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NATURALISM AND THE GENESIS OF LOGIC*

Abstract. This paper investigates the genesis of logic as a philosophical problem treated from a naturalistic point of view. Logic is defined via the consequence operation *Cn*. This operation is a kind of closure operation similar to that studied in topology. Since logical competence (the skill to use *Cn*) is a manifestation of logic, the main problem can be framed as the question: How the consequence of operation emerged in biological organisms, particularly the human one. Various data from microbiology suggest that organisms have various devices protecting information from its dispersion. One can even say that sequences of DNA have some topological properties. The main thesis is that *Cn* is superstructured on such properties.

It is traditionally accepted that we differentiate between *logica docens* and *logica utens*, that is, between theoretical logic (logic as theory) and applied or practical logic. Both can be defined with the use of the notion of logical consequence. The first is a set of consequences of an empty set, symbolically $LOGT = Cn\emptyset$, provided that the operation Cn satisfies the well-known general Tarski's axioms, i.e. denumerability of the language (a set of sentences) L, $X \subseteq CnX$ (the inclusion axiom; X, Y are sets of sentences of L), if $X \subseteq Y$, then $CnX \subseteq CnY$ (monotonicity of Cn), $CnCnX = Cn$ (idempotence of Cn) and, if $A \in CnX$, then there is a finite set $Y \subseteq X$ such that $A \in CnY$ (Cn is finitary). Cn is a mapping of the type $2^L \rightarrow 2^L$, that is, transforming subsets of L into its subsets. In order to make things simpler, I assume that Cn is based on classical logic. $LOGT$ can also be defined as the only common part of the consequences of all sets of sentences.

Otherwise speaking, logic is the only non-empty intersection of the family of all subsets of L. What follows from this is that logic is included in the consequences of each set of sentences, which underlines its universal character. If $CnX \subseteq X$, then $X = CnX$ due to the inclusion axiom. Moreover, if $CnX \subset X$, we say that that X is closed by the consequence. This is the definition of a deductive system (a deductive theory). Thus, in the case of deductive systems, Cn does not extend X beyond itself. The concept of logical consequence belongs to the syntax of language. The notion of logical following (entailment) is a semantic counterpart of Cn. The properties of both of these notions are such that if $A \in CnX$ and X consists of true sentences, the sentence A also must be true as well. If X is a theory and the set CnX coincides with a set of true sentences (specifically: true in a determined model M or relevant class of models) of X, this theory is semantically complete.

The statement that Cn closes sets of sentences as long as $CnX \subseteq X$, suggests some analogies with topology, since certain properties of this operation satisfy Kuratowski's axioms for topological spaces. Let Cl denote the closure operation of a topological space, and X, Y – any subspaces (subsets); I intentionally use the same letters for denoting sets of sentences and sets investigated by topology. Then [Duda, 1986, p. 115]:

1. $Cl\emptyset = \emptyset$;
2. $X \subseteq ClX$;
3. $ClClX = ClX$;
4. $Cl(X \cup Y) = ClX \cup ClY$.

Operations Cn and Cl differ from each other as far as the matter consists of axioms 1 and 4, because, in the case of logic, set $Cn\emptyset$ is non-empty and $CnX \cup CnY \subseteq CnY$ (but the reverse inclusion does not hold). The first difference is founded on the specific definition of logic, which does not possess a clear topological sense (I will return to this question below), while the other one indicates a partial analogy between closed sets in the topological sense and deductive systems in the logical sense, because 4 does not hold for arbitrary sets of sentences. Thus, "logical" closure is weaker than a topological one. The set of theses of logic is for sure non-empty and it is a system. It can be treated as a specifically closed topological space, with individual theorems as its points.

Topology $\{\emptyset = Cl\emptyset, X\}$ is minimal (see [Wereński, 2007, p. 124]) in the sense that the smallest one cannot be examined. Next, $Cl\emptyset \subseteq ClX$, since for each X, $\emptyset \subseteq X$. Let us agree (this is a convention) that $Cl\emptyset$ is a topological equivalent of logic. Motivation for this convention consists in taking into consideration that a proof of logical theorems does not require

any assumption. The evident artificiality of this convention can be essentially weakened by the acknowledgment that closing an empty set produces any theorem of logic. It can be shown that if A and B are theses of logic, then $Cn\{A\} = Cn\{B\}$, which means that any two logical truths are deductively equivalent. Let us assume that X (this time as a set of sentences) is consistent and consists of the set X' of logical tautologies and a set X'' of theorems outside logic. Thus, $X' = Cn\emptyset$ and $X'' \subseteq J \setminus X'$. Sets X' and X'' are disjoint and constitute mutual complements in the set (space) X. Since set X' is closed, its complement, i.e. X'' is an open set. The introduced convention about $Cl\emptyset$ allows one to "topologize" the properties of sets of theses; in particular it makes it possible to treat the set X (of theses) as a clopen set. From the intuitive point of view, the operation of logical consequence encodes inference rules for deriving some sentences from other sentences; that is, a deduction of conclusions from defined sets of premises. Deduction, at the same time, is infallible; that is, it never leads from truth to falsity.

