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How does the environment affect human ageing? An interdisciplinary review

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The multifactorial process of ageing is one of the biggest biological and medical challenges of the 21st century with age-related conditions such as cardiovascular diseases, neurodegeneration and cancer being among the leading causes of death among industrialized countries. Rather than one single causative factor, a range of environmental, demographic, biological, behavioral and social factors determine the development and onset of age-related diseases (ARDs). While it remains a challenge to assess the cumulative effect of environmental influences on human ageing, growing evidence indicates that both ARDs and non-pathological ageing processes are driven by environmental influences. The present review takes a closer look at the different environmental factors including air, climate, water, soil, urban green, social and individual environments and their influence on common ARDs and other life-limiting pathologies. It is of major public health relevance, to understand the interactions between these factors to develop preventive strategies both at individual and societal level to support healthy ageing.

Key words: environmental influences, ageing, human-environment-interaction, exogenous influences, healthy environments, senescence

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INTRODUCTION

Ageing is a unidirectional, intrinsic process occurring in all cells and characterized by functional decline related to an increased risk of morbidity and mortality. Both genetic and environmental factors have an impact on cellular senescence [1,2]. People age at different rates and this diversity is the result of the cumulative impact of advantage and disadvantage within the physical and social environments they live in. The environment itself is a complex and manifold combination of different dimensions such as physical, psychological, social and cultural [3]. As estimated by the World Health Organization, only as less as approximately 25% of the diversity in longevity is explained by genetic factors, while the other 75% is largely the result of the impact of our interactions with environments and exposures [4]. The degree to which environmental factors exert a profound effect on these processes is currently investigated in multiple studies and to date not fully understood, yet some risk factors have been identified. It is a major challenge to link environmental factors to specific cellular processes due to the complexity of the interaction, the long-term efficacy, the multifaceted interactions and the interference of several confounding factors. In light of the demographic change and considering that environmental exposure is potentially one of the modifiable risk factors for different diseases, the identification of such factors is a major strategy in lowering the burden of disease in elderly people [5].

We here critically review the most appealing findings regarding environmental factors influencing and accelerating the ageing process and supporting the development of life-limiting ARDs such as cancer, dementia and cardiovascular disease because they represent the leading causes of death in industrialized countries and pathologies deriving from specific environmental influences (air, climate, water, soil, built and social environments) and associated with intrinsic mortality leading to premature death.

Given the complexity of this extensive topic, the present review can only provide a basic overview.

Age-related diseases

ARDs are generally viewed as being triggered by and evolve around the physiologic deterioration that occurs with advancing age. Thus, ARDs, which may manifest with both chronic and acute symptoms, are usually the results of long-term processes [6]. It remains however of debate, whether ARDs are an integral part of the physiologic aging process or rather a pathophysiologic process. The trans-National Institutes of Health Geroscience Interest Group (GSIG) has identified a set of seven highly intertwined processes at the core of ARDs: i) adaptation to stress; ii) loss of proteostasis; iii) stem cell exhaustion; iv) metabolism derangement; v) macromolecular damage; vi) epigenetic modifications, and vii) inflammation [7,8]. In regard of the fact that both "normal" ageing and ARDs share these common mechanisms, it has been hypothesized that ARDs and geriatric syndromes are to be understood as acceleration of the ageing process and therefore part of one continuum [6]. This acceleration, however, is dependent on molecular and cellular processes that are influenced by both genetic and environmental factors (Fig. 1).

The most common examples of severe ARDs leading to premature death are dementia, cardiovascular diseases and cancer. Other age-related conditions, such as type 2 diabetes, hypertension, osteoporosis or arthritis may act as modulating risk factors. Several ARDs are among the leading causes of morbidity and mortality [9] and pose an enormous emotional, physical and financial burden on affected patients, caregivers and societies. Recent findings and a broader knowledge of the underpinning mechanisms of ageing and age-related diseases have led to the consensus that human health span is potentially to be prolonged [8].

