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Links between human and animal life in the Age of Anthropocene: From molecules, through reactions to cells, development and ethical implications

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In the last two hundred years, discoveries in animal and human physiology, disease, and drug development have been made. Animals stood at the centre of the experiments to optimise the drug doses and administration routes. Human progress has been driven by various anthropogenic aims and desires. The knowledge development and discoveries continue to increase about the fundamental reality of human existence and the ontological realm in which the socio-ecological systems continue to evolve. Members of *Homo sapiens* have now reached an understanding, power of knowledge and actions which have the ability to influence the Earth's ecosystem. This produces the by-products of human progress, *e.g.* CO_2 and these have started to alter the fundamental/situational reality boundary of human existence and the ontological realm of the socio-ecological systems. Benefits and suffering of humans and animals, separately and together, can be viewed through various lenses, *e.g.* the precautionary principle. The current article uses the methodology which is a combination of bioethical analysis and a theoretical biology analysis of the precautionary principle and its implications into the relationship between human and broader socio-ecological systems. The principle can provide some guidance on ethical understanding of the duality of human actions during Anthropocene and the Great Acceleration and how it is linked to the very chemical essence of life. Humans develop their knowledge about the fundamental reality as part of their search for truth, for understanding of the chemical and other dimensions of the nature of life. This is 'normal science', *i.e.* the search for 'truth' or human understanding of fundamental reality of existence, moves humanity forward. However, its deployment for human development creates by-products that require 'regulatory science', or settings of rules for regulation of the deployment of the normal-science-derived knowledge. An examples of this can be the need to take action and to mitigate the climate change impacts across the globe, impacts on both human and animal life.

Key words: precautionary principle, levels of biological organisation, ethical framework

Introduction

Progress of humanity has resulted in the development of new technologies. These facilitated the improvement of quality of life of humanity, *e.g.* by the use of coal, as a source of energy from about the 1800's [19]. This was a catalyst for development, population growth and other improvements in the nature of human reality, and other human achievements since the industrial revolution that would not have been possible without the use of coal and fossil fuels [24]. Humanity has now reached a stage of Anthropocene and the Great Acceleration [19]. The epoch in geological time is characterised by numerous discoveries in areas of biomedical science, manufacturing, energy, transportation and so on. Humans have conquered Earth’s surface in that they have reached and settled the entire planet, with very few exceptions [24]. The carbon intensive economy and the related development have created feedback loops, where the actions of humanity have created conditions under which the greenhouse gases and their release into the atmosphere and environment have created a negative feedback loop and effects on humanity/human wellbeing [39]. Humans need to act to mitigate further impacts of climate change on nature and on humans themselves [66]. Expansion of human reach and the climate-change-related feedback loop contribute to increased impacts of CO_2 on the environment and on human health across all geographical scales. One way to demonstrate this is that 250000 additional human deaths per annum have been estimated to occur between 2030 and 2050 due to climate change [9]. In addition, there will be an additional 2×10^9 to 4×10^9 USD of healthcare costs due to climate change for the same time period [9]. Increases in the global population means that there will be more emissions of CO_2 and other greenhouse gases, which in turn expose more people to the climate-change related risks or impacts. Humanity started acting to decrease these impacts and releases of greenhouse gases by adopting the international guidelines and agreements to mitigate climate change.

Goal 13 of the Sustainable Development Goals promotes finding solutions to issues that are linked to climate change, *e.g.* by taking measures to combat climate change itself and its derivative impacts on the socio-ecological systems [58]. In this context, the issue of resilience is indirectly addressed in Goals 9 and 11 [58]. The Paris Agreement was adopted in 2015, where all participants of 194 countries from across the globe accepted to limit the increase in global temperatures up to 1.5 °C [62]. An argument could be made that there are often time lags between environmental pressure (such as those of anthropisation of space [24]), and tangible impacts of such actions, *e.g.* climate change impacts on humans and animals. However, the current phase of the Great Acceleration is specific as the impacts are happening in our life time. This distinguishes the current climate change problem from other issues facing the socio-ecological systems and their components. Such impacts apply to the human population and the environmental nexus, because the direct cost of any successful mitigation will be borne in large part by people and environment now, and in the future. An argument could also be made that any positive action taken would mostly benefit the future human populations on Earth. However, no positive actions by humanity to address the climate-change feedback loops, will surely mean disaster for today’s and future socio-ecological systems. Careful considerations must be made in order to weigh the costs, benefits and impacts of any relevant decisions in the short term and the in the long term.

The social cost of carbon dioxide (SCC) is the economic cost of each additional ton of carbon dioxide emissions due to climate change [37]. Climate change policies and their implementation can be explained and also evaluated through the SCC concept [37]. To choose the best mitigation strategy, considerations based on the SCC concept must take into account two aspects. The first one is the assessment of the CO_2 emission pressures/effects created by the human population, the related human population growth rates and future impacts/costs [37, 54]. Achieving reliable estimates in this context has proven somewhat challenging in relation to the predicted increases with greenhouse gas emissions [37, 54] The second requirement that the SCC must meet, and which policy advice might be influenced by, is the need to create a consistent and transparent strategy to evaluating the wellbeing of future human generations over several time scales, and in connection to the CO_2 release and to climate change in general [54]. Approaches such the SCC evaluate the use and impact of anthropogenic technologies on the environment surrounding humans [21]. From a decision-making point of view, the decision-making based on concepts such as the SCC is critical to management of the climate-change-feedback loops that humans have contributed to creating. Such decisions require consideration of the following characteristics of the current ontological realm of socio-ecological systems:

a) humans have reached the technological know-how and state of understanding of the fundamental reality of their existence that allows them to, however indirectly, alter said fundamental reality [24];

b) such level of knowledge and possible alterations will manifest at the boundary between the situational and fundamental reality of human existence and the existence of the socio-ecological systems, *i.e.* animals and abiotic compartments in these system will be impacted by human actions alongside *Homo sapiens*;

c) whatever the original intention behind the search for knowledge and technological development was by humanity as a species, once the power of fundamental reality alterations is in the humans’ hands, they live in it, but they are also responsible for managing it in a benign and non-destructive manner, they must prevent malign and destructive manner of management — a manner which could decimate all of the socio-ecological systems worldwide.

Points a)–c) are a distillation of various principles that have been investigated and talked about in the various types of literature over the last century. Humans have reached the ability to influence life on Earth, *i.e. Homo sapiens* has reached the ability to influence the global ecosystem and life itself. Humanity has reached the status of *Homo deus* [22, p. 20]. Examples can include the deciphering of the molecular essence of life by elucidating the structure of DNA [60] This then led to the original and then the ‘reformulated central dogma of molecular biology’, which describes the flow of information from DNA to proteins, while capturing any ‘detours’ from across all living organisms to complete the picture [20]. Theory of evolution and its adjustment or modifications happened in the last century [6], as new elements of fundamental reality of human existence became known to *Homo deus*, as analysed [24]. Discoveries in nuclear physics led to realisation by humanity that nuclear radiation can cause mutations and the inducement of the single- and double-strand breaks in DNA, as well as aberrations in chromosomes [31]. Systematic development of sequencing methods, genetic manipulation and related IT advancements got humanity to the point of sequencing of all vertebrate genomes [46]. Existence of the non-human animals, its molecular basis, categorisation of non-human living organisms had been discovered and/or clarified. Synthetic life has been created by various scientists (*e.g.* [63]). These examples and points summarise the level of human beings’ knowledge of about their surrounding… the power to alter the very essence of such surroundings, and the need to manage the application and impacts of such knowledge. Principles of the decision-making under the weight of such human power must balance human progress and protection of non-human parts of socio-ecological systems. One basis for the decision-making is the precautionary principle, which can be defined as follows [47, article 15]:

> “In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”

The precautionary principle summarises the three elements of the necessary approach of humans to the deployment of their knowledge in the Age of Anthropocene and the Great Acceleration [19, 24], namely [44]:

> “Action-guiding principles tell us which course of action to choose given certain circumstances; (sets of) epistemic principles tell us what we should reasonably believe under conditions of uncertainty; procedural principles express requirements for decision-making, and tell us how we should choose a course of action.”