What is applied logic or *logica utens*? When X is any non-empty set of sentences, then applied logic $LOGA(X)$ of this set can be associated with operation Cn applied to X. This is applied logic in a potential sense. This understanding of *logica utens* is, however, decidedly unrealistic, since its user applies only these rules that he needs, independent of whether or not he does so in a conscious way. In other words, real applied logic of a given set is the stock of those logical laws (or rules) that are used in a concrete inferential work. This circumstance makes it impossible to give an abstract definition of real applied logic. It is worth observing that Cn can be based on a non-classic logic, e.g. intuitionistic, many-valued or modal logic. Furthemore, we can neglect the monotonicity condition in order to obtain a non-monotonic logic. These remarks point to the fact that non-classical logics are similarly definable as the classical system. Since applied logic operates on closed-open sets, they, by this assumption, contain extra-logical sentences beside theorems of logic; the inclusion condition decides that logic can be deduced from any set of sentences. This fact has serious methodological importance. If deduction within closed sets 'leads' to accumulation points in the topological sense, adding new extralogical sentences can be executed in an extra-deductive manner. This corresponds to the definition of an open set as such that includes all of its neighborhoods. To put it in a different way, the transition to neighborhoods of sentences as points in spaces in the set X" – that is, extension of this set – can be non-deductive. The above considerations suggest that there was *logica docens* 'at the beginning' and it became *logica utens* through application. According to this image, logic is thus applied like already ready mathematics in a concrete physical theory,

e.g. Euclid's geometry in classical mechanics or non-Euclidean geometry in a specific theory of relativity. This circumstance makes a naturalistic interpretation of logic difficult, and even impossible, because, generally speaking, laws of logic are considered abstract to the highest degree and as such are thought to belong to Plato's world of forms.

A contemporary follower of Plato says that naturalism is helpless with respect to the domain of abstracts for two reasons. Firstly, because the naturalistic view acknowledges the existence of temporal-spatial objects as the only ones (there exclusively exist temporal-spatial and changeable objects), while the logical realm exists out of time and space. According to Platonism, this is the main ontological difficulty of naturalism. Secondly, the naturalist also faces an epistemological problem, since as a genetic empiricist with respect to sources of cognition he or she cannot elucidate the genesis of the genuine universal and infallible knowledge represented by logic and mathematics. In particular, the follower of Plato adds that no empirical procedure is able to generate logical theorems as true, independent of empirical circumstances. Platonism is – as a matter of fact – a historical and metaphorical label on the above remarks. From the systematic point of view, it is much better to use transcendentalism (or anti-naturalism) as the opposition against naturalism, since every criticism of naturalism (sooner or later) makes references to transcendental arguments in the sense of Kant. It is in this way that, for example, criticism of psychologism (as a version of naturalism) was executed by Frege and Husserl; one could say the same about Moore's arguments against the reductibility of axiological predicates to non-axiological ones. In general, transcendentalists reproach naturalists with what Moore defined as a naturalistic fallacy on the occasion of his criticism of reduction of moral values to utility. Dualisms of facts and values or logical and extra-logical theorems are not the only ones which naturalism has difficulties with. Other oppositions, from which – in the transcendentalists' opinion – naturalists are cut off in the sense of the impossibility of their satisfactory explaining are, for example, the following: physical information – semantic information or quantity – quality.

It, of course, is fairly true that naturalism must meet various difficulties. Criticism of this view, however, overlooks problems of anti-naturalism, which Moore had already drawn attention to. The arguments he used were that super-naturalistic (Moore used this qualification) grounding of morality as rooted in the supernatural world is a similar error to that of reduction of axiological predications to ones definable in purely natural categories. Another problem of transcendentalism arises in connection with the so called Benacerraf argument indicating the enigmatic character of cogni-

tion of mathematical objects provided that each cognition consists in causal interaction on the part of the object of epistemic acts, while numbers – on the power of their nature according to Platonism – do not interact in a causative way on people. How, then, can an anti-naturalist explain the genesis of logic? He or she can either assume – as Plato did – that the world of abstract forms is eternal, or argue – like Descartes – that certain ideas are inborn, or still – like some theists – that man obtained logic as a gift from God when he was created as *imago Dei*. The Platonic and Cartesian paths are *ad hoc*, whereas that of the theists is based on extra-scientific premises. In any case, the situation of an anti-naturalist is not to be envied as it must resort to secret beings (souls, spirits, ideas) and secret kinds of cognition (intellectual intuition, etc.). The naturalist can paraphrase the title of Hoimar von Ditfurth's book *Der Geist fiel nicht vom Himmel* (*The Ghost Has Not Fallen From Heaven*) by saying that logic has not fallen from the other world, Platonic or other (see [Ritchie, 2008] for a general discussion about naturalism; as regards defense of naturalism in other contexts compare [Woleński, 2006; 2010a; 2010b; 2011]; see [Papineau, 1993] for a defense of philosophical naturalism).

