*Chernigovskaya T., Yu. Natochin, V.Menshutkin.* Principles of evolution of natural and computer languages and physiological systems. // In: "Becoming Loquens" – Bochum Publications in Evolutionary Cultural Semiotics, (Bichakjian, Chernigovskaya, Kendon, Moeller – Eds.), Peter Lang, Frankfurt am Main-Berlin-Bern-Bruxelles,New-York,Oxford,Wien. 2000 vol.1, pp. 211-236

# Principles of Evolution of Natural and Computer Languages and of Physiological Systems

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ABSTRACT

The laws of evolution seem to be relevant not only to biological domains, but also to for informational systems. In the present paper we discuss features of evolutionary tendencies as seen in biology, and in human and computer languages. The search for the common features of evolution in such different spheres is intriguing since changes within these evolving systems occur at different rates and over vastly different time scales. Animals needed millions of years to develop homeostatic systems providing physico-chemical stability within the body; human languages have been developing for thousands of years, while computer languages have only existed for a few decades. In this paper we compare the three systems. We are well aware of sets of restrictions presented by each of the domains: the linguistic changes under discussion did not occur in all languages, in many cases changes are still going on, there are "old" and "new" languages,etc. We argue that *the patterns of evolution of functions* are hierarchically organized and can be described according to 4 main levels: I - *primary level* - "a cell"-in biology, "a phoneme" -in natural language, "an identifier"-in BASIC; II - *functional units* - "a nephron", "a morpheme", "an operator"; III - "*organs*" - "a kidney" ,(lung, heart,etc.), "a word", "a procedure"; IY - *a system* - "water-salt balance", "sentence-or phrase", "program". The data indicate that such extravagant comparisons appear to be relevant and show that the same patterns exist in such far removed objects as human languages, computer languages and physiological systems. It allows us to suggest some general evolutionary principles.

In recent decades there has been progress in the development of such multidisciplinary domains as language origins and evolution. This progress has resulted from the sharing of paradigms and data between researchers who study such diverse subjects as historical linguistics and archeology on the one hand and primatology, anthropology, anatomy and neurosciences - on the other ('Language Origins:multidisciplinary view',1992).

The contribution of paleoanthropological research into the problem of language evolution is clear (Wind,1970, 1976; Tobias, 1971;Falk,1987; Delson et. al.,1991; Ragir,1992; Wallace,1994; Budil, 1994). Most interesting for the purpose of this paper are the studies which support a relationship between linguistic typology or differenciation and evolutionary affinities (cf. Cavalli-Storza et al.,1988; Mellars, Stringer,1989; Vigilant et al.,1991; Ward et al.,1993, Greenhood,(in press). In demonstrating congruence between genetic and linguistic evolution, Cavalli-Storza et al.(1994) draw the conclusion that the association between linguistic families and the genetic history of humans is far from random . Reformulating Darwin's prediction (Chapter 14 'Origin of Species'-Darwin) that information on the genealogy of man would assist classification of languages now spoken, Cavalli-Storza et al indicate that when general principles of correlation between the genetic tree and linguistic families and super-families are established, predictions of times - and even places - of linguistic families' origin can be made It is evident that 'realization' of human language is achieved through articulation, audition and mental processing ( cf. Lieberman, 1984,1992; MacNeilage,1987, 1991; Allott,1989; Fabro,1992; Kien,1994; Daniel, 1994). Therefore evolution is seen in peripheral (articulatory, auditory systems) - and in the integrating systems of the brain. In comparison with the first two - the higher cortical functions are a subject of constant debate. While behaviorists and some artificial intelligence researchers treat the brain as a general purpose processor, Chomsky's followers describe it as a bundle of highly specialised 'instincts' ('universal grammar' among them) designed by evolution to learn certain things (cf. Comsky, 1986; Catania,1992 ; Donald,1993 ).

How does linguistic evolution compare with biological evolution? Does it reveal the same principles? Of course, its rate is much faster than that of biological changes, to say nothing of changes seen in artificial languages to be described below. Nethertheless, at least some traits seem to be comparable.

The principles of the evolutionary process go far beyond the province of biological evolution and appear to be of a general nature. In the present paper, concerned with supporting the above view, three different subjects of study have been chosen: natural language, artificial (computer programming) language and a physiological system. The physiological system chosen is the one that maintains the constancy of the physico-chemical parameters of the internal milieu in the body, enabling effective function of the brain and sensory organs but depending itself on the brain's coordinating activity. Natural language, a product of a long period of evolution as a communication system is also examined. Finally, we examine the artificial languages of computer programming, which have been created and have reached a high degree of development in the course of just one human generation.

A little more than a century ago, C. Bernard (1878) framed the concept of the milieu interieur (internal medium), a controlled environment that surrounds the cells of the body in advanced animals such as mammals. The (brain-controlled) homeostatic systems provide a high degree of constancy in the internal milieu in the face of wide fluctuations in the external milieu. Almost six decades after Bernard, Barcroft wrote that over the ages, the constancy of the internal medium was regulated with increasing accuracy until, in the long run, this regulation reached such a degree of sophistication that it enabled the human capabilities to develop, so that man could cognize the world around him in terms of abstract knowledge. Barcroft gave a graphic answer to the question of why the highest degree of stability is required in the physico-chemical parameters of the internal milieu. He wrote that the chemical and physiological processes associated with mental activity are so delicate by their nature that beside them changes measured with the ‘thermometer’ or the ‘hydrogen electrode’ look enormous, catastrophic. To presume a high intellectual maturity in the milieu the properties of which are not stabilized is the same thing as to seek music in the crackling of ill-tuned broadcast, or ripple from a boat on the stormy Atlantic surface.