The precautionary principle takes into account the possibility of the impacts of human of knowledge and its development on non-human parts of the socio-ecological systems, while human development and existing knowledge exploitation are taking place. Application of the precautionary principle acknowledges the uncertainty about the outcomes of the human actions and tries to strike a balance between the need for humans to explore the ontology of existence in the climate-change-feedback loop time. The time when the socio-ecological systems around the globe and their existence are in peril. Actions by humans, according to the precautionary principle, are fundamentally seen as those by custodians of the socio-ecological systems. Application of the precautionary principle in some decision-making will be a tool for management of the human existence at the boundary between the fundamental and situational reality, the current reality of *Homo deus* (based on [22]). It is against this background that the current article seeks to investigate the significance of the precautionary principle at evaluating the practical implications of human existence at the boundary between the fundamental and situational reality boundary. This existence is relational to non-human animal life and the environment. The chemical and organisation structure of life, both human and non-human, is used as the start of the discussion about the link being the essence of life and the drivers/necessary drivers of the regulation of human research and deployment of the results. Precautionary principle and the ethics of management/deployment of the human knowledge, for the way to conduct research that impacts, or involves non-human animals, are then presented and subjected to analysis from the viewpoints of theoretical biology and bioethics.

Methodology

Methodology in the current article will be focused on examination of the relationship between humans and non-human components of the socio-ecological systems. The analysis will be bioethical and theoretical-biological in nature, and it will start with performing a set of small thought experiments to set the stage for demonstrating the links between humans, human activity, and nature. This analysis will be aimed at presenting the links and implications between the fundamental and situational reality of human existence in the Age of Anthropocene and during the Great Acceleration [19, 24]. More specifically, it will be aimed at establishing the link between the human existence and the nature of the discoveries that drive human development and the general improvement of the human condition, and the general ontological realm of the existence of the socio-ecological systems globally. After that, the duality of the chemical elements, molecules in living organisms and their impacts on the organisms themselves are linked to the human actions and their impacts on the socio-ecological systems. The duality of the nature of life and the nature and essence of human actions put and presented side by side to close the analyses with the precautionary principle. Finally, the bioethical analysis is linked to the framework for the ethical treatment of non-human parts of socio-ecological systems. The need for the ‘normal’ and ‘regulatory’ science is outlined, as a way to manage the impact of human knowledge generation and application at the boundary between fundamental and situational reality in the Age of Anthropocene and the Great Acceleration.

Thought experiments and real-world examples on the relationship between human, living organisms and socio-ecological systems in the Age of Anthropocene

A Balance and mass at the boundary of the fundamental and situational reality

The human knowledge of the fundamental reality has been researched and defined in terms of fundamental constants, as tools for humanity to have a language of scientific discourse and the standardised notation. An example of this notational unity of our fundamental reality of human existence (designated as notational unity in further text of this article) is the SI unit system. The one kilogram, as the basic unit of mass in the SI system, was based on the international standard until 2019, which has been housed in Sèvre, France [12]. This was changed in 2019, when the kilogram was redefined to be based on the fundamental constants of the human existence, *e.g.* the Planck constant. This can be summarised as outlined [56]:

> "The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be $6.62607015 \times 10^{-34}$ when expressed in the unit Js, which is equal to kg m^2s^{-1}, where the metre and the second are defined in terms of c and Δv_{Cs}."

Ever more accurate equipment to measure mass have been developed and so balances/scales have been omnipresent in scientific institutions and non-scientific contexts for a long time. The measurement of mass is an elemental unit operation in the scientific process. For example in the biomedical and laboratory/clinical chemistry, a mass of crystals of $FeCl_3$ must be weighed out to prepare the calibration solution with an accurately known concentration of iron to analyse a blood sample, if a patient might be suffering from anaemia. Such omnipresence of the mass measuring equipment makes a balance or scale a manifestation of the fundamental reality of human existence, the human knowledge about it, and the situational reality of human existence in which the balance/scale is used. The construction or manufacturing of the balance is an expression of the human interpretation of the fundamental reality, as the construction or manufacturing of a balance/scale would not be possible without the definition of the kilogram. Neither would it be possible without the application of the mass concept to the design and manufacture a relevant measuring instrument, *i.e.* balance or scale by members of *Homo deus*. Using a scale to measure mass, a fundamental constant for measuring the 'size of living organisms for specific purposes' would then be a manifestation of the boundary between fundamental and situational reality of human existence in the Age of Anthropocene and during the Great Acceleration [19]. Let us look at the sizing up of living things.

Now considering, the omnipresence of mass measurement and the related equipment will indicate that each part of the human life and the existence of the wider socio-ecological systems. Let's consider the following short thought experiment. A hypothetical animal welfare organisation in a hypothetical city in the developing world looks after the cats and dogs (this organisation is referred to as AWO in further text of the article), as well as provides callouts and investigative capacity in relation to suspected case of animal cruelty. The AWO is in need to get a balance to determine the mass of the kittens and puppies, young cats, and dogs. These cats and dogs have been rescued in the AWO's area of jurisdiction. In the vicinity of the AWO facility, there is a hypothetical university which is a research-intensive one, and it has a spare balance available. That balance makes it possible to measure mass accurately up to 50 kg, and calibrated weights of 1, 5 and 10 kg are available to ensure accurate mass measurements. This balance/scale is normally used for the weighing out of kilogram quantities of environmental sorbents and/or pharmaceutical formulation ingredients. The AWO makes informal enquiries around the city of their geographical location, about the possibility to procure a new balance for measuring of mass of young cats and dogs, as well as the rescued and emaciated adult/strayed animals. The need for a balance/scale is a manifestation fundamental reality that species individuals, belonging to *Felis catus* and *Canis familiaris*, have evolved to have an expected body mass. The body mass and chemical composition of the animals body are an indication of the inexorability principle of the nature of life, and the vital determinism related to it [20]. The inexorability principle means that life is present in front of us, as it is meant to be, or it has developed into an optimised form based on evolution. The lack of a working scale at the AWO is a time-sensitive matter, as not monitoring the weight of the cats and dogs housed at the AWO can have detrimental effect on the animal welfare and on the life of the animals. Therefore, this time dimension of life is a potential source of animal suffering, if a rescued animal is underweight or malnourished it may die if a mass of it is not determined due to the lack of balance, and veterinary medical care is not be initiated as needed [20]. Potential animal suffering is a manifestation of the situational reality of the rescued animals, and it is also linked to the fundamental reality of animal lives. That suffering must be decrease as much as possible, and its management takes place at the boundary of the situational and fundamental reality of animal lives, where humans are an important interventionist force. The human boundary of situational and fundamental reality is also implicitly relevant here, as the AWO staff care about animal welfare and wellbeing as the protection of animal life is the call to duty of the AWO staff and the *raison d'être* of the AWO.

In this context, the research-intensive university through their staff, who are in charge of the 50 kg balance, should apply their knowledge of the fundamental reality of the mass and kilogram to assist the AWO.

Deployment of the fundamental reality knowledge, through derivative epistemic authority of the researcher, the particular human being, who is knowledgeable about the use of balances and the definition of a kilogram, should assist the AWO with deploying their knowledge and to decrease/prevent animal suffering. That researcher should and likely would deploy this knowledge to help the AWO to manage the situational/fundamental reality boundary, they should loan the balance to the AWO and provide a calibration service on a regular basis. This would all be done free of charge. In this way, the humans in question use their epistemic authority to prevent animal suffering or alleviate it by the provision of a body mass monitoring tool. The action-based nature of the engagement and mass monitoring assistance would be in line with the precautionary principle. At the same time, the action is driven by the derivative epistemic authority of the researchers with the mass measurement knowledge. Finally, the decision about the provision of assistance by the researcher to the AWO with the mass measuring is based on the inherent nature of life time commandment and element of life's essence. Time is essential from the sensitivity of the matter of animal life prevention. The AWO can also reject the offer of a balance loan from the research-intensive university on the grounds that there is a need for a researcher to interact with the AWO, and the recipient of the loan might perceive that a power imbalance might exist there. Using researcher's epistemic authority to assist the AWO might be perceived to act outside of the normal scope of professional practice of the AWO, and the researcher if they are not an animal scientist, zoologist or any kind of scientist that works with animals. The AWO might be of the impression that the researcher is not qualified or in the best professional position to assist the AWO and the animals they house. The AWO might therefore be placed in a difficult position due to the potential *ad hoc* funding model of the organisation, and potential perception that a financial gain will be sought by the researcher because of the balance loan.

Ultimately, a researcher assisting the AWO would likely have an ethical and moral interest in diminishing the animal suffering and would offer to help the AWO to decrease animal suffering of the currently and future housed cats and dogs there. This would likely be the case, as the AWO would reach out to the research-intensive university via unofficial or official contacts, or via word of mouth. Therefore the AWO is likely to be actively seeking, at least to some extent, assistance from the university and indirectly from the researcher who might ultimately provide a balance for the body mass determination of animals. Thus the power relationship between the researcher and the AWO would likely be more equitable than not. Based on the considerations in this thought experiment, the researcher should provide the assistance where necessary expertise and equipment in the body mass monitoring is needed so that the AWO. The AWO should work with the researcher, the community, and the veterinarians in the area to decrease the animal suffering. The ethical drivers for the support by the researcher would be voluntary in nature but would be linked to the professional knowledge of the researcher and caring nature of the researcher. It might also be an expression of the categorial imperative [25], *i.e.* the moral imperative of the researcher to contribute to decreasing the human and animal suffering wherever they might encounter it, or where they foresee it developing. This would be the suffering of the housed animals and potentially the staff at the AWO. Said action would be taken, because it is based on the social context which commands it as necessary to diminishing of animal suffering if, where and when possible. By the same token, there is also necessity to diminish or prevent the suffering or mental health problems of the AWO staff when seeing animal suffering. It would be ethically right and morally necessary because it is the right thing to do, it is the right action to take in the context of the researcher's epistemic authority, knowledge about the fundamental reality of human life, its deployment and application at the boundary with the situational reality in connection to AWO's existence at this boundary.