For a positive naturalist's account of the genesis of logic it is indispensable to combine the *dychotomy logica docens – logica utens* with the notion of logical competence, modeled on grammatical competence in Chomsky's sense. Both abilities play a similar role. The grammatical competence generates the right usage of linguistic devices, while the logical competence determines the application of logical rules in inferential processes. Nevertheless, the analogy is not complete, at least according to my own concept of the question. Much as Chomsky defines grammatical competence simply as grammar, the distinction which I am going to use differentiates logic, both theoretical and applied, from logical competence. The last category refers to a determined disposition of the biological organisms which are able to perform mental functions (compare further comments below). Speaking more precisely, logical competence is the ability to use operation Cn. A logical theory is not thus logical competence, but its articulation. The dispositional character of logical competence does not settle whether each element of logic as a theory finds its coverage in its natural generator. By the way, a negative answer is rather obvious as the development of logical theories was and is heavily dependent on nature and the need for communicative interactions within human society. Further considerations in this paper will be devoted to the genesis of logical competence. They refer to the genesis of logic inasmuch as without the possibility to create and apply rules of logic, there would not appear logic in either of the two distinguished

senses. In other words, *logica docens* and *logica utens* are derivatives (precisely speaking – one derivative) of logical competence. This circumstance justifies the title "Naturalism and the genesis of logic". Anyway, one of the main theses of this paper says that logical competence is not eternal; it appeared in the Cosmos at some time and is rooted in the biological structure of organisms. However, I have to make it clear at once that I do not treat my comments relating to the biological question as empirical. My cognitive interest is of a philosophical nature and remains within evolutionary epistemology. Yet, however, in compliance with my metaphilosophical convictions, I have to take into consideration the output of empirical sciences, biology, in particular, in the analysis of philosophical problems. Speaking otherwise, philosophical analysis, though somehow speculative in its character, is superstructured on empirical knowledge.

In accordance with the above explanations, logical competence precedes logic, both theoretical and applied; nevertheless, there is also a feedback because theoretical reflection on logic and its applications to concrete questions can enhance the logical competence. Everything points to the fact that logical theory required prior application of rules of logic and the development of language. In the case of Mediterranean culture, applied logic appeared, for sure, with Greek mathematicians and philosophers. When Anaximander said that there does not exist the principle of closeness, since it would create a boundary of *apeiron* which is boundless, he made use of a rule similar to *regressum ad absurdum*. Pythagoras proved the existence of irrational numbers and his reasoning was a proof by reduction in the modern sense. Various paradoxes formulated by the Eleats were of a similar character. The first logical theory, that is Aristotle's syllogistics, originated much later, although on the basis of extensive practical material accumulated earlier. It was also, in a vital way, linked to the structure of sentences of the Greek language. One cannot, however, say that carrying out logical operations requires knowledge of language because they are typical of infants (see [Langer, 1980]), and the latter do not have linguistic material at their disposal yet.

The question of the sense of understanding in animals, other than humans, is controversial, yet the following example (which can be treated as an anecdote) is only too suitable in this place (see [Aberdein, 2008]). In 1615, in Cambridge, there was held a debate devoted to dog logic, which was attended by King James I. The problem concerned the question whether hunting dogs which were used for locating game during hunting, applied logic, in particular the so-called law of disjunctive syllogism in the form "*A* or *B*, thus if *non-A*, then *B*" (this question had already been consid-

ered by Chrysippus). Let us suppose that a hound reaches a fork in the road. The trailed game runs away to the right or to the left. The hound establishes that it is not to the left, and therefore runs to the right. The debate had a very serious character and a truly academic form. John Preston (a lecturer of Queens' College) defended the thesis that dogs apply logic, whereas his opponent, namely Matthew Wren (of Pembroke College) argued that hounds are directed solely by scent and it is the only reason why they choose the right direction. The role of moderator was played by Simon Reade (of Christ's College). When the latter acknowledged Wren to be right, the King, himself a great enthusiast of hunting and relying on his own hunter's experience observed that the opponent, however, should have a better opinion of dogs and lower of himself. Wren, very skillfully managed to get out of the tight situation by saying that the King's hounds – in contrast to others – were exceptional, since they hunted upon the ruler's order. This compromising solution is said to have satisfied everybody. After all, even if hunting dogs do apply disjunctive syllogism occasionally, they certainly do not do this making use of a language.

The debate held in the presence of the King of England is a good illustration of a certain difficulty as regards the analysis of the genesis of logic. There appears the question of what evidence could help here. The debaters in Cambridge considered dogs' behavior and drew conclusions from that. In the case of humans we can observe signs of inferential processes in people or base ourselves on the written evidence of the past. Anyway, the empirical base is greatly limited. Not much can be inferred from the inscriptions found on walls of caves inhabited by our distant predecessors. All the information through which human logical competence manifested itself has been recorded in a language developed to such a degree that it made it possible to encode the deductions carried out factually, even if it did not suffice to formulate a logical theory. In this respect, the genesis of logic appears to be more mysterious than the appearance of mathematics (see [Dehaene, 1997]) or language (see [Botha, 2003; Johansson, 2005; Larson *et al.*, 2010; Talerman and Gibson, 2012]). In both mentioned domains, especially in the latter one, there have appeared a host of works. In particular, the question relating to whether animals can count and make use of a language, at least of a protolanguage (see [Hauser, 1998; Bradbury and Vehrencamp, 1998]).