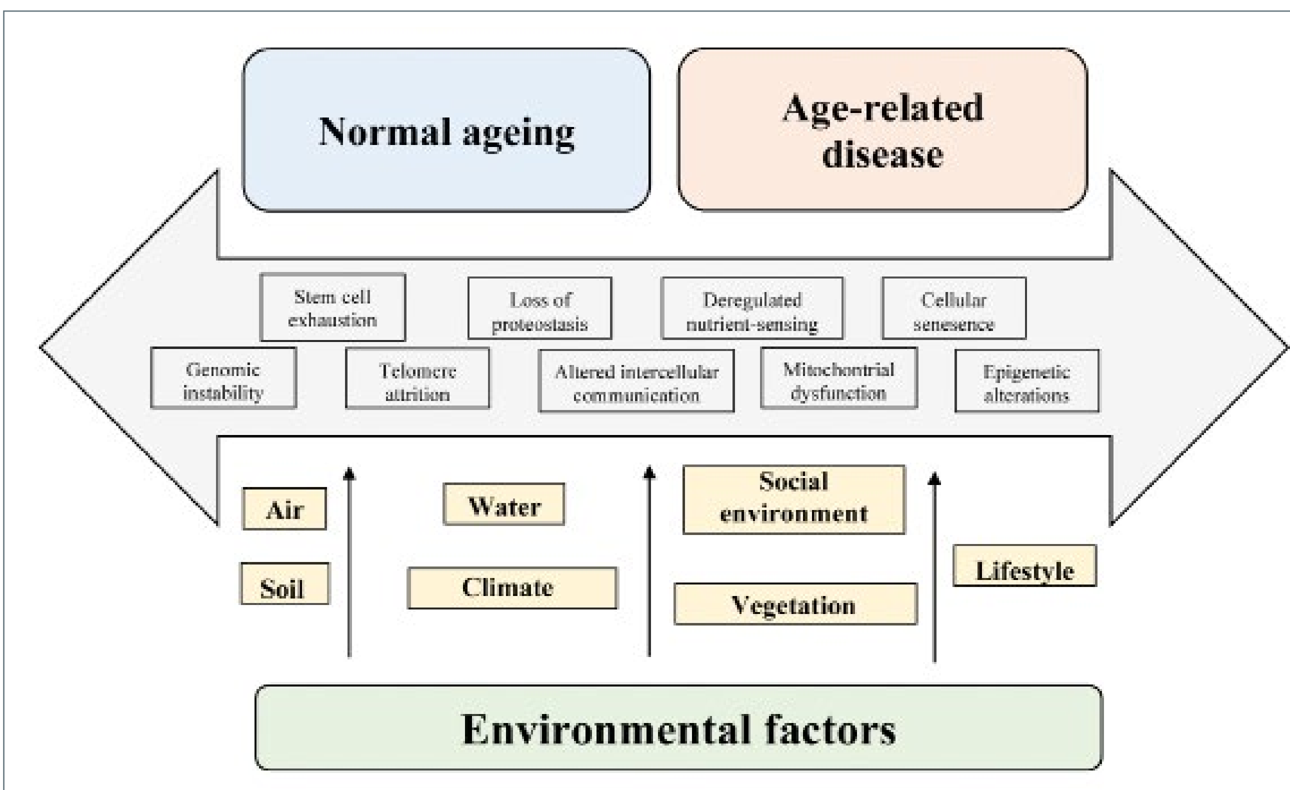

Figure 1. Normal ageing and ARDs, boundaries, interactions, and possible environmental factors.

METHODS

Within an in-depth PubMed-search we considered studies (including meta-analyses and reviews) published in the past 15 years (2004-2019). For each of the environmental and socioeconomic factors (e.g. “air”) and the keyword “ageing” (e.g. “air AND ageing”) and the most frequent ARDs, a literature search was performed (Fig. 2). In case of less than five or fragmentary results, an additional search within google scholar was performed. References from selected papers were manually reviewed for additional studies and other age-related pathologies outside the three disease clusters.

ENVIRONMENT AND HUMAN AGEING

The human environment with its abiotic and biotic compartments is complex and encompasses different dimensions on multiple layers all of which are constantly interacting. As described by Dahlgren and Whitehead (1991) and others, an individual with his inherent constitutional factors finds himself at the center of different interacting layers, framed by socioeconomic, cultural and environmental conditions [10]. All of these dimensions interact such as the conditions of one level determine those of another (e.g. lower socioeconomic status is more likely to be associated with a lower education level, poorer living environment).

