Chapter 3
Governance of Societies

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3.1 Skipping Centralization

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3.1.1 Key Messages

It is no secret that the world is urbanizing very fast. If UN estimates turn out to be true, by midcentury 2.5 billion people will have joined the approximately 3.9 billion living in cities today, an urban population increase of over 60 %! It is one of the biggest questions of our time, how the 6.4 billion who will live in cities by 2050 will be fed, housed and provided with basic services in a sustainable way. What kind of infrastructure and governance models will be the most healthy in the progressing urbanization of the planet? What is the best mix between decentralization and centralization of services, infrastructure and government structures?

These are highly complex questions and there are no simple answers to complex questions especially in complex contexts. Urbanization is diverse, living is diverse, situations differ, landscapes differ, cities vary, people vary. As a trained landscape architect, I would say, the answers to the above questions are highly dependent on the context, on the social, physical and political landscape they are embedded in.

3.1.2 Where and How Urbanization Will Occur

Future urbanization processes on the planet will be very unevenly distributed. Most of our global urban growth in the coming decades will occur in Asia and Africa. Much of South America is already urbanized (for instance, 90 % in Brazil), North American cities will only grow moderately, and many European cities will rather stagnate in population numbers unless immigration policies will change (some do even shrink). That means that Europe and large parts of the Americas are experiencing urban consolidation processes where existing cities will be redeveloped and restructured (hopefully in a more sustainable way), while cities in Africa and Asia will rapidly expand.

What will this coming urbanization look like? Urbanization processes will look very differently pending on the respective development level of a singular country, region or city. In more authoritarian governments with centralized planning agencies the development of new cities and urban additions will be centrally planned in a strict top down process. For example the Egyptian government plans to build 40 new cities to house millions in the desert. China plans to build homes for an additional 100 million inhabitants by 2020. Brazil has programs to build millions of new homes under a federal program called Minha Vida, Minha Casa.

Vast master plans are drawn up covering many square kilometers with the attempt to create new living environments for millions from scratch. As previous new town examples have shown, the success and livability of formally planned city expansions are questionable; authoritarian master-planned cities with little to no participation processes rarely function as desired. They often lack employment opportunities, public transportation, affordability, social cohesion and diversity. There are not many examples in the world where the creation of new towns has been completely successful. The creation of new homes and livelihoods is a highly complex undertaking and one could question how much of it can be even planned.

It would go beyond the frame of this essay to go into further detail, especially because formally planned urban expansions by governments with sufficient funding capacities will be actually the smaller part of planetary urbanization.

Much of the urbanization pressure will be in the developing and least developed countries of Africa and Asia where urban planning, funding and implementation capacities are limited. Per UN Habitat, the majority of future urban growth will occur in cities with less than 500,000 inhabitants, throwing overboard common perceptions of an urban world dominated by sprawling megacities (cities over 10 million inhabitants). These smaller to mid-sized cities will double, triple, quadruple in size and are typically not very well equipped nor have the financial resources to handle this type of massive increase of their populations. In the absence of viable alternatives, the majority of these urban expansions will occur outside of legal planning frameworks (if they exist). People will build houses and neighborhoods if not whole cities on their own without a master plan or official city permit. These people are forced to act on their own, not because they act like criminals, but because they have no other choice (lack of serviced land, lack of affordability, common custom). If the UN prognosis is correct, the majority of our future urbanization will be dominated by what UN-Habitats coins as "slums". Slums are not always correlated with informal housing activity, but most informal neighborhoods in their early stages would fall under this definition. UN-Habitat estimates that almost one billion people currently live in slum-like conditions. It is estimated that by 2050 two billion more will live in slum-like conditions, or two-thirds (!) of our new urban population. That means we are looking at a global urbanization process where city planning as a classical achievement of normative centralization efforts will be the exception and decentralized decision making as a ancient act of settlement formation will be the rule.

Decentralization as the Urban Default

De facto, the majority of our future urbanization will occur in a predominantly decentralized manner where many individuals will make individual decisions where to build a house or an annex thereby creating completely new cities. These individuals will make these decisions based on a complex set of aspects with the proximity to employment as the overriding factor. Most of the new informal urban expansions will have very little public infrastructure as in cities of the developing world basic accommodations like running water, permanent electricity or paved roads (a given in cities of highly industrialized countries) can be more the exception than the rule. In rapidly industrializing countries with growing prosperity and democratic governments (Brazil, Chile, Colombia, Argentina etc) informal settlements might gain some form of access to water, sanitation, public transport, schools or health services once they have been accepted by authorities and are not anymore in danger to be forcibly removed. There are many examples especially in Brazil, Colombia and other parts of Latin America where informal settlements have been retrofitted with new social and technical infrastructure. They are typically connected to a centralized infrastructure system (water, sewage, electricity) based on nineteenth and twentieth century technologies that these countries have inherited from more industrialized countries. Centralized infrastructure emblematic through flush toilets or central heating is seen as a sign of modernity, progress and urbanity; decentralized infrastructure systems like rain water harvesting or local energy production can be valued as signs of a rural lifestyle that most of the migrants tried to leave behind by moving to the city.

That means we live in some kind of a time warp. While highly industrialized countries like Germany think about more decentralizing their hard-won twentieth century achievements of centralized services like sewage treatment, potable water provision, energy and food production, less industrialized and industrializing countries are going full speed for centralized services in their cities.

3.1.3 The Case of São Paulo

How centralized infrastructure and large scale engineering projects have problems to manage the complex metabolism of a megacity can be studied on the case of São Paulo and its water management. São Paulo grew in the last century from a mid-sized town to a 20 million metropolis. Over that time it adopted and implemented the centralized engineering and infrastructure approaches typical for industrialized countries. São Paulo's water management is indicative of a classical sectoral thinking where potable water provision, stormwater management and sewage treatment is thought of as separate problems and handled through separate large-scale infrastructure systems. Potable water is provided through a series of reservoirs far away from the city. Older reservoirs closer to the city are engulfed by urbanization and are only in small parts usable. Most lately (2015) São Paulo is facing the largest water shortage in its recent history, with reservoirs almost depleted, whole neighborhoods without running water and no additional water sources available in the short term (there are plans to build new reservoirs in the North).

While São Paulo is pondering how to master its water shortage, it releases its precious used water into the rivers flowing away from the city. Sewage treatment is a fairly new concept and São Paulo has built several large treatment plants only in the last decades. The system is characterized by a few plants that process the sewage of millions, often pumping effluent for over 70 km across neighboring watersheds. On top of the great energy loss of pumping, approximately one third of the water is lost on its way through leaky pipes. The remainder of the treated sewage is then finally released into the rivers eventually flowing thousands of kilometers later into the Atlantic Ocean.

Water scarcity has not been on the list for the typical problems of São Paulo. To think about a decentralized recycling and harvesting water system in the city itself is a fairly new consideration that São Paulo had not to make so far in a tropical climate with lots of rainfall. Normally it had the opposite problem. São Paulo is known for its crippling floods. The city is built over an inner delta where several rivers confluence. All rivers are channeled, all floodplains have been lost to urbanization and all major highways and railway lines run along the rivers. Given the high impermeability of the urbanized watershed, the engineering of the channels cannot keep up with the amounts of water flowing through, hence flooding occurs. The next flood will come for sure, turning the cities attention away from the drought problem.

Floods, droughts, pollution—it is clear that a more integrative decentralized management of water is needed where water is harvested, treated and recycled in its respective watershed. In contrast to the twentieth century, São Paulo has now moderate growth rates and the city has the chance to reconstitute itself and hopefully will rethink its approach towards a more integrative infrastructural thinking. It is not only the technical issues that are insufficient, its stream channeling and subsequent highway construction have robbed the city from its fluvial landscape as a fundamental recreational asset that will be very hard to regain.

3.1.4 Skipping Centralization

São Paulo is special in its size and financial might, and as mentioned before most urban growth on the planet will occur in cities below 500,000 inhabitants in locations with less financial resources. However, São Paulo can still provide important lessons for cities which are right now experiencing the frantic growth spurts that São Paulo had to register in the twentieth century. For these mid-sized cities it might be worthwhile to try an alternate approach of how to service their new citizens with basic infrastructure that is more adaptive and resilient. There is a historical chance to leapfrog traditional, sectoral large scale infrastructure provision towards a more decentralized, approach that begins at the individual household, extends to the block, neighborhood, district and eventually to the city and its region, and where at each scale the appropriate level of service provision is handled.

Thereby it will not be a matter of just transferring decentralized infrastructure systems of highly industrialized countries such as green roofs, solar panels, small scale power plants, sewage treatment wetlands or rooftop farming to less industrialized countries. As laid out before, two thirds of our future global urbanization will be informal, an urbanization typology that is at its core a radically decentralized decision apparatus. It will be of matter that the new, mostly low income residents will be supplied with the capacity to make sustainable decisions about their environment versus being connected after the fact to a resource wasting apparatus that brings small cities into financial turmoil. One could argue for a hybrid approach where cities with little funding capacity get the help to anticipate the incoming migrants and actively engage them in the planning and building process of their future environments. Historic ideas of the 1970s to provide land and core housing are currently being revived and need to be updated towards a more participatory and integrative public space and infrastructure design. More decentralized, localized infrastructure could be a source of jobs and revenue that is desperately needed by low-income residents.

There are substantial challenges to implement a more livable and sustainable environment for future urban populations. Unavailability of land, unclarity of land ownership, real estate speculation, negative attitudes towards newcomers and new climate induced hardships are just a few among them. The hardest challenge in my eyes though will be to overcome the lure of twentieth century Western technology that magically brings running water and electricity into everybody's house without exposing the side effects of urban degradation and high utility bills.

3.2 The Balance Between Efficiency, Effectiveness, Resilience and Cohesion

Ortwin Renn

3.2.1 Key Messages

The design of policy making should be guided by a discursive attempt to find the optimal balance of all four sectors of society, namely effectiveness, efficiency, resilience and social cohesion. This may also imply that in some instances highly centralized systems should be preferred while in other instances decentralized solutions provide the better alternative.

3.2.2 Basic Considerations

At the foundation of sustainable development is the need for a well-rounded balance between effectiveness, efficiency, resilience and social cohesion.

Effectiveness refers to the need of societies to have a certain degree of confidence that human activities and actions will actually result in the consequences that the actors intended when performing them.