Studies in the origins of logic are limited to research into the logical competence of children going through their pre-language period, or that of people living in primitive societies. This provides solely epigenetic and ontogenetic material, whereas phylogenetic only to the extent in which the traditional and strongly speculative Haeckel's assumption that ontogenesis

reproduces phylogeny is accepted. Nevertheless, considerations concerning the origins of the genesis of calculating competence and language competence are important also to the discussion on the origins of logic. This concerns, in particular, the concept of the origin and development of grammar and sign systems (see [Heine and Kuteva, 2007; Hurford, 2012]). According to a fairly common conviction, signs were the earliest to appear, especially expressive ones, then iconic signs, followed by symbols. This corresponded to the evolution of grammatical structures from nominal through sentential-extensional to sentential-intensional. Thus, the development of language progressed on the basis of transition from a-semantic or little-semantic objects to fully-semantic (intensionality symbolism). The origin of language has always been an object of animated interest on the part of philosophers (compare [Stam, 1976] for a review of earlier theories). In 1866, the French Linguistic Society decided that considerations on this subject should be excluded from the sciences. As a matter of fact a renaissance of studies of the appearance and evolution of language was observed beginning with the middle of the 20th century. One can speculate that works which treat of the genesis of logic, if they had been written on a mass scale in the first half of the 19th century, would have shared the fate of linguistic dissertations on the origin of language as too speculative.

It is not without significance to model microbiological and neurological processes, for instance through cell automata (see [Ilachinski, 2011]) or even with the help of advanced mathematical techniques (see [Bates and Maxwell, 2005]) and computational ones (see [Lamm and Unger, 2011]). These enterprises indicate that the organisms themselves and whatever is happening inside them possess properties which can be formulated mathematically. However, far-fetched methodological carefulness is indispensable. The title of one of the quoted books runs as follows *DNA Topology*. It can be understood in a dual way: firstly, it suggests that, for instance DNA in certain circumstances has a looped structure; secondly, this can be understood in a weaker manner, i.e. in such a way that the topological notion of a loop models certain properties of DNA. Reading the book by Bates and Maxwell inspires to conclude that the authors make use of both meanings. My opinion on this problem consists in recommending another sense of modeling. It is assumed here only (or as much as that) that the world is mathematizable (that is describable mathematically) due to its certain properties, yet is not mathematical. Works in the field of the evolution of language and those devoted to modeling biological phenomena, as a rule, accept naturalism, silently or explicitly. An expression of that is the appearance of biosemiotics (see [Barbieri, 2011; Bar, 2008; Hoffmeyer, 2008]), cognitive biology

(see [Auletta, 2011]; this author declares the theistic *Weltanschauung*, yet suspends it in his book) or the ever more popular physicalization of biology (see [Luisi, 2006; Nelson, 2008]). Since syntheses of biology and semiotics or biology and cognitive science can be conducted, there is no reason why we should not link logic to biology.

The only advanced attempt at naturalistic grounding of logic that I am familiar with derives from William Cooper (see [Cooper, 2001]), who considers the following sequence: ($\star$) mathematics, deductive logic, inductive logic, theory of decision, history of life strategies, evolution theory. The relations between elements ($\star$) are such that from evolution theory to mathematics we deal with implication, whereas reduction proceeds in the opposite direction. As far as deductive logic is concerned, it is directly implied by inductive logic and reduces itself to the latter. The evolution theory is the ultimate basis, both for implication and reduction. Briefly speaking, deductive logic arose at a certain stage of evolution (Cooper does not make it precise in detail) through natural selection and adaptive processes. Cooper's schema leaves a lot to be desired. Omitting the lack of a more detailed definition of 'production' of logic through the process of evolution, which was indicated earlier, the notions of implication and reduction are not clear in Cooper's model. Since deductive logic (that is $Cn\emptyset$) is implied by any set of sentences, the role of inductive logic (I neglect here disputes relating to its existence; however, see below) is not specific. In consequence, reduction of deductive logic to inductive logic appears to be highly unclear. Moreover, the phrase 'logic as part of biology' (the subtitle of Cooper's monograph) is ambiguous. It may mean that *logica docent* is a part of biological theory (more precisely: evolution theory) or, also, that deductive competence (Cooper does not use this name) is an element of the biological equipment of a human being. Indeed, in compliance with the well-known maxim of Theodosius Dobzhansky, nothing has sense in biology if it is not considered in the context of evolution, but this does not mean that everything can be explained on the basis of evolution theory. Cooper, in his analysis, ignores genetics completely which is, perhaps, the most serious deficiency of the model.