Natural environment

The ecological environment comprises abiotic (soil, water, air) and biotic factors (organisms) [11]. These factors determine human evolution and are the most basic framework to any social and cultural development since people need to interact with the environment to obtain basic needs such as food, shelter and to create social and cultural networks. However, the natural environment does not only promote evolution and longevity, but triggers pathologies, mutations and tissue aberrations. With increasing civilization (i.e. invention of antibiotics, hygienic conditions, biomedical understanding) acute threats coming from the natural environment have been minimized. Within the Anthropocene with significant human impact on natural environments, a shift from acute to chronic and ARDs is observed [12].

Air

The interaction, manipulation and exploitation of the environment for human purpose leads within a modern Western perception towards improved living standards but introduced also environmental damage such as air

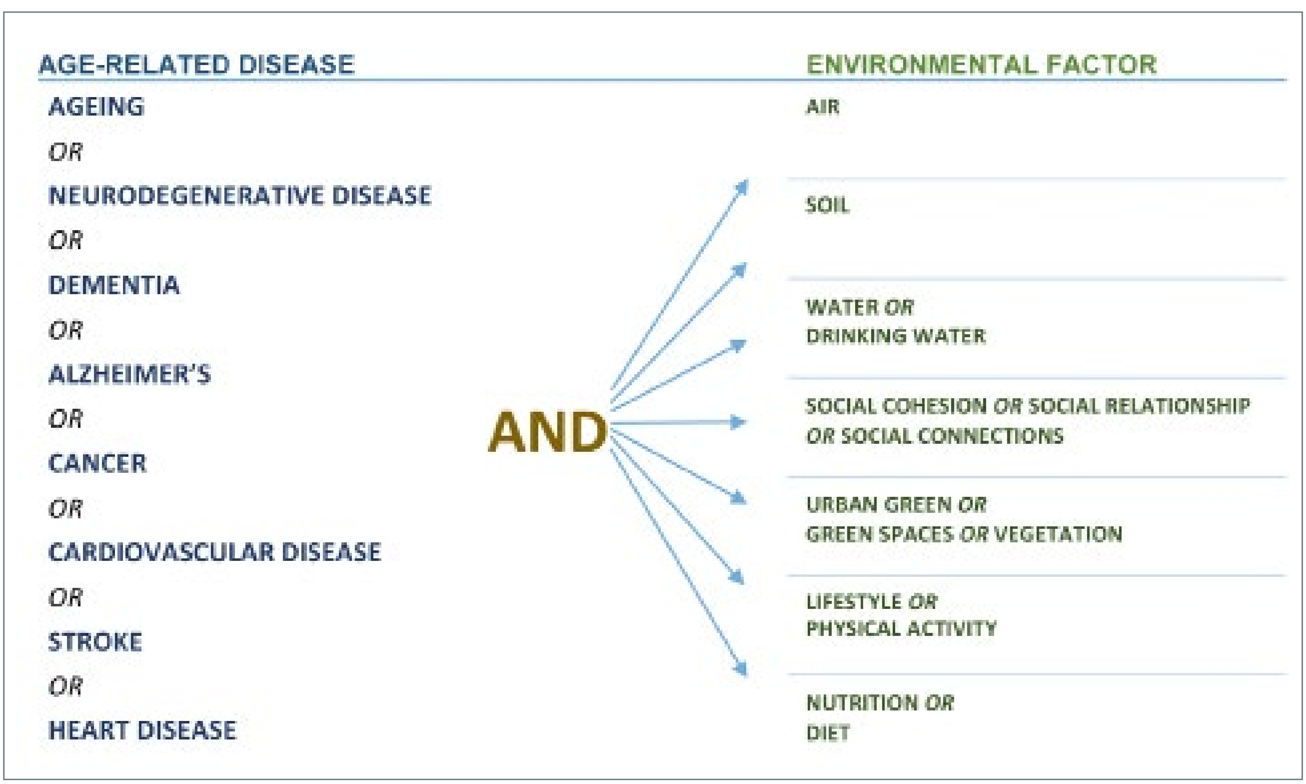

Figure 2. Key words used for the literature research. For the search, one age-related disease keyword plus one environmental factor keyword was entered into the search engine.