Thus, it can be inferred that a progressive development of higher cortical functions, including informational systems, needs as stable internal milieu as possible. This idea was expressed aphoristically by C. Bernard: “La fixite du milieu interieur est la condition de la libre”

Finally, we need to explain why we have analysed the principles of kidney evolution. The kidney plays a key role in the maintenance of the physico- chemical constants of the internal medium in humans and animals (Smith,1951,1953). The more advanced the organism in its evolutionary history, the more stable is the volume, chemical composition, osmolality, and pH of extracellular fluids (Natochin et al., 1976,). So, the purpose of this paper is to assess features of evolution of in homeostatic and informational systems in order to compare the principles of evolution in these systems. Darwin (1872), in “The Origin of Species” and his various followers, including Haeckel (1874,1940), Dohrn (1875), Lucas (1909), and Orbeli (1961), discussed the problems of the origin and evolution of functions. Toward the end of the $19^{th}$ Century, and in the first decades of the $20^{th}$ Century, some basic principles for the evolution of organ function were put forward. In 1875, Dohrn suggested the principle of function change in the evolution of organs; in 1886, Kleinenberg advanced the principle of substitution of organs; Severtsov (1939) and Schmalhausen (1949) showed the intensification of functions and multifunctional nature of organs as principles of evolution of functions. The above concepts were built largely on morphological grounds, but from the physiologist’s point of view it is obvious that each organ can perform its function only as a part of the whole functional system. For this reason, it was believed that the principles of evolution of function in physiological systems should be regarded at different levels of their organization (Natochin,1984, Natochin et al.,1992) In the case of a homeostatic system, particularly, that of ensuring the water-salt homeostasis, we deal with the evolution of functions on primary level - in specialized *renal cells(I).* The next level is the evolution of functions in the *nephron* (II)which is the functional unit of the organ (the kidney); the third level is the evolution of the *organ*(III), that is, the kidney itself. The high level involves the evolution of the *physiological system* (IY).Regulation of the water-salt balance include specific receptors (osmoreceptors, volume receptors, ion receptors), central nervous system integrating centres, efferent nerve outputs, humoral regulatory factors and effector organs (kidney,salt glands,gill,etc),which provide for fulfilment of neuronal system decisions.

A similar four-level approach may be applied to both natural and programming languages. In the present paper, an attempt is made to consider the principles of evolution of function for all the subjects of analysis on the basis of the hierarchy of their functional organization. As distinct from biology, evolutionary ideas in linguistics are not well recognized.

Nevertheless, in the 19 th century, when languagere first came under the scrutiny of sistematic science, a few successful attempts were made to apply evolutionaryideas from biology to the description of language (Schleicher,1873). Although these attempts were made by such prominent linguists as Sapir (1921) and Jespersen (1964), they were not taken seriously until recently. This is because, in the 20th century, through the influence of Saussure (1916), Jakobson (1964), and others up to Chomsky (1986), language came to be viewed as a static system with a set of rules for combination and substitution of elements, regardless of how it may have evolved from protolanguages to modern languages. Thus the central idea in the study of language from an evolutionary perspective, that human languages evolve and become more effective, although generally accepted in biology, is quite paradoxical in linguistics.

Nevertheless, since the beginning of comparative linguistics and throughout its subsequent extensive development in the 20th century, there has been much discussion of the issue of language typology, comparing both related and widely separated languages and also the question of what features may be shared by all languages. Studies on the reconstruction of protolanguages are progressing rapidly, especially in recent years (Gamkrelidze,1985; Gamkrelidze, Ivanov,1984). General features of language evolution can be seen in the family of Indo- European languages, because they are best studied for the longest period of time (6-7 thousand years). The regularities revealed in studies of Indo-European languages have turned out to be applicable to the evolution of other language groups: Hamito-Semitic, Altaic, Uralic and others (Burrow, 1955; Benveniste, 1962; Coleinder,1965; Diakonov,1965; Poppe,1965; Ivanov, 1979, 1982; Elizarenkova, 1982; Thomsen,1984; Gamkrelidze,1985; ; Hopper,1992). Thus there appear to be regularities of evolution that are widely shared among different languages, which can be traced at different levels, from that of. *phonology (I) up to the sentence level (IY)*

It is important to bear in mind that these regularities will be expressed differently, according to the type of language being considered. For example, in tone languages (Chinese, Burmese, Vietnamese) changes can take place only in tones, the segmental sounds remaining the same. In languages of other phonological types changes may occur in the segmental sounds or phonemes. Furthermore, linguistic features are “scattered” over different languages and not necessarily are present in each of them.

Despite all aforesaid, the evolution of language, characterizing comparable, though differently expressed phenomena, are quite evident, in much the same way as basic features of evolution can be traced in the course of evolution of different groups in the animal kingdom. For the interdisciplinary analysis of principles of evolution it seems promising to compare data in historical linguistics, on the one hand, and ontogenetic data on the first language acquisition, on the other hand.

The work on the fossil anthropoid sound-producing apparatus simulation and on the synthesis of sounds that could be articulated by this apparatus is of considerable importance. Also significant is to compare these data with both cognitive level of hominids and anthropological evidence of particular cerebral areas development

(Bunak,1958, 1968, 1980; Leiner, Leiner,1991; Lieberman, 1992). Valuable information on this topic is to be found in neurolinguistics, in studies of linguistic functions as related to cerebral mechanisms (Pribram,1971; Luria, 1980; Fabro, 1992, Chernigovskaya, 1993, 1993a, 1994, 1995).

In recent years, attempts have been made to discuss language development in terms of processes recognized in biological evolution, such as paedomorphism, neoteny, recapitulation, language hybridization, mono- and polygenesis, etc. Substantial contributions to this have been made by Bichakjian (1988,1991). In our paper, only the data on the evolution of the best-studied Indo-European languages will be briefly considered.

As noted above, it is of interest to compare natural and artificial languages. The programming languages, as distinct from natural ones, are intended for dialogue between man and computer. Compared to physiological systems, the evolution of programming languages is very short, dating only to the 1950s. The theoretical basis for programming languages was provided by Chomsky's concept of formal grammatical structures. In the present paper, we will dwell only upon BASIC , which early in its development was hardly recognized by programmers, since it was considered a language for beginners. BASIC flourished, however, because of the wide distribution of personal computers. Modern versions of BASIC have become almost as powerful as such high-level languages as PL1, PASCAL, and C. This makes a consideration of the evolution of BASIC especially inviting (Kameney, Kurtz, 1985).

When programming language is looked upon as an evolving functional system, the following structural levels can be distinguished: *identifier(I), operator II*), *( procedure(III), and program(IY*). The simplest language element, a symbol, is not discussed here, since the set of symbols now in use has remained almost unchanged since the computer language was invented and hence it does not show any evolution. It is more closely connected to input- output devices than to the construction of programming language.

The identifier, or, more precisely, the name of the identifier nominates a certain object referred to in a certain storage area in the computer. The operator is capable of doing simple information processing. For example, the simplest assignment statement transfers an object's value to a new storage area and assigns a new name to it. The next structural level, represented by procedure, is capable of performing rather sophisticated operations that are, to a certain extent, closed and autonomous. The program serves to solve particular computational or informational problems.