A purely evolutionistic classical approach towards the establishment and development of human mental competences such as the ability to use a language or reasoning is – in outline – as follows (it can be found in countless publications dealing with the theory of evolution and its application to different specific problem areas; compare for instance [Lieberman, 2005; Tomasello, 2010]). The Universe appeared about 15 billion years ago (all the dates here are given in approximation). The age of our Earth is 4.5 billion

years. The first cell appeared a billion years later, and multicellular organisms after the next 2.5 billion years. Plants have been around for 500 million years, reptiles – for 340 million years, birds – 150 million, and apes – for 7 million years. The species of *homo* appeared two million years ago, *homo erectus* – from 1 million to 700 thousand, and *homo sapiens* – 200 thousand years ago. The cultural-civilization evolution marked by language (in the understanding of our modern times), the alphabet, and writing began 8,500 years ago. Three and a half billion years from the moment of the appearance of the first cell to that of the appearance of civilization and culture was completely sufficient to form a mind capable of performing typical intellectual activities, in particular, to carry out a logical operation. *Homo sapiens* must have been able to do so much earlier; maybe it happened at the beginning of this species. It cannot be ruled out that the rudiments of logical competence had already been available to *homo erectus*. Establishing the date of the appearance of logical competence in the course of evolution, and also attributing it to other organisms than human seems here not particularly important. A safe evolutionist hypothesis in this respect can claim, for instance, that inferential ability appeared by way of randomly acting mutation, and because it proved to be an effective adaptive tool, it was developed by *homo sapiens*, also thanks to available and more and more perfect linguistic instruments. The logical theory appeared as the final product of a long evolution process. This is an adaptation of the classical concept of the evolution of language (compare, however, the conclusions at the end of the paper).

Neo-Darwinian evolutionism connects the appearance of life and its further evolution with entropic phenomena (see [Brooks and Wiley, 1986; Küppers, 1990]). This perspective leads to the need for indicating anti-entropic phenomena, i.e. mechanisms which maintain the stability of organisms and their internal order, and thereby determine the continuance of their existence (see [Kauffman, 1993]). The decisive event to enhance a serious revision of evolution theory was the discovery of DNA structure by Crick and Watson in 1953 (the model of the double helix), as well as further research into genetic encoding. Those results demonstrated the necessity of more profound linking of evolution with genetics. The notion of genetic information and the manner of its transfer became key instruments of a new biological synthesis, obviously, while keeping suitably modified classical categories of evolution theory. Notice that formal analogies between information and entropy have caused biologists and philosophers of biology to become interested more closely in relations between the first notion and the course of biological processes since as early as the 1920s (see [Wereński, 2005]).

Several facts established by molecular biology are significant from the point of view of this paper (for a while I mention them without a 'meta-logical' commentary; I entirely omit the physical-chemical questions, likewise the mechanism of hereditariness). Firstly, passing genetic information is directed from DNA through RNA (more precisely: mRNA – the letter 'm' denotes that RNA is in this case a messenger, that is an agent passing information) to proteins. This observation makes the so-called main dogma of molecular biology. There are, as a matter of fact, certain exceptions in this respect (e.g. in the case of viruses), but at least in the so-called eukaryotic organisms (humans belong to this biological group) transmission of information is in compliance with this dogma. Secondly, genetic information is passed in ordered, linear and discrete, and sequential a manner. Thirdly, DNA particles are subject to replication (copying) and recombination (regrouping). Fourthly, the intracellular information system encodes and processes information, which causes the encoding in question to be interpreted as a computational system and to be modeled accordingly. Fifthly, the passing of genetic information is not deterministic but random in its very nature, thanks to which there may appear genetic novelties. This last fact is vital from the point of view of evolution theory because it explains the way in which mutation appears on the microbiological level.

The view that genetic information is of a linguistic character is only too tempting. Indeed, it is very often that we can see it treated as a language. And thus, we can speak about alphabets, words, syntax, codes and encoding, or about translation (in the sense of transfer from the genetic language into another one); this is done especially by representatives of biosemantics, who – in the genetic information – detect a semantic dimension or, at least, its germs. Such an approach is, however, very debatable (compare the discussion in [Kay, 2000; Sarkar, 1996] which rejects the notion of genetic code, but this solution seems too radical). In true fact, technical elaborations of genetics avoid comparing the genetic code with a language (see, for example, [Klug *et al.*, 2006]). Independent of the applied language, for instance, some authors write about 'words' as components of the genetic code, surely using quotation marks to indicate a certain metaphorical investing of genetic information with the linguistic dimension, while others do so about words; we can easily find here the problem of relation of physical information as something quantitative to the semantic information as qualitative. The mathematical theory of information concerns the former, and only indirectly relates to the latter. Shannon's well-known statement on the capacity of channels of transmitting information and limiting so-

called information noise has sense only with reference to its quantitative understanding. The genetic information is a kind of physical, not semantic information. On the other hand, processing the former, i.e. quantitative, into the other, i.e. qualitative, is a notorious fact; for example, reading a book – as long as we understand the language in which it has been written, we rapidly process the physical stimulus into semantic units, i.e. such that we understand them according to their linguistic sense. For the time being we do not know the mechanism of this transformation and it makes the biggest anthropological puzzle (see [Hurford, 2007]). Perhaps, the properties of the genetic information lie at the foundations of, so to say, the semiotization of mental processes, yet this is a fairly speculative assumption from the biological assumptions, though one could consider it as philosophically justified to some degree.