pollution. Air pollution is a major global health problem with severe effects on human health [13]. While the health-associated risks have been identified for decades and policies towards a less polluted air have been initiated, many middle and high-income countries have failed to decrease urban pollution levels [14]. The World Health Organization estimates that 7 million premature deaths per year are linked to global air pollution [14,15]. While in Asian developing countries residential energy use (e.g. heating and cooking) have the largest impact, in Europe, USA and Russia agricultural emissions make the largest relative contribution to particulate matter (PM) 2.5 [16]. Overall, 20% of the global burden of air pollution are due to ammonia, which contributes to PM2.5 formation, whereas in much of the USA and in a few other countries also traffic and power generation account for air pollution [16].

Exposure to polluted air was in multiple studies described as a major threat to human health triggering different severe somatic and psychiatric diseases with respiratory diseases, cancer and cardiovascular damage being among the most prominent ones. A broad range of pathophysiological processes are initiated or enhanced after acute short-term exposure to polluted air, i.e. altered inflammatory and oxidative status, reduced heart rate variability, arrhythmias, endothelial dysfunction, promotion of thrombosis, progression of atherosclerotic damage, stroke, atrial fibrillation and heart failure can be associated with acute exposure to air pollution [17]. The International Agency for Research on Cancer has defined air pollution as a group I carcinogen [18,19]. A prospective analysis from the European Study of Cohorts for Air Pollution Effects used within the framework of a longitudinal study the data of 17 cohort studies from nine European countries with over 4 million participants and concluded that PM air pollution contributes to lung cancer incidence [20]. Importantly, not only lungs and airways are affected, but air pollution can also damage most other organ system of the body as the smallest particles can reach the bloodstream [21]. A recent study underlined, that long-term exposure to PM10 and O3 increases cancer risk but the effect on cancer risk was compounded by obesity, smoking, and physical inactivity among subjects over 50 years old [22]. Additionally, inhaled or ingested pollutants contribute to vascular morbidity since the heart and vascular system are highly vulnerable and susceptible to environmental agents [23]. Most strikingly, air pollutants can trigger a broad range of cardiovascular symptoms, including myocardial infarct and stroke, as they can occur within hours of exposure [24]. Supporting evidence comes from epidemiological studies linking roadway-proximity to an elevated risk of myocardial infarction, sudden cardiac death, fatal coronary disease, post-stroke mortality and elevated mortality risk after hospitalization with acute heart failure [25].

Alzheimer's (AD) pathology with its well-described amyloid beta plaques and tau tangles as histopathological key components can only account for around 50% of all reported dementia cases in most industrialized countries, while for most other forms such as vascular or mixed dementia environmental determinants may play a major role [26,27]. The effect of air pollution on cognitive decline is mirrored in epidemiological research pointing towards differences in cognitive performance between individuals of all ages living in more and less polluted areas [28-30]. The Health Retirement Study found a specific memory deficit with increased exposure to PM2.5 that was the equivalent of a 1.7 to 2.8-year age difference [31]. For individuals living close to a major road, Wellenius et al. (2012) found 34% increased odds of having a low score in cognitive testing [32]. These results were mirrored in other studies, where BC concentrations were associated with 30% increased odds of lower scores [33] and a five-year average PM2.5 and PM10 with changes in memory function [34].

Besides, some studies suggest an increased risk of Parkinson's disease, a neurodegenerative disease clinically characterized by motor symptoms such as resting tremor and muscle rigidity [35,36]. While more research is needed to fully understand the interaction between air and neurodegenerative diseases, a recent meta-analysis of the major published data concluded that long-term exposure to NOx, NO_2, CO, and O_3 was associated with an increased risk of PD [37].

