BASIC PROBLEMS IN HUMAN BIOLOGY

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ABSTRACT. Research in human biology can be synthesized into three mayor axis: 1. The evolutionary history of acquiring the erect posture; its physiological and morphological transformations as a response to the changing environment. 2. The brain increase and mental development, related to ecological and social demands. Here regulatory genes played a central role in the morphogenesis and evolution of the human brain. 3. The impact of mankind on the world ecosystems based on two basic interacting features that mark its evolution: sociality and intelligence. These are analyzed, including the demographic, ecological and ethological concerns about the earth's carrying capacity. Finally, some anthropological evaluations and perspectives are posted.

KEY WORDS. Human biology, primates, evolution of the brain, erect posture, morphogenesis, sociality, intelligence, earth's carrying capacity, demographic limits, anthropological perspectives.

In Italy, the study of the natural history of our species—anthropology and related disciplines as human biology, human ecology and paleoanthropology—are defined by a general description under the code BIO/08 (Anthropology) of the Ministry of University Education. The definition reads as follows:

> BIO/08. Anthropology: The sector is looking at the Natural History of Man, considering the origin and physical and biocultural evolution. The fields of competence are: the taxonomy, ethology and evolution of the Primates to understand the evolution and human variation, classification and analysis of fossil remains of the Hominids to reconstruct the phylogeny and to improve human understanding of the processes and mechanisms that have led the evolution of Mankind and the reconstruction of the history of human populations of specific geographic areas through the study of the distribution of morphological and molecular markers, the origin and evolution of cultures the comparative demographics aspects; the archaeological anthropology, even in its molecular aspects, and the comparative aspects of the ontogenetic development of man and the biological characteristics of living human populations and their adaptations to environmental conditions, including applications in the filed of ergonomy and museology.

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The discipline obviously has a great attraction to students in general and opens different potentialities of research. The sections of human biology (which in many Italian universities have a separate and more deeper approach in research) develop interest mainly in the living individuals and on present populations. In Florence, the course of anthropology covers the following program:

A. Primate Evolution and the origin of Humans. 1. Anthropology as the Natural History of Humans. 2. Genetic characterization of individuals and the genetic basis of evolution. 3. Environmental Pressures in the differentiating of human populations. 4. Non-human Primates living today and their bio-molecular and karyological differentiation. 5. Time in Primate evolution. 6. The tectonic theory and climate changes during primate evolution. 7. The fossil data of primates and hominids. 8. Primate posture and acquisition of bipedalism in humans. 9. Differentiation of forelimbs and the acquisition of thumb opponibility in humans. 10. Erect posture, change in cranial capacity and the evolution of human intelligence.

B. Origins of sociality and human culture. 1. Biological bases of social aggregation in non-human primates. 2. Inter-individual communication, vocalization and the origin of human language. 3. The transfer of experiences across generations and development of material culture. 4. The origin and development of the omnivorous diet in humans. 5. Territorialism, ownership, urbanization. 6. Biological bases of aggression and altruism. 7. Origins of arts and esthetic sense. 8. Intellectual capacities of the human brain as adaptive process. 9. Death and the emergence of the concept of divinity. 10. Religious thought and its present organization.

C. Humans, environment and society today. 1. Problems in the third millennium. 2. The demographic explosion: challenges in science, ethics and politics. 3. Demographics: causes and possible control. 4. Migrations: anthropology and history of a contemporary revolution 5. Racism: ethical consequences of a lie 6. Ecosystems: distribution across the planet and environmental pollution .7. Accumulation of atmospheric CO_2 and global warming. 8. Energetic alternatives. 9. Ethical problems presented by the development of bio-medical technologies 10. Genomic technologies from today and the future of humans. 11. From biological entity to the concept of person. 12. Biodiversity and global bioethics.

The main lines of research in human biology at present can be synthesized into three major aspects.

A. PROBLEMS RELATED TO THE ACQUISITION OF THE ERECT POSTURE

Around twelve million years ago, the eastern region of Africa began to undergo profound changes with the advent of a drier climate, due to which the forest was for the most part transformed into open forest and grasslands with shrubs. Consequently, the hominoid forms living in those places had to adjust to a new niche of open forest (savannah), whose conditions of life represented selective factors in relation to higher mental performance. Around 5 million years ago, they evolved into Australopithecines, with erect posture and a greater encephalization quotient. As a result of these changes, our ancestors had to adapt to this new environment.

The adaptation to a landscape with reduced arboreal vegetation and a savannah-like environment induced physical differentiations, which produced specific social behaviors; it was a succession of changes that have severely affected other choices with no possible reversal. All these changes are related to the transformation of the vertebral axis from beam-like to column-like. The change in body statics from four-handed to clinograde and later to an upright posture has conditioned the anatomical-physiological mechanics of our body, changing the physical and socio-cultural context of our species (Fig. A1).

Life as users of natural resources in a savannah environment with its seasonal changes has been determinant for the acquisition of the upright posture and the fundamental morphological differences between males and females in our species.

What were the reasons and pressures that drove our ancient ancestors to change their posture from four-handed to bipedal? Life in the bush was certainly a reason. In a field of maize, where many of us have played hide and seek as children, a four-handed posture does not allow for detection of the presence of another being that can be a potential partner, an enemy, a prey or a predator. These are occasions that facilitate, but that can also threaten the very existence and survival of a species.

In this environment, another important adaptation must have taken place: the transition from a frugivorous diet to an omnivorous one. This new alimentary adaptation produced new social coordinations within the division of labor between males and females. It happened gradually by first exploiting the resources available from the hunting activities of the big cats of the savannah: the strategy of "scavenging" that use the remains of their prey. The living conditions of the savannah have imposed on our earliest ancestors some other typically human conditions: the division of labor between males and females and coordination for the hunt. The hunting parties involved males and females, without children, while the females with small children had to stay in secluded places and wait for the return of the hunters with their prey. The coordination of hunting required the use of phonemes indicative of specific animals or appropriate instructions to coordinate a hunt. That is, a true language as compared to vocalization. Thus, language as a means of inter-individual communication must have originated between 3 and 2 million years ago. Fossils of this period in fact document a reshuffle of the deep brain structures and a transformation in cranial capacity, which over a period of one million years enlarge from 600 to 1200 cc.