At first sight, if the genetic information were a language in the full sense or even if only in an approximate one, we could look for the genesis of logical competence directly on the microbiological level. After all, the properties of the genetic code, whatever it is, stand far from those that can serve to define operation Cn. Nevertheless, these properties can be tied to logic in their understanding of today. Before I pass on to essay to show this relation, I will draw attention to certain theoretical questions. Kazimierz Ajdukiewicz (see [Ajdukiewicz, 1955]) divided inferences into deductive, increasing probability (inductive in a broad sense), and logically worthless. The first are based on operation Cn which holds between the premises and the conclusion (the conclusion results logically from the accepted assumptions), the second ones increase the probability of the conclusion on the basis of the premises, and the third ones are devoid of any logical relation between the links, e.g. "if Krakow lies on the Vistula, then Paris is situated in France". Logic, in this context is understood in a broader way than at the beginning of the paper, since it includes also induction rules. We can, too, extend respectively the notion of logical competence, still I do not wish to consider such a generalization. Treating the thing from the information point of view (see above), while deduction does not broaden the information included in the premises (although it does not allow it to be lost), the conclusion is false, which disperses (in the sense of entropy) the information acquired earlier; whereas logical inference that is worthless is redundant from the information point of view.

The infallibility of the rules generated by operation Cn derives from the fact that they correspond to theorems of logic, i.e. to sentences (formulas) that are true in all circumstances. One of the axioms of probability calculus is the assumption that there exists an event whose probability obtains the

value 1 (the whole space on which the probability measure is defined constitutes this event). An interesting interpretation of this axiom consists in acknowledging that it prevents the leveling (dispersing) of probabilities ascribed to particular occurrences; that is, subsets of the whole space. In other words, this axiom saves the differences in the amount of information which condition its flow. Thus, it performs the anti-entropic function, i.e. blocks dispersion of information: it protects it in this way. Operation Cn can be understood also as an instrument for protecting information from its dispersion, since it prevents formation of false information on the basis of true information. As I have already mentioned, the logic of induction is debatable, yet – on the other hand – nobody contradicts the fact that at least certain induction rules, e.g. those of statistical induction, are rational. It is true that they do not exclude dispersion of information, but still are able to somehow normalize its flow and in this way save or control it. Inferences that are logically worthless do not play any role in the processes of information protection.

Saving information (obviously it is not problems of a legal or moral nature that I mean here) both physical and semantic, appears as a vital function of all organisms which operate with a given type of code. Since we treat operation Cn as an information-protective instrument, saving the possessed content (in the sense of information content, not necessarily meaningful in the sense of intensional semantics), then – at least from the naturalistic point of view – the logical consequence has a biological rooting. With relation to this, I will return to the properties of the genetic codes and genetic information mentioned earlier, this time in the metalogical context. Here are the features of the genetic code (see [Klug *et al.*, 2006, p. 307]; I keep abstracting from the nature of elements of the code with one exception only amino acids due to the comprehensiveness of certain formulations):

1. genetic code is written in a linear form;
2. if we assume that mRNA consists of 'words', then each such word has three 'letters';
3. each three-letter group, that is, the codon, determines another element in the form of an amino acid;
4. if the code is unambiguous, it delineates one and only one amino acid;
5. if the code is degenerated, the given amino acid can be determined by more codons;
6. the genetic code includes the initial signal and the terminal one in the form of codons initiating and finalizing the processes of passing the genetic information;

7. the genetic code does not contain punctuation characters (commas);
8. elements of the genetic code do not overlap, that is, a concrete 'letter' can be a part of only one codon;
9. the genetic code is nearly universal, i.e. apart from a few exceptions, the same 'dictionary' of encoding serves all viruses, procariotic, and eucariotic organisms.

Completing the remarks offered earlier, I would like to add (see [Klug *et al.*, 2006, pp. 264–265]) that replication of DNA (forming two new strings of the primary helix) can be semi-conservative (each replicated particle of DNA has one old string and one new one), conservative (the parent string is conserved as a result of synthesis in two new strings), or dispersed (old strings are dispersed in new ones). The most frequent is the case of semi-conservation. Nevertheless, the genetic information that exists earlier is inherited by helixes formed by way of replication.