The analogy between the homeostatic system and the program in BASIC is that identifiers, much like specialized cells, are elements of a functional system and are able to perform elementary operations but not the functions of the whole system. At the next level, functional unit and operator are capable of transforming specific substances and information. The organ, like procedure, is to some extent morphologically and functionally isolated and autonomous.

Further on, the principles of evolution of functions inherent to all the four levels will be considered separately for each of the three systems being analyzed.

‘PRIMARY ELEMENT’(I)

***The evolution of physiological functions at the cellular level.***

To provide homeostatic activity it is necessary to develop specialized systems for reabsorption, secretion and excretion of substances. Excretory organs in the Metazoa can consist of different parts that carry out reabsorbtion of filtered substances from blood their return back to blood, and the synthesis of new compounds necessary for more effective removal of substances from the organism. The kidney, in addition, participates in many functions including incretory and endocrine. For these functions to be effective, directional transport of substances ( reabsorbtion or secretion) from the cell into the blood or urine is required. The primary event in the origin of the excretory organ was the specialization of initial (‘ancestor’) forms with the emergence of the asymmetric cell capable of directionally transporting substances. This process involved the functional biochemical differentiation of the opposite side of the cell (the apical and basal plasma membranes) with the allocation of ion channels principally to the former, while allocating ion pumps, hormone and transmitter receptors to the latter, as well as the redistribution of mitochondria throughout the cell. Therefore, the evolution of the excretory organ cell has its origin in the formation of an asymmetrical cell - the *cell specialization*.

The basis for the evolution of the kidney function in vertebrates, especially in warm-blooded animals in contrast to cold-blooded animals is the increase in energy metabolism and energy consumption. This process is reflected in the intensification of transcellular transport of substances, the increase in the oxygen consumption and numbers of mitochondria, the rise in the oxidative enzyme activities. All of these events represent another important principle of evolution - the principle of *intensification of the cell function*.

The comparison of cells from the homologous parts of nephrons in representatives of various classes of vertebrates (from hagfish to mammals) reveals the increase in the number of cell types that differ morphologically and functionally from each other, ie. evolution of function is related to differentiation of the nephron cells. This may be the result of *simplification or complification of certain cell functions, the increase (or loss) of only separate forms of initial cell activity*.

The evolution of cell function is accompanied by an increase in its ability to perceive and respond to outside stimuli, to fulfil more accurately its functions in the whole organism. This is reflected in an increase in the number of specific receptors of various kinds for hormones and transmitters, selectivity of cell response together with different intracellular signalling systems. The evolution of functional system depends not only on the effect of distant regulators (hormones, transmitters), but on the intercellular interactions accompanied by the specialization of cell-to-cell junctional complexes.

***The evolution of the phoneme function***

In this part of the paper we are trying to analyze linguistic data to show similarities and differences seen from the evolution of phonemes as compared to the evolution of the first level of a physiological system - a cell.

The phoneme is a minimal sound unit of a language, enabling us to distinguish the meanings of different words and morphemes. The sound system of protolanguage most probably comprised very few vowels. The most frequent was the sound /e/, less frequent was /a/, still less frequent were /i/ and /u/. There existed the laryngal h-like sounds which later dropped out (the example for the decrease in the number of similar units- sound regression, phoneme regression). Language development led to the increase in the number of vowels /i/, /e/, /a/, /o/, and /u/ grouped in two subclasses, long and short vowels *(the increase in the number and a change of quality*). Different variants of articulation of the same cardinal (basic) set of vowels, as they are generally called, subsequently arose with a tendency toward increasing differentiation: nasal, mid-, front-, etc.

The same is also evidenced by the abandonment of the “complex”, “mixed” sounds with the tendency towards formation of the “simple”, more clearly articulated sounds, and the elimination of co-articulations. This can be readily illustrated by the example of those consonants that evolved from the complex, mixed sounds to a “variety of separate” sounds covering the full range of possible articulations, from stops to fricatives.

Undoubtedly, these events reflect an *increase in intensification of the phoneme function, the specialization of the contact types, and an increase in the number of modes of functioning*. This is manifested in the possibility for combining certain sounds, whether other combinations are not possible. This is most clearly seen when comparing different languages. The vowel changes resulted in changes of quality of the adjacent consonants, e.g. in making them voiced or voiceless. The process of can be exemplified by the merging of the Indo-European sounds /e/, /o/, /a/ of different timbres into the Sanskrit /a/.

The *regression* shows itself in the disappearance of glottalization and in the degradation or substitution of aspiration for other sounds, e.g. fricatives. aspiration. Noteworthy is the division of the “double” sound into two different classes, e.g. labio-velar sounds disappear in the course of evolution being substituted for labials and velars.

The same new sound type could have different origins, e.g. the voiceless aspirate consonants in Sanskrit could stem from either the voiceless nonaspirate sounds plus “h”, or from the voiced aspirate consonants. The long vowel in Sanskrit came from the Indo-European short consonant plus /h/ (an example of *the substitution of function*). Thus, the general tendency in the development of speech sounds in our examples is towards a higher phoneme differentiation.

***The evolution of identifiers***

The change in the form of identifiers in BASIC, starting from the first version, involved an *increase in the number of symbols*, from only one letter and one figure in the earliest version, to the point where, now, the number of letters and figures is almost unlimited. The change also involved the development of the use of special symbols, placed at the end of the identifier (%, $, !, #). These serve to designate the type of a variable. The analogy with cell specialization can easily be drawn.

*Intensification of identifier functioning* is related to the shift of BASIC from the interpretive mode to the translating mode during which, instead of matching the identifier with the variable-storing memory cell, whenever the given identifier is addressed, this search is carried out only once in the beginning of the program's work, which markedly speeds up the program. *Increase in objects* being specified by identifiers is expressed in the appearance of the one- and multidimensional arrays as well as of the variable prescribed by a user.

In the process of the evolution of the language, the identifier began to extend its functions. Thus label-, procedure-, graphic primitive-, and musical phrase- identifiers appeared. This points to identifier  differentiation.

*Specialization* of the identifier-constituting symbols consists in using the first symbol as a value type descriptor. This feature is particularly characteristic of FORTRAN-IV. In modern BASIC versions, an arbitrary type specification by a user according to the first symbol (DEFINT, DEFSNG, DEFSTR) is allowed. In terms of physiology, this is similar to the increase in the number of specific receptors.