Climate

Climate (assessed via temperature, precipitation, humidity, wind, atmospheric pressure etc. on the long term) defines and directly affects public health as exposure to ambient temperature has an immediate and strong impact on people's health and wellbeing. While humans are capable of adapting to small changes in mean ambient temperature, both being exposed to extreme cold or hot temperature is problematic for the human body. Generally, extreme cold and increased heat are associated with higher mortality especially amongst the elderly [38]. Meanwhile, it is widely consensus that global climate change mainly due to anthropogenic causes will lead to a rise in mean temperatures and frequency of extreme heat waves, in particular in urban settings [39]. While political controversy regarding causation is ongoing, over the past decades the global average surface temperature has been steadily increasing and the frequency, duration and severity of heat waves have become more frequent. Especially in the elderly, exposure to extreme temperatures causes health problems leading to increased morbidity and

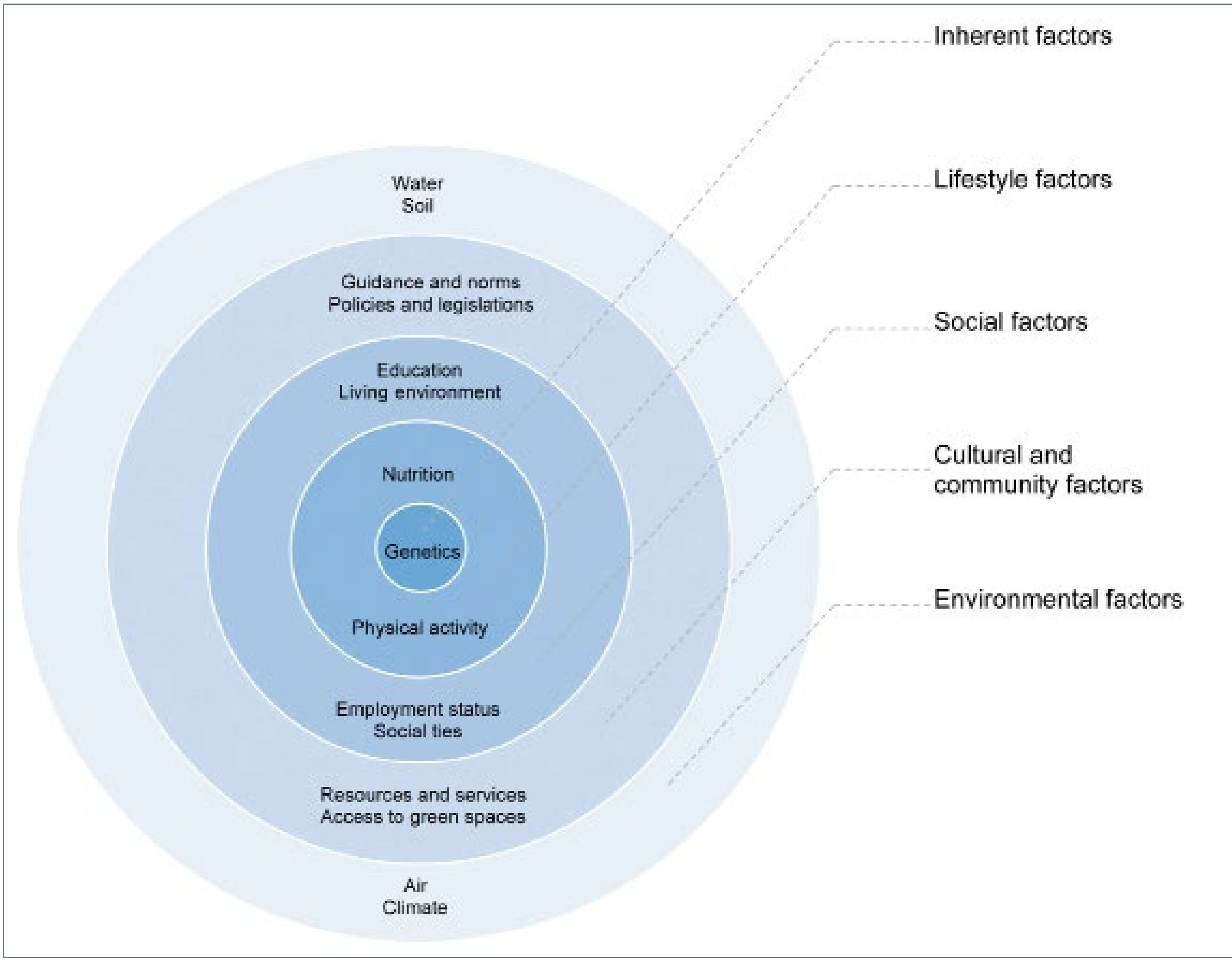

Figure 3. Human environment is multidimensional and different interacting layers including inherent factors and environmental and socioeconomic factors (few examples per layer given) determine the overall health status of an individual (from Dahlgren and Whitehead, 1991, mod.) [10].