The researcher is able to use a scale, and the calibration is available using the calibrated weights. The mass of a kilogram, as the SI unit and the construction of the scale, are an expression or the outcome of the accumulation of the knowledge about the fundamental reality of human existence by scientists and researchers, by *Homo deus*. This knowledge can then be used to manage or deal with the animal welfare issue at the AWO. Such activities take place on the boundary between fundamental and situational reality of human and non-human animal lives. Assistance and the will of the researcher to help the AWO with application of their knowledge of fundamental reality of human existence and life must be aimed at decreasing or preventing animal suffering which is the result of human actions. More specifically, the researcher's assistance with weighing the cats and dogs housed at the AWO is aimed at decreasing the animal suffering which is, at least in part, caused by human actions, where the human owners have let the animal to become strays. This embodies a precautionary action against the occurrence of the animal suffering, and indirectly some mental health suffering among the AWO staff. The latter type of suffering might arise among the AWO staff if they can't carry out their mandate and help the animals they look after unless animal weighing tools are available. The researcher and the AWO staff could extend the project to research that can collect information about the body mass of rescue cats and dogs in a particular. Such data can be linked to optimisation of the animal welfare and wellbeing management by humans at the AWO. The data and research can help optimise the deployment of the human knowledge about the fundamental reality of animal health and its human understanding towards optimisation of the situational reality of the AWO animal health management. These links to the operational aspects and optimisation of knowledge deployment, about the fundamental reality, might maximise the action-driven and voluntary application of the precautionary principle.

Antibiotic development and potential impacts on the environment

Antibiotics and antimicrobial agents have been one of the backbone of the antimicrobial therapy and infectious disease prevention in the 20th century [2]. They were discovered through a series of exposure of staphylococcal cultures to the ambient environment and isolation of a *Penicillium* spp. which had produced penicillin [18]. Even though some discoveries might have been accidental over time the discovery and development of antibiotics led to the increase in life expectancy in the developed world by about 75 % [2]. Development of antibiotics will be demonstrated on the quinolone antibiotic development. Quinolone antibiotics are a specific class of antibiotics and are classified into four generations, with the more recent drugs (4th generation) having a much broader antimicrobial spectrum. The 1st generation includes nalidixic acid, which was the first quinolone antibiotics and discovered in the early 1960s [35]. First-generation quinolone antibiotics have activity against Gram-negative bacteria. Recent generations have a broader spectrum of activity and enhanced pharmacokinetics compared to nalidixic acid. The second-generation quinolone antibiotics include ciprofloxacin, norfloxacin, lomefloxacin, enoxacin, and ofloxacin. These have higher activity against Gram-negative bacteria, some Gram-positive organisms and achieve higher serum levels of the active pharmaceutical ingredient, as compared to the predecessor-generation drugs [41]. The third-generation quinolone antibiotics include levofloxacin, moxifloxacin, sparfloxacin, and gatifloxacin, and these have second-generation qualities, further having activity against atypical pathogens. Trovafloxacin is a part of the fourth generation and has activity against anaerobes [5]. Levaquin and trovafloxacin have since been removed from the market due to hepatotoxicity reported in patients.

Though alternative first-line treatment exists, quinolone antibiotics are often prescribed in uncomplicated urinary tract infections (UTI), bronchitis, and bacterial upper respiratory infection [50]. They are prescribed due to their low dosing frequency, high potency, a broad-spectrum of activity, and low chances of side effects [50]. However, adverse effects have been associated with the long-term use of quinolone antibiotics, such as tendonitis, higher chances of experiencing retinal detachment, angiosis, and the 'quinolone-associated disability syndrome' (FADS) [33]. In May 2016, the FDA issued a box warning, suggesting alternative uses to quinolone antibiotics in cases where the side effects of the quinolone antibiotics outweighed the benefits of treatment [17]. These include bacterial sinusitis, acute bacterial exacerbation of chronic bronchitis and uncomplicated urinary tract infection. In the 1st generation of quinolones, nalidixic acid was first marketed in 1962 and a two-year study on mice and rats that were given feed containing nalidixic acid determined the possible carcinogenic properties of the drug over long periods [33].

The 2nd generation started with norfloxacin, ciprofloxacin, ofloxacin, enoxacin, and lomefloxacin; these have a broader action against Gram-negative pathogens, Gram-positive bacteria, and atypical pathogens [28]. The addition of a methylated piperazine at position R7 adds activity against gram-positive bacteria by inhibiting efflux pumps [41]. A quinolone at position R6 increases the drugs' potency, and in the case of ciprofloxacin (commonly used in South Africa), the addition of cyclopropyl at position R1 makes the drug 4-fold more active [41]. Due to having similar joint anatomy to humans, sheep are the animal model of choice in investigating the growth-inhibiting properties and drug safety of ciprofloxacin and gemifloxacin for use in pediatric patients [51]. Through such studies, quinolone antibiotics for patients below 18 years are limited because the drug is now known to have anti-growth effects. In a separate study, immunocompromised mice were treated with levofloxacin and ciprofloxacin [49], after inoculation with pneumonia from the causative agent *Klebsiella pneumoniae*. Such animal studies have allowed for the formulation of a time-saving essential drug list for pneumonia infections.

Next there was the 3rd generation of quinolone antibiotics which had the same activity as the predecessor group plus improved action against atypical pathogens [55]. The list of drugs includes gatifloxacin, grepafloxacin, sparfloxacin, and clinafloxacin. They have a cyclopropyl ring at position R1, which improves the potency of the drug. The addition of NH_2 or CH_2 at position R5 increases the drug's activity against Gram-positive bacteria [48]. The presence of fluorine/chlorine at position R8 increases the drug's half-life and tissue penetration. Finally, the 4th generation quinolone drugs include moxifloxacin, gemifloxacin, and trovafloxacin, and they have activity against gram-positive bacteria, gram-negative bacteria, atypical pathogens and extended anaerobic activity [8]. Structural modifications include the addition of 3-methoximine-4-aminomethyl-pyrrolidin-1-yl/amine-substituted bicyclic pyrrolidin-1-yl group/azabicyclo group/ azabicyclo group at position R7 improves the drugs' activity against Gram-positive bacteria [48]. Animal studies enable predicting adverse effects of quinolone antibiotics [32], *i.e.* human suffering has been decreased by animal suffering instead.

Mechanism of action of quinolone antibiotics has mostly been inhibition of the replication of DNA in bacteria. DNA is a highly condensed structure, and for cell replication to proceed, the structure needs to be unwound to expose the DNA template to DNA primase and DNA polymerases. DNA gyrase enzyme relieves the positive super helical twists that are a result of DNA strands unwinding. Topoisomerase IV separates the newly formed prokaryotic chromosomes and eliminates the DNA knots using the energy of ATP hydrolysis. Quinolone antibiotics act by inhibiting to the DNA gyrase and topoisomerase IV and induce cell death is by DNA inhibition and/or production of stress response proteins [41]. In South Africa, gonococci have built up resistance for ciprofloxacin (a quinolones antibiotic), proving it ineffective against gonorrhoea [50]. It should also be noted that moxifloxacin and levofloxacin are a part of second-line tuberculosis drug treatment, so quinolone antibiotics are essential in the South African context [50]. Quinolone antibiotics are therefore important in the public health in South Africa and resistance against them poses a severe threat in this regard. There are three main resistance mechanisms of resistance microbial pathogens against quinolone antibiotics [13]: firstly, an increase in efflux pumps. Drug resistance is built by limiting drug concentration within the cell. This is achieved by increasing the number of efflux pumps present on the cell envelope [41]. Next, mechanism is lowered porin expression and mutation of lipid-mediated pathways. This limits the amount of quinolone able to enter the bacterial cell cytoplasm [48]. Finally, mutation of topoisomerase IV and DNA gyrase can occur. These mutations reduce quinolone affinity for the target enzyme, and thus reduce drug effectiveness [41]. There have been clear benefits ciprofloxacin and other quinolones, but the development was done against animal suffering, as many active pharmaceutical ingredients were done by testing on animals [38, 52].

