in monkeys and similar injuries in humans is obvious lack of fear, which indicates *that there is no usage of previous knowledge /experience.* Results suggest that the left amygdale is more included in performing and interpreting detailed characteristics and stimuli, and in processes related to language, while the right amygdale is assigned for requiring information with special emphasis on graphically-emotional. It is concluded that these sets primary refer to importance of perception of situation and objects in environment, and for evolutional reasons are less included in objective learning (Judaš & Kostović, 1997, 385) but obviously help to process *aposterior* concequences through actions directing (Judaš & Kostović, 1997, 404).

Glia and granula cells

According to several sources, primary glia cells are, so called, radial, that are through their development forming into other shapes, e.g. astrocites etc., which can be shared entire life. It is obvious their role is very important in the beginning of nervous system formation and then in some other situations. According to behavior of radial glia cells it can be concluded they are the key in implementation of plan of neuron migration as well as later „maintenance". It is similar with granule neurons which dominate by the number in the nervous system, and the majority lacks axons, which means they do not significantly participate in primary impulse transmission. All this is already sufficient for assumption they serve for some other purposes, also for memory and learning. For this learning glia cells are required as well as activation of long structures like amygdale, hippocampus etc. Literature mentions some of glia cells can be shared entire lifetime, do not transmit information, have only one ending, and probably are not intended for mere transmission (Pašić, 1987).

It is similar with granule neurons in sensor areas (Judaš & Kostović, 1997, 182) that could serve as storage for information, which differ from motor areas (Judaš & Kostović, 1997, 348, 360). In both cases information are not memorized by electronic but some other, probably by chemical way.

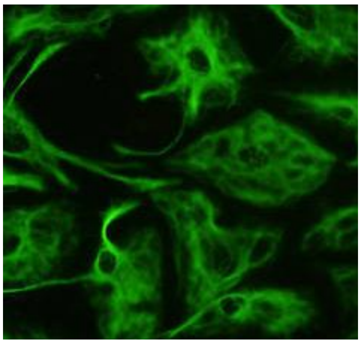

Figure 9. Astrocytes (Wikipedia, 2010)

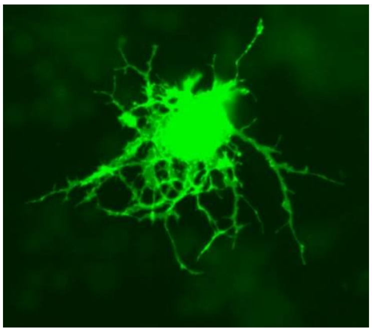

Figure 10. Oligodentrocytes (Wikipedia, 2010)

The fact that glia cells do not transmit impulses, and granule cells make ¾ of brain cells, there is a question whether they are the storage of this huge knowledge that can be used for preparing new solutions? This idea is supported by researching conducted on cells in early phases of development. Once the primitive migrating nerve cells have reached their final position, they begin to develop extensions from their cell bodies (Scheibel, 1997). The process of synapse formation probably starts in the mid or late second trimester and continues during the life of the individual. Careful ultramicroscopic studies show that synapse formation proceeds at its highest rate during the first 6-8 years of postnatal life, then plateaus and begins to decrease with the onset of puberty. This process of numerical decrease can be thought of as a pruning process in which excess or unwanted connections are discarded. During the first 6-10 years of life, the young individual undoubtedly achieves the highest density of synapses per unit volume of neural tissue (and the highest level of cortical glucose metabolism as revealed by PET scans) that he/she will ever have. This is also a period of enormous information input and acquisition, social, environmental, linguistic, etc. The growing brain may well be in its most sponge-like phase of learning as the child becomes acquainted with the endless range of symbols, rules, facts and behaviors that make it a member of its culture (Scheibel, 1997).

Neuron mylinization through sensor and motor areas becomes right after birth, and for higher functions (executive functions, intentions, planning…) later, up to younger adult ages (Scheibel, 1997; Guyton & Hall, 2002).

Conclusion

A man is only one spot in whole Comprehensive continuum (Bonacin, 2005). Direct influence (of cultures, knowledge, artistic and scientific works) is visible a few years in the past (at him) and some in the future (at the others). However, it is forgotten that all this cognitions are built into fabric of cognitive continuum and make material for the following, but related to the previous. Nothing of "imaginary" does not really belongs to individual, but it's only about detection of the current in the form of existing natural laws that man articulates according to actual cognitions. In order to do so, a man is learning in any way possible way. Thereby the functions of memory are ensured, since without them the learning would be impossible. On the specific physiological level, it seems it's easy to recognize a few ways of learning in central nervous system. Primarily on the level of neurons who are able to transmit impulses.