## FUNCTIONAL UNITS OF AN 'ORGAN' (II)

### ***The evolution of nephron function.***

The nephron is the principal morpho-functional unit of the kidney. Each human kidney has about 1 million nephrons. This, however, does not imply that all of them are uniform. In the kidney of mammals there are up to eight distinct nephron populations (superficial, intracortical, juxtamedullary). *The increase in nephron heterogeneity* may be regarded as one of the features of the evolution in functional units. The kidney of lower vertebrates does not have such a variety of nephrons, and lacks a number of functions that originated later in the kidney of mammals and birds.

*Increased differentiation of nephrons* is characteristic of mammals and birds, being greater in these animals than in lower vertebrates. Kidney efficiancy is demonstrated in the degree of constancy in the composition and volume of the body fluids.

Another feature of the evolution of nephron functions is *intensification of reabsorption and secretion* in warmblooded as compared with coldblooded vertebrates. This is due to both intensification of cell activity and reorganization of cell-to-cell junctional complexes in different parts of a nephron forming prerequisites for the reabsorption of greater amounts of number of organic and inorganic substances and water.

In kidney evolution the formation of new morpho-functional complexes takes place and the complex of the vasa recta and the loops of Henle develops in warmblooded vertebrates. In the former case, this serves as a prerequisite for the appearance of the structure which analyses the tubule content. In the latter case, these elements make up a system which contributes to the development of the new kidney functions related to osmotic urine concentration.

The increase in nephron heterogeneity and differentiation, the intensification of the basic nephron functions , the formation of complexes with the tubules vessels and intersticial cells with intercellular matter involved - all these raise the regulation of the renal functions to a quantitively higher level, and, thereby, ensure greater efficiency in maintaining physico- chemical constancy of the internal milieu. Thereby, mammals, as compared with lower vertebrates, gain homeostatic precision as a result of the ability to regulate kidney function.

***The evolution of morpheme function.***

In linguistics, a morpheme is a minimal meaningful segment. There are several types of morphemes: - root, affixal, suffixal, derivational (word-formative), etc. Language structure underwent a number of successive changes as it developed from protolanguage to its modern forms (Bichakjian,1988). This pertains both to changes in grammatical features and to the way in which they are marked.

*Increase in differentiation* appears as a progressive separation of the element's roles: i.e.the inflexions become particles with specific fragmentary meanings. *Narrowing of functions* also takes place: the morphemes previously incorporated into words become separate units - words with the distinct grammatical functions; the ancestral absolute (indefinite) case splits up into different cases.

*The reduction or complete regression of functions* is observed in, e.g., the decrease in the number of categories (for numbers and genders - from 3 to 2); the complete elimination of cases is possible; the trend to abandon the declension is observed.

These processes are compensated by *the intensification (increase*), development of the roles of prepositions, the appearance of articles, the shift toward a more economical algorithm - from synthetic to more analytical forms. It is achieved by strengthening the regulation, particularly, by the introduction of the syntaxically relevant order of elements, their tougher agreement in a system. As a result, the formation of '*morpho-functional complexes'* (analogous to those, described above for biological objects) takes place which provide for new functions through merging two or more forms with different meanings.

We can see the increase in the number of the same-class units, each of them having different meanings (e.g. prepositions), and the emergence of a new class (articles); these are required for providing a new function - analiticity,leading to a more flexible syntax . The change of morpheme functions becomes apparent in the emergence of new qualities in the already existing units with possible *regression* of the earlier ones: the future tense and the subjunctive mood originated from three archaic aspectual forms (aspects), which took place after the splitting of the common Indo-European protolanguage. This can be exemplified by the conversion of the aspectual and modal forms into the temporal ones: the three aspectual forms (Present, Aorist, Perfect) in Indo-European language become two tenses (Present, Preterite) and two moods (imperative and indicative) in Anatolic lanuages. The Perfect aspect turns into a temporal form, and the Objective Future Tense is formed from the subjective modality (Bichakjian,1988).

In general, we see the narrowing of element's role from polyfunctional towards *more specialized* ones, with a vector to fragmentary, independent expression of one or another function, i.e. the tendency can be traced for a shift from the "heavy" synthetic forms, peculiar to the Russian syntax, to the "light" analytical constructions of the

English type. We can also observe the *increasing heterogeneity* when the polysemy of an element may arise depending on its position in the whole structure.

***The evolution of operator function***.

*Increased differentiation* of operators consisted in the emergence of several repetitive statements instead of a single one, in the development of the operators IF...THEN by adding ELSE, in the shifting to the operators of the CASE type, and in the emergence of graphic operators, interactive operators for the keyboard communication with joystick and light pen. *Heterogeneity* of the operator's structure increases with computer language evolution. Thus, rather complicated forms of file operators have appeared (OPEN...FOR...ACCESS...AS...LEN-), or the drawing operator for the circumference, ellipse or their parts (CIRCLE) with a large command qualifier set.

Increased intensity of the operator's functioning during the process of computer language evolution can be well illustrated by the shifting to the matrix operators, e.g. in BASIC for the computer PDP-11. Formation of *morpho-functional complexes* can be exemplified by the appearance of the operators DRAW or PLAY able to draw a simple picture or to produce a musical phrase through the sound-generator.

Complication of regulatory mechanisms of the operator functioning is evident in the example of the operator CLS evolution. In the initial language versions this operator was absent at all. Later, it appeared in order to clean the CLS display, and evolved further to CLS0, CLS1, CLS2, cleaning either the whole display or the graphic (text) windows only.

AN 'ORGAN'(III)

***The evolution of kidney function***

It is worthwhile to survey the principles of morpho-functional evolution because they provide deeper insight into the principles of development of both structure and function of the physiological systems being investigated.

*Increased multifunctionality* should be marked as a characteristic feature of organ evolution. The low vertebrates kidney provides fluid volume and ion regulation. The possibility for the lamprey to adapt to fresh water was dependent on the appearance of a new function in the kidney - hyperosmotic regulation, i.e. adaptation for living not only in sea water. In vertebrates, the kidneys, in addition to excretion, produce a number of hormones and autacoids which participate in the regulation of mineral metabolism, arterial pressure and perform some other functions.

Glomerular filtration rate and tubular reabsorption are 10-100 times greater in mammals than in lower vertebrates, as calculated per gram of kidney weight. Since relative kidney weight in relation to body surface does not increase during the evolution of vertebrates, *intensification of processes* responsible for kidney function is one of the main lines in the evolution of renal function.