Drug development and the development of antimicrobial agents is where many animal models have been included [67]. During the animal testing of antibiotic and drug development, some negative impacts on animal health were recorded. More specifically, penicillin is fatally toxic to Guinea pigs [57]. Aspirin was suggested to be toxic to rat embryos [65] and repetitive administration of paracetamol to dogs and cats led to toxic side effects [64]. Testing of ciprofloxacin showed that monkey embryos and dogs did not suffer from toxicological side effects from quinolones administration [53]. The use of antibiotics in human medicine was led to environmental contamination and the presence of antimicrobial resistance elements in the Great Apes in previous unanthropised areas of the world [61]. Selection of the animal models and the types of experiments have been based on the progressive improvements of the fundamental reality by humans throughout the Age of Anthropocene and recently during the Great Acceleration. The knowledge accumulation about this fundamental reality has been related to the understanding of animal physiology, genetics and biology. Application of that knowledge to the situational reality of human existence has then been taking place, *i.e.* deployment of the use of animal models in the antibiotic development to fight infectious diseases in the Age of Anthropocene and recently during the Great Acceleration. Many animals have been euthanised and the subjected to injuries/welfare impacts, when animals are used in the drug development. Human suffering has been alleviated by suffering of animals, and the animal models have not always been optimum in transfer of results for humans [67]. Over time, this search and application of the fundamental reality knowledge at the boundary with situational reality has led to the realisation by humans that more care and protection must be extended to animals. This led to adoption of preventative measures that protect animals as quasi-participants and the draw down of the human suffering (see section on Integrating remarks below). There has also been a move away from the use of animal models in drug testing and development; and towards the use of replacement systems and potentially challenge trials. It can, therefore, clearly be seen as a progressive adoption of the precautionary principle in drug development.

Precautionary principle and its links to the fundamental and situational reality

General aspects application in the Age of Anthropocene and the Great Acceleration

Ultimately, the human actions such as release of nuclear radiation and excess CO_2 into the environment must be seen as possible examples of threat to life on Earth, *e.g.* through the alteration of the conditions under which socio-ecological systems will exist in the Age of Anthropocene. The precautionary principle expresses that causality of human actions can be unpredictable, *i.e.* the consequences of the release of CO_2 and other gases and chemical compounds into the environment due to the anthropogenic activities cannot always be understood, modelled, or completely quantified/mitigated at the point of creation of those impacts or even long time after the onset of such impacts. The decrease of the use of animal models in drug development can be seen as a decrease of the animal suffering at the fundamental and situational reality boundary. At the same time, future suffering is to be prevented. Therefore human actions can have unpredictable impacts on the human-animal-environment impact nexus, and this is taken into account at the boundary between fundamental and situational reality. Application of the precautionary principle is aimed to preventing the alterations in the amount and sometimes even the bonding nature of life. It is an expression of the fact that humans and their actions set the terms of concrete and indirect impacts of a set of chemical molecules onto the socio-ecological systems. As a result, the precautionary principle is aimed at preventing the destruction of life, to limit the potential impacts of human activities in the Age of Anthropocene and the Great Acceleration on the non-human components of the socio-ecological systems. The precautionary principle is aimed at preventing harm to other living organisms and directly or indirectly due to the application of the human knowledge and the search for new knowledge, as well as its potential applications. This should and does apply to the current and/or future generations of humans, animals, and environmental settings [24].

Human actions, putting aside colonialism and other forms oppression for now, can have benign, beneficial, or detrimental impacts on the other components and compartments in the socio-ecological systems. Therefore, the precautionary principle allows for the continuation of the 'normal science', which is aimed at discovering the nature of the fundamental and situational reality of human existence and the environment humans share with animals and other living organisms [44]. However, the principle strongly suggests normative, cautious, and deterministic actions in the domain of the 'regulatory science'. In other words, the precautionary principle is guiding principle for drafting and implementing of the policies and regulations of human actions that can result in unforeseen impacts of application of knowledge, development and deployment of normal science. Such impacts might be irreversible in effect on non-human animals, on all living organisms and the socio-ecological systems as a whole. The regulatory science and precautionary principle are aimed at mitigating potential human errors in the deployment of the human knowledge at the boundary between the fundamental and situational reality of human existence, as well as the existence of the socio-ecological systems. They aim to limit human errors to the type I errors, where human causality of detrimental effects on socio-ecological system is not necessarily proven, but is plausible [44]. Precautionary principle and all human impacts must be managed or pre-emptied in order to eliminate impacts on the socio-ecological systems which are of type II, *i.e.* human causality of such impacts is unforeseen and ignored until it is too late to prevent it and the impact had occurred, and it is deemed irreversible [44].

Precautionary principle is also the result of human action, human understanding, and collective interpretation of current and potential future changes at the boundary between the fundamental and situational reality of human and socio-ecological system's existence. Changes can and do apply to both realities of existence as well. The precautionary principle has been deemed irrelevant or problematic by some authors for the following reasons [44]:

a) the principle limits human decision-making and even goes against rationality, *i.e.* limiting the decisions based on hypothetical consequences is irrational and/or precautionary principle prevents a human being from making any decisions;

b) the principle is vacuous;

c) the principle is contradictory in its very essence.

This is a truncated version of the objections by scientists and philosophers, but many of them can be allayed or even eliminated. These objections will be discussed in a shortened version, and it will be based on the [44] reference, as well as on the authors own interpretation of the precautionary principle.

Normal and regulatory science as justification for application of precautionary principle in biological sciences

Firstly, the limitations and irrationality of the precautionary principle are not actually an accurate interpretation of its essence and scope of the principle's application. The precautionary principle is in its very nature a principle that is action-based, that would have epistemic and knowledge-creating dimension, and which is to be a procedural measure to guide human actions under the conditions of uncertainty of the actions' outcome. The precautionary principle is not in any shape of form itself to be applied to all decisions that humanity makes, *i.e.* it cannot be seen as a generally-applied and only normative principle to direct all human actions and decisions. Rather, humans are still able, free and obliged by the need to generate knowledge about fundamental and situational reality improve the overall human condition and to decrease/try to eliminate injustice and inequality among humans. Humans can explore fundamental reality of their world, ontological realm of existence… humanity can, in spite and because of the precautionary principle still, continue to strive and understand the laws of nature and the links between that and human health, wellbeing, the welfare of animal and abiotic components of socio-ecological systems. In other words, the precautionary principle does not stop, impede, or weaken the human's rights, need and entitlement to conduct normal science. On the contrary, the precautionary principle should only be used in the regulatory science domain to indirectly guide the normal science. However, the precautionary principle should only be applied in situations where humans action, *e.g.* increase in the atmospheric concentration of CO_2, can have (un)predictable and detrimental consequences on broader environment.

Offering a deontological ethical framework that complements the precautionary principle is Immanuel Kant's first formulation of the categorical imperative, which asserts, in the first instance, that one should act only according to maxims that can be universally applied [26]. This means that ethical decisions should be made based on principles that could be universally endorsed without contradiction. The second instance of the imperative emphasizes the need to treat individuals as ends in themselves, rather than merely as means to an end [26]. For example, if a proposed genetic modification could potentially harm the living organisms which are part of the existing socio-ecological system along with human. As a results, applying the precautionary principle means rejecting such modifications unless they can be universally justified as safe and beneficial [45]. By ensuring that scientific and ethical decisions respect the intrinsic value of living organisms and their molecular integrity (as far as possible at the boundary between the fundamental and situational reality of existence), the precautionary principle upholds the need for ethical treatment of all entities involved. Therefore and from a moral, as well as rational point of view, humans must act to mitigate or prevent a type II error in terms of impacts of human actions on non-human animals, living organisms and the abiotic components of the socio-ecological systems. Humanity must follow the precautionary principle, in the regulatory science domain, from the moment that there exist sufficient evidence, strong indications or pragmatic human consensus that anthropogenic actions might be the cause for detrimental or non-benign impacts on any part of the socio-ecological systems in the holistic understanding of this ontological term or notion.