It follows from properties 1–9 that the 'syntax' of the genetic code is rigorous. It is based on a detailed specification of simple elements ('letters') and their combinations (codons). The lack of commas points to the fact that it is a series of concatenations. A code is unambiguous inasmuch as it is not degenerated. This property can be likened to syntactic correctness, while degeneration to a lack of it. 'Letters' are atoms in the same sense as a simple expression, which is non-decomposable any further. Transformation of a codon into an amino acid is a function, unless the code is degenerate. The beginning and the end of the procedure realized by the code is clearly marked with separate 'words'. I have marked some expressions with letters so as not to suggest treating the code as a language. The linguistics-oriented terminology could easily be avoided through speaking about configurations and their elements. Genetic codes treated in this manner can be and are similar to electric nets or cellural automata, which – as a matter of fact – is underlined by the above-mentioned modeling of genetic phenomena. The essence of things relies on the idea that the outline 'syntax' is of an effective character and is trivially recursive, since operations realized by the codes are of a terminal character.

Although there hold similarities between the structure of the genetic code and the syntax of formal languages, there is no reason why we should see the genetic concatenation as a result of the action of operation Cn. On the other hand, if we were to consider the configuration determined by codons, it is clopen in the topological sense, which is also characteristic of the space of sentences on which the logical consequence operates together with non-deductive rules of organizing semantic information. The semi-conservative character of the most typical replication of DNA corre-

sponds to this. Closing of a part of this space protects the information accumulated earlier, and the fact that it includes also open subsets secures the appearance of new information. Sometimes this is said (see [Kauffman, 1993, p. 2003, pp. 447–449]) about channeling of processes of genetic regulation through extensional (Boolean) functions. Let x be an active element in such a process, and object (x or y) a regulated element. Then, the object (x or y) is also active. The procedure, in this case, is analogous to that applied in the synthesis of electric networks. In the terminology used in this paper, the channeling (in the sense of Kauffman) is a partial objective case of logical consequence. A general conclusion which can be derived from the registered analogies is as follows: the genetic code is the biological foundation of logical competence. Since speculation becomes a philosopher, the thing can be framed as follows: topological or proto-topological properties of the 'genetic space' directed the biological evolution in such a direction that it developed – perhaps by way of relevant mutations, with the appearance of dispositions to operate with logical consequence.

It is not a feasible thing to establish various vital details. It is not known when logical competence appeared in its fullest beauty, so to speak, and what its scope is with reference to other species than ours. Putting it differently, it is not known whether the logical ability is only granted to humans, or – maybe – is also available to other species, or even to what extent real human logical competence corresponds to its abstract image formulated in logical theory. Perhaps evolution theory could add something relevant in this matter. It seems, for instance, that species which invest in a lower number of offspring (birds and mammals) have been 'forced' to create stronger means of protecting genetic information than insects, reptiles and fish, in which dispersion is compensated with a great number of potential specimens. Be it as it were, a naturalist claims that, to repeat once again, logical competence has not fallen from another world but came into being on the planet Earth. This makes, similarly to other mental operations, a realization of dispositions determined by the genetic equipment and the course of the evolution. If it is inborn, then it is phylogenically, not ontogenically. Independently of how the proposed approach is general, it somehow contributes to (in order to use Andrzej Grzegorczyk's phrase; see [Grzegorczyk, 1997]) understanding logic as a human affair. If, as Grzegorczyk claims, logic displays human rationality, both, logic and rationality, are deeply rooted in our biological equipment.

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Bibliography

[Aberdein, 2008] A. Aberdein. Logic for dogs. In S. D. Hales, editor, *What Philosophy Can Tell You about Your Dog*, pages 167–181. Open Court, LaSalle, 2008.

[Ajdukiewicz, 1955] K. Ajdukiewicz. Klasyfikacja rozumowań (classification of reasonings). *Studia Logica*, 2:278–300, 1955.

[Auletta, 2011] G. Auletta. *Cognitive Biology. Dealing with Information from Bacteria to Mind*. Oxford University Press, Oxford, 2011.

[Bar, 2008] In M. Barbieri, editor, *Introduction to Biosemiotics. The New Biological Synthesis*. Springer, Berlin, 2008.

[Barbieri, 2011] M. Barbieri. *The Organic Codes. An Introduction to Semantic Biology*. Cambridge University Press, Cambridge, 2011.

[Bates and Maxwell, 2005] A. Bates and A. Maxwell. *DNA Topology,*. Oxford University Press, Oxford, 2005.

[Botha, 2003] R. Botha. *Unravelling the Evolution of Language*. Elsevier, Amsterdam, 2003.

[Bradbury and Vehrencamp, 1998] J. Bradbury and S. Vehrencamp. *Principles of Animal Communication*. Sinauer, Sunderland, Mass., 1998.

[Brooks and Wiley, 1986] D. Brooks and E. Wiley. *Evolution as Entropy. Toward a Unified Theory of Biology*. University of Chicago Press, Chicago, 1986.

[Cooper, 2001] W. Cooper. *The Evolution of Reason. Logic as a Branch of Biology*. Cambridge University Press, Cambridge, 2001.

[Dehaene, 1997] S. Dehaene. *The Number Sense. How the Mind Creates Mathematics*. Oxford University Press, Oxford, 1997.

[Duda, 1986] R. Duda. *Topologia ogólna (General Topology)*, volume Wprowadzenie do topologii, 1 (Introduction to Topology). Państwowe Wydawnictwo Naukowe, 1986.