However, this learning is local, so for the higher level the neurons are connecting into more complex sets – reverberation circles that are able to remember information that lasts for few seconds or minutes. Their networking maybe enables memorizing of more complex material, or longer remembering, is not satisfying electrical potential since for different reasons it could be lost. For that purpose chemical storage serves, which could be ensured with the help of glia cells in neuron granules, also in ways that don't have to be fully understand. In physiological sense, learning is actually acting directed toward exercise (return) of homeostasis with attempt to equalize the difference between internal and external; the unknown and recognized.

In order to store some information temporary, high frequency and intensity of the event is required, since in primary memorization, if something appears often and intensively in the environment it is probably very important. The final decision about whether to remember something probably comes from the set of hippocampus-amygdale, where these information's are stored in special storages, like cortex probably by granule cells. So the following general model can be assumed: 1. genetic record opens the door for expansion of neurons (global record); 2. Glia cells act as designers and authorities responsible for conducting site (construction and maintenance); 3. Granula cells are the storage of information (library records) 4. Neurons of long axons with a lot of dendrites electrically pass information to storage where they can help write/read them if needed (infrastructure). 5. Hippocampus-amygdale is highly responsible for the evaluation of new information. The possibility of this assumption confirms the fact that in all mentioned situations the main transmitter is glutamate, which is the most frequent transmitter ever in vertebrates and considers being included in the process of learning and memorizing, and it was found in membranes of neurons glia cells, just like in intensive engagement of hippocampus. Mineralization of neurons (bodies of previously used neurons), as well as epithel layers, liquor, supplies and other, makes CNS structure stable. All together looks like development of structures known in nature like trees and corals, of course, much more expressed connection between the elements and specialized layers.

Figure 11. Coral (Wikipedia, 2010)

Literature

Andrilović, V., & Čudina, M. (1988). *Psihologija učenja i nastave.* [Psychology of learning and teaching. In Croatian.]. Zagreb: Školska knjiga.

Bonacin, D., Bilić, Ž., & Bonacin, Da. (2008). *Uvod u antropološku analizu*. [Introduction to anthropological analysis. In Croatian.]. Travnik: Faculty of kinesiology.

Bonacin, D., & Blažević, S. (2006). Avant-garde model of motor abilities. *In: Bala, G. (Ed.) Anthropological status and physical activity of children and youth. Interdisciplinary scientific conference. Novi Sad,* Proceedings: 39-44.

Bonacin, D., Blažević, S., Bilić, Ž., & Bonacin, Da. (2010). *Uvod u kineziološku analizu*. [Introduction to kinesiological analysis. In Croatian.]. Travnik: Faculty of education.

Bonacin, Da. (2008). Prapovijesni čovjek, moderni čovjek, čovjek koji upravlja. [Ancient man, modern man, man that manage. In Croatian.]. *In: Ćaklovica, F. (Ed.) Proceedings of international symposium "Human and modern world "*, *University of Sarajevo, Sarajevo*, pp. 73-80.

Fanuko, N., et al. (1995). *Sociologija*. [Sociology. In Croatian.]. Zagreb: Školska knjiga.

Freeman, W.J. (1963). The electrical activity of a primary sensory cortex: analysis of EEG waves. *International reviews of neurobiology, 5,* 53-119.

Freeman, W.J. (1992). Tutorial on neurobiology: From single neurons to brain chaos. *International journal of bifurcation and chaos, 2*(3) 451-482.

Greene, S. (2007). Including young mothers: Community based participation of active citizenship. *Community development journal, 42*(2), 167-180.

Grgin, T. (1997). *Edukacijska psihologija*. [Educational psysiology. In Croatian.]. Jastrebarsko: Naklada Slap.

Gross, L. (2006). A new window into structural plasticity in the adult visual cortex. *PloS Biology, 4*(2), e42.

Guyton, A.C., & Hall, J.E. (2002). *Medicinska fiziologija*. [Medical physiology. In Croatian.]. Zagreb: Medicinska naklada.

Hobart, M.O. (1950). *Learning theory and personality dynamics: selected papers*. Oxford: Ronald Press.

Judaš, M., & Kostović, I. (1997). *Temelji neuroznanosti*. [Basics of neuroscience. In Croatian.]. Zagreb: MD.