Qualitatively new in the evolution of renal function in birds and mammals was the ability to regulate osmotic homeostasis under conditions of water deficiency, to survive for prolonged periods on land without water. Development of this new function was determined by the formation of two layers in the kidney - cortex and medulla. The principle of a “superstructure” may be regarded as one of the fundamental principles of the evolution of organ functions, including that of kidney.

*A change of functions* is another essential principle in the evolution of functions. For example, the kidney of teleosts (bony fish) takes part in excretion, but is also involved in blood cell production). In higher vertebrates, the latter function is lost, although the kidney still participates in the regulation of blood cell production.

The principle of *substitution of an organ or its functions* can be illustrated for the kidney by several examples. In bony fishes, the ion excretion occurs not only in the kidney but also in the gills. The salt glands bear the main burden in osmotic regulation of many species and only in mammals does the kidney becomes the main organ of osmoregulation.

*Decrease in a number of similar organs and increase in a number of functional units* are significant for the increased role of the kidney as a main homeostatic organ. The numerous, metamerically arranged metanephridii in earthworms give way to the paired excretory organs in molluscs, crustacea, and vertebrates, in which there are numerous functional units - the nephrons (about 1 million in each kidney in man).

The principles of evolution of functions characterizing the progressive kidney evolution, such as *multifunctionality, intensification of functions*, etc., have been dealt with above. However, the development may be accompanied by a *regression of at least some of the functions*. This may be illustrated by the loss of the ability to produce a hypo-osmotic urine in marine bony fish, as compared to their ancestors -fresh-water fish- and by a reduction in the number of glomeruli and glomerular filtration rate,to decrease water loss by the kidney.

*Regression* of renal function is illustrated by the water vole (water rat) which has lost the ability to osmotically concentrate urine and, therefore, the ability to osmoregulate under conditions of water deficiency. The second migration of bony fish from river to sea water hundreds of million years ago led to irreversible changes in a number of systems, including the kidney, which resulted eventually in a loss of hyperosmotic regulation- the ability to excrete hypoosmotic urine, excrete osmotic free water and hence survive in fresh water. In anadromic migration of monocyclic salmon soon after the fish enter the river from the sea, they are unable to return to the sea due to a functional switching of the osmoregulatory system and irreversible loss of physiological mechanisms of hyposmotic regulation - ‘producing’ fresh water in the sea to keep water balance. Only a few fish have adapted for living both in fresh and sea water.

***The evolution of word function***

Language development demonstrates *the increase in the number of morphemes in a word, resulting in the decrease in the number of words*. The earlier existing morphemes are used for coining new words in modern language - these are: archi-, anti-, poly-, etc. The word groups are formed on the principle of *suprastructure*: coordinative - “bread and butter”, subordinative - “fresh milk”, constructions - “I saw him coming”.

In Indo-European protolanguage, the words in the sentence did not subordinate but adjoin each other as if they were on their own. Later on, they began to be united into groups, with the form of one word beginning to affect the form of the other (DeGroot,1957; Hawkins,1983), however, this was not yet a sentence. *Change of function* reveals itself in that pronouns start playing the role of conjunctions. Combining cognitively dissimilar phenomena into a new single linguistic unit takes place.

*Differentiation of word function* is apparent in that particular meanings evolve from more amorphous ones; differentiation of the cognitive and grammatical roles takes place - separation of subject and object, agent and patient, etc. The tendency towards the regulation, fixed word order in the sentence and constructions is a very significant feature of the evolution of this linguistic level.

*Increase of multifunctionality* is manifested in the appearance of dissimilar, sometimes very different meanings of the same word.

*Regression of functions*, including irreversible ones, can be seen in the disappearance, dropping out of the words or some of their meanings (archaisms). One is justified in speaking about valency (Tesniere, 1959; Helbig, Schenkel, 1973; Fillmore, 1977),i.e. ability of words to combine with each other, both strongly varying in different languages and universal.

***The evolution of procedures in Basic***

Originally, the procedure in BASIC was designed simply as a part of the program that can be repeatedly addressed (GOSUB...RETURN). In the process of the language evolution, the procedure functions considerably expanded: there appeared the variable and label localization, the procedure became such a universal *multifunctional programming* tool as it was initially intended in such a language as PASCAL which emerged much later than the first versions of BASIC. *Intensification of procedures* consists in the emergence of the possibility to translate them previously into the assembler language. *The effect of suprastructure* becomes apparent in the possibility to call one procedure from the body of another as well as to apply the recursive procedures. It proved to be feasible to build up hierarchical systems of any complexity.

With relation to the procedures, the principle of decrease in a number of some ‘organs’ can be interpreted as an embodiment of Wirt’s basic idea of “structural programming” with full abandonment of the GOTO operator. In the last BASIC versions, these ideas were put into effect, although the classical language for the structural programming is, undoubtedly, PASCAL.

At the procedure level, *a change of function* occurs easily. For example, the procedure for solving a differential equation system by the Runge-Kutta method may as appropriately be applied to solving the model of ecological system or the problem on the solid thermal conductivity. This principle underlies the creating of all computer software systems. *The substitution* of one procedure for another in the process of language, or, to be more precise, the software system evolution can be illustrated by the example of a procedure for the multidimensional function extremum search. These procedures evolved from the exhaustive search procedures up to the gradient methods, or the random-search method and their combinations. Thus, different procedures perform the same function.

Procedures tend to get out of date, and cease to be in use. For example, this has happened to almost forgotten at present linear programming that was widely employed in 60s. The table-printing procedures died out because of the progress in the character graphics facilities. It is not quite correct to call this process a regression, but the phenomenon of *disappearance* of certain programming methods and facilities and emergence of the others is obvious.

'SYSTEM'(IY)

***The evolution of water-salt balance system***

The system of water-salt metabolism governs the stability of physico-chemical parameters in animals and humans, including body fluid volume, osmolality, pH, and ion concentrations in plasma and other extracellular fluids. The investigation of the Proto- and Deuterostomia, (different classes of vertebrates) at different stages of postnatal development points to the following principles for the evolution of system functions: There is *: (1) an increase in the number of regulatory factors, (2) an increase in the number of regulated parameters, and (3) an increase in the precision of homeostasis control.*

In most marine invertebrates and hagfish, the regulated parameters of the internal milieu include pH and the concentration of certain other ions. Lamprey, fish and other higher vertebrates have the systems for stabilization of the blood and body fluid osmolality which enabled these animals to occupy new sea-water, fresh water and terrestrial areas. A comparison of functional organisation of the systems for regulation of water-salt balance in animals at different levels of development indicates that a number of humoral regulatory factors changes. Thus, for each of the ions of a particular significance for the cell activity, there are not one but two and even more hormones and other regulatory factors. In the present paper, where a special attention is focused on the informational systems, it is important to point out that both regulatory peptides, various hormones, autacoids may be considered "words" of the biological language of the homeostatic systems (Mayer, Baldi,1991).