Efficiency describes the degree to which scarce resources are used to reach the intended goal. The more resources are invested to reach a given objective, the less efficient the activity under question remains.

Resilience describes the capacity to sustain functionality of a system or a service even under severe stress or unfamiliar conditions.

Finally, *social cohesion* covers the need for social integration and collective identity despite plural values and lifestyles.

All four needs or functions of society build the foundation for legitimacy. Legitimacy is a composite term that denotes, first, the normative right of a decision-making body to impose a decision even on those who were not part of the decision-making process (issuing collectively binding decisions), and second, the factual acceptance of this right by those who might be affected by the decision. As a result, it includes an objective normative element, such as legality or due process, and a subjective judgment, such as the perception of acceptability.

Within the macro-organization of modern societies, these four functions are predominantly handled by different societal systems: economy, science (expertise), politics (including legal systems), and the social sphere. In the recent literature on governance, the political system is often associated with the rationale of hierarchical and bureaucratic reasoning; the economic system with monetary incentives and individual rewards; and the social sphere with the deregulated interactions of groups within the framework of a civil society (Rosa et al. 2014; Renn 2014; Parsons and Shils 1951) Another way to phrase these differences is by distinguishing among competition (market system), hierarchy (political system), and cooperation (sociocultural system).

Each of the four systems can be characterized by several governance processes and structures adapted to the system properties and functions in question.

In the market system, decisions are based on the cost-benefit balance established on the basis of individual preferences, property rights, and individual willingness to pay. The conflict resolution mechanisms relate to civil law regulating contractual commitments, Pareto optimality (each transaction should make at least one party better off without harming third parties), and the application of the Kaldor–Hicks criterion (if a third party is harmed by a transaction, this party should receive financial or in-kind compensation to such an extent that the utility gained through the compensation is at least equivalent to the disutility experienced or suffered by the transaction). The third party should hence be at least indifferent between the situation before and after the transaction. In economic theory, the transaction is justified if the sum of the compensation is lower than the surplus that the parties could gain as a result of the planned transaction. However, the compensation does not need to be paid to the third party. Additional instruments for dealing with conflicts are (shadow) price setting, the transfer of rights of ownership for public or non-rival goods, and financial compensation (damages and insurance) to individuals whose utilities have been reduced by the activities of others. The main goal here is to be efficient. In most instances, up-scaling and centralizing production and distribution services improve the scores for efficiency.

In politics, decisions are made on the basis of institutionalized procedures of decision-making and norm control (within the framework of a given political culture and system of government). The conflict resolution mechanism in this sector rests on due process and procedural rules that ideally reflect a consensus of the entire population. In particular, decisions should reflect the common good and the sustainability of vital functions to society. This is why resilience lies at the heart of public activities. In democratic societies, the division in legislative, executive, and judicial branches; defined voting procedures; and a structured process of checks and balances underscore the institutional arrangements for collective decision making. Votes in a parliament are as much a part of this governance model as is the challenging of decisions before a court. The target goal here is to seek resilience as a major prerequisite of legitimacy. Both resilience and legitimacy are best served by decentralized systems as they provide diversity, more control options and less dramatic effects if one system fails.

Science has at its disposal methodological rules for generating, challenging, and testing knowledge claims, with the help of which one can assess decision options according to their likely consequences and side effects. If knowledge claims are contested and conflicts arise about the validity of the various claims, scientific communities make use of a wide variety of knowledge-based decision methods, such as methodological review or re-tests, meta-analysis, consensus conferences, Delphi, or (most relevant in this arena) peer review to resolve the conflicts and test the explanatory or predictive power of the truth claims. These insights help policymakers understand phenomena and be effective in designing policies. To be effective is not related to the degree of centralization. However, effectiveness can be an important moderator between efficiency and resilience.

Finally, in the social system, there is a communicative exchange of interests, preferences, and arguments assisting all actors to arrive at a unanimous solution.

Conflicts within the social system are normally resolved by finding favorable arrangements for all parties involved, using empathy as a guide to explore mutually acceptable solutions, referring to mutually shared beliefs, convictions, or values or relying on social status to justify one's authority. These mechanisms create social and cultural cohesion. The most important aspect here is fairness towards the present and the future generation. Fair solutions tend to be more decentralized but often at the expense of optimal allocation of resources and services.

Socially relevant problems are rarely dealt with within the limits of one single system rationale. Instead, they go through interrelated procedures, either sequentially or in parallel. For example, the political system can decide on a specific goal or target by parliamentary vote (e.g., a limit on automobile emissions) and then leave it to the market to implement this decision (such as organizing an auction to sell emission rights to all potential emitters). Or a governmental decree is reviewed by an expert panel or a citizen advisory committee. Of particular interest are decision-making processes that combine the logic of two or more systems. The settlement of conflicts with the method of mediation or negotiated rulemaking can, for example, be interpreted as a fusion of economic and social rationale. The cooperation between experts and political representatives in joint advisory committees (i.e., the experts provide background knowledge, while politicians highlight preferences for making the appropriate choices) represents a combination of knowledge-oriented elements and political governance. Classic hearings are combinations of expert knowledge, political resolutions, and the inclusion of citizens in this process.

3.2.3 Conclusion

These insights suggest that for complex policy decisions that are crafted to enhance the sustainability of society representatives of all four sectors of society need to be included in order to ensure that decisions are effective, efficient, resilient and fair. It seems also prudent to conclude that representatives of one sector should not be able to outvote the representatives of the others sectors since each contribution is needed for sustainable decision making. Maximizing efficiency on the expense of the other goals may compromise resilience and maximizing effectiveness may compromise fairness.

3.3 What Can We Learn from Natural Ecosystems to Avoid a Civilization Breakdown?

Anastassia Makarieva, Victor Gorshkov, and Peter A. Wilderer

3.3.1 Key Messages

An attempt is made to formulate a comprehensive cross-disciplinary view on the environmental problems of modern humanity by considering principles of order maintenance in living systems at different levels of organization. It is argued that while decentralization is key to order maintenance in living systems, which occurs by competitive interaction of independent units, the ecological services provided by the biota in terms of climate and environmental stabilization range in scale from local to regional and global. Thus, international and global cooperation is indispensable for preserving these services. The role of large animals in ecosystem stability is discussed together with its implications for the ecological requirements of *Homo sapiens*. It is suggested that adding an ecological dimension to the conventional hierarchy of human needs and motivations can shed light on many important problems of modern society.

3.3.2 Introduction: Does Civilization Progress Have a Direction?

During the last two centuries of rapid scientific and technological progress an advanced set of views emerged on the relationship between the *Homo sapiens* and the biosphere. The accumulated data on biological fossils testified that in the course of the biological evolution morphology and behavior of species were getting more and more complex and sophisticated. It appears that *Homo sapiens* is—at least at the time being—the winner of the evolutionary process. Owing to the scientific and technological progress humans have colonized practically all land having displaced other species from their natural ranges. The scientific and technological progress is considered—in analogy to evolution—as a process during which the human society has gotten progressively more and more complex and organized. As a result, the ever-increasing complexity is expected to trigger an increase of energy consumption since a diminishing flow of external energy is known to drive all systems to a state of thermodynamic chaos. At the same time, it is commonly assumed that the ongoing transformation of natural ecosystems is not a major threat for our global civilization. Despite the fact that many natural species of the biosphere are already eradicated and replaced by artificially modified sorts of plants and animal breeds it is generally believed that human life is not in danger.

At the commencement of the era of "Internet of Things", in Germany called "Industry 4.0 (forth industrial revolution) (Aslak and Bruaset 2013; Dombrowsky and Wagner 2014), this spontaneous development continues even though the currently available knowledge does not allow a solid evaluation of its consequences. But there are efforts to make this development sustainable by, for instance, keeping economic growth from getting undermined by either political or ecological crises. However, unlike the sustainable development of an embryo that transforms into an adult governed by the genetic program of its species, the scientific and technological progress as well as the economic development is not governed by such a program. Sustained movement of the global civilization in an unpredictable direction can lead to a global catastrophe. To examine and exclude unfavorable scenarios it is needed to elaborate a scientific theory that would be able to predict the future of the civilization based on the known laws of nature and the scientific evidence about the human society and the biosphere. In this article we make an attempt to advance in this direction.

Life on Earth is at least 3.8 billion years old (Mojzsis et al. 1996). In the face of the myriad external forcings that impacted our planet during the last four billion years the process of life never discontinued. It is therefore of interest what the major principles are that underlie such an apparently unique sustainability and resilience. In the first part of this paper we attempt to outline such principles to show that the maintenance of order in life is essentially decentralized and strongly contingent upon interactions between numerous and independent living systems at different levels of complexity. We then discuss how living order maintenance is inseparable from environmental sustainability, which thus emerges as a product of life functioning. Thus a global scale loss of natural ecosystems is incompatible with long-term environmental safety.

By analyzing the energy flow through natural ecological communities we discuss how the environmental impact of different living organisms crucially depends on their body size. Large animals including humans are potential destabilizers of ecosystem biomass and productivity and have very specific functions in natural ecological communities.

In the second part of the paper we consider how scientific knowledge about life-environment interaction and principles of ecological sustainability can enhance understanding of the global problems faced today by our civilization. We discuss how considerations of the ecological requirements of *Homo sapiens*—traditionally excluded from consideration of the pyramid of human needs (e.g., Kenrick et al. 2010)—can provide clues to understanding important global processes of today.

Indeed, while there are many optimistic voices about a bright future associated with further technological progress, there are also well-substantiated doubts spreading as to whether such progress is still able to further improve human conditions as it used to do (Cowen 2011; Atkinson and Ezell 2012; Mokyr 2013; Gordon 2014).

With presenting a broad picture of seemingly diverse but, as we argue, deeply interrelated concepts and problems we aim to stimulate a discussion of how the evidence from different fields of modern science—from ecology and genetics to climatology and economics—could be meaningfully synthesized across disciplines into a coherent scientific framework that would guide the development of our civilization and allow us to avoid a global collapse.

3.3.3 Informational Precipice Between the Biosphere and Civilization

One apparent feature of life is its complexity in comparison with the inanimate world. We begin our consideration by quantifying this complexity in terms of information fluxes operated by living systems.