The objection premise that the precautionary principles is 'vacuous' or devoid of meaning, content, or practical significance [44]. This objection can be addressed and debunked as follows. Human actions are unavoidable and a fact of life and will be assumed to be part of epistemic or perceived human reality and not illusion in the discussion/analysis going forward. One could theoretically argue that human action is only an illusion, but the impacts of anthropogenic action on Earth and the ontological realm of the socio-ecological systems are a reality, as indicated to and perceived by humans and indicated by the ontological existence in the Age of Anthropocene and during the Great Acceleration [19]. This last point is supported by addressing of climate change in the international treaties such as the Paris Agreement. Therefore the precautionary principle is a manifestation, a component of the human endeavour to mitigate the impacts of the real actions, that human development and its side effects can have on non-human animals and abiotic components of the socio-ecological systems. The unity of human mind, the collective one of *Homo deus*, its drive to change and improve the human condition, and the impacts, such endeavours have on the nature, are thus not vacuous. It is clear that such lack of vacuousity does have limitations, as Paris Agreement implementation is currently not meeting of its targets [36]. However, the precautionary principle is not vacuous, and it is driven by specific regulatory science consideration and intended epistemic actions by *Homo deus*. Regulatory science and the human search for new knowledge could both be seen as an expression of unity of human mind and nature. Such an interpretation is similar to the view of Jonas, who saw human mind and nature as one [21]. If one accepts this unity and the moral implications of it, as well as the fact that the precautionary principle was drafted, one can then state and argue that humans have realised, at least to some extent, that they have an impact on the environment and that at least some of those impacts are likely not positive or at minimum not benign. Therefore, the precautionary principle has substance and drives, in however limited fashion, human actions in the Age of Anthropocene, as well as during the great Acceleration, where applicable and in unison with scientific discoveries [24]. This pre-empts any sense that the principle is or could be vacuous. There is an essence of subject and action-driven decisions, and ethical implications, are based on decisions that are made based on the broad understanding of the human ontological essence and existence, and links to the wider socio-ecological systems. Human actions, such as drafting of the Paris Agreement and its adoption by the United Nations, indicate that human understand their link to the other parts of the socio-ecological systems. As a result, the precautionary principle is not vacuous.

The most difficult objection to deal with about the precautionary principle is the contradictory nature of it. It is true that regulatory science and the application of the precautionary principle could, at face value, very seen as limiting scientific progress, knowledge generation and ultimately the impacts of humans on the non-human parts of the socio-ecological systems. The point being that regulatory science, which strictly or predominantly, adheres to the application of the precautionary principle, can impose such limitations on the normal science that it becomes impossible for *Homo deus* to deepen their understanding of fundamental reality of existence. This in turn then prevents humans from dealing with the challenges at the boundary with situational reality, *e.g.* understanding the exact nature of the climate-change-feedback loops and the anthropogenic impacts of humanity on non-human parts of the socio-ecological systems. However, this point of view and line of argument are not an accurate representation of the current, perceived reality of human existence… the reality of the Age of Anthropocene and the time of the Great Acceleration. The precautionary principle is only one of many political, legal and ethical/moral ways to deal with anthropogenic impacts on the non-human parts of socio-ecological system. The freedom to conduct research still goes on and the normal science has not stopped after the 1992 adoption of the precautionary principle [47]. Such science has been updated, as the knowledge on climate-change-feedback loops and impacts has been updated between 1992 and the 2015 adoption of the Paris Agreement [36, 62]. For the biological sciences, the number of papers published has steadily increased between 2000 and 2017 [27]. At the same time, the number of authors per paper and the apparent interdisciplinarity in biological sciences publishing has increased for the same time period [27]. Therefore, the precautionary principle is not just contradictory, and so the regulatory science seems to have a limited impact on the normal science based on the reasoning above. The impact is likely limited to specific aspects of the biological science research, *e.g.* demonstrated by the 0.2 % increase in the similarity between the topics of papers in biological sciences and the likely increased level of this type of coherence between 2017 and 2040 [27].

Precautionary principle as a foundation for a balance between regulatory and normal science

In summary, the precautionary principle has an epistemic foundation for its derivation, *i.e.* there is an admittance by humanity that we do not know everything but that there are some of our actions which have the potential to cause good/benefits and harm at the same time. This is in relation to humanity, to *Homo deus* and non-human components of the socio-ecological systems. There is epistemic humility in the principle that we cannot predict all the outcomes of our actions, even though they might only be based on positive intentions. This humility is an expression of the need for the iterative process of normal science to continue, and the regulatory science to adopt some of the major findings, facts, findings, and knowledge about uncertainty from the normal science, translating those into its regulations and policies. The precautionary principle and its application are thus a flexible framework for the management of uncertainty of knowledge generation by *Homo deus*. They are somewhat contradictory in nature, but the contradictions are like to be limited. Finally, the precautionary principle and the related uncertainty are manifestations of the boundary between the fundamental and situational reality of human reality of existence, and that this boundary is in a permanent state of change and flux [24]. Thus, the uncertainty arises from the promotion of the discoveries of normal human science, development of technologies and the improvement of the overall human condition and the side effects of the deployment of normal science knowledge in the Age of Anthropocene and during the Great Acceleration [19]. The discussion in this section shows the duty of humanity to address and pre-empt, where possible the effects of the actions by *Homo deus* on non-human components of the socio-ecological systems. There is an inherent rationality in this duty, as demonstrated by the application of the categorical imperative above. The actions based on the precautionary principle are not vacuous and neither is the principle itself. Contradiction might, and probably do arise, from the precautionary principle in the decision-making about the human actions impacts on the socio-ecological systems. However, the precautionary principle leads to updating of the commitment and treaties that manage human actions and management of the climate-change-feedback loops on humanity and socio-ecological systems.

The time is an important factor in the nature of the boundary between the fundamental and situational reality of the existence of *Homo deus* during the Age of Anthropocene and the Great Acceleration. Dynamic nature of this boundary is an important factor in human endeavours and so it must be a consideration in the decisions that can impact the ontological realm of the socio-ecological systems. That time is often limited, as shown for the most part of living organisms [20]. Implicitly, the precautionary principle has a temporal dimension, and time is an important variable in the considerations in relations to anthropogenic activities, in relation to the manifestation of human lives and lives of all organisms on Earth. Thus precautionary principle is supportive of protecting life, it shares fundamental features with it, and it is aimed at recognition of life’s inherent value [21]. As a result of this reasoning, any contradiction in relation to the precautionary principle is temporary and quickly dissipates in case an action needs to be taken by *Homo deus* [22]. Such action would apply to the boundary between the fundamental and situational reality of the humans, non-human animals and living organisms in the ontological realm where they are part of socio-ecological systems. Precautionary principle and the balance between the normal and regulatory science are an outcome of the long line of discoveries, as mentioned above, that humans have already performed since the onset of fossil fuel use and application in the promotion of human development. Those discoveries led to impacts and by-products, which over time led to the generation of the uncertainty at the boundary between the fundamental and situational reality. Further examination of the precautionary principle and some regulatory science policies, or best practices, need to be understood from the view point of the inherent link between the molecular basis of all or most living organisms. It is also necessary about to explicate more clearly the duality of the use and possible nature of the knowledge that *Homo deus* has accumulated. One can start with the byproducts of the anthropogenic knowledge generation and deployment by *Homo deus*, which are simple in chemical structure, and which are also essential components of living organisms.

Said by-products are often dual in character, *e.g.* CO_2 is produced by living organisms and used in maintenance of their normal functioning (see next section for details). At the same time, the greenhouse gases can be produced anthropogenically, such as CO_2, and these can cause changes to the conditions of life, and they can also damage or terminate life itself. CO_2 is a symptom of the duality of chemical molecules that are related to life. In other words, CO_2 and other elements/molecules have wide-ranging impacts in terms of the human and animal wellbeing, as well as environmental health. These molecules play essential roles in the normal functioning of the living organisms, *i.e.* they are part of the molecular mechanism of the inexorability principle. However, there is an inherent duality in them: they can become a source of harm to humans and socio-ecological systems when released outside of living organisms and in much higher concentrations. Below the duality of impact of CO_2 and other chemical components of life will be interpreted more broadly in the ethical domain and in the context of the human-with-animal-with-environment interactions. The duality was discovered based on the execution and practice of normal science by *Homo sapiens* and later *Homo deus*. The knowledge deployment about CO_2 and other dual-inexorability chemicals has been the basis for the regulatory science, *e.g.* such as that which led to the drafting of the Paris Agreement. In the next section of the article, duality of inexorability chemicals is used to demonstrate the need for the regulatory science to be applied as a tool to manage the normal science. That management does take place at the boundary between the fundamental and situational reality of everyday existence of *Homo deus* in the Age of Anthropocene and during the Great Acceleration [19, 24].