An increase in the number and role of regulatory factors is not the only mechanism employed in the evolution to gain a higher quality of regulation. Our studies show that, as with the impact of the nervous system on the muscle, when the stimulation of one group of nerves may have a triggering effect, while the stimulation of the others exerts adaptation control adjusting the muscle to its instant demands, and with the specific hormones, particularly, vasopressin, the effects of two types are established. One of them, produced when V2 receptors are stimulated by vasopressin, induces the increased permeability to water of the epithelium in some osmoregulating organs; the other one depends on the stimulation of V1 receptors in the same cell. In the latter event, there takes place the release of different second messengers, the modulation of the permeability level, and, thereby, the change of intensity of the water transport. As a result, a greater precision of the blood osmolality regulation is attained, which is of prime importance for the cell activity in many systems, especially nervous, and ,consequently, for higher cortical functions including state of cognitive functions. The cell volume fluctuations depend on the changes in extracellular fluid osmolality. This parameter must be maintained with utmost precision in order to provide great efficiency for the cell to perform its functions. During the evolution of vertebrates, the homeostatic ability of the kidney with respect to various physico-chemical parameters of the internal milieu as well as that of other effectory organs and systems increases.

***The evolution of sentence functions***

Inasmuch as the sentence is formed from the words according to certain rules, both universal, reflecting general cognitive characteristics of humans, and specific, inherent to a particular language, when considering this level, one cannot but touch upon the evolution of the rules themselves (i.e. syntax). In this respect, a number of general trends should be emphasized.

First of all, the linguists reveal the following tendencies in the syntax evolution from the cognitive (role definition - action, agent, object of action, etc.) to the proper linguistic (appearance of such parts of a sentence as the subject, predicate, object, not necessarily coinciding with the cognitive roles). This indicates *the increase in the function specialization.*

We can also see a reorganization of the sentence structure aimed at *increasing its functional adequacy* - the ability to express complex systems of notions and relations. The structural hierarchy reveals itself in the emergence of subordination - first, in word groups within the simple sentence, then at the formation of the specialized subordinate clauses.

Noticeable is the increase in the syntax of degrees of syntactical freedom - the shift to more mobile rules applied to both separate sentence parts and separate sentences within complex sentences, the substitution of the declension system for the syntactical functions (which represents a more economical algorithm), and, accordingly, the introduction of syntactically more relevant word order.

The trend of syntax evolution can be tentatively presented as follows: from groups of equivalent words to the correlated ones, the combination of two simple equivalent sentences patterned as to correlate the origin of the subordination within the sentences, and, at last, the origin of the complex sentences. The development proceeds further towards the emergence of the complex sentences with subordination and co-ordination at different levels (e.g., one inside the other). Various participial and other constructions can be included here too. The concept of the syntax depth (i.e. of co-ordination and subordination levels) (Yngve, 1960) has been developed to describe these extremely complicated constructions. The language historians point to the interesting phenomenon of “reversion” the grammatical structure in the process of language evolution: from the “object-action” type to the “action-object” type, and from the “left-branching” structure

(John's brother's car) to the "right-branching" one (the car of the brother of John) (Bichakjian,1988).

All we have stated above both about linguistic description and of biological systems, provides evidence of *the increase in the number of regulatory factors and regulated parameters*, that is contributes, in this case, to the most effective conveying the information and framing the thought.

***The evolution of a program as a single whole***

The program evolution runs the way of increasing the program independency of a particular computer type. For example, there were specific BASIC versions for the computers PDP-11, ZX-Spectrum, and FX-702P. In the process of evolution, the language became computer-independent, which may be interpreted as *the increase in the degree of the language "homeostasis*". Another trend in the program evolution consists in *the increase in the number of parameters* whereby the quality of the program and of the process of its creation can be assessed. Thus, in addition to the basic requirement of the prescribed algorithm realization, an extra requirement of being descriptive and readable has been placed upon the program. Another additional requirement that was introduced during the language evolution consisted in the convenience to checkout and test the program. This gave rise to a whole store of facilities for searching, tracing (TRACE ON), watching (WATCH), command memorizing (HISTORY ON), breaking at the preset point (BREAKPOINT), and syntax checking of the code line (Kameney, Kurtz,1985; Inman,Albrecht,1989).

## CONCLUSION

The foregoing parts of the paper have attempted to substantiate the applicability of some principles of evolution of functions to such different phenomena as the natural language, the programming language, and the physiological system. The paper should be taken as an attempt to analyze principles of evolution of these systems from a novel, unconventional point of view. It has been shown above that close analogies can be drawn between the processes of evolution in physiological systems and those in natural and programming languages. It is the more surprising that the mechanisms of evolution of the homeostatic systems and languages differ sharply. For example, the natural selection and the genetic inheritance of characters are replaced by the market competition between the software- supplying companies and almost worldwide accessibility of the information about programming languages. The analogies observed suggest that there exist some general regularities of functional system's evolution. In physics, the parallel between the mechanical, acoustic, and electrical phenomena has long been known and productively employed . The advent of cybernetics has led to the understanding the uniformity of control processes in living and inanimate nature. It is conceivable that the same uniformity exists in the evolution processes of different systems.

***Acknowledgements***

We are extremely grateful to Prof.Adam Kendon for his patience during the overly long time taken to complete this paper and adopting the text for multidisciplonary readers. We wish to express our deep appreciation for his critical comments on this paper.