The Sun sends to the Earth ordered energy in the form of short-wave photons. On Earth this energy transforms into the chaotic energy of thermal photons that are emitted back to space. Photon's energy is proportional to kT, where $k = 1.4 \times 10^{-23}$ J K^{-1} is Boltzmann constant, T is the absolute temperature of radiation. The energy of solar and thermal photons is determined by temperatures of the Sun and the Earth, respectively, $T_S \sim 6000$ K and $T_E \sim 300$ K. The energy of solar photon as it dissipates into thermal photons is conserved. Hence, we have $kT_S = n\ kT_E$ and $n \approx 20$: each solar photon decays on Earth into about twenty thermal photons.

This decay can go through different channels. The unbounded diversity of possible decay channels maintains all ordered processes on Earth, both in animate and inanimate nature. If the Sun were sending to the Earth the same flux of energy but in the form of thermal photons that are emitted by the Earth, the temperature of the Earth's surface could be about the same as it is now. But the decay of these thermal photons would be impossible. All the decay channels were closed. The Earth would remain warm, but no ordered processes would occur on its surface. Life could not exist (Fig. 3.1).

The main difference between life and inanimate nature pertains to the fact that life uses decay channels that are by many orders of magnitude more numerous and complex than in the non-living world. Orderliness of biological systems is characterized by molecular (not macroscopic as in the inanimate nature) "memory cells" or degrees of freedom. Per each square micron of the Earth's surface there are

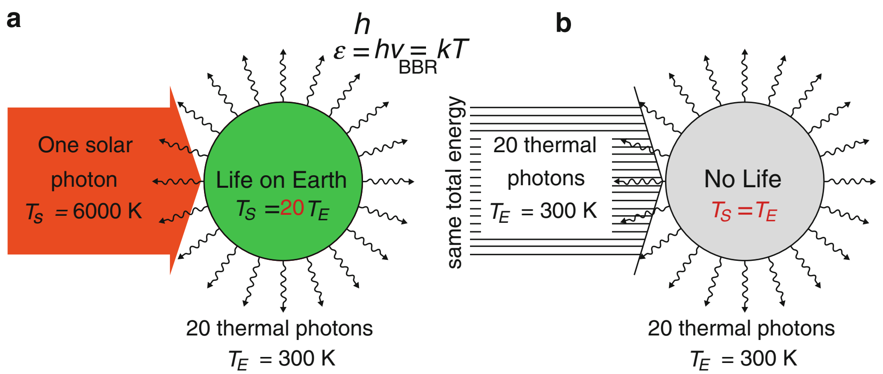

Fig. 3.1 Solar energy transformation on Earth. (**a**) 20 thermal photons $T_B = 300$ K. (**b**) 20 thermal photons $T_B = 300$ K

several independently functioning living cells—plankton in the ocean, plants, bacteria and fungi on land. These cells react to local changes of their environment in a non-random way. They exchange energy, matter and information with the environment as prescribed by their genetic program coded in the DNA molecules.

Radiation consists of particles—photons. Photon energy is $\varepsilon = h\nu = kT$ for blackbody radiation (BBR) of temperature T. Radiation power is $J = n\varepsilon$ (n is the number of photons radiated per unit time). (a) Earth receives power $J_S = 1.4 \times 10^{17}$ W of solar radiation with $T_S \approx 6000$ K and emits power $J_E = J_S$ of thermal radiation with $T_E \approx 300$ K. Energy on Earth does not accumulate (steady state): $J_S = J_E$, so $n_E/n_S = \varepsilon_S/\varepsilon_E = T_S/T_E = 20$. Each solar photon decays on Earth into 20 thermal photons. Any events on Earth are possible because Earth's temperature is 20 times less than Sun's. (b) If those temperatures coincided, Earth would have been almost completely "uneventful", existing in a state close to thermodynamic chaos. Life on Earth would be impossible even if the Earth remained as warm as it is now.

The rate of information exchange between the living cells and their environment can be estimated from the known rate of their energy consumption. Absorption of one solar photon by a plant cell changes the state of about twenty molecular memory cells within the cell as the solar photon decays into thermal photons. Assuming that one molecule corresponds to one memory cell with two possible states—excited (after absorption of energy of the order of kT_E) and non-excited (after release of this energy)—we obtain that one act of excitation and relaxation corresponds to a flux of information of one bit per act. With the global mean efficiency of photosynthesis of about $\varepsilon = 0.5$ %, global mean flux of solar energy absorbed by the planetary surface of about $F = 170$ W m^{-2}, total global flux I of information processed by living cells on the Earth's surface of area $S_E = 5 \times 10^{14}$ m^2 is estimated as $I = \varepsilon F S_E/(kT_E) = 10^{35}$ bit s^{-1}.

There is virtually a precipice between the information processing capacities of the biosphere and our civilization. It pertains to the total fluxes of information as well as the energy efficiency of information processing. If all people on Earth had a modern PC that runs about 10^{11} operations per second, total flux of information processing by the humanity would not exceed 10^{21} operations per second, which is 14 orders of magnitude less than in the biosphere. Real rates of information processing in our civilization are much lower. For example, GOOGLE search processes data at rate of about 10^{13} bit s^{-1}, i.e. by 22 orders of magnitude slower than does the biosphere (Dean and Ghemawat 2008).

Modern supercomputers are able to perform about 10^{16} operations per second, occupy an area of about 10^2 m^2 and consume power of about 10^7 W. Their energy expenditure per operation—about 10^{-9} J per operation—is 12 orders of magnitude larger than in the biosphere ($kT_E \approx 4 \times 10^{-21}$ J). If the entire Earth's surface had been covered with such supercomputers their total flux of information processing would be 5×10^{28} bit s^{-1}. This is two million times less than in the biosphere. Meanwhile the energy consumption rate of such a global computer network would have been 500 times larger than the flux of solar energy at the surface, a hundred

Fig. 3.2 Technological and ecological information processing systems. *Left panel*: Tianhe-2, world's fastest supercomputer located in China (Photo credit Jack Dongarra). Tianhe-2 performs 34×10^{15} operations per second, occupies 720 m^2 and consumes 24×10^6 W. The supercomputer information processing rate per unit area is 5×10^{13} operations per second per square meter and energy consumption is 3×10^4 W per square meter. *Right panel*: Rainforest in Papua New Guinea (Photo credit Rocky Roe and UPNG Remote Sensing Centre) has a rate of information processing 2×10^{20} operations per second per square meter, which is over a million times faster than Tianhe-2. The rainforest energy consumption does not exceed the solar power flux of 200 W m^{-2}, i.e. the forest is at least a hundred times more efficient than Tianhe-2

thousand (10^5) times larger than the energy consumption of the biosphere and one million times larger than the energy consumption of modern civilization (Fig. 3.2).

To make use of the huge diversity of possible decay channels for solar photons life must have been minimized energy losses within each channel. The energy efficiency achieved by life is unprecedented. An egg transforms to a chicken without any external energy consumption. Internal energy losses (heat dissipation) during embryonic development in some reptilian and insects do not exceed 10 % of the initial energy store of the egg (Makarieva et al. 2004a). The egg-to-chicken transformation represents an irreversible process of decay that is characterized by a diversity of channels that is unimaginable in the civilization. Living and non-living nature consume not energy but the information of the Sun. Living matter uses this information with maximum efficiency.

3.3.4 Biotic Regulation of the Environment

Thus, we can view the biosphere as a global distributed network of microscopic computers. Total number of such simultaneously working computers (living cells) in the biosphere is in the order of 10^{28}–10^{30} (Gorshkov 1995; Whitman et al. 1998). From the same perspective life can be viewed as a unique self-sustainable algorithm that has been operating on Earth governed by the genetic program of the living cells for about four billion years. One can ask: what information must be contained in the genetic program of life to account for such an extraordinary persistence?

Apparently, information about copying (reproduction) of living objects is an indispensable but also the simplest module of that program. Indeed, copying is common to many simple processes in the inanimate nature—for example, to chain reactions. What is unique about life is that the algorithm by which the living organisms re-create themselves has never aborted during the nearly four billion years of life existence. Since life as a whole can only exist in a narrow interval of external conditions, life's persistence means that the genetic program of life comprises information about what the suitable for life conditions are and how to maintain them. If this information changes in the course of biological evolution, this entails respective changes in the environment maintained by life. Thus, environmental changes by themselves do not necessarily represent evidence of broken biotic control.

The suitable for life environment is physically unstable. Biota (the totality of natural living organisms) uses the huge information fluxes to control the environment and stabilize it in an optimal for life state. Below we briefly discuss several key aspects of the biotic regulation of the environment (Gorshkov 1995; Gorshkov et al. 2000).

For the biota to function, stores of organic as well as inorganic carbon must be present in the environment. These stores in the modern biosphere are of the order of 10^3 Gt C (1 Gt = 10^9 t). For example, atmospheric carbon dioxide, which is necessary for the photosynthesis, contains 700 Gt C. The biotically active stores of organic carbon in soil, wood and ocean are of the same order of magnitude. The biota recycles carbon at a mean global rate of about 10^2 Gt C/year. If the fluxes of synthesis and decomposition of organic carbon by the biota had not been strictly correlated with each other (as they are not correlated, for example, in our civilization), the stores of carbon in either organic or inorganic reservoirs would have been depleted just in several decades. To stabilize the reservoirs of all life-important elements is only possible if the organisms that synthesize and decompose organic matter interact with each other in a non-random, coordinated manner such that in the course of this interaction all deviations of the environment from an optimal state are compensated.

A conspicuous example of the biotic control of global environmental conditions on a geological scale is the atmospheric carbon. Carbon dioxide enters the atmosphere in the result of magmatic and metamorphic degassing in geological processes related to volcanoes, continental rifts, seismically active regions etc. The removal of atmospheric CO_2 in inorganic form occurs by weathering: the formation of carbonate rocks from silicate rocks (Berner 1990). These opposing processes are controlled by independent factors: e.g., weathering strongly depends on the size and elevation of the continents as well as on the intensity of the river runoff. The rates of inorganic carbon removal and burial are such that any of these processes alone could have changed the atmospheric CO_2 concentration by an order of magnitude in just a few thousand years (Berner 1990). While the biota profoundly impacts weathering, i.e. the rate of carbonates formation (Berner 1990; Schwartzman and Volk 1989), the two opposing fluxes of the inorganic carbon do not match. The net rate of carbon emission to the atmosphere turns out to be positive and similar in the order of magnitude to the gross inorganic carbon fluxes by weathering and degassing (Garrels and Lerman 1981). On a longer time scale—over Phanerozoic time—such an imbalance between weathering and degassing could have brought about catastrophic fluctuations of the atmospheric carbon concentration. However, no catastrophic changes in atmospheric CO_2 amounts actually took place as the biota deposited the excessive carbon in sediments in the form of inert organic compounds. If the carbon deposited in organic form (about 10^7 Gt C) had remained in the atmosphere, CO_2 concentration would have been a hundred thousand times higher than it is now (Gorshkov 1995; Gorshkov et al. 2000).