[Grzegorczyk, 1997] A. Grzegorczyk. *Logic – a Human Affair*. Wydawnictwo Naukowe Scholar, Warsaw, 1997.

[Hauser, 1998] M. Hauser. *The Evolution of Communication*. The MIT Press, Cambridge, Mass., 1998.

[Heine and Kuteva, 2007] B. Heine and T. Kuteva. *The Genesis of Grammar. A Reconstruction*. Oxford University Press, Oxford, 2007.

[Hoffmeyer, 2008] J. Hoffmeyer. *Biosemiotics. An Examination itno the Signs of Life and the Life of Signs*. University of Scranton Press, Scranton, 2008.

[Hurford, 2007] J. Hurford. *The Origin s of Meaning. Language in the Light of Evolution*. Oxford University Press, Oxford, 2007.

[Hurford, 2012] J. Hurford. *The Origin of Grammar. Language in the Light of Evolution*. Oxford University Press:, Oxford, 2012.

[Ilachinski, 2011] A. Ilachinski. *Cellular Automata. A Discrete Universe.* World Scientific, Singapore, 2011.

[Johansson, 2005] S. Johansson. *Origins of Language. Constraints on Hypotheses.* John Benjamins, Amsterdam, 2005.

[Kauffman, 1993] S. Kauffman. *The Origin of Order. Self-Organization and Selection in Evolution.* Oxford University Press, Oxford, 1993.

[Kay, 2000] L. Kay. *Who Wrote the Book of Life? A History of the Genetic Code.* Stanford University Press, Stanford, 2000.

[Klug *et al.*, 2006] W. Klug, M. Cummings, and Ch. Spencer. *The Concepts of Genetics.* Prenticed-Hall, Upper Saddle River, NJ, 2006.

[Küppers, 1990] B.-O. Küppers. *Information and the Origin of Life.* The MIT Press, Cambridge, Mass., 1990.

[Lamm and Unger, 2011] E. Lamm and R. Unger. *Biological Computation.* CRC Press, London, 2011.

[Langer, 1980] J. Langer. *The Origins of Logic. Six to Twelve Months.* Academic Press, New York, 1980.

[Larson *et al.*, 2010] R. Larson, Y. D]'eprez, and H. Yamakido, editors. *The Evolution of Human Language. Biolinguistic Perspective.* Cambridge University Press, Cambridge, 2010.

[Lieberman, 2005] Ph. Lieberman. *Toward an Evolutionary Biology of Language.* Harvard University Press, Cambridge, Mass., 2005.

[Luisi, 2006] P. Luisi. *The Emertgence of Life. From Chemical Origins to Synthetic Biology.* Cambridge University Press, Cambridge, 2006.

[Nelson, 2008] Ph. Nelson. *Biological Physics. Energy, Information, Life.* W. H. Freeman, New York, 2008.

[Papineau, 1993] D. Papineau. *Philosophical Naturalism.* Blackwell, Oxford, 1993.

[Ritchie, 2008] J. Ritchie. *Understanding Naturalism.* Acumen, Stocksfield, 2008.

[Sarkar, 1996] S. Sarkar. Biological information: A sceptical look at some central dogmas of molecular biology. In S. Sarkar, editor, *The Philosophy and History of Molecular Biology: New Perspectives.* Kluwer, 1996.

[Stam, 1976] J. Stam. *Inquiries into the Origin of Language. The Fate of a Question.* Harper and Row, New York, 1976.

[Talerman and Gibson, 2012] M. Talerman and R. Gibson, editors. *The Oxford Handbook of Language Evolution.* Oxford University Press, Oxford, 2012.

[Tomasello, 2010] M. Tomasello. *Origins of Human Communication.* The MIT Press, Cambridge, Mass., 2010.

[Wereński, 2005] S. Wereński. *Information Theory, Evolution and the Origin of Life.* Cambridge University Press, Cambridge, 2005.

[Wereński, 2007] S. Wereński. *Topologia (Topology).* Wydawnictwo Politechniki Radomskiej, Radom, 2007.

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[Woleński, 2006] J. Woleński. Naturalizm, antynaturalizm i podstawy statystyki (naturalism, anti-naturalism and the foundations of statistics). *Filozofia Nauki*, 9(33):147–153, 2006.

[Woleński, 2010a] J. Woleński. Naturalizm w teorii prawa (naturalism in legal theory). In S. Czepita A. Choduń, editor, *W poszukiwaniu dobra wspólnego*, pages 899–911. Uniwersytet Szczeciński, Szczecin, 2010. Księga jubileuszowa Profesora Macieja Zielińskiego.

[Woleński, 2010b] J. Woleński. Zdania aksjologiczne w świetle naturalizmu (axiological sentences in the light of naturalism). *Estetyka i Krytyka*, 19(2):131–147, 2010.

[Woleński, 2011] J. Woleński. Naturalizm, antynaturalizm i metaetyka (naturalism, anti-naturalism and metaethics). *Folia Philosophica*, 29:241–257, 2011.

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