The research was supported by the RSS of the OSI/HESP, grant No.653/1996, by grant No.95-01-00288 from Russian Foundation for Basic Research and by No.97 06-08242 and 97-04-012035 from Russian Scientific Foundation for Research in Humanities

REFERENCES

Allott, R.1980.*The motor theory of language origin*. Sussex: The Book Guild
Benveniste E. 1962.Hattite et Indo-Europeen Etude Comparatives.Paris.
Bernard C. 1878. *Life Phenomena Common to Animals and Plants*. St.-Petersburg: Publ. I.I.Bilibin
Bichakjian, B. 1988. *Evolution in language*. Ann Arbor: MI Karoma
Bichakjian, B. 1991. Evolutionary patterns in linguistics. *Studies in Language Origins*,vol.2 (Eds. W.von Raffler-Engel,Jan Wind, Abraham Jonker), 187-224. John Benjamins Publ.Co :Amsterdam/ Philadelphia,
Budil I. 1994. A funcional reconstruction of the supralaringeal tract of the fissil hominid from Petralona. ,In: *Studies in Language origins*, vol.3,pp.1- 20 (Eds.J.Wind; A.Jonker; R.Allot; Rolfe). John Benjamins Publ.Co: Amsterdam/Philadelphia
Bunak, V.1958. L'Origine du langage.- In: *Les processus de l'hominisation.* Colloq. Intern., Paris
Bunak,V .1968 *Die Entstehung der Sprache und des Denkens.* Homo, *13, H.4*
Bunak, V. 1980 *Homo species: its origin and subsequent evolution*, Moscow: Nauka
Burrow T. 1955. *The Sanskrit language*. London.
Catania, Ch. 1992. *Learning.* Prentice Hall, Englewood Cliffs, N.Y.
Cavalli-Sforza, .L.; Piazza, A; Menozzi, Pand Mountain, J. 1988. Reconstruction of human evolution: bringing together of genetic, archeological and linguistic data. *Proc. Natn. Acad. Sci. USA*, 85
Cavalli-Sforza, L.; Menozzi, P.; Piazza, A. 1994*. The history and geography of human genes*. Princeton, NJ: Princeton Univ.Press.
Chernigovskaya T.1993. Die Lateralizierung von Sprachen bei Bilingualen. //In: *Psychosemiotics-Neurosemiotics*, - (Ed.Peter Grzybek), Universitatsverlag Dr.Norbert Brockmeyer:Bochum, 37-53.
Chernigovskaya T. 1993a. Die Heterogenitat des verbalen Denkens als cerebrale Asymmetrie. //In: *Psychosemiotics - Neurosemiotics,* (Ed.Peter Grzybek), Universitatsverlag Dr.Norbert Brockmeyer, Bochum, 15-35.
Chernigovskaya T.1994. Cerebral lateralization for cognitive and linguistic abilities| neuropsychological and cultural aspects. In:*Studies in Language Origins*, pp.55-76 (Eds. J. Wind, A.Jonker, R.Allot; L.Rolfe). John Benjamins Publ.Co: Amsterdam/ Philadelphia;
Chernigovskaya T.1995. Cerebral asymmetry. A neuropsychological parallel to semiogenesis, *Acta Coloquii Bochum Publications in Evolutionary Cultural Semiotics*, 27- 56

Colleinder, B. 1965. *An introduction to the uralic languages*. Berkeley: Univ. of Calif.Press
Chomsky, N. 1986. *Knowledge of language: its nature, origin and use*. New York: Prager.
Daniel, H.1994. A much-too-brief evolutionary history of the mammalian middle ear. In: *Studies in Language Origins*, vol.3 (Eds.J.Wind; A.Jonker; R.Allot; L.Rolfe). John Benjamins Publ.Co: Amsterdam/Philadelphia; 21 - 30.
Darwin Ch. 1872 *The origin of species by means of natural selection or the preservation of favoured races in the struggle for life*. John Murray: London.
Delson, F., Tattersall, I., Van Coveringy (Eds).1991. *Paleoanthropology Annuals*. vol.1., Gazland Publ.Inc., New York.
De Groot, A.. 1957. *Classification of word-groups*. Lingua, 6, 2, 113 -158.
Diakonov, I. 1965. *Semito-Hamitic Languages*. An Essay in Classification. Moscow: Nauka.
Dohrn A. 1947 *Origin of Vertebrates and Principles of the Succession of Functions*. Moscow, Leningrad:Publ. Biomedgiz .
Donald, M. 1993. *Origins of the modern mind*. Cambridge, Mass. and London: Harvard Univ.Press.
Elizarenkova,T.. 1982. The Sanskrit. *Comparative-historical study of languages from different families*. Moscow ,3- 31
Fabro, F. 1992. Cerebral lateralization of human languages. Clinical and experimental data. In: *Language origin: A multisciplinary approach*. Wind J.; B.Chiarelli.; B.Bichakjian; A.Nocentini; A.Jonker (eds)..195-224 NATO ASI Series, Kluwer cad.Publ.: Dordrecht, Boston, London
Falk, D. 1987. Hominid paleoneurology. *Ann. Rev. Anthrop*., 16, 13-30.
Fillmore, Ch. 1977. Topics in lexical semantics. In: *Current issues in linguistic theory.* (Ed.by R.W.Cole). Bloomington and London, 76 - 138.
Gamkrelidze,T.1985.The ancient Near East and the Indo-European Question: Temporal and Territorial Characteristics of Proto- Indo- European Based on Linguistic and Historico- Cultural Data. *The Journal of Indo-European Studies* ,13: 3-48.
Gamkrelidze, T., .Ivanov. 1984 *Indo-European language and indo-europeans*. 2 vols. Tbilisi: Tbilisi Univ.Press.
Greenhood,W. (in press) Homeotic mutations and the origin of syntax.
Haeckel E. 1874 *Anthropogenie oder Entwicklunges geschichte des Menschen*. Leipzig
Haeckel E. 1940. Principal law of organic development. In Mul ler F. and Haeckel E. *The Principle Biogenetic Law. Selected Works*, 169-186. Moscow:Publ. USSR Acad. Sci.
Hawkins, J.. 1983. *Word order universals*. New York:Acad. Press.
Helbig, G., Schekel, W. 1973. *Worterbuch zur Valenz und Distribution deutcher Verben*. Leipzig Verlag Enzyklopadie.
Hopper, P.J. 1992. A discourse perspective on syntactic change: text-building strategies in Early Germanic. In: *Trends in linguistics*. Studies and Monographs, 58: Reconstructing languages and cultures (Eds. E.C.Polone, W.Winter),217- 238,. Mouton de Gruyter: Berlin, New York.
Inman, D., B. Albrecht 1989 *Using quick BASIC 4.5*, McGraw Hill

Ivanov V. 1979. Syntactical archaisms of old Hattite. In: *Hettitisch und Indogermanisch.* Innsbruck .