In the discussions of life-environment interactions the focus has conventionally been on *recycling*: the life-mediated enhancement of the geological fluxes of elements (e.g., Downing and Zvirinsky 1999; Free and Barton 2007). The carbon cycle example discussed above illustrates that the main principle of biotic regulation is not a *recycling* of life-important chemical elements (see Chap. 20, Bloesch) but a directional compensation of their unfavorable environmental changes. It is not closeness, but a non-random *openness* of the biochemical cycles that result in environmental homeostasis. Without this mechanism the uncorrelated fluxes of inorganic substances to and from the biosphere would have made it unsuitable for life in a relatively short period of time.

Photosynthesis is the energetic basis of modern life. For it to be possible, temperature of the Earth's surface should be compatible with the liquid phase of water, i.e., it must be higher than 0 °C. On the other hand, it cannot exceed or approach ~60 °C, which is the limit when cell structures start to disintegrate. Only very few species of archae and bacteria, termed extremophiles, can live at ambient temperatures of even higher than 100 °C, but they do not photosynthesize (Anitori 2012; Canganella 2012). Meanwhile for the Earth's surface, two thirds of which are covered by the ocean, two physically stable states are a completely glaciated Earth with surface temperature of about −100 °C and an Earth with its oceans evaporated and surface temperature about +400 °C. In the absence of stabilizing biotic processes a random climate state that occasionally happens to be suitable for life would undergo transitions to any of the two stable states in time periods of the order of thousand years. Biotic regulation of the environment has ensured biotic stability of the environment with a global mean temperature in the vicinity of 15 °C over the entire period of life existence (Makarieva and Gorshkov 2001; Gorshkov and Makarieva 2002).

Despite occupying over two thirds of the Earth's surface, global biological productivity of the ocean is smaller than productivity of forests and swamps on land. Since the forest cover formed on land about three hundred million years ago land biota has been playing a major role in the regulation of the global environment and climate. Evolution of tree plants made it possible for the biotic pump of atmospheric moisture (Makarieva and Gorshkov 2007; Sheil and Murdiyarso 2009; Makarieva et al. 2014) to operate on land, which enabled life to colonize all land. Moisture evaporated from the ocean surface is transported to the continental interior only in the presence of an extensive forest cover. Forest cover absent, land can turn into a lifeless desert on a time scale of a few decades. Thus, water on land, which is indispensable for human life, is also controlled by the biota (Makarieva and Gorshkov 2010; Wilderer 2009).

3.3.5 Principles of Order Maintenance in Life: Decentralization Is Key

Theoretical biology conventionally highlights evolution as the central process of life, rather literally reflecting the widely quoted formulation of “nothing in biology making sense except in the light of evolution” (Dobzhansky 1973). Scientists debate how and why the genetic information of species changes with time. A more fundamental question, however, receives little if any attention: why no erosion of life information has occurred in four billion years. With mutation rates in the DNA-based world being universal, about 10^{-10} base pairs per division, and assuming about 10 divisions in the germ line as a grand mean for life based on its universal metabolic rhythm (Makarieva et al. 2008), we conclude that all genetic information of life could have been completely eroded by mutations in one billion years. In other words, the genomes of species would have represented a chaotic random sequence of the four genetic letters (base pairs). Since about 1 % of the genome does not tolerate any changes at all (such changes are incompatible with viability), this means that life could go extinct in a hundred times shorter period—just in 10 million years.

This did not happen. Besides the program of biotic regulation, the genetic information of life also comprises a program preventing its own decay (erosion). The orderliness of living systems is maintained by a mechanism that has no counterparts in the inanimate world. This mechanism is among the key features that differentiate life from non-life.

All living objects form populations. Individuals of a given biological species are all similar to each other, which is why they can be assigned to a particular species. But there are no species composed of just one individual! Within each population individuals compete with each other. This competitive interaction reveals individuals with eroded genetic programs leading to deviation from the species’ behavioral and morphological norm. Such individuals are forced out from the population in one way or another, while copies of individuals with normal genetic program fill the vacancies. It is this mechanism that prevents the loss of order in living objects at different levels of organization, from cells to local ecological communities (Gorshkov and Makar’eva 2001).

Many animals form internally correlated social structures, where individuals share a communal living (for example, bee hives, ant hills or tribes in mammals). Within a social structure all individuals continuously interact with each other. In the course of competitive interaction the social status of all individuals is determined. Individuals with a lower than average competitive capacity get a low social rank but remain within the social structure and are not eliminated unless their competitive capacity drops below a certain threshold. Such hierarchic social structures represent a peculiar form of correlation between individuals that can be compared to correlation of cells within a multicellular body. Information about the internal correlation of the social structure is contained in the genetic program of the species. It is maintained by competitive interaction between different social structures, with defective structures eliminated from the population of such structures. Noteworthy, in theoretical biology related concepts raise heated debates (e.g., Nowak et al. 2010; Nowak et al. 2011; Gintis 2012), with the alternative (conventional) view being that internal correlation of living systems (like bees in a beehive) could be explained by selection acting on individuals. While a detailed discussion of these problems is outside the scope of this paper, we note that a crucial point missed in the conventional evolutionary paradigm is the need to explain genetic *stability* of such internally correlated structures rather their appearance in the course of evolution.)

We conclude that decentralized organization is key for order maintenance in life. Decentralization presumes lack of correlation in the functioning of living objects. In a centralized system like for example a beehive or a multicellular organism, the various parts of the system strongly depend on each other (they are internally correlated). One part cannot win when another part loses (e.g. brain in a multicellular organism does not benefit from a kidney failure). In a decentralized population of independently functioning living objects the situation is different: if a certain object loses functionality this does not impair functioning of the neighboring objects. For example, if a certain object had a poor program of coordinated behavior (e.g. if the foraging bees cease to feed the queen or if cells in a multicellular body start proliferate on their own forming a cancer tumor), such an object perishes, and its place in the ecosystem is occupied by the progeny of other, normal, objects.

Once an object becomes globally correlated such that competitive interaction becomes impossible, such an object is prone to disintegration and decay, whatever the nature of the object is. Thus, life cannot exist in the form of a single globally correlated super-organism Gaia, as Lovelock called it (Lovelock 1988). This is a consequence of the unique complexity of living objects: their orderliness cannot be maintained merely by interaction with the inanimate world which is virtually disordered compared to life. Rather, order maintenance is an intrinsic property of life itself.

Regulation of global environmental conditions, e.g. atmospheric CO_2 concentration, by the biota does not require a global correlation of life. The highest level of organization of life—local ecological community—is the elementary operational unit of biotic regulation (Gorshkov 1995; Gorshkov et al. 2000, 2004). In forest ecosystem local ecological community is represented by a tree or a group of neighboring trees together with the accompanying local microbiota: bacteria, fungi, small animals, which function in a coordinated manner similar to cells within a multicellular organism. For example, the understorey herbs with help of the network of mycorrhizal fungi connecting individual plants within the local ecological community can share their stores of carbohydrates with the tree to facilitate tree awakening from the winter season (Lerat et al. 2002, see also Van der Hejden and Horton 2009).

Every local community tends to stabilize its local environment towards the optimum. For example, if CO_2 concentration is too high, the community will act to remove CO_2 from the atmosphere and deposit in chemically inert compounds such as, for example, live biomass. Because of global mixing, a local community is not able to fully control local CO_2 concentration. However, if the small relative change of the local environment is sufficient to impart competitive advantage to the community, then all local communities will perform the same stabilizing function. This will result in a global inflow of CO_2 from the atmosphere into the refractory reservoir (organic or inorganic carbon). The sensitivity of the ecological community to small relative changes of local environment is a fundamental parameter of biotic regulation (Gorshkov et al. 2000).

3.3.6 Information Losses During Evolution of Large Animals

We now turn to the role played by large animals in the life-environment interaction. As we shall see, the principles of life-environment sustainability can provide useful information relevant to the problems of modern civilization.

Animals interact with their environment mostly via cells at their body surface. With increasing body mass the relative number of such surface cells diminishes inversely proportionally to the linear size of the animal: $(S/s)/(V/v) = l/L$, where S/s is the number of cells with surface area $s = l^2$ on the body surface of area $S = L^2$. Here l and L are, respectively, linear sizes of an average cell and the animal, V/v is the total number of cells of cellular volume $v = l^3$ in animal body of $V = L^3$.

In particular, for large animals with $l \sim 50$ μm and $L \sim 0.5$ m, the share of surface cells is just one ten thousandth (10^{-4}). Information flux in the animal body is proportional to total energy consumption of the animal. The larger the animal, the smaller is the share of its energetic and information flux it can spend to participate in the biotic regulation of the external environment, on which the animal depends. Large animals use the available fluxes of energy and information almost exclusively to maintain the orderliness of their internal milieu rather than external environment.

Living matter is characterized by a universal rate of energy consumption per unit volume (Makarieva et al. 2008). Thus across evolutionary domains the total energy consumption of organisms grows proportionally to the cube of the linear body size, while energy consumption per unit area of the ground surface occupied by the organism grows directly proportionally to the linear body size. Per unit area of the ground surface large animals consume an energy flux that is several orders of magnitude higher than the solar energy flux consumed by life. For example, a human body with a metabolic power of 150 W and area of the body projection of about 0.5 m^2 consumes about 300 W/m^2, which is 3000 times larger than the global mean power of photosynthesis 0.1 W/m^2 (Note that in trees only the surface cells of leaves, roots and cambium are active, while the bulk of wood is, unlike animal bodies, biologically inert and does not consume either energy or information. That is why the effective linear size of the metabolically active parts of the trees is very small.).