Keros, P., Krmpotić-Nemanić, J., & Pećina, M. (1986). *Anatomija čovjeka: lokomotorni sustav*. [Human anatomy: locomotor system. In Croatian.]. Zagreb: Faculty of medicine.

Katić, R., & Bonacin, D. (2001). *Kineziologija za sva vremena.* [Kinesiology for all times. In Croatian.]. Kaštela: Personal edition.

Morris, K., & Burford, G. (2007). Working with children's existing networks-building better opportunities? *Social policy and society, 6*(2), 209-217.

Mraković, M. (1994). *Uvod u sistematsku kineziologiju*. [Introduction to systematic kinesiology. In Croatian.]. Zagreb: Fakultet za fizičku kulturu.

Nikolić, Z. (1995). *Fiziologija fizičke aktivnosti.* [Physiology of physical activity. In Serbian.]. Beograd: Fakultet za fizičku kulturu.

Pašić, M. (1987). *Fiziologija nervnog sistema.* [Physiology of nervous system. In Serbian.]. Beograd: Naučna knjiga.

Petrović, K., & Hošek, A. (1986). *Prilozi za sociologiju sporta 1 i 2*. [Sociology of sport 1 & 2: Adendum. In Croatian.]. Zagreb: Fakultet za fizičku kulturu.

Pellionizs, A., & Llinas, R. (1985). Tensor network theory of the metaorganization of functional geometries in central nervous system. *Neuroscience, 16*(2), 245-273.

Ribeiro, S., Gervasoni, D., Soares, E.S., Zhou, Y., Lin, S.-C., Pantoja, J., Lavine, M., Nicolelis, M.A.L. (2004). Long-Lasting Novelty-Induced Neuronal Reverberation during Slow-Wave Sleep in Multiple Forebrain Areas. *PLoS Biology, 2*(1), e24.

Rosenstock, I.M., Strecher, V.J., & Becker, M.H. (1988). Social Learning Theory and the Health Belief Model. *Health Education & Behavior, 15*(2), 175-183.

Sadler, T.W. (2000). *Central nervous system*. In: Katz, S., Scogna, K.H., Cady, B. (Eds.) Langman's medical embriology 8th ed. Philadelphia: Lippincott Williams & Wilkins.

Scheibel, B.A. (1997). Embryological Development of the Human Brain. News from the neurosciences. *New horizons for learning, 3*(2).

Schmidt, R.A. (1975). A schema theory of discrete motor skill learning. *Psychological Review, 82*(4), 225-260.

Smit, E. (2006). *Morhological changes in chick embryo neural tissue associated with hydrocortisone use during prenatal development.* (Dissertation). Pretoria: University of Pretoria.

Ullman, M.T. (2005). A Cognitive Neuroscience Perspective on Second Language Acquisition: The Declarative/Procedural Model. *In Sanz, C. (Ed.), Mind and Context in Adult Second Language Acquisition: Methods, Theory, and Practice,* Washington, pp. 141-178.

* * * (1967). *Opća enciklopedija*. [Encyclopaedia general. In Croatian.]. Zagreb: JLZ.

* * * (1998). *Enciklopedija povijesti*. [Encyclopaedia of history. In Croatian.]. Zagreb: HLZ.

O FIZIOLOŠKIM TEMELJIMA UČENJA

Sažetak

Svrha članka je razumijevanje ljudskog učenja s fiziološkog aspekta. Metodološki, izvršena je usporedba ciljanih publiciranih informacija koje se dominantno bave metodologijom učenja i fiziologijom nervnog sustava. Promišljanja su pokazala da je moguće usmjeriti pozornost na nekoliko segmenata koji su vjerojatno ključni za razumijevanje ove materije. Tu svakako treba spomenuti razne vrste nervnih stanica, a naročito glija stanice i granule. Članak adresira problem učenja u biološko-fiziološki prostor nudeći globalno rješenje u 5 segmenata: globalni genetski zapis, konstrukcija, skladištenje, infrastruktura, evaluacija.

Ključne riječi*: učenje, procesi, fiziologija, neuroni, migracija, glija, granule, hipokampus-amygdala*

Received: March 24, 2010.
Accepted: May 10, 2010.

Correspondence to:
Danijela Bonacin, MSc st.
University of Travnik
Faculty of Education
72270 Travnik, Aleja konzula 5, Bosnia & Herzegovina
Tel: 00 387 (0)62 42 20 52
E-mail: danijelab@actakin.com