Duality of the chemical composition of life and its relation to the existence of *Homo deus*

CO_2 binds the normal and regulatory science together

CO_2 is a good example of the duality that simple molecules and greenhouse gases, or their dissolved forms, can play in the living organisms and the biosphere in general. Fig. 1 shows that CO_2 plays a fundamental role in the chemistry of life. It is the ‘very raw material’ for the production of the universal energy source of living cells and organisms, regardless of their complexity, namely glucose. This is formed in the process of photosynthesis, where CO_2 or the HCO_3^- in marine environments are utilised by autotrophs to synthesise glucose (fig. 1). Glucose provides the ability for the living organisms to produce ATP and other important molecules of life, *e.g.* the pentoses for the nucleotide production in the pentose phosphate shunt. CO_2 has also evolved into the basis for the maintenance of the pH homeostasis of the living cells and (micro)organisms and the supply of H^+ in various compartments of living cells and (micro)organisms

[22, 40]. In the gaseous form, CO_2 is not toxic to human respiration at low concentrations, but it causes the following symptoms as its local atmospheric concentration in a confined space increases [30]: "increased respiratory rate, tachycardia, cardiac arrhythmias and impaired consciousness". If the volume fraction concentration of CO_2 in the ambient air reaches ten percent or more, humans start experiencing results in convulsions, coma and/or death. In other applications, carbon dioxide has been used as a cooling agent or a sorbent for contaminants, *i.e.* dry ice [29]. The bicarbonate ions also play a role in the exchange of single carbon atoms in living organisms, *e.g.* propionyl-CoA-carboxylase [3]. In this case, the CO_2 central role in the pH homeostasis, as a reactant in some enzymatic reactions, and the preservation of those role across many of the species and level of biological organisation in the Earth's biosphere, is an expression of the conservation rule of life as defined by J. Gómez-Márquez [20], namely

> "once the evolutionary process finds and selects a structure or a process that works well at any level of complexity (from macromolecules to multicellular organisms) it will not change it or if it does it would consist only in a fine-tuning".

Discussion of CO_2 shows that molecules of this compound are clearly tied into the very essence of life on Earth. It also shows that human and other living organisms, *i.e.* including non-human animals are tied together at the molecular level. The tying forces of the essence of life happen at the most fundamental level of it, *i.e.* they can be seen as an expression of the conservation rule of life [20]. As an expression of fundamental reality of human and living organisms' existence, the conservation of the favourable traits among living organisms is maintained in all organisms where it is favourable for the survival of the species [20]. Depending on the concentration CO_2 and carbon indirectly, this element and molecules in which it has covalent bonds with other atoms of life can be beneficial or dangerous to human life. This is an expression of the duality of threat *vs.* carbon's role in the essence of life will depend on human role in relation to the molecules such as CO_2 and its application. The duality in turn will be a manifestation of the human influence on the use of molecules such as CO_2 at the boundary between fundamental and situational reality of the ontological realm of human existence and the existence of the socio-ecological systems [24].

Such a role of humans can be passive, *i.e.* humans can only live with the way carbon is arranged in their body, and how CO_2 is exchanged with the environment due to the functioning of the human body. The normal scientific endeavours of humans led to the discovery of the roles that CO_2 has played in the essence of life [44]. By extension, the normal science would include exploitation of that knowledge for the management of the CO_2 essence role in human wellbeing and health, *e.g.* the management of

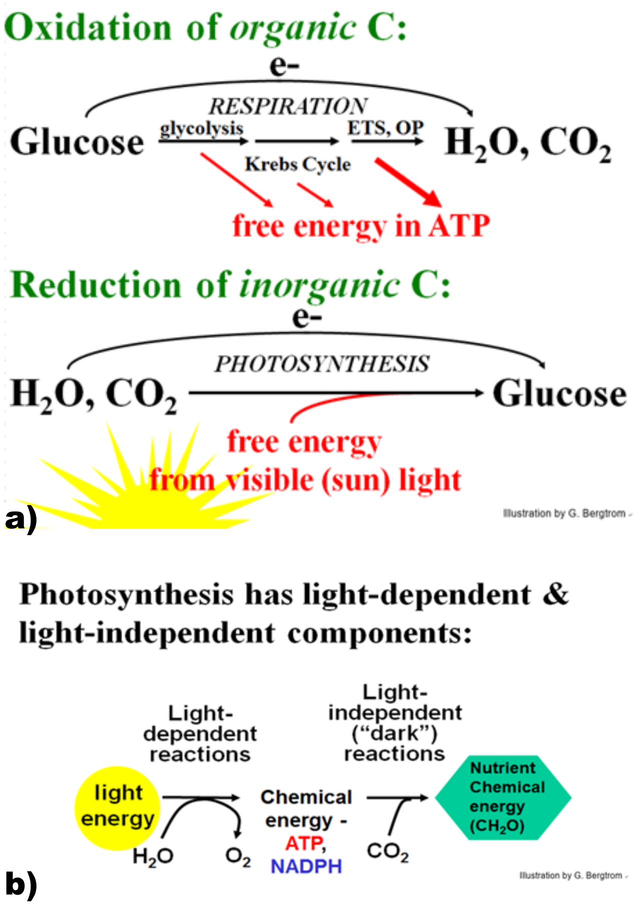

Fig. 1. Cycling of the carbon between inorganic and organic pools in the environments. The figure ultimately demonstrates the central role of the carbon dioxide in the cycling of C in the biosphere [42]

carbon dioxide in context of human health… treatment of hypocapnia and hypercapnia [4]. At the same time and in this context, CO_2 will also play a role in the maintenance of the human wellbeing, *e.g.* through medical treatment. The human role in the 'molecule's application' is passive in this context, and it is the result of the fundamental reality of human existence. The molecule executes its role based on the laws of nature (its chemical potential and energy) and based on the fundamental reality of human existence and molecular essence of life. The role of molecules such as CO_2 in the situational reality of human existence will be observed when humans actively 'deploys the molecule for a specific purpose, which they choose [24]. In that context, humans will play an active role in way that the molecules are dispersed or applied. For examples, if a human plays an active role in the way they use their knowledge of the fundamental reality to deploy a technology and to generate/contribute to the release of molecules such as CO_2 into the environment.

When looking at the development of the human deployment of CO_2, one can argue that this was done by humanity in a semi-intentional way. This line of argument will be explained in the following paragraph. Since about the 1800's, humans have been changing their reality, *i.e.* technological advancement is derived from the way in which human's discovered the fundamental laws of nature, the chemical composition of fossil fuels and technologies that could harness the energy such fuels release during combustion. The fundamental reality knowledge led to human progress, to wars and to human suffering but it also launched an era of progress and discoveries, which have improved the overall human condition over several generations. Humans have been altering their situational reality by intuitively exploiting the fundamental reality laws, etc. (based on [24]). Situational reality has, however, recently become characterised by the excessive release of human-initiated/produced CO_2 molecules into the environment and living space of human, non-human animals and all living organisms. At least since the 1980's, humans have realised that there are impacts of this intentional deployed CO_2 and it is starting to alter the socio-ecological systems, *e.g.* decreasing biodiversity and impacts of human activities on coral reefs [59]. Into the ontological realm of existence of the human's lifetime, a new evolutionary force entered, namely humans or *Homo deus*. Progress of humanity and the development at the boundary between fundamental and situational reality have reached the stage that humans have started to exercise influence on the evolutionary imperative [20], *i.e.* humans have started to create global conditions where selection pressure is exerted onto the non-human parts of the socio-ecological systems. This can lead to natural selection of species, genetic changes and drifts to adapt to the human-induced climate change. Extinction can also be result of these action of *Homo deus* in the Age of Anthropocene and during the Great Acceleration [19].

This power is realised by humanity and solutions such as continued research in normal science, as well as regulatory science of treaties such as the Paris Agreement. The level of CO_2 deployment is being regulated and controlled by humanity. Precautionary principle is being implemented, however in a limited fashion, applied by action-based, epistemically-humble and justified, and filled with the collective, anthropogenic intent to protect life. Changing human ways is not always easy and continuous negotiation ethical, moral, and scientific iteration of knowledge from normal science must be re-examined and where appropriate to feed into the regulatory science. Approaching dealing with the climate-change-feedback loops, based on the precautionary principle, requires one to realise that knowledge of *Homo deus* about the fundamental reality of their existence and the duality of the CO_2 molecules in it. It requires individual humans and the collective wisdom of humanity to manage the unknown impacts of climate change by strongly considering and by always keeping in mind the life and death nature of what *Homo deus* knows about CO_2 and similar molecules. Striking the right balance here makes it clear that normal science expresses the drive to gain move knowledge and to move forward. Regulatory science, on the hand, charts the way forward to getting that new knowledge. How this balance is struck is critical to the success of *Homo deus* in the Age of Anthropocene and during the Great Acceleration [19, 22].