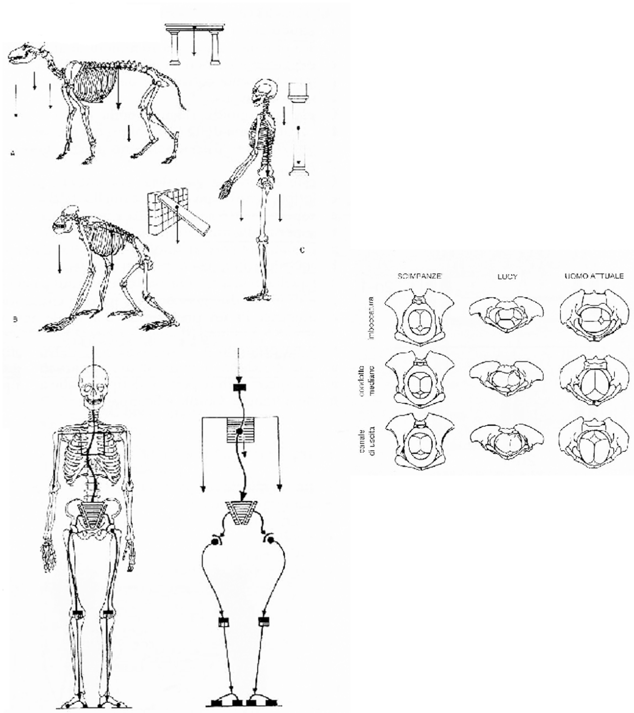

Fig. A1. Static changes due to the acquisition of the erect posture.
The vertebral axis, from a structure similar to a beam (vertebral beam) of the quadruped mammals, assumed the features of a column (vertebral column) with complex transformations in the forces to which the different body parts are submitted: strong development of the gluteal muscles, development of feet as the only support structure, transformation of the pelvic girdle, which for statical reasons, tends to become narrow with complex consequences in the function of childbirth.

The savannah has therefore been an important stimulus for the acquisition of an upright posture, suitable for scanning the environment above the top of an herbaceous vegetation, such as the one in the new environment.

Furthermore, the savannah has seasonally limited seeds and fruits. This is undoubtedly one of the reasons for the presence of additional basal body fat in females of our species, who in order to ensure the maximum survival of the offspring, in the absence of suitable food had to use their basal body fat to produce milk. Even today, a woman who does not have the 18-20 per cent of basal fat is anorexic and cannot conceive. The characteristic steatopygia of Bushman women is a classic example of this physiological need to ensure survival of a population in a harsh environment such as the Kalahari Desert [1].

This set of assumptions and theories on the acquisition of the upright posture induces the interest in comparative anatomical studies of skeletal and muscle structures in order to properly set a course in kinesiology with applications in sports medicine and physiotherapy.

B. PROBLEMS RELATED TO BRAIN INCREASE

During the evolutionary history that led to human mind, the first environmental change related to the development of brain functions was what marked the appearance of mammals around 220 million years ago. Exploiting a nocturnal niche to survive predation, they manage to coordinate the interaction of visual and acoustic information, with a consequent expansion of the brain as compared to the original reptiles.

The second enlargement of brain mass happened at the beginning of the Cenozoic, 65 million years ago, with the appearance of the order of primates. As a result of the extinction of the large reptiles due to a cosmic event (meteorite impact) which darkened the sky and then deprived the heterothermic reptiles of the opportunity to digest, the primates' niche changed again and became both diurnal and arboreal in order to escape competition from other more specialized mammals (rodents and lagomorphs) and to integrate into the vegetarian diet insects and larvae that were abundantly present in the new hardwood forests and constituted the typical prey of their insectivore ancestors (Fig. B1 and B2).

Around 5 million years ago, the Australopithecines made their appearance, with an erect posture and a greater encephalization quotient. The acquisition of upright posture resulted in the release of the hand from key support and facilitated new ways to acquire food and to defend themselves against potential attackers. The verticalization of the skull enhanced the increase in brain mass, thus expanding the cognitive potential with which mankind has prevailed in the surrounding environment, appreciating its diversity and anticipating its control (Fig. B2).

Within 3 million years, the Australopithecines evolved into *Homo habilis* and then into *Homo sapiens*. During these evolutionary stages, the dimensions of brain volume went from 500 to 1500 cc. The rate of increase in brain mass from one to three in about 2 million years is the biggest quantitative change that has ever happened in the evolutionary history of mammals, given that it took no more than a hundred thousand generations.

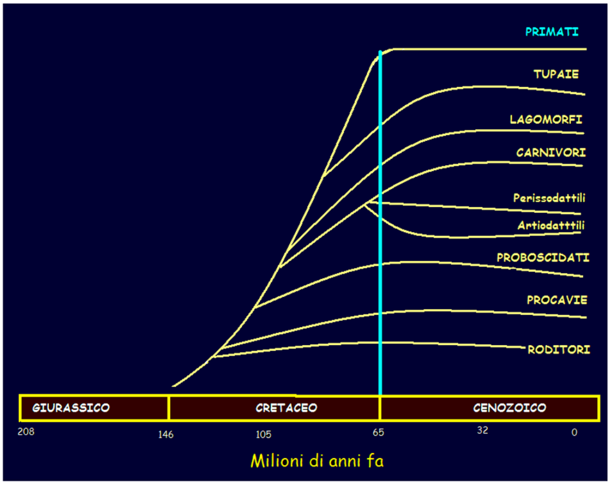

Fig. B1. The evolutionary history of mammals with the change in the ecological niche from night to daytime, around 65 million years ago at the origin of the Cenozoic, when the fall of a meteorite darkened the sun, producing the extinction of large reptiles that were heterothermic.

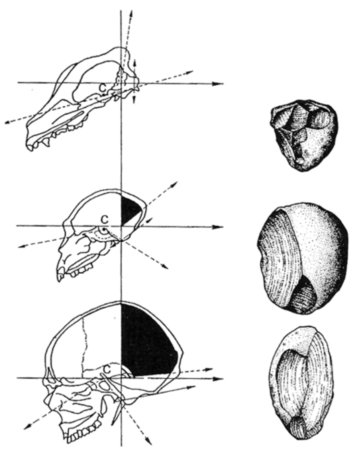

Fig. B2. Changes in brain dimension and structure due to the erect posture. A movement of the basis of the skull came off, according to the postulate of the constancy of the horizontal position of the semicircular channel (gravitational force, equilibrium) during the acquisition of the erect position. This involves the creation of a hiatus (shown in black) in the occipital region of the brain.