To summarize, an increase in animal body size leads, first, to a higher dependence of the animal on the environment owing to rising energy consumption per unit body surface area. Second, it leads to a decrease of the share of consumed energy flux that the animal spends on the regulation of the external environment. In other words, during evolution of large animals the genetic information about their interaction with the environment was continuously being lost. This process can be compared to reduction of various organs in parasitic species—for example, some parasitic worms lost their digestive system (and the corresponding genetic information from their genome) exploiting instead the internal milieu of their hosts. By analogy, large animals can be viewed as parasitizing on the environment maintained for them by the rest of the species of the biosphere.

3.3.7 Why Do Large Animals Exist?

Having lost a major part of the original information about environmental regulation large animals nevertheless enjoy a nearly ubiquitous presence in the biosphere. This suggests that the regulating part of the biota for some reason keep them in existence, and that they do play a certain role in biotic regulation. Surprisingly, this role is related to the ability of large animals to destroy biomass, at the expense of which they exist.

Physical destruction of biomass of the regulatory part of the biota is a rare event. It may happen in the result of physical catastrophes like volcano eruptions, hurricanes, tornadoes, windfalls, and fires. The regulatory part of the biota has a program of self-recovery after such physical disturbances. This recovery is performed by professional "species-repairers" whose population densities under normal undisturbed conditions are low. Such species can be compared to populations of T-cells in our blood. In the boreal zone conifers predominantly belong to the regulatory part of the biota, while species-repairers are represented by deciduous trees like birch, aspen, alder and various herbs and shrubs. After disturbances these species restore the environment to a state optimal for the regulatory biota. They thus work to their own disadvantage, as they change the environment in a direction that eventually is unfavorable for them. For this reason, when the optimal environment is restored, population densities of species-repairers radically decline. But these species must not disappear altogether. Otherwise there would be nobody to restore the environment after infrequent but catastrophic physical disturbances.

Physical disturbances arise infrequently and unpredictably. Long periods of time can pass without such disturbances affecting a given region. During such periods population densities of species-repairers could drop below a certain critical threshold, when the intensity of competitive interaction weakens and the genetic information of the species deteriorates. Large animals help prevent such a scenario as they destroy the regulatory part of the biota in a more regular way independent of physical processes. Introducing disturbances to the vegetation cover large animals create favorable conditions for the existence of plants-repairers. Such plants increase their population densities in areas of such disturbances (e.g., animal-made lawns, paths etc.).

Since humans are also large animals, the genetic program of our species must also carry information about how to destroy the regulatory part of the biota. As a manifestation of this program, humans thrive in recently disturbed areas inhabited by plants-repairers which humans, as well as other large herbivorous animals, use for food. These are relatively open green landscapes along riverbanks, lakes and seashores that closely border with the undisturbed regulatory biota (the so-called climax or primary forest). Views of such landscapes, often shown in famous paintings, bring about positive emotions in the majority of people (Haber 2004). Few famous paintings show undisturbed climax forest (see for example paintings by Ivan Shishkin)—it is apparently not the optimal environment for *Homo sapiens*.

3.3.8 Ecological Rights of Animals and Man

For biotic regulation of the environment to be stable, an important condition is that population densities of such species-destroyers (large animals) do not rise above a certain safety threshold. The regulatory part of the biota (trees, bacteria, fungi and small animals composing local ecological communities) is organized in such a manner that the share of energy consumption available to large animals is strictly limited. In stable ecosystems the share of ecosystem primary productivity consumed by all larger animals combined (from mice to elephants) does not exceed 1 % and rapidly declines with increasing body size of the animal (Fig. 3.3). Modern humans have exceeded this cumulative threshold by about an order of magnitude: with an account of wood consumption, cattle fodder and food for people, our civilization consumes about 10 % of global net primary productivity of the biosphere.

Since high population densities of large animals are not compatible with ecosystem stability, the ecological restrictions for large animals to keep a low density must be genetically encoded. This limitation takes the form of dependence between the animal home range and body size (Fig. 3.4). Animal home range, an individual territory where no aliens are generally tolerated, is approximately proportional to animal body mass. The larger the animal, the larger territory it must possess to normally function. Territory deprivation results in physiological disorders in many species, from tiny jerboas to rhinoceros. For instance, in captive rhinoceros populations those animals that were kept in open areas (where they could just see, albeit not move across, a large territory) reproduced better than those enclosed by high walls (Carlstead et al. 1999). This means that the territorial requirements of the species are genetically encoded on the physiological level: a visual signal that a large territory is potentially available is essential for facilitating reproduction process in the species.

As one can see from Fig. 3.4, the ecological right of humans to have a large individual territory of about 4 km^2 is significantly violated in modern densely populated societies. As with other large animals, there are all grounds to expect that overpopulation has had profound impact on human physiology and behavior.

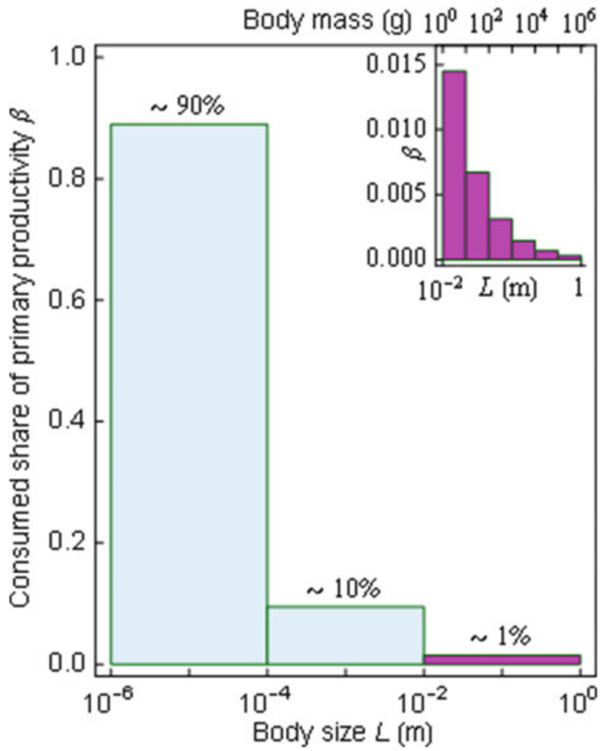

Fig. 3.3 Distribution of consumption of plant production in stable ecosystems. Unicellular organisms have controlled energy consumption at all times from the very beginning of life: in the modern biosphere over 90 % of plant production is consumed by the smallest organisms (bacteria and fungi). Arthropods, the smallest mobile animals, consume about 10 % of primary productivity. Ecological function of insects is similar to that of immune system: invasions of locusts, bark beetles etc. destroy defective plant communities. Insects are also important as pollinators. Dark pink diagram shows consumption of forest herbivores (mammals and birds) in the boreal zone (Makarieva et al. 2004b)

Data on human evolution appear to support this view (Knauft 1991; Boehm 2000). For the most part of our history as a species, humans existed in small groups containing about 30 individuals. Unlike great apes and more recent human societies, those simple human groups represented egalitarian and decentralized societies where all adult males were equal. Studies from such simple societies preserved until recently in the least disturbed tropical areas (e.g. in Papua New Guinea) confirm that the moral code in such groups discouraged dominance and hierarchy. These egalitarian societies, which represent a puzzle for anthropologists and evolutionary biologists, were characterized by low population densities and practically absent inter-group aggression. In other words, wars and massive killings of conspecifics were absent. In more recent societies where population densities rose to 2–3 person/

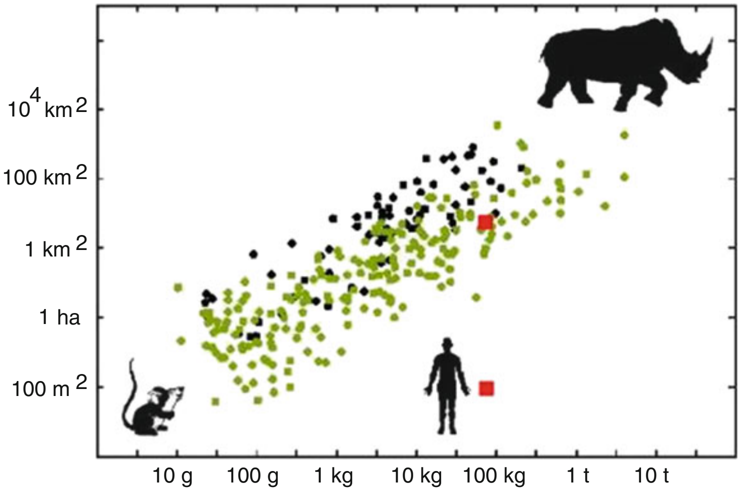

Fig. 3.4 Individual territories of mammals in their natural environments (*green symbols*—herbivores, *black symbols*—carnivores) as dependent on body mass (Data of Kelt and Van Vuren 2001). Humans were endowed by nature with at least 4 km^2 per capita

km^2 (i.e. where the ecological threshold of 0.25 ind/km^2 was exceeded by about one order of magnitude, Fig. 3.4) the egalitarian social order was replaced by a strict hierarchical structure with male-over-female dominance and individual property accumulation. It was in these overpopulated conditions that inter-group aggression (wars), people by people subordination and enslaving became part of human life which they unfortunately remain today. We will now discuss which human features might be held responsible for this development.

3.3.9 Principle Differences Between Animals and Man

Cellular processes in all living organisms proceed according to the genetic program encoded in DNA macromolecules. For plants, bacteria and fungi this is the only source of information to govern organism functioning. Plants, bacteria and fungi lack head and brain.

Locomotive animals cannot live on the basis of their genetic DNA program alone. Locomotion necessitates acquisition of additional information about new places visited earlier by the animal. This information accumulates in brain and is stored as memory. Animal behavior is governed by the genetically encoded positive and negative emotions that ensure animal's life in its natural environment. The animal tends to perform actions associated with positive emotions (sex, feeding) and escape actions entailing negative emotions (angst, pain). However, environmental factors that bring about these genetically encoded emotions can vary during the animal lifespan and be different for different generations in a population. This underlies the phenomenon of volition: the animal can undertake immediate actions associated with negative emotions ("to overcome itself") in order to experience positive emotions later. Information about factors that can bring about such delayed positive emotions is stored in the animal memory. This effect is used in animal training.