Knowledge and the power of life in the Age of Anthropocene and during the Great Acceleration

Discussion in this article so far shows that the humans and non-human life are tied together with the chemical elements and molecules they form their bodies, that give them their material character. Humans are composed of a mixture of the chemical elements and component of life, and they share these features and molecular basis with the other living organisms. Life has been defined by many authors and the article/thought piece by J. Gómez-Márquez [20] will be used here to demonstrate the links to normal and regulatory science. This is not to copy that author's thoughts or arguments, but rather to provide a unified framework for finishing the argument in this article. Evolution and a certain level of natural determinism in the way chemical composition of living organisms evolved and has common features, and these are maintained across different living organisms, as well as in the optimum solution to the chemistry of life and its functioning at the molecular level. This is summarised in the inexorability principle that states [20]

"life is like that because it should be like that"

However, the inexorability principle does not imply intelligent design, as the chemical composition and other commonalities between various living organisms are not based on a pre-determined plan [20]. At the same time, the chemical nature of human life and other life is not the result or sign of causal determinism, *i.e.* the chemical composition will not be fixed in time at the scale of the fundamental reality of human existence [20]. It can undergo changes as a result of evolution and the chemical composition will thus be the result of a combination between deteminism and contigency [20], *i.e.* they are subject to change over a long period of time. By the same token, all living organisms exchange energy and matter with their environment to maintain their order, the essence of life and to continuously increase the entropy of their surroundings in order to comply with the second law of thermodynamics [20]. Life is maintained by maintaining the chemical composition of its cells and bodies, *i.e.* the order of the non-equilibrium existence of humans and non-human animals, of all life is maintained. However, given that life has survived and has been self-maintained over billions of years, throughout varying fudamental reality, life is worth protecting. It must be studied, understood and protected. In the course of the human situational reality, the study of life, at least since the progress of humanity of the 1800's had started, and it has led to the continuous discovery of the nature of fundamental reality by humans. This knowledge has developed over the situational reality of generations for the human beings, and it led to the Age of Anthropocene and the Great Acceleration. The relevant knowledge acccumulation and deployment of that knowledge at the boundary between fundamental and situational reality has led to *Homo deus*.

Besides CO_2 and carbon, other molecules and atoms with duality attached to them include those that contain nitrogen or N, and four other of the six macroelements, or atoms which are found in all living organisms, and that all biologically important molecules are made out of, namely O, H, S, and P. Each of the macroelements has a biogeochemical cycle, *e.g.* nitrogen and other atoms undergo chemical reactions which result in the movement of the macro-element atoms between various environmental and biosphere compartments. The movement can be based on physical laws, *e.g.* the Fick's law of diffusion, or based on biological agents catalysing the changes in the covalent structures which in turn allow for the inter-compartmental movement of the macro-element in question. *Azotobacter* spp. can fix atmospheric N_2 and convert it into NH_3 due to the activity of the nitrogenase enzyme [1]. Then ammonium/ammonia molecules can be converted into the amino acids and proteins [43]. Similar reactions also play a role in the conversions of NH_3 and its detoxification in the brain tissue of humans [10]. Other processes in the biogeochemical cycle of nitrogen can be seen in fig. 2. There is, however, a clear conclusion that humans and non-human animals will contain at least some of the same chemical reactions and molecules that contain nitrogen in their cells and bodies. Human discovery of the individual processes that are involved in the cycling of macroelements and the deciphering of their impact on human understanding of natural laws and biological essence of life. This can be seen as a manifestation of the fundamental reality of the human existence — an understanding of the fundamental principles and laws that govern the nature functioning, that 'control' the human existence and the space and broad parameters of the ontological realm of human existence [24]. The nitrogen cycling is another example that shows that humans and non-human animals/parts of the socio-ecological systems are intertwined at the very molecular and fundamental level of life. This manifestations of the fundamental reality of human existence proves that humans have an understanding of the interlinking and the inexorability principles of human and non-human life. As a result, *Homo deus* has a duty to manage and to be a custodian of the life at the boundary of the fundamental and situational reality of human and animal life.

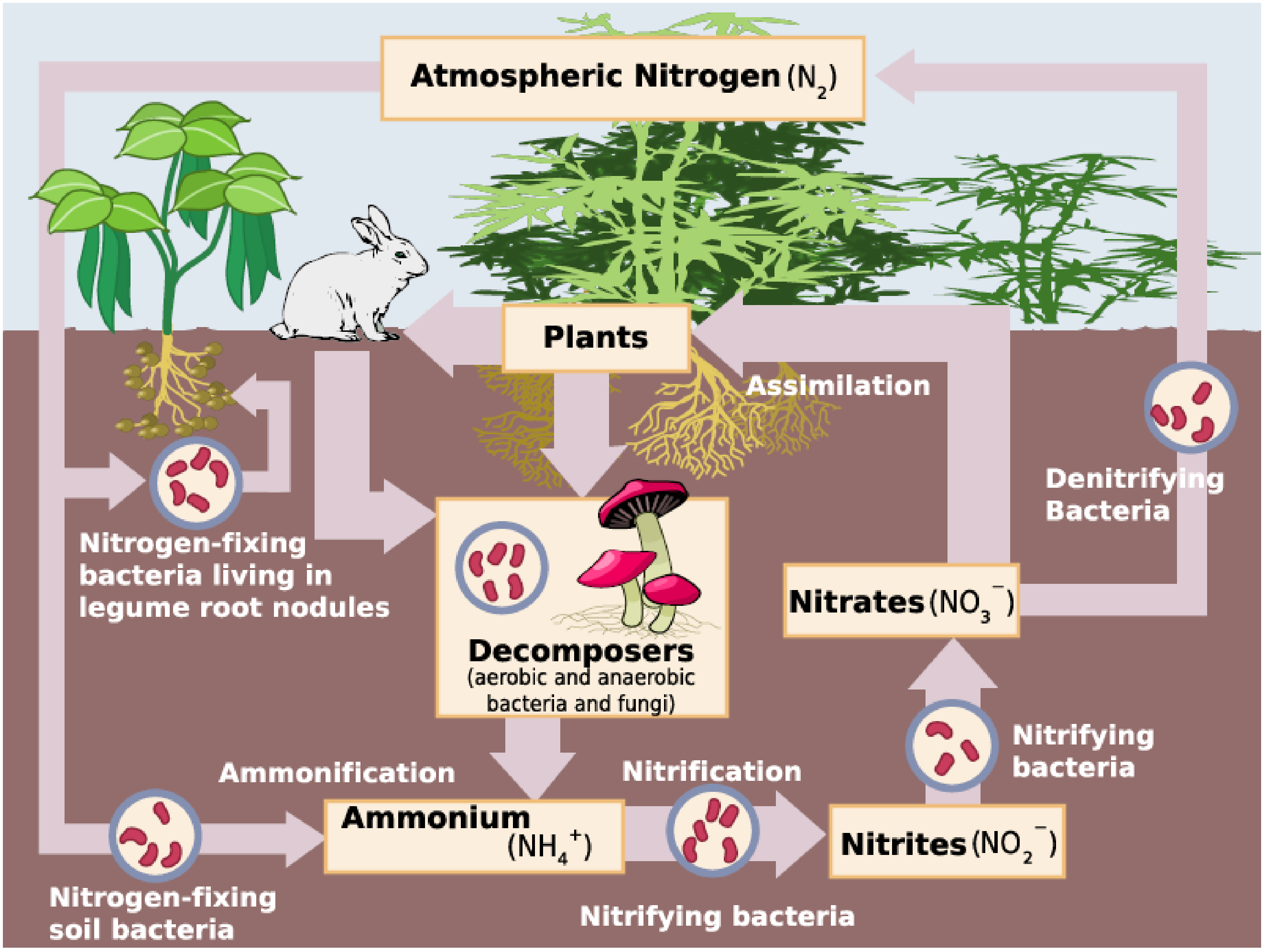

Fig. 2. N_2 is first fixed from the atmospheric nitrogen pool and then the atoms of nitrogen undergo changes from NH_3, to glutamate and glutamine, and more complex monomers and biopolymers. Cycling is completed by the processes of ammonification, nitrification and denitrification. Protein degradation in lysosomes and through the ubiquitin system provides the other steps in the nitrogen cycle [7]

Knowledge about the fundamental reality, *e.g.* the toxicity of a specific form of nitrogen, has been deployed by humans and *Homo deus* for various uses. [16] examined the ‘ethical duality of nitrogen, N_2’. Dinitrogen or N_2 is a gas which it accounts for 78 % of the total gas volume in Earth’s atmosphere [16]. This is the pool from which nitrogen can be converted into organic and bioavailable form for the biosphere (as shown in fig. 2). Yet, it has been used by humans in other uses that can demonstrate of the link of the fundamental and situational reality, based on human knowledge deployment of the N_2 molecular properties. Specifically, R. Escandon [16] talked about the inhumane suffering caused by using the properties of N_2 as an asphyxiant to execute an inmate, to carry out the punishment of death penalty. The ethically-questionable ‘humanness of the execution’ using dinitrogen as an asphyxiant can be seen as occurring at the interface of the fundamental reality of human existence, the chemical nature of the electron density distribution and the presence of one sigma and two pi bonds in the molecule of nitrogen make it inert. Those chemical and atomic properties make nitrogen chemically stable and chemically inert in the atmospheric compartment in the biogeochemical cycle of nitrogen on Earth (fig. 2). However, the inertness of N_2 also leads to the possibility to affect the situational reality of a human being executed, *e.g.* by being used as an asphyxiant in the death penalty execution N_2 deprives the death row inmate of oxygen and the ability to breathe [16]. Deliberate human use of nitrogen, specifically flooding the death penalty chamber with $N_2(g)$, eliminates another human’s access to oxygen and after a short period of time that human dies of oxygen deprivation.