In the reptilian encephalon, the predominant structures were and are the visual cortex of the roof nuclei of the midbrain and striatum body (Fig. B3). The striatum is primarily responsible for the basic functions, yet crucial to the survival of individuals and the species, such as the selection and defense of the territory within which the animal carries out its vital activities (the capture of prey or food in general, the competition for the achievement of social rank). The behavior patterns of the reptilian mind follow a rigid code and ritualization, giving rise to stereotypical attitudes that perpetuate, in different animal species, through a genetic substrate which determines their transmission. These codes, characteristic of the reptilian mind, allow the recognition of conspecifics and their acceptance in the group and identify the sexual characteristics that are typical of their species.

As mentioned earlier, during the evolutionary history that led to the human brain, the first environmental change gave rise to the appearance of the first mammals in the Jurassic. Being forced to exploit a nocturnal niche, they were asleep during the day and at night were forced to co-ordinate visual with auditory informations in order to survive, with a consequent increase in the complexity of the brain mass compared to the original reptiles. Furthermore, these environmental conditions induce the valorization of the olfactory sense and the related regions of the telencephalon: the paleopallium and archipallium.

Thus, the development of the paleopallium or limbic brain (Broca 1878) took place. Its structures surround the brain axis, covering the striatum bodies. The limbic brain adds to the social behavior of the reptiles an affective-emotional dimension. In this portion of the brain, informations from outside are modulated and made plastic from visual, acoustic and odor perceptions, sense of taste and skin sensations, as well from endogenous and endocrine stimulations (this portion of the brain enables the amplification of both brain activity and behaviors that govern the preservation of the individual and the species).

The second increase in volume and structure of encephalon occurred about 65 million years ago, following the climatic crisis that led to the extinction of large reptiles being ectothermic or only partially endodermic (Fig. B1). At that time, in fact, mammals, taking advantage of their homeothermia, changed their niche again and became diurnal. The primates were later induced to exploit the arboreal niche in order to avoid competition from other more specialized mammals with the benefits of integrating into the vegetarian diet insects and larvae abundantly present in the new forest hardwood. This choice of an arboreal environment by the primates was then accompanied by other needs that led to further brain development. In order to mate and to be able to raise their offspring in an arboreal environment, they were forced to develop a social structure that involved higher cognitive functions: this requirement must have selected a new set of gene mutations that produced a new increase in brain mass.

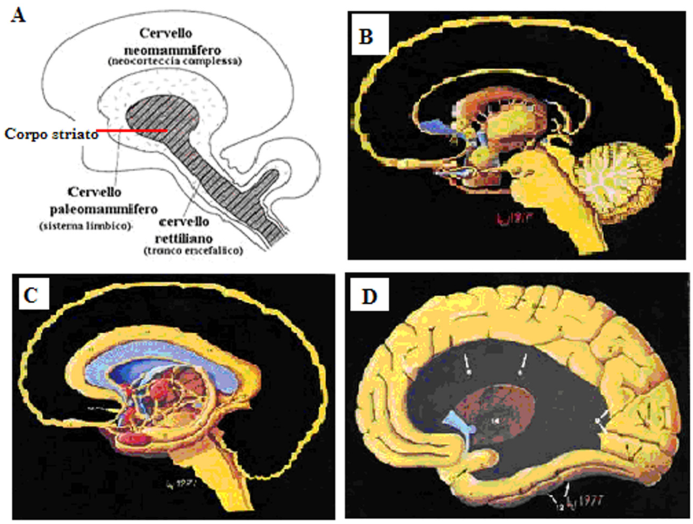

Fig. B3. The brain of primates (A) can roughly be divided into three stages of organization: (B) the basal one characteristic of reptiles, the trunk-encephalic (spino-spinal cord, the midbrain and the nucleus of the striate processes which control self-basic instincts and activities. The one characteristic of paleomammals (C) (limbic system), and the one characteristic of neomamals (D), which deals with the neocortex learning processes and adaptation complex.

Therefore, the neopallium developed as the characteristic of evolutionary more recent mammals. It completely covers the two previous cerebral entities, reaching its greatest development in humans with its complex neocortical organization (neocortex). The neocortex has many routes of connection, both incoming and outgoing, with the structures of the two underlying cerebrotypes, the reptilian one (archipallium) and the limbic one (neopallium), but does not have direct channels of information connecting it with the environment. Accordingly, all informations from outside and the visceral environment come to the neocortical assessment only through the other two cerebrotypes, modulated by the affective-emotional charge given to them by the limbic brain. The food of our ancient ancestors was predominantly vegetarian, enriched by insects. The need to hunt insects on the trees must have facilitated the development of upper limb dexterity and sense of balance (Fig. B2). Once again, a long history of ecological changes underlies this quantitative leap in the development of the brain and mind.

Within 3 million years, the Australopithecines ran an evolutionary path, although not in strict phylogenetic continuity, to *Homo habilis*, *Homo erectus* and then *Homo sapiens*. During these evolutionary stages, the size of the brain progressed from 500 cc. to 1 500 cc. The increase in brain mass from one to three within two million years is the biggest quantitative change that has ever happened during the evolutionary history of mammals. Two million years is equivalent to a biological time span of 100 thousand generations (50 thousand generations per million years). If it were a continuous phenomenon this would amount to about 500 cc. per fifty thousand generations, or 0.01 per generation!

It was the selective pressure of the new ecological niche, alongside the acquisition of the upright posture, that determine this additional increase in the neopallium. The increase in brain mass, however, also originates from the emergence of a highly cooperative social structure, which in turn, with the release of the hand from the key support, facilitated the production and use of instruments whose use in turn enhanced the acquisition of language as a means of social communication.

Particularly in humans, the neocortex is home to abstract thinking, logical reasoning, inventive processes, and the processes of analysis and synthesis of ideas, imagination and intuition. The human brain differs from that of other animals in its ability to filter through the neocortex sexual stimuli (odors, tactile signals from contact with the partners, direct and indirect vision of the partner), which in animals are immediately suggested and demand a sudden instinctive reaction. The control of the neocortical section over the other two ancestral portions (paleopallium and archipallium) in humans is expressed through symbolic thought and language.

In humans, therefore, three different cerebrotypes merge into a single structure, the reptilian, that paleomammalian and the neomammalian, each one endowed with its own type of mental performance, memory, sense of time and space, motor activity and other functions. Moreover, these three levels of mind, although widely interconnected and functionally interdependent, are able to operate independently from each other. Each of these components is a fundamental distinct evolutionary stage. Populations of *Homo erectus*, around one million years ago, became widespread in Eurasia. The problems of survival in the cold and temperate climates of Eurasia were overcome by the integration of abundant amounts of protein and animal fat into their diet. Hunting became a regular activity, especially during the glaciations in Eurasia. This practice was an important stimulus for the development of technology and social cooperation. However, while populations of *Homo sapiens* in Eurasia had to solve survival associated with low temperatures and the difficulties of the subarctic, populations in Africa evolved in tropical and subtropical environments: two completely different environments that may also have influenced the evolution of intellectual characteristics in different ways.

B.1. HOMEOBOX GENES AND THEIR ROLE IN THE MORPHOGENESIS AND EVOLUTION OF THE HUMAN BRAIN

The knowledge of the eukaryotic genome and the development of embryology have provided new experimental tools to study cognitive morphogenesis. Regulatory genes, growth factors, transcriptional regulatory mechanisms now allow us to address the phenomenon and to assess the morphological shape of an organism as a fact to be biologically understandable and therefore comparable between different species (Boncinelli 2001).

In recent years, the so-called HOX genes have been discovered. In mammals there are over 200. They constitute a super-family of gene sequences comprising more than 49 different families, each consisting in a number of genes that regulate a particular aspect of development. These DNA sequences, containing about 180 identical base pairs, are indispensable for the identification of embryonic segments of the development of certain structures of the nervous system of vertebrates, including humans (Mc Ginnis 1994). Their peculiarity lies in the fact that these genes are virtually identical. Their function is to act as regulators, activating other genes that in turn will trigger others to guide the development of cells and tissues in a particular direction and to act on morphogenesis. The family of HOX genes thus plays an important role in the developmental stages of the body plan during embryogenesis. An analysis of homeobox genes of different organisms also shows that the total number of these genes in the genome of an organism determines its complexity (Galliot 1999). In vertebrates, these genes are organized in groups of repetitions of very similar units, distributed in four clusters. In humans, they are located on chromosomes 2, 7, 12 and 17 (in mice on chromosomes 2, 6, 11 and 15).

In humans, the central nervous system represents the most complex organ of the embryo. In all living animals (vertebrates as well as invertebrates), neurons of different form and function are organized between themselves to form specialized connections, thus rising a dense network of communications. The study of HOX genes could therefore play an essential role in anthropology, since it involves the development of human cognitive abilities and its variability. During the past decade, several genes involved in morphogenesis of the encephalon have been identified. The adult brain consists in a number of regions and subregions that are characterized by different types of cells derived from the neuro-ectoderm of the embryo (Fig. B4).

During brain development, these regions are specified by a precise mechanism, which attributes suitable regional identity to different types of nerve cells (Rubinstein, et al. 1998; Acampora, et al. 2001, 1999, 1995). The development of the central nervous system is a complex process characterized by sequential and coordinated inductive phenomena that first specify the anterior neuroectoderm and then divide it into areas that give rise to the telencephalon, the midbrain and the diencephalon.

The genes that control the development of the encephalon in all vertebrates including humans belong to families of EMX and OTX genes. The way in which these genes are active in the embryonic encephalon is interesting and is one of the research projects of our "Cognitive Anthropology" group in Florence. The spatial domains of their activity are represented by four regions that enclose each other. The broadest of these includes the whole brain consisting of the embryonic telencephalon, the midbrain and the diencephalon; the rear end of this region borders on the cerebellum.

This broad region marks the activity of the OTX2 gene, which is also the first to become active during the embryonic development. The region where OTX1 is active lies inside the domain of activity of OTX2, and the EMX2 domain is in turn situated inside the OTX1 region. EMX1, which during embryonic development is the last of the four genes to come into effect is active in the narrowest region, where the future cortex is to be formed (Boncinelli 2006).

So what are their functions? The first gene, OTX2, activated very early during embryonic development, controls the formation of the head and determines the region of the telencephalon-midbrain-complex, distinct from the cerebellum and the spinal cord. The second gene, OTX1, which acts at a moment when OTX2 has already completed part of its job, further divides the brain. Likewise does EMX2, unless EMX1 completes the work determining the cerebral cortex.

It is important to reconstruct the genetic steps that led to the structure of the "trium brain" (Mac Lean 1969) at the level of mammals and the development of the neocortex with all its implications for the social cognition and interaction in humans. The process of human brain's increase is not only a quantitative one. The brain is organized in repeated units of columnar structures of neurons in the cerebral cortex and this columnar structure in the human brain surface is what may be most interesting for our colleagues in the information technology. It consists of anatomical and functional units upon which the evolutionary variability of the brain is based. The increase in intellectual skills of the neocortex can be compared to units of computers that are added to each other during evolution.

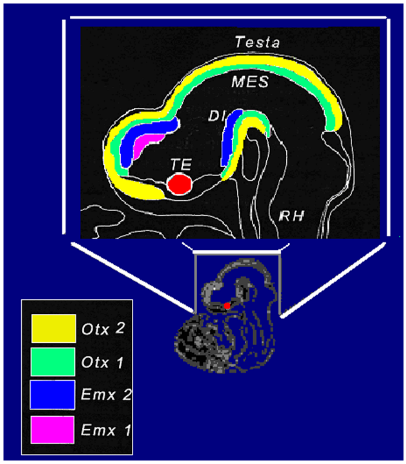

Fig. B4. Schematic representation of the domains of expression of EMX and OTX genes in the central nervous system of a mouse embryo of ten days. The regions indicated are: telencephalon (TE), diencephalon (DI), midbrain (MES) and rhombencephalon (RH). The red circle indicates the future position of the eye. The Otx2 gene is the first to be effective during embryonic development, followed by Otx1 and Emx2, and finally, much later, by Emx1.