Ivanov, V.. 1982. Hetto-Louvian (Anatolian) languages. *Comparative-historical study of languages from different families*. Moscow

Jakobson, R. 1964 Pripcipes de phonologhie historique. *Principes de phonologie*. pp.315-336 N.S.Trubetzkoy. Tr.Jean Cantineau. Paris: Klincksieck

Jakobson, R. 1966. Implications of language universals for linguistics, *Universals of language*, 2nd ed., Eds. J. H. Greenberg, Cambridge,Mass : The MIT Press, 263.

Jespersen, O. 1964. *Language. Its nature, development and origin*. New York: Norton.

Kameny, J.G., T. E. Kurtz. 1985. *Back to BASIC*. London: Adisson, Wesly

Kien, J. 1994. Developments in pongid and human motor systems as preadaptations for the evolution of human language ability. In: *Studies in Language origins,* vol.3 (Eds.J.Wind; A.Jonker; R.Allot; L.Rolfe). John Benjamins Publ.Co: Amsterdam/Philadelphia; 271-292.

Kleinenberg N. 1886 *Die Entstehung des Annelids aus der Larve von Lopadorhynchus.* Z. Wiss. Zool. 44, 1-227.

Leiner, C., A. Leiner. 1991. Evolution of the cerebellum. Did it contribute to the evolution of the language?, In: *Studies in language Origines*, vol.2 (Ed. by W. Fon Ruffel-Engel, Jan Wind, A.Jonker), John Benj.Publ.Co: Amsterdam/Philadelphia

Lieberman Ph. 1987. *The biology and evolution of language.* Cambridge, Mass.: Harvard Univ. Press.

Lieberman Ph. 1992. On the evolutionary biology of speech and syntax. In: *Language origin: a multidisciplinary approach*. NATO ASI Series. Kluwer Acad.Publ.:Dordrecht, Boston, London. Wind J; B.Chiarelli;B.Bichakjian; A.Nocentini, A.Jonker (eds.),399-420

Lucas K. 1909 *The evolution of animal function*. Sci.Progr., . 3, 472-483.

Luria, A. 1980. *Higher Cortical Functions in Man*. New York: Basic Books.

MacNeilage P. 1987. The evolution of hemispheric specialization for manual function and language.In *Higher Brain Functions* (Ed.S.Wise),285-310. New York:J.Wiley and Sons.

MacNeilage P.1992. Evolution and lateralization of the great primate action system. In: *Language origin: a multidisciplinary approach*. NATO ASI Series. Kluwer Acad.Publ.:Dordrecht, Boston, London. Wind J; B.Chiarelli; B.Bichakjian; .Nocentini; A.Jonker (eds.), 281-300.

Mayer, E.A., J. P. Baldi, 1991.Can regularity peptides be regarded as words of biological language?, *Amer. J. Physiol*., 261 -271

Mellar P., Stringer C.(eds).1989. *The human revolution*. Edinburgh: Edinburgh Univ.Press.

Natochin Yu. 1976 *The kidney: regulation of ion balance*. Leningrad:Nauka

Natochin Yu. 1984 *The problems of evolutionary physiology of water and electrolyte balance.* Leningrad:Nauka

Natochim Yu., Menshutkin V.,Chernigovskaya T. 1992. General features of evolution in homeostatic and informational systems. *J. Evol. Biochem. Physiol*. 28, 623-636

Orbeli L.A. 1961 Major goals and methods in evolutionary physiology. In L.A. *Orbeli Selected Works*, Vol. 1, pp. 298- 309. Moscow, Leningrad: USSR Acad.Sci. Publ.

Poppe, N. 1965. *Introduction to Altaic Linguistics*. Wiesbaden: Harrassowitz.
Pribram R. 1971. *Languages of the Brain: Experimental Paradoxes and Principles in Neuropsychology*. Engelwood Cliffs: Prentice Hall Inc.
Ragir, S. 1992. Adaptationist and nativist positions on language origin: a critique. In: J.Wind, B.Chiarelli, B.Bichakjian, A.Nocentini and A.Jonker (Eds). *Language origins: A multidisciplinary approach*, Dordrecht: Kluwer Acad.Publ., 39-50.
Sapir A.1921 *Language. An introduction to the study of speech*, New York: Harcourt Brace and World
Saussure F.1916. *Le Course de linguistique generale*, Paris: Payot
Schleicher A., 1873.*Die Darwinische Theorie und die Schprachwissenschaft*, Weimar: Bohlau .
Schmalhausen I.. 1949 *Factors of evolution: the theory of stabilizing selection*. Blakinston, Philadelphia.
Severtsov A.. 1939 *Morphological Patterns of Evolution*. Izd. Moscow, Leningrad: Publ. Acad. Sci. USSR,
Smith H.W. 1951 *The Kidney. Structure and Function in Health and Disease*. New York: Oxford University Press,.
Smith H.W. 1953 *From fish to philosopher*. Boston: Little Brown.
Tesniere, L. 1959. *Elements de syntaxe structural*. Paris.
Thomsen, M.L. 1984. *The Sumerian language. An introduction to its history and grammatical structure*. Copenhagen: Academisk Forlag.
Tobias, P.V. 1971. *The brain in hominid evolution*. New York: Columbia Univ.Press.
Vigilant, L., Stoneking, M., Harpending,H., Hawrs, R., Wilson, A.C.1991. African population and the evolution of human mitochondrial DNA. *Science* 253; 1503-1507.
Yngve.V. 1960.*Mjdel and hypothesis for language structure*. Cambridge,Mass., Technical report No.369
Wallace R.1994. Spatial mapping and the origin of language: a paleoneurological model. In:*Studies in Language origins*, vol.3 (Eds.J.Wind; A.Jonker; R.Allot; L.Rolfe). John Benjamins Publ.Co: Amsterdam/Philadelphia;31-44
Ward R., Redd, A., Valencia, D., Frazier B., Paabo, S. 1993. Genetic and linguistic differentiation in the Americas. *Proceed.Nat.Acad.Sci. USA*, Nov.15, 90 (22)
Wind, J. 1976. Phylogeny of human tract. *Ann. N. Y. Acad. Sci*., 280, 612.
Wind, J. 1970. *On the Phylogeny and Ontogeny of Human Larynx: a Morphological and Functional Study*. Groningen: Wolters-Noordhof Publishing.
Wind ,J.B Chiarelli, B. Bichakjian, A. Nocentini, A.Jonker (eds.) 1992.*Language origin: a multidisciplinary approach*. NATO ASI Series. Kluwer Acad.Publ.:Dordrecht, Boston, London.