In animal species the genetic information of the DNA is transmitted to the next generation, while the information of memory accumulated during animal lifespan is lost with the death of the animal. This one-generation cycle of information accumulation and erosion contributes to the stable existence of species in their environment. The genetic information of DNA macromolecules has been tested on many generations of animals: it guides how the animal interacts with its environment in a sustainable manner and can remain practically constant during the entire period of species existence of the order of several million years. Meanwhile information accumulated in the memory inevitably contains some false elements that can prove useless or detrimental to the next generations. Thus memory must vanish with the death of the animal.

Homo sapiens is the only animal species who violates this rule. Memory information that accumulates during life of one individual is shared with and is assimilated by the next generations. This additional information of memory with trans-generational transmittance comprises the human culture. Indeed, humans are different from animals in having a culture (e.g., Kesebir et al. 2010). Cultural information, like individual memory, contains false and detrimental elements, but also useful elements enhancing population stability at least on a certain time scale. Some of these useful elements take the form of mystic and religious rules and social dogmas governing people's behavior.

The variable cultural information is inherently in conflict with the invariable genetic information that determines the strategy of the human behavior. False and detrimental cultural information could often make whole populations perish. Those cultural elements propagated contributed to or were compatible with social stability over a larger number of generations. People used cultural knowledge to survive on new territories by transforming local biota to a state resembling their natural ecosystem, for example, when replacing natural forests by pastures and agricultural fields. Cultural knowledge was used to exploit the biosphere more and more intensely. As the natural biota degraded and global environment started to lose its stability under the growing anthropogenic impact, those cultural rules that were used to stabilize the society in a globally stable environment, became destructive and threatening the existence of the civilization in a new, changed environment.

In the modern world specific social structures propagated in territories now termed countries. Territorial integrity of countries whose population comprises different ethnic groups and nationalities is maintained by what can be termed the culture of multi-ethnic patriotism. However, cultural integrity in a large population is unstable and spontaneously disintegrates into the genetically programmed cultural integrity of small social structures containing the normal (low) number of members. Therefore, the culture of patriotism demands continuous efforts on its maintenance and propagation in the younger generation.

3.3.10 Scientific and Technological Progress and Ecological Human Needs

In animal populations in the course of competitive interaction the least competitive individuals are forced outside the species range where they cannot live normally (they either die or survive but do not leave progeny). Individuals of *Homo sapiens* forced out of the natural environment where our species came to existence did not perish but were able to spread all over the world owing to the accumulated cultural knowledge.

However, human existence outside the natural species-specific environment is associated with excessive physical exercise and emotional stress. When humans colonized high latitudes with their low biological productivity and unfavorable temperature regime they had to exert more physical efforts to obtain food and maintain optimal temperature in their homes. Ecosystem productivity in the tropical zone is about three-four times higher than the productivity in the temperate and boreal zones where the modern technological progress was born. This gives an idea of the very significant amount of overworking that *Homo sapiens* individuals had to experience outside their natural ecosystem. This genetically encoded dissatisfaction with the unfavorable environment determined the direction of the technological progress, of which there was no need in human populations remaining in their optimal environments in the tropics.

From this perspective, one cannot expect the technological progress to be improving human conditions for ever. If the technological progress has a start (the moment when a sufficient number of humans were forced out of their natural ecosystem) and a cause (these humans were genetically dissatisfied with their new conditions where they had to work too much), it must also have an obvious end—when the human needs that motivated this progress get satisfied and the motivation disappears.

If we look at the major achievements of the technological progress in the last two centuries we notice that to a large degree they were aimed at freeing people from hard physical labor. In the pre-industrial era a major difference in lifestyle between the poor and the rich was that the poor had to perform hard work, while the rich did not. From the viewpoint of the genetic program of our species this was a fundamental difference: some individuals had to overwork exhausting their biophysical capacity, while the others did not. In the industrial era this fundamental difference was practically erased by a wide variety of technical aids.

Today almost all people in the developed world have running water, central heating, various electric appliances to facilitate housekeeping and to permit cars to get moved around. In the result, the vast majority of the population has been deprived of the ancient stimulus to participate in the technological progress. Unsurprisingly, the remaining islands of rapid economic growth today are concentrated in those regions where a major part of the population is still engaged in rough physical work (China, India, African countries). Another indication that life style improvements have reached a plateau is the dynamics of leisure time change in the developed countries. Aguiar and Hurst (2006) showed that in the United States in 1965–2003 the leisure time increased most in those population cohorts that were primarily occupied with hard physical labor (low educated males).

Indeed, today many professionals voice skepticism concerning the future potential of the technological progress to improve human life (Cowen 2011; Atkinson and Ezell 2012; Mokyr 2013; Gordon 2014). However, few existing analyses view the apparent technological slowdown in a broader scientific perspective that would include ecological human needs. For example, the middle income trap, a major obstacle for economic growth perceived by economists (Kharas and Kohli 2011), appears to be readily explainable in terms of a greatly reduced motivation for working efforts after a majority in the population have freed themselves from hard labor.

While the idea of a hierarchy of human needs has been highly influential in modern thinking (Peterson and Park 2010), the ecological human needs associated with overworking and lack of appropriate individual territory have been invariably ignored. Physiological needs residing at the bottom of the pyramid have been traditionally considered as being the most “straightforward”, almost invariably exemplified just by hunger and thirst (Kenrick et al. 2010; Ackerman and Bargh 2010; Lyubomirsky and Boehm 2010). Meanwhile in the more comprehensive picture that we have presented the last two centuries appear as a point of singularity in human history, because it is for the first time that technological progress eliminated the need for exhaustive physical labor in the majority of human population. One of the essential ecological rights of *Homo sapiens* was for the first time in human history satisfied outside the natural ecological niche.

However, at the same time the other equally essential ecological rights of humans remained unsatisfied or became violated. In particular, owing to the exponential growth of population density and total number of members in social structures people lost their rights for an appropriate individual territory and social significance. A major human right that was respected in the natural environment is the right of any large animal to move, using muscle power, over an individual territory free from aliens and competitors (Personal car transportation is popular with modern humans as it creates an illusion of the possibility of such movements). This right was violated in our species at an unprecedented, global scale. Individual territories of modern people are comparable to individual territories of shrews (Fig. 3.4).

Continuing automation turns labor, which in the right amounts is necessary for the normal human existence, to a privilege and at the same time into a deficit. As a growing number of people become unemployed, they lose the right to participate in the maintenance of their society and thus lose their social significance. The deficit of social significance aggravates. The explosive development of Internet, mobile connections and social networks, which were largely responsible for the global economic growth of the last two decades, made profit exactly from this deficit of social significance. With help of the Internet it became possible for people to group by interests and form small social structures (reference groups) with their size resembling that of the normal social structure of humans.

There is principle difference between scientific and technological progress. Scientific progress reflects the accumulation of objective knowledge about the external world. It is based on the genetically encoded ability of humans to accumulate culture. People experience positive emotions when they get to know something new about the world irrespective of the field of knowledge to which the new information belongs. Scientific research is continuously generating an enormous amount of new knowledge. From this treasure of knowledge technological progress selects information that could be used to satisfy human needs and make the artificial environment resemble natural environment of our species. Great scientists and engineers who made outstanding discoveries opening new horizons for technological progress appear in the human population very infrequently. Fundamental breakthroughs like the discovery of electricity or invention of the Internet did not lead to financial prosperity of the creators. Rather, the new inventions are brought to mass culture by active entrepreneurs. In the large global population of individuals unsatisfied with their living conditions the number of such entrepreneurs has always greatly exceeded the number of new potentially useful inventions.

Nowadays there appear few remaining ways in which technological progress could satisfy real human needs: its potential has been almost exhausted. Practically, technology has been able to improve human lives in but one essential way—it freed people from rough tiring labor. In this situation it is quite useless to call for an increase in the buying capacity of the consumers and consider them as the main drivers of technological progress and economic growth (Hanauer 2012). As we discussed above, what modern consumers might wish to buy to live a satisfactory life, worthy to human beings the technological progress can hardly offer anymore.

The only direction of modern technology that remains of real interest to mass consumers is medicine, which appeals to the fundamentally insatiable genetically encoded human instinct of self-preservation. It is for the first time in human history that technological progress caters mostly for the needs of the sick and the elderly who continue to play a significant role in the society.

In modern world per capita energy consumption is about 2.5×10^3 W, which exceeds the biological energy consumption of a human adult, 150 W, by more than one order of magnitude. One can say that every person has more than ten servants—robots working with a power equal to the power of an adult man. With increasing automation of all the spheres of life (term the Internet of Things), increasing pension age and decreasing load by children, the increase of the mean population age does not pose any economic problems. (Indeed, even in primitive societies people are able to support themselves up to the age of 60–65 years (Kaplan et al. 2000).) Only those concerned about the decelerating economic growth perceive this increase as catastrophic. However, as we discussed above, global economic growth very likely will cease in any case.

At the same time as the global resources become depleted this global challenge creates a novel stimulus for technological progress. If the global stability of the environment is not lost, technological progress will be directed at maintaining modern living standards in the situation of aggravating shortages of all resources and degrading global environment. This global role of technology is new and distinct from what it used to be until recently—improving (at least some aspects of) human conditions rather than merely sustaining the status quo.

3.3.11 Conclusions

Considerations of the major principles behind sustainability of living systems allow us to formulate a strategic vision on the global problems of the humanity as well as on their possible solutions. First of all, our considerations urge a significant shift in the direction of globally centralized efforts aimed at preserving the global environment and climate. We have discussed how natural ecosystems perform regulation of the global and regional environment and climate, which is a self-sustainable, ultra-complex and highly energy-consuming planetary process that cannot in principle be replicated by technology (Sects. 3.3.2 and 3.3.3). Thus, to preserve a climate suitable for life on Earth we need to preserve and restore natural ecosystems in the first place, allowing them to perform their work for the benefit of the humanity and life as a whole.

The prevailing view on environmental problems in the modern society appears to have a different focus. Environmental issues are understood by modern society as the challenge to protect the environment from technological pollution. One assumes that if the technological cycle becomes closed based on environmentally friendly and renewable 'green' energy, such that the pollutants including CO_2 emissions are quantitatively diminished, the environmental problems will be solved. Such a view underscores an entirely different strategy of coping with the global crisis: for example, it can encourage elimination, rather than preservation, of natural forests in favor of growing biofuel. Within this perspective, the transition to renewable energy sources and recycling is thought to be able, at least in principle—neglecting the practical limitations (e.g., Abbasi and Abbasi 2012), to overcome environmental problems and thus lift any limitations on further growth of global economy and population.