On the ‘flipside of the same coin’, it can be argued that the execution of a convicted inmate ‘balances the equation of justice’ in that taking the life of the murderer in a state-sanctioned execution returns some justice to the oxygen-deprived murder victim that succumbs to the violence of the executed prisoner. In any case, the death penalty use of the dinitrogen molecules is derived from the human understanding of fundamental reality of their existence, the chemical properties of one of the macroelements that compose molecules of living organisms. However, the application of the properties of N_2 is driven by human interpretation in situational reality of the death penalty convict and the relatives of their victims. The exploitation of this fundamental reality for one sigma and two pi bonds is a specific manifestation of the nitrogen molecular properties in the situational reality of the executed convict and the victim’s family members. N_2 is a quasi-agent of life at the interface between the situational and the fundamental reality of human existence. *Homo deus* makes a judgment call how to apply its understanding of the fundamental reality at the boundary with the situational one. The dinitrogen part of the argument in this section indicates that humanity can act with a strong sense of choice about the deployment of their knowledge of the fundamental reality of human existence at the boundary with the situational reality of it. At the same time, the CO_2 part of the argument shows that *Homo deus* can reach the understanding of the intertwined character of the fundamental chemistry and reality of the human and animal life at the molecular level. Therefore, humanity and *Homo deus* has the ability, and due to the climate-change-feedback loops on human health the duty, to apply caution and rational decision making in mitigating the impacts of the greenhouse gases, such as CO_2, onto the socio-ecological systems. This calls for deployment of the humanity’s knowledge, about fundamental reality of their existence, according to the precautionary principle at the boundary, inside the situational reality of the socio-ecological system *Homo deus* is part of.

Integrating remarks and suggestions for the way forward

Discussion in the previous sections point to the benign and extreme examples of the chemical properties of the simple molecules of life and their significance in the socio-ecological systems. The N_2 example is similar to the increase in the atmospheric concentrations of CO_2, a molecule which is essential to the molecular functioning of cellular-level of life, but which can be toxic in high concentrations and if resulting from the deployment of fundamental reality knowledge by humans for a derivative/situational purposes. At the same time, excess production of CO_2 and its triggering by the Age of Anthropocene and the Great Acceleration have now made such simple molecules, outside of the life-supporting systems, a source of suffering for humanity and non-human parts of the socio-ecological systems [24]. Both N_2 and CO_2 are examples of the knowledge duality in the relation of *Homo deus* to humanity and other living organisms. Duality of life has an inside and outside dimension, as health and normal functioning of cells and death of living organisms are related to the concentration and chemical form of N or C, and also in the nature and manner of their release into the environment. The information from this article clearly shows that *Homo deus* has the power to decide whether a set of simple molecules will be deployed or produced to sustain or to end life. The boundary between the fundamental and situational reality of human existence and the existence of the socio-ecological systems is thus a manifestation of the ability of *Homo deus* to choose to support life or to end it. Therefore, *Homo deus* has the ability to choose to act in a preventative fashion in relation to life, *i.e.* to follow the precautionary principle.

More specifically, inside the living organisms, in molecule such as proteins and amino acids, inside the carbohydrates such as glucose, N and C are sources of life’s very essence. Their understanding and use by humans in relation to those ‘inside functions of life’, *e.g.* for the maintenance of health and wellbeing of humans and other parts of the socio-ecological systems, is supportive of life. The inside dimension of life’s chemical duality is ultimately aimed at decreasing pain and suffering of all living organisms, or a substantial number of them. Actions by *Homo deus* in support of life and the adherence to the precautionary principle facilitate this outside of humanity's physical bodies, but next to or in the environment of non-human animals and other parts of the socio-ecological systems. Precautionary principle can thus be seen as a way to positively manage the outside settings of life by humanity, by *Homo deus*.

If humans act inside the biogeochemical cycle of the macroelements, *e.g.* humanity directly or indirectly act inside the fundamental reality of their existence and not disruptively towards other components of the socio-ecological systems or in relation to them… if they act in support of life, then human actions are ethically justified to maintain human and non-human life. Precautionary principle is part of such efforts. However, if the CO_2 and N_2 molecules are used in relation to outside of the biogeochemical cycle of the macroelements, or indirectly in relation to them, then the situational reality of human life and the existence of the socio-ecological systems is at play — humans apply the building blocks of life in non-essential way, in a way that has caused the Age of Anthropocene and the Great Acceleration. Such application can have lethal consequences on humans and non-human animals. Such lethal consequences do occur at the interface of the fundamental and situational reality can then lead to the negative impacts on the single human life, *e.g.* inhumane death penalty due to the exposure to the N_2 overdose. The same would apply to the wellbeing and welfare of humans and animals by the ever-increasing CO_2 concentrations in Earth's atmosphere and the cascading impacts on the socio-ecological systems. From the drug discovery point of view, similar situation would be observed if the animal suffering would continue if the humanity would not have stopped or decreased the suffering of animals in the drug testing despite the experimental results showing that transfer of the knowledge from animal experiments to humans has limitations. Improvements have been made over the years in mandating the ethical review of animal studies, the changes to the addressing and naming of animal welfare to animal wellbeing, the shutting down of research facilities with primates [34]. Regulatory science has taken in the normal science findings about the fundamental reality and the end points in the animal testing have been updated to decrease animal suffering, *e.g.* the suspension of the LD50 dose experiments [15]. Some controversies still occur [14], and so precautionary principle and its application in the management of the non-human animal wellbeing is necessary. It is a critical to maintain a balance between the knowledge development and deployment, between the normal and regulatory science.

The current article shows that the precautionary principle is a way to manage the need for the normal science, *i.e.* knowledge and data collection about the fundamental reality of human existence, and the knowledge management and deployment at the boundary of the fundamental and situational reality of existence of *Homo deus* (regulatory science). It is clear that humanity has the ability to choose to act and to deploy their knowledge in a specific way, and also in an ethical way. Precautionary principle is grounded in the inherent uncertainty of the Age of Anthropocene and the Great Acceleration. The current article clearly shows that the precautionary principle can be applied effectively is *Homo deus* chooses to do so. There is also a continuous need to provide regulatory science oversight in order to protect or to minimise the suffering experienced by the non-human animals and other parts of the socio-ecological systems globally.

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Зв'язки між життям людини та тварин в епоху антропоцену: від молекул, через реакції до клітин, розвитку та питань етики

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Протягом останніх двохсот років зроблено відкриття у фізіології тварин і людини, хворобах та розробці ліків. Тварини стояли в центрі експериментів з оптимізації доз ліків та шляхів введення. Прогрес людства зумовлений різними антропогенними цілями та прагненнями. Невпинно зростають розвиток знань та відкриття щодо фундаментальної реальності людського існування та онтологічної сфери, в якій продовжують розвиватися соціально-екологічні системи. Представники *Homo sapiens* зараз досягли розуміння, сили знань та дій, здатних впливати на екосистему Землі. Це призводить до побічних продуктів людського прогресу, наприклад, CO_2, які почали змінювати фундаментальну/ситуативну межу реальності людського існування та онтологічну сферу соціально-екологічних систем. Переваги та страждання людей і тварин, окремо та разом, можна розглядати крізь різні призми — наприклад, принцип запобіжних заходів. У цій статті використовується методологія, яка поєднує біоетичний та теоретичний біологічний аналіз принципу запобіжних заходів і його наслідків для взаємозв'язку між людиною та ширшими соціально-екологічними системами. Цей принцип може надати певні вказівки щодо етичного розуміння подвійності людських дій під час антропоцену та Великого прискорення, а також того, як це пов'язано з самою хімічною сутністю життя. Люди розвивають свої знання про фундаментальну реальність як частину пошуку істини, розуміння хімічних та інших вимірів природи життя. Це «нормальна наука», тобто пошук «істини» або людського розуміння фундаментальної реальності існування, який рухає людство вперед. Однак її використання для розвитку людства створює побічні продукти, які потребують «регуляторної науки» або встановлення правил для регулювання використання знань, отриманих з нормальної науки. Прикладом цього може бути необхідність вжити заходів та пом'якшити наслідки зміни клімату по всьому світу, вплив як на життя людини, так і на життя тварин.

Ключові слова: принцип запобіжних заходів, рівні біологічної організації, етичні рамки

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