mortality during heat waves [40]. Within the thermoregulatory responses to heat stress, the human body increases blood flow trying to redistribute blood volume from the central to peripheral circulations and sweat rate placing therewith a great demand on the ageing cardiovascular system [41]. While for humans short-period physiological homeostasis through evaporation of sweat is even in extreme temperatures possible, prolonged moderate heat stress is difficult to outbalance for older individuals, which have, amongst an aged vasculature, also a decreased sweat rate [42]. Consequently, especially in the elderly, the majority of excess deaths during heat waves are due to cardiovascular problems, but an increase in respiratory deaths and cerebrovascular deaths contribute to the increased mortality as well [41]. During the 2003 heat wave in Europe, three days after the start and until four days after the conclusion of the heat wave, 70.000 excess deaths across the entire continent were counted [43,44]. With rising temperature due to climate change, older adults with a low socioeconomic status – since owning air condition, hydrating, dressing in light clothes and having access to transportation and social contacts are associated with decreased mortality – and poorer health conditions are most at risk to suffer from heat stress [45]. Climate is therefore a tolerance factor relating to longevity with a moderate climate being more conducive to human longevity than extreme climate [46,47]. With the increasing number of older people on the one hand and the rapidly warming earth's climate on the other, further measurements in order to lower anthropogenic pollution leading to global warming and irreversible changes in ecosystems around the world are therefore much needed to allow human longevity.

Water

The quality of drinking water is closely linked to human health as the consumption and use of water is an essential and everyday part of human life. Lack or excess of certain chemical elements may result not only in acute but also in long-term adverse health effects. Classic contaminants in water such as nitrites leading to gastrointestinal infections are well documented and strictly limited in drinking water regulations. However, also chronic and ARDs may be triggered by the specific composition of water and due to human's needful lifelong consumption of it. Accordingly, several studies suggest a relationship between water hardness, calcium (Ca) and magnesium (Mg) levels in drinking water and cardiovascular diseases: Many but not all studies found a protective association between Mg levels and cardiovascular diseases while for Ca and water hardness little evidence was found regarding these diseases [48]. However, as Ca is one of the most abundant elements in humans – being a major component of bones and also essential for both muscle and nerve functioning – drinking water rich in Ca may have a positive impact on both bone density and reduce associated diseases such as osteopenia and osteoporosis in elderly population [49-51]. Additionally, several studies link deficits in both Ca and Mg to an increased mortality regarding oncological diseases).

Recently, a study assessing the entire Slovakian territory found worse health status and lower life expectancy with regard to an increase in oncological, cardiovascular, gastrointestinal and respiratory diseases at low level of both Ca and Mg [52]. The scientists concluded that drinking water from public supply should be increased at the following concentrations: Ca > 50 $mg \cdot l^{-1}$, Mg > 25 $mg \cdot l^{-1}$, and Ca + Mg > 2 $mmol \cdot l^{-1}$ [52]. Additionally, when examining water properties in Southern Chinese regions high total hardness and Mg/Ca ratio was found to be positively associated with a prolonged lifespan [53]. Regarding alkaline drinking water, often discussed of having beneficial effects on vessels and prevent cancer, a systematic review suggested lately that to date findings are insufficient to either support or dismiss this hypothesis [54].

Often discussed is the effect of lithium (Li^+) in drinking water: Zarse et al. (2011) found that long-term and low-dose intake of Li+ via drinking water may exert anti-aging capabilities in nematodes and decrease mortality in humans [55]. In 2014, a systematic review concluded that according to findings thus far, Li^+ in both standard and trace doses appear to have biological benefits for dementia [56]. Meanwhile, a recent Danish nationwide study found a lower level of lithium exposure to be associated with a lower incidence rate of dementia in a non-linear way while confounding factors can clearly not be excluded [57]. Chinese regions associated with longevity seem to have