However, if we take into account that the environment on Earth is under biotic control, recycling and renewables are not a strategic option but may in some cases significantly aggravate the environmental situation. The only possibility to preserve an environments suitable for humans is to reduce the anthropogenic consumption of the biosphere resources down to the natural threshold of about one tenth of per cent to preserve biotic regulation on a global scale. This means that the modern rate of the anthropogenic consumption of primary productivity and consequently the global population number should decrease by two orders of magnitude. Energetic needs of such a population, where the right for appropriate individual territory will be respected (see Fig. 3.4), could be fully met by the hydropower—theoretically at least—which is the only renewable energy flow that can be exploited by people without a continent-scale destruction of the biota. The per capita energy consumption can remain the same or even grow.

Recognition of global overpopulation and degradation of the remaining natural ecosystems as a major threat to global and regional conditions will demand a centralized program of responding to this challenge. How can we ensure that such a program, if it is proposed and agreed upon, makes practical sense and does not lead to dangerous outcomes?

At this point we come back to the issue of the right balance between central and decentral solutions. As we discussed in Sect. 3.3.4, "centralization" is equivalent to "internal correlation" of an object, while "decentralization" is equivalent to local independence of the various objects or parts of the object. In the context of human civilization, an object might be equivalent to the population of a country, a region, a city or a village, whereas the parts of the object are constituted by individual people, the population of a region, a city or a village. Moreover, to a large degree our civilization itself represents an internally correlated object that, unlike any other object in living nature, exists in a single number. As such, it is a priori highly vulnerable.

Decentral solutions are based on the knowledge of and respect for climatic, economic and social conditions and competences at the local scale. If some local strategy fails, the country (or region, or civilization as a whole) will not collapse. The local community of people will suffer but they will be able to borrow more efficient local solutions from their more successful neighbors. In this way good solutions will spread, while bad solutions will be abandoned without threatening the society (life) as a whole. Therefore, it is not just desirable but vital to delegate all functions that can be locally maintained to local communities. The subsidiarity principle (Vause 1995; see Sect. 2.2) takes care of such local interest and is therefore associated with decentralization. It suggests that the central authority should support, rather than subordinate, local functions. It should perform only those tasks which cannot be performed effectively at the local level.

The situation of finding global, centralized solutions presents a significantly greater challenge. For a single object like global civilization there is no opportunity to test in an experiment, using some other objects, whether the strategy that we as a planetary community choose is salvaging or suicidal. In natural ecosystems new meaningful genetic information that ensures centralized functioning of a system to the benefit of all of its parts does not emerge all of a sudden in the face of some environmental challenge. Such new information appears in the course of the evolution by an infrequent chance—in the result of mutations the overwhelming majority of which are harmful, but very few turn out to be useful. Once established, the information about a successful centralized strategy is further prevented from disintegration by competition of many centralized but mutually independent structures.

During evolution of large animals, of which *Homo sapiens* is an example, the genetic information about environmental regulation got lost (Sect. 3.3.5). Moreover, the genetic program of *Homo sapiens* as well as of other large animals prescribes a behavior that to a certain degree destroys the biotic environment (Sect. 3.3.6). If the humanity possessed unlimited energy sources then following this genetic program would have led to a complete degradation of natural ecosystems. As a consequence, the environment that is favorable for humans would have been also destroyed on a global scale. Degradation of the biotic pump on deforested land would have led to disruption of the water cycle, while overexploitation on land would have resulted in irrecoverable soil erosion. Therefore, we conclude that the program for centralized actions to avoid a global collapse cannot be formulated solely on the basis of intrinsic human desires, instincts and emotions that are all governed by the genetic program of *Homo sapiens*.

However, humans are unique organisms whose life is governed not only by genetic but also by cultural information (Sect. 3.3.8). Cultural information of the humanity comprises, along with other elements, objective scientific information which is not subject to pluralism. Scientific information is truth, because it is checked for its concordance with observations and scientific trials. So there is only one opportunity to find a successful centralized strategy for the civilization as a whole: to derive it from the best available scientific knowledge synthesized across disciplines into a coherent, non-contradictory framework. This is a new challenge for the intellectual elite of the Earth.

Until recently the achievements of science were judged by their ability to enhance human transformation of the biosphere that was accompanied by a rapid population growth, destruction of the natural biota and its regulatory environmental potential. Thus, the humanity has got into the present critical situation, which threatens the very existence of the civilization, owing to science and technology (Sect. 3.3.9). However, now it is only with help of comprehensive scientific knowledge about the humanity, that our planet and life as a whole get a chance to overcome the current global environmental crisis and preserve our civilization.

3.4 Nature and Human Nature: Ethical Concerns Should Not Be Disregarded in the Process of Decentralization

Verena Risse

3.4.1 Key Messages

Global problems often have local effects and demand local action. This supports the claim that it could be advisable to envisage decentralized solutions. Still, ethical concerns may not be ignored when this process is implemented.

3.4.2 Introduction

Among the most pressing problems today are the environmental degradation and political instabilities. Both problems are global insofar their causes and effects have a planetary dimension that knows no borders. At the same time, the effects become visible in concrete places and situations. Therefore, considering the principle of decentralization to approach these problems seems reasonable.

When it comes to finding solutions for global problems that do not concern humans alone, but also their environment, several interventions at the wbk3 suggested to investigate nature for inspiration. Indeed, nature as a complex system that has survived, evolved and got adapted over billions of years shows a variety of patterns of how to deal with changes and obstacles.

Human beings are part of nature and share many characteristics with other living species. Yet, they are also special in that they are—at least as far as we know—the only species granted with moral insight and the capacity for ethical reflection. This moral capacity is not merely something created to occupy philosophers. Rather it is a capacity that is crucial for the survival of mankind, especially for people living together in communities.

This contribution therefore argues that ethical considerations may not be ignored whenever new technical, social or political solutions are developed—even if this is done with an inspiration from nature itself. To make this point, the first section recalls some of the global problems and considers why decentralized solutions might be pertinent. The second section lays out why ethical concerns must be taken into account and what this can amount to in different situations.

3.4.3 Global Problems: Local Effects

The world faces a considerable number of problems most of which are man-made. Some of these problems like environmental degradation, climate change or diseases like Ebola significantly determine the lives of humans today and of future generations as well as they deeply affect the animal and plant life. Moreover, there are signs that in some cases, nature has lost its capacity to recover from or to adapt to the changes it suffered. A case in point is the increasing mortality of certain submarine species in the warming Mediterranean (Rivetti et al. 2014). Also in the social and political dimension, a new degree seems to be reached. Just think of spreading terrorist networks, more refugees than ever since the Second World War (UNHCR 2014) or rising social inequalities between and within countries.

Both sets of problems, the environmental and the socio-political ones, are global in scope. This means that they are affecting the entire planet and are not bound by the territorial borders of a state. Take the case of climate change. CO_2 emissions are considered the major cause for climate change and CO_2 emissions cannot be held within the territory of those who produce them. This example also suggests that the problems are not only global, but that the line between mere natural and socio-political problems is hard to draw. As in the case of climate change, often it is not the countries that emit most CO_2 that suffer most from its effects. This therefore prompts an issue of inequality and by extension of injustice that deserves attention (Caney 2005).

Moreover, while these problems are global in scope, their effects are experienced locally. This is to say, due to rising sea levels specific islands are flooded and the habitat is being destroyed. Likewise the refugees arrive at and seek asylum in a specific state. Therefore, it seems pertinent to address these problems in a decentralized fashion. What this can (technically) amount to is the subject of other contributions to this volume and will therefore not be explored here. Instead, the following section intends to show why ethical reflections should accompany the process of finding and implementing (decentralized) solutions.

3.4.4 Taking into Account Ethical Concerns

We can not only find inspiration from nature as to how to improve technical or institutional solutions, we can also learn something about ourselves as humans. This is to say, insights from evolution theory remind us that human beings are unique in possessing rationality which involves the capacity to raise ethical concerns (already in Aristotle, (1998) *Met.* 103b1-2, 1041a25-32). In fact, this edited volume is just an illustration of ethical concerns being articulated. At the same time evolution theory suggests that acting according to these concerns is contrary to our nature, for we intuitively choose the easier, cheaper, faster way which is not always in accordance with what moral behavior demands. This implies that behaving morally often means making an effort and perhaps overcoming one's inclinations.

These difficulties notwithstanding, it must be born in mind that the ethical concerns arise for a reason. This means that solving the global problems does not merely depend on finding the before-mentioned solutions—be they centralized or decentralized—even if these are inspired by nature itself. Instead, ethical considerations are likewise important and pertinent in several respects.

First, they are necessary to clarify the relations between human beings as well as their relation with nature and other species. This may include questions such as who is responsible for certain degradations, how are the costs and benefits of technical solutions to be distributed, should some areas or resources be preserved or granted to indigenous groups or future generations etc.

Besides this socio-environmental dimension, ethical considerations ought not to be ignored, secondly, because they can help individuals to get a grip on their own role, concerns and rights within the process of adaptation. This, for instance, involves how to deal with the loss of a job, a home, maybe even a whole home country as happens to inhabitants of certain island states due to rising sea levels.

Finally, it must be stressed that these ethical questions are not to be regarded as a separate endeavor discussed by some specialists only. Rather, they are present in all aspects of life including technology and should therefore be treated there, too. Neither are ethical concerns bound to a specific institutional structure or level, so that they can follow the request for decentralization. Quite the contrary, it is important to bear in mind that the opposition between local and global can rarely be upheld as many seemingly ‘global’ decisions are locally rooted. The most obvious example is perhaps that UN staff as global decision-makers work in offices which are located in New York City (Scholte 2008). In this sense, also ethical reflections such as the ones articulated here have their place and location.

3.4.5 Conclusion

This contribution has not argued for a particular set of ethical principles. Rather, the argument is located at an earlier stage in that it stressed the importance to apply ethical considerations and to make them a part of those processes of adaptation or decentralization that are outlined in this volume.

3.5 Transformation Towards a Resilient and Humane Environment and Culture: What Needs to Be Done?

Carolin Böker, Bettina Haas, and Ortwin Renn

3.5.1 Key Messages

We need a transformation towards a development that emphasizes resource efficiency, effective governance structures, fair distribution of opportunities and resources, and a resilient approach to risk taking. This includes a special attention to underprivileged individuals, groups and nations and we need a global agreement on the goals that we want to accomplish with respect to a sustainable path to future development.