Through the study of microscopic preparations and the distribution of different cell types in the embryonic stages in which these genes become active, one could get an idea of the genetic control of the organization, thus the evolution of the human brain.

C. MANKIND IMPACT ON THE WORLD ECOSYSTEMS

The course of human evolution, from 6 million years ago to the present, is set in a series of stages. Each of these was made possible by what happened in the preceding ones. Every generation has played a role in driving mankind to new unanticipated and unimagined directions. Nowadays, just as in the past, every one of us can influence the future of humanity with his/her decisions.

Two basic interacting features have marked human evolution: (1) *sociality,* the predilection that connects individuals into groups thanks to a continuous and effective influence of the four basic biological stimuli of socialization (i.e., mother-offspring interaction; sexual attraction; collaboration in the search for food, and the defense of the group (Fig. C1); and (2) *intelligence,* defined as the peculiar skill of acquiring, elaborating and communicating information, and the ability to anticipate, plan and resolve tensions and troubles. These two features were highly selective factors in the first stages of the hominid evolution.

The first hominids lived in small migrant groups since food of high energetic content is neither abundant in nature nor available in delimited spaces. Accompanying the mobile groups were exogamy and demographic fluxes, which not only established social ties but also permitted a constant gene flow. With gene flow, adaptive features were able to spread quickly through the entire population, maintaining a general uniformity in the gene pool of the species. In addition, sociality determined the deme, i.e., the minimum number of individuals to assure the genetic variability necessary for the survival of the population from one generation to the next.

C.1. DEMOGRAPHIC ASSESSMENT OF THE EARLIEST HUMANS

Archaeological data suggest that the human population was limited during the Pleistocene and Paleolithic cultural stage, probably not exceeding 10 million. The nature of subsistence and frequent climate changes were the limiting factors.

Frequent climatic alterations played a decisive role between 14 and 6 thousand years BC. In that period, humanity produced technological and social innovations to overcome the unpredictable environmental fluctuations. Such interactions between humans and the environment also gave rise to technological developments leading to agriculture and animal domestication. These innovations were the basis of established settlements and for the first demographic revolution. In the Paleolithic, 250 km^2 were required for the subsistence of 3 hunter-gatherers, whereas the same area could support 12 of the more expert Mesolithic gatherers. Whereas the global population was no more than 10 million at the end of the Paleolithic, it was 50 million around 5 000 BC, at the birth of the first state-societies.

The Neolithic transition occurred independently but almost simultaneously in the Near East, China and Central America. The beginning of agriculture (Fig. C2) as well as management of pasture and stable settlements constituted additional factors for the development of intellectual capacity. The domestication of plants and animals has always involved more sedentary groups. The concentration of people facilitated the development of refined skills and the exchange of innovations. As a result of this new and more active interaction, an intellectual and technological progress took place that led to the creation of writing, a mathematical system, and to the understanding of nature as something separate from man himself, a breakthrough that leads to cultural evolution. Thus, the expansion in brain volume and intelligence developed through constant interaction with the environment.

Fixed settlements, the development of animal breeding and agriculture, and the discovery of fermentation, made possible a considerable expansion in the number of people able to live in a given territory: 2 500 people per 250 km^2 for the first communities of farmers gathered in villages and 5 000 people in the same area for the next preindustrial and urban stage. In that first era, biologically defined demes in permanent territories gave birth to the notion of ethnicity and territoriality and favored the establishment of cultural diversity through regional linguistic differences.

Agriculture and breeding was the forceful interaction of man with natural environments. A territory, deforested by fire, was abandoned when considered no longer productive and the population began to transform other neighboring territories.

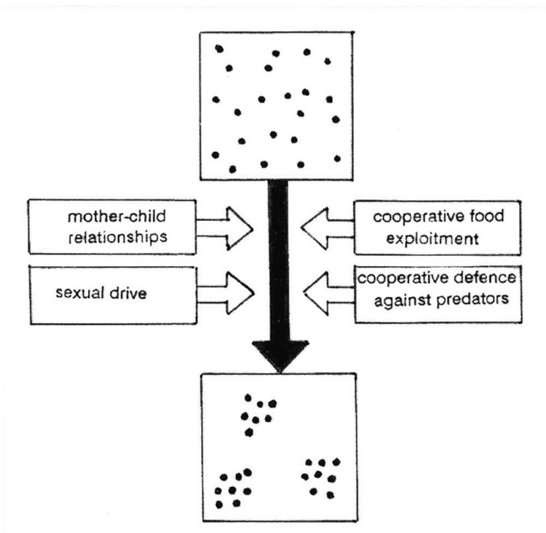

Fig. C1. Generally speaking, the social organization of every group of mammals follows four stimuli, two related to the biology of the species (the mother-child stimulus and the sexual one) and two related to the environment in which the population is living (cooperation to search for food and defense of the group). The interaction of these stimuli with the environment determines the best adaptive choice regarding the social structure. The differences in the intensity of the biological stimuli for the different species allow to determine the minimum number of individuals necessary to maintain the survival of the populations from one generation to the next (deme), while the productivity of the environment where they live determines the maximum number
$(A+B) + k(C+D) = \Delta$

Fig. C2. Primary and secondary centers of cultivated plants: 1. Sorghum, cotton, pepper. 2. Banana, cane sugar, coconut, citrus fruits, bamboo, 3. Wheat, onions, grapes, hazelnuts. 4. Rye, oat, green peas, flax, grapes, figs. 5. Wheat, flax, olives, sugar beet. 6. Barley, flax, coffee. 7. Maize, cotton, sweet potatoes, broad beans. 8. Cotton, potatoes, tomatoes, tobacco. 9. Oat, barley, millet, soy, cane sugar, citrus fruits, tea.

Agricultural innovation made possible the accumulation of energy-food surpluses, which removed the most important restraint on demographic increase in hunter-gatherer communities. Between 4 and 3 thousand years BC, in the Middle East the success of monotheistic religions, with their conception of mankind as the center of nature, was a fundamental stimulus to the idea of domination and possession of the earth by humans. However, the rapid and substantial increase of the population must have caused cyclic energy imbalances and periods in which global food requirements exceeded the limit of the carrying capacity (i.e., the maximum number of people that could survive in the actual environmental conditions). These were pre-crisis situations, frequent in primitive agricultural societies, in which even moderate seasonal decreases in output caused substantial mortality: epidemics, ritual limitations of births (exposure of neonates to the elements, elimination of the first-born, especially if female) or limitations of the reproductive potential (vestal virgins, etc.) of a large part of the population.

C.2. DEMOGRAPHIC INCREASE IN HISTORICAL TIME

At the beginning of the Christian age, humanity numbered 250 millions and had needed 15 centuries to reach 470 millions at the time of the discovery of the Americas. The human population reached 750 millions around 1750, with 65 living in Asia, 17 in Europe and the rest in the other continents.

The rate of population growth up to 1750 was not constant. Plague and other epidemics caused a contraction of the population in at least two periods, between 500 and 600 and between 1350 and 1500. The development of geographic knowledge, with the discovery of new utilizable territories, and the expansion in food supply were fundamental factors for the subsequent increase period (Chiarelli 1992).

The industrial revolution and better hygienic-sanitary conditions, since the middle of the seventeenth century, accelerated the population increase, first in Europe and then in other industrial regions. In the two centuries between 1750 and 1950 (the end of World War II), the population grew with an average rate 10 times greater than in the preceding centuries. This rate caused a doubling of the population in less than 120 years. The level of one billion people was achieved around 1830, two billion in 1925, and in 1950 the world population was already 2.5 billion. In 1987, the global population was 5 billion and in 1995 we numbered 5 billion 750 million. Nowadays, after 12 years, the human population on the earth exceeded the 6.5 billions.

In the last two centuries, the enlargement in life expectancy at birth, the exploitation of resources and the control of humans over the environment have contributed to the demographic growth. Furthermore, the last 59 years (from 1950 to the present) must be considered a period on its own, not only because of the huge global rise in the annual rate of population growth (more than a doubling of the population), but also because this increase concerns specific geographic regions. Although the average global rate is 1.8 per year, it is only 0.6 in Europe, while greater than 2 in Asia and America and 2.5 in Africa. These differences between human populations have anthropological relevance. The doubling of the population, which took place in thousands of years, presently occurs in a matter of decades. This phenomenon has been defined as "biosphere cancer" by the American biologist Hem Warren (1995). In a large number of areas of the so-called Third World, the population is growing at a dizzy rate despite shortages of food resources. This multiplication is a consequence of the submission to Western cultural patterns, and of the acquisition of better hygienic conditions as well as the defeat of many diseases.

In the Mediterranean area, a huge difference exists between the south (Africa) and north (Europe) coasts: the average birth rate is 6 children per woman on the southern shore versus less than 2 on the north. Therefore, an expansion in immigration from south to north is inevitable in the next few years.

It is necessary to ask: What is the number of people that can be supported by the planet? With the information at our disposal, we hypothesize some possible scenarios for the future. The current human demographic explosion can be compared to a car at high speed. The driver (i.e., human social intelligence) can make the following decisions:

a) to continue increasing speed;
b) to take the foot off the accelerator;
c) to apply the brakes.

Scenario 1: No obstacles to a constant population augmentation up to 10 times. Some political and religious leaders think that the carrying capacity of the earth is practically unlimited. They think that technology will be able to support a highly populated world, not only providing basic needs but also prosperity. According to Marchetti's theoretical figures (1993), with avant-garde housing solutions (Soleri 1969), one billion million people can live comfortably for an unlimited time, without overloading the planet. Nevertheless, this idea cannot be taken as an invitation to multiply, it is only a theoretical perspective. The choice here is ethical and ethological. Indeed, subsequent generations would have to adopt a completely different life style, in some ways closer to that of social insects!

Scenario 2: The population growth will continue but with natural deceleration. According to the United Nations and the World Bank estimates, the world population around 2020 will be 7-8 billion. If the fertility rate were to remain at 2.1 children per woman (i.e., the level necessary for long-term, zero growth), the world population will be 10 billion in 2050, and will reach a balance of about 11.6 billion at the beginning of 2200. Obviously, these figures would change according to the assumed fertility rate. If fertility were around 2.5 children per woman, the world population would reach 28 billion in 2150, an amount that could not be tolerated by the planet. However, the average number of children per woman is far from 2.1 in most parts of the world at present (1.1 in Germany, 1.3 in Italy). Yet women in Africa average more than 6 children and in South Asia and Latin America the rate is still close to 5 (but tending to decrease quickly).

The situation is even more alarming since life expectancy at birth is increasing, particularly in those countries, which are contributing most to the population increase. According to UN projections up to 2025, 70 por cent of the population increase will be in only 20 developing nations: India, China, Nigeria, Pakistan, Bangladesh, Brazil, Indonesia, Ethiopia, Iran, Zaire, Mexico, Tanzania, Kenya, Vietnam, Philippines, Egypt, Uganda, Turkey and South Africa (black population).

Scenario 3: The human population will cease to increase in the next few years on the basis of common agreement, which will set a birth rate of 2 children per woman. The Peking conference seems to have opened up this prospect. Due to the natural ageing of the population, we can assume a considerable population decrease between 2050 and 2080, with perhaps 4-5 billion deaths in 30-40 years. Apart from the problems which will be raised by that situation, a New Renaissance is foreseeable immediately afterwards.

Scenarios 1 and 2 run the risk of facing a shortage of food and energy between 2020 and 2025. The car driver now has the choice between these three scenarios. We have the choice, and it is an ethical decision that must be made at once, to spare the next generation from the risks involved. Indeed, the very survival of our species is the venture. This was the main subject discussed during the UN conference in Cairo on population and development, and at the one in Peking on women. Discussed at these meetings were some methods to obtain a slowing down of the population growth by means of decreasing fertility: the promotion of modern methods of contraception, incentives for economic development in the poor countries better living conditions for neonates and children, progress in the condition of women and in education. Many countries are trying in various ways to decrease the birth rate and to improve living conditions, despite the interference of some ideologists. The methods attempted include the restriction by the Chinese government of one child per woman, the renewed encouragement of prolonged breast-feeding, and the effort to emphasize the value of women in society.

There are three anthropological features involved in the problem of the future of humanity: a) the global carrying capacity; b) the differential increase among human subgroups (national, ethnic or biological ones), and c) the ageing of the population in industrial societies. The last two problems have an immediate anthropological impact on the well-being and social relations of human beings. Humanity has to maintain a balance with nature, but also with the different gene pools in order to avoid their extinction. For example, a balance is necessary between the sexes and between age groups. However, of all these problems, the one concerning the carrying capacity is the most crucial for human survival and leads to deep worries on ecological and ethological grounds.

C.3. ECOLOGICAL AND ETHOLOGICAL CONCERNS ABOUT THE EARTH'S CARRYING CAPACITY

Humanity has only a few hundred weeks left to plan responsibly its demographic future and thus its impact on the biosphere for the immediate future. Scientists, politicians and theologians have little time left to think about this topic. They have to revise their positions on problems that concern the interactions between our species and the environment. Anyhow, their cultural background regarding the fundamental features involved in this man-nature relationship is weak, sometimes very superficial. Indeed, it seems that quite often-irresponsible guidance by leaders is replaced by a collective social intelligence, which independently tackles and resolves ethical and moral problems. Some experts state that new biotechnologies will be able to offer us sufficient food and energy resources, as it occurred in the Neolithic with the discovery of the domestication of animals, agriculture and fermentation.

On what basis is our future to be planned? What kind of life and world do we want to leave to our children? The UN demographic projection says that the world population in 2050 will inexorably reach between 7.8 and 12.5 billion, after which it will begin to decrease. Is the earth able to support this projected population? If so, under what living conditions?

Already in 1679, Anton van Leeuwenhoek estimated that 13 billion people would be the maximum population supported by the earth. The estimates of other geographers and demographers vary from a minimum of one billion to a maximum of 1 000 billion. Such different estimates give rise to deep skepticism.

During the UN Rio Conference in 1992, some economists urged that each single country should evaluate its human carrying capacity. However, even if some specific resources, like mineral deposits, can be defined region by region, the knowledge, energy and technology for the exploitation of local resources often depend on other countries. The human carrying capacity cannot be defined on a national (regional) level. Moreover, all of us share the same atmosphere, oceans, climate and global resources. As a matter of fact, the human carrying capacity depends on natural limits (not yet completely defined) and on individual and collective decisions about the distribution of products, the use of technologies, political institutions, the guidance ideologies, family structure, migration trends and the adaptation to urbanization. In other words, it depends on how many people will eat meat or sprouts, how many will demand parks and how many will want parking places, how many want fields of maize or fields of tobacco, and so forth. These are the choices that will condition the number of people that the earth is able to carry.

In 1798, Thomas R. Malthus described the dynamic relation between the human population and a country's carrying capacity:

> Welfare doesn't depend at all on a country's poverty or wealth, on its young or old age, if it's more or less populated, but it depends on the speed of its development, on the relation each year between the increase in alimentary resources and the uncontrolled increase of the population .... in simple words, the economy of a population is the contest between two rates of increase: the one of population, and the one of economic output.

Cohen (1995) tried to integrate the dynamics population model of Malthus-Condoret and Mill's population growth model with the earth's

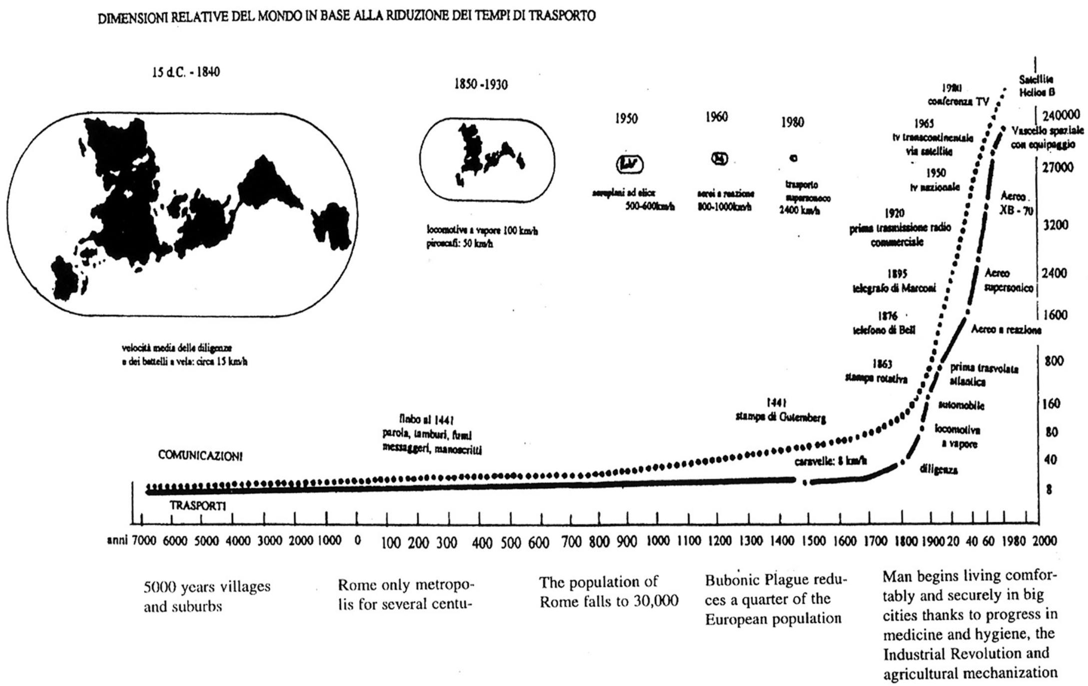

Fig. C3. Increase in population size, speed of transport and communication showing their interconnectivity during the history of man. The time scale shown comprises 9000 years, form 7000 BC to the present. The dramatic increase of the curve during the last century is striking. With the development of technology, the relative size of the world reduced progressively thanks to the reduction of transport time and communications. Yet, the future survival of mankind is related to the maintenance of the biodiversity and the heterogeneity of cultures.

carrying capacity. The difference between the curve of the human carrying capacity K(t) and that of population size P(t) in the last 2000 years is quite clear. Up to 1970, the data concerning population size (theoretical and real) lie on a convex curve, whereas after 1970, they lie on a concave one. K(t) was slightly above P(t) in the ninth to tenth century, but has been increasing exponentially between the eleventh and twentieth century. According to this pattern, the acceleration of population growth in the seventeenth century was preceded by a long period expansion of the carrying capacity (Cipolla 1994). The discovery of new territories, like the Americas and Australia, which placed new resources at the disposal of the peoples of the Old World, was certainly a substantial contribution to this phenomenon (Chiarelli 1992).

The closeness of the two curves, near 1970, is the fundamental problem that humanity is facing now and in the near future. Only new technologies and new energy resources can offer concrete opportunities for a future increase of the global population (Repetto 1985; Ferace, et al. 1993). However, novel technologies have caused new pollution and environmental damage. Population increases aggravate primary forest cutting, contribute to the erosion of the earth's surface and to the production of chlorofluorocarbons and plutonium. Moreover, problems caused by increasing urbanization (proxemics) have to be resolved by an ethological and cultural approach.

The restraint of population growth is both urgent and necessary. Even the Accademia Pontificia delle Scienze, the principal scientific authority of the Catholic Church, has declared as much: "The necessity of a global limitation of births is unavoidable." A goal that must be reached "with all the intellectual and moral energies of humanity, in the respect of social equity and fairness to various religions in the world and to actual and future generations." Therefore, a global restriction of fertility, at a rate of less than two children per woman, is a necessity for the survival of humanity, as underlined in the 1999 conference in Peking.

C.4. ANTHROPOLOGICAL EVALUATIONS AND PERSPECTIVES

People nowadays must be ready to accept the notion of the "natural history of man." Everyone must appreciate human evolution and the difficulties overcome with obstinacy during the human history, from its very origins. In this way, one can very well understand the cultural and technological developments of today. The example of the past is the key to understand the present and foresee the future. Experts on present populations and the planners of the future have to consider demographic growth and its causes. Anthropology, in the sense of the natural history of man, not only has to satisfy our curiosity about our past but also, and above all, has a wider and greater importance in the understanding of our place in the natural world, i.e., our way of confronting the environment and facing future adversities. At present, humanity must reconsider its idea of nature and must give new value to its interaction with her. Ethics must reconsider its social milieu and include nature, in order to free the earth from the idea of domination and exploitation. This was suggested by A. Leopold's broadmindedness in 1939, and is now warmly proposed again as an "ethic of responsibility" by Van Potter (1992), Jonas (1990) and Chiarelli (1992).

Humans now begin to look at nature as a supporting milieu for life (ecology) as its very substance. A substance that is common to every other being (comparative biology and DNA as the unity of life). While knowing nature, humans must realize that they are part of it. Hence, we should say that nature thinks itself through the human brain. It follows then the anthropic interaction between human consciousness and the knowledge of nature. The reflection of the mind about the matter, in which mind is matter itself. In other words, as already stated by Teilhard de Chardin: "the matter is full of life, life rises to conscience and mind."

Nevertheless, this period of rethinking is dimmed by the risk of ecological disaster and by a catastrophic increase of the human population, which not only restrains the development of knowledge, but undermines human life itself.

The adaptive choices of human social structures and the ethical choices themselves (which are also biotechnological and biomedical) are a consequence of this interaction between human population and natural environment, a balance that must be preserved for the very survival of our species. The natural world may not be interested in man's survival. Modern man, *Homo sapiens*, as a result of biological evolution is just another living species. As has already happened, and continues to happen with other species, if human persists with unlimited reproduction and an impetuous abuse of resources, he can cause his own extinction as well as the extinction of other species of plants and animals.

Bioethics, therefore, is basically an anthropological and naturalistic science, which tries to set up a pact between man and nature in order to ensure the possibility of our continued life on this planet (Chiarelli 2003).

TABLE
BASIC ETHICAL PRINCIPLE IN THE HISTORY OF LIFE (BIOETHICS)

The definition of Bioethics: “Preservation of the DNA typical of the species and maintenance of its intraspecific variability.”

HIERARCHICAL ORDER IN THE HISTORY OF LIFE AND ITS ETHICAL SIGNIFICANCE

FIRST LEVEL	HAPLOID (n): microorganisms, gametes, spores, haplophytes
SECOND LEVEL	DIPLOID (2n): sexual reproduction (meiosis). In this 2nd level peculiar ethical concerns must be reserved to the biological entities as: a) *cutting:* they are identical copies of an original individual, ad they do not have variabilities, they are produced asexually. It regards mainly cultivated plants and lower animals, now also artificial cloning in animals and possibly man (nucleo-transfer). b) *subsidiary class of social insects: t*hey do not transmit the DNA of the species and they do not have reproductive potentialities. c) *early stages of life as embryos and seeds:* they have no certitude to reach the reproductive stage. d) f*inal stages* as they have lost reproductive potential. *Diploid Biological Entities:* defines moreover the individual as unique, unrepeated and indivisible for its entire biological cycle.
THIRD LEVEL	*Vertebrate animals* in which the maintenance of the DNA variability typical of the species and its intraspecific variability is assured by socialization defined by the interaction of internal and external factors (A. mother-offspring relation; B. sexual partner relation; C. cooperation in food research; D. cooperation in defense) and quantitative formula could be created to give the maximum and minimum number of individuals who could survive in a certain environment. $(A+B) + k(C+D) = \Delta$
FOURTH LEVEL	*Mankind* in which the maintenance of the DNA typical of the species and its intraspecific variability is assured also by the product of the brain activities (history, traditions etc.). In this case, ethics can also become moral code ad the four types of socialization input can be influenced by history.

NOTE

1 Even though the savannah environment is certainly crucial to the acquisition of upright posture a very interesting theory was developed by Lia Amaral of the University of San Paolo (Amaral, 2008). According to this researcher, the acquisition of upright posture is linked to the transport of babies by their mothers. In apes, the transport of infants is facilitated by the coat that allows the children to grasp the body of their mother even if placed on the back or supported by one of the upper limbs. But when body hair is reduced, children carried on the shoulders tend to fall down and it is therefore necessary to hold them, thus having one limb constantly occupied. The consequence would be a tripodal gait, but this prevents the use of the other limb and the hand from collecting food. This would have led the females to acquire an erect posture! The solution to this evolutionary change of reduction of body hair was proposed by Gioacchino Sera with the "Theory of the aquatic phase" of human evolution that would explain many of the typically human features.

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