3.5.2 Introduction

The perception of humane living and working conditions differs between variable cultures and parts of the world. Access to sufficient food and safe drinking water, electricity, education, humane labor and medical care has been accomplished in most North American and European countries, whereas in many African, Asian,

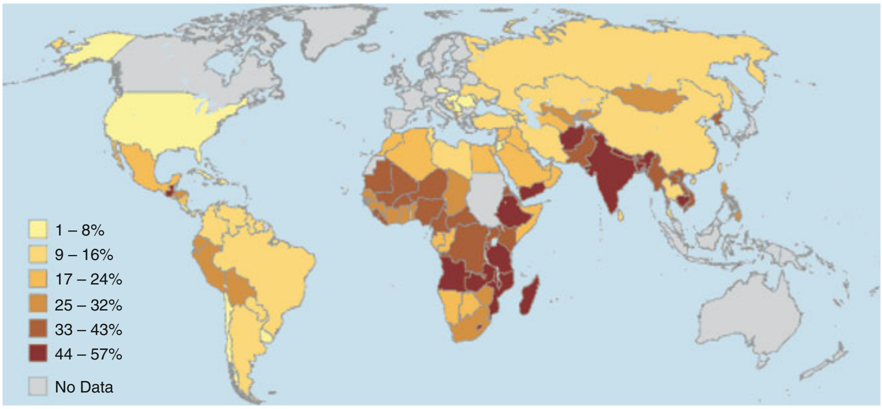

Fig. 3.5 Map of the world, different colours visualize the percentage of children under the age of five suffering from stunting (The Global Education Project)

Indopacific and South American countries these basic services are still lacking for a large proportion of the population. Taking Brazil as an example of South American countries, many children have to face maltreatment, street work, urban violence and abuse in Saõ Paulo, which correlates with poverty, single motherhood and a troubled family background (Mello et al. 2014). Additionally, due to these circumstances, children do not regularly attend school and thus often stay in bad living and labor conditions. Bad living conditions all over the world are also reflected by a high percentage of young children suffering from stunting (Fig. 3.5). In developed countries poor living conditions are more a concern to social underprivileged, often older people. In Germany for example, poverty among the elderly is not an exception: especially women are affected by the privatization of pensions with a reduction of the pension level at the same time (Fachinger 2008).

Poor working conditions might be divided into two different types of effects: physiological and mental maladies. Physiological effects include threats to health due to insecure work-flows, such as handling toxic substances without precautions and suitable safety equipment. A good example for negative physiological impacts on workers' health are the small-scale gold-mines in South American, Asian and African countries. Gibb and O'Leary (2014) reviewed the impacts of mercury due to the direct exposure during work (inhalation of vapours) and the indirect exposure after work (e.g. uptake of contaminated food such as fish). This can harm the nervous system, the intestine, the lungs and kidneys. In contrast to that, in developed countries, mental problems caused or promoted by a negative working environment (e.g. pressure of time and competition), are more and more evolving. Thus, selective serotonin-reuptake inhibitors as antidepressants are very popular in North America and Europe (Kirmayer 2002).

Taken together, all countries—undeveloped, developing, as well as developed ones—have to deal with problems concerning a humane environment for living and working together. We urgently need a transformation towards an economically just and socially fair development without disadvantages for underprivileged groups of people (e.g. children, elderly).

The International Expert Group on Earth System Preservation discussed some ideas how to get a step further towards humane living and working conditions all over the world.

3.5.3 How to Define "Humane Living Conditions"?

Pre-industrial societies lived more or less in a system of "subsistence"—i.e. the consumption and production of goods was mainly aimed at self-supply. Although trading took place in its pristine form, the main task was to ensure the living (subsistence), leaving little room for gaining or maximizing profit. Due to industrialization, the economic system changed to market economy or capitalism. Among many other characteristics, production and consumption are decoupled and maximizing profit is one main goal embedded in the economic system (Kilching 2008). Due to the digital revolution and political decisions (liberalization of trade), within the last 50 years the so called "globalization"—international exchange of goods and capital—even further decoupled production and consumption.

Societies living in a system of subsistence seem to be roughly in balance with available resources, as long as population growth was more or less constant. With the advent of capitalism and capital growth, the demand for ecosystem services and long-term resource availability have become more and more separated. Today, mankind uses statistically the resources of about 1.5 planets earth—going versus 2 planets in 2030 (Global Footprint Network 2014). It is obvious, that this cannot be in line with sustainability as well as humane living conditions.

The question "what are humane living conditions" is a very difficult issue and would demand a comprehensive answer that would reach far beyond the scope of this paper.

Nevertheless, some principal points seem to be beyond dispute:

- Drinking water and food in adequate quality and quantity
- Housing and sanitary facilities
- Health care
- Basic security (against violence, criminal acts, suppression, etc.)
- Access to education
- Work/job/occupation
- Contentment, happiness
- Self-determined living

These considerations are focused on the human individual or groups of individuals.

Another approach may be to postulate, that overexploitation of earth's resources in general is inhumane, as its logical consequence will be to render it very difficult (to impossible) for human societies to live on earth in distant future.

3.5.4 Basic Points of Transformation

The earth is home to many different terrestrial and aquatic ecosystems. Without anthropogenic impacts, these complex and sensitive networks would be self-regulating without any central supervision. Why not taking them as models for managing nations or regions was one of the questions of the third Meeting of the International Expert Group of Earth System Preservation. The answer was unexpectedly clear: ecosystems are suitable models to study networks and dependencies, but not for managing cities, provinces or even states (Haber 2010). Anthropogenic systems cannot be self-regulating, they need governance and guidance based on ethical values. How governance and ethics are organized and achieved depends on many different factors such as cultural backgrounds and geography. In short, there are two possible extremes to organize governance and abidance by the law: centralized and decentralized. What we need is a governance combining the advantages of both forms depending on the specific requirements that are time- and context dependent. On the one hand centralized systems, such as dictatorships, hold a certain amount of risk that the power is misused. On the other hand, centralized systems allow for quick and direct decisions, which can be an advantage in cases of pending catastrophes. In decentralized systems it is often vice versa: decision-making can be a time-consuming and a cumbersome bureaucratic process. However, a misuse of power is more unlikely or at least more difficult.

No matter of how centralized or decentralized a system is organized, the ultimate goal must be sustainability. With the increasing world population there is no sustainable future for humankind if we continue at the present consumption and exploitation rates.

The further depletion of ecosystems such as forests, oceans and streams must be averted. Additionally, these systems cannot be used as sinks for emissions and non-biodegradable waste (e.g. plastic, chemical, radioactive, toxic waste) anymore. Moreover, better recycling processes must lead to a reduced use of natural resources. The re-use of resources will probably be one of the greatest challenges to future generations.

The transformation to a sustainable management of resources must go along with the protection of individual rights accompanied by a governance system that includes self-determined living as well as the access to resources for basic needs (e.g. safe drinking water).

One way of how the transformation can be facilitated might be through better education programs including all age groups. The development of a broader understanding of environmental and social topics is necessary for preparing a mindset for sustainability and encouraging behavior that promotes sustainable practices rather than end-of-pipe solutions. In a social context sustainability means a pathway to a just and fair distribution of living opportunities and resources. This includes the need to minimize the gap between the very poor and the very rich.

3.5.5 Conclusion

Decentralized, self-regulating ecosystems may help to better understand anthropogenic networks, but ecosystems cannot serve as a normative model for humane behavior.

The fist condition for mitigating the environmental impacts of an unsustainable lifestyle (to surrounding nature as well as other humans) is human awareness and attention. Based on a general agreement that sustainability is the major goal of global governance, the second step is to create a governance structure that ensures resource efficiency, effective transformation steps towards sustainable living conditions, a fair distribution of opportunities and resources, and a resilient approach to risk taking. For that purpose the world needs externally established and controlled structures (good governance) in order to reach an improvement (Grambow 2013).

Significant changes in behaviour of the "world community" are necessary—and this within a comparatively short time frame. "Climate change" is one prominent example—the problem has been identified well in advance, but effective and consistent reactions are still lacking due to individual (industrial branches to whole states) egoism. Already now one can witness accelerating negative effects.

There are important principles that could guide humankind through the process of transformation, including:

- A balance between resources and environmental ecosystem functions
  - No depletion of oceans, forests, etc.
  - No overuse of the earth as sink for emissions and waste
- Respect for basic human needs
- Sufficiency as a goal for individual wealth accumulation
- Resilience with respect to risk taking
- Fairness with respect to opportunities and resources
- etc...

Today we do not face a lack of perception of the problem or ideas for potential solutions. For example *Nazrul Islam* 2013] (p. 2–3) states that a "new social model" is necessary, as ".... the current model is leading to breaches in planetary boundaries, jeopardizing the very existence of human civilization on this planet. ... the current model is not proving efficient for achieving human development goals in developing countries. ... the current model is not proving that helpful in improving life satisfaction in developed countries either" and describes the benefits of a change: "...acceptance of and steps toward the sustainable social model can bring environment and development together. The process has to begin with transition to sustainable consumption in developed countries. This transition will however require transformative changes in the economy, society, culture, and lifestyle. These changes will constitute a new phase of human development for developed countries. Thereby human development will become a universal goal applicable to both developed and developing countries . . . The transition of developed countries toward sustainable consumption pattern will increase the resource and environmental space for developing countries to grow and improve their material standard of living. It will also have a demonstration effect by offering a different 'aspiration model,' so that developing countries may no longer strive to adopt the unsustainable consumption pattern currently observed in developed countries."

The most difficult and yet unanswered question is how to convince decision makers, economic and political leaders and high profile opinion leaders that the long-term sustainability of humankind depends on a radical transformation of established economic and social patterns towards a balance between demand and long-term availability of natural resources and a fair and equitable distribution of these resources among nations and individuals. This implies daring to re-think decision patterns, focusing on long-term effects, and not on short term economic gain.

The scientific community can offer support for this transformation by developing better interdisciplinary system sciences for exploring the impacts of human interventions into the natural and social environment. It can provide important transformative insights of how to pursue an effective path towards sustainability given the knowledge about systems and how they respond to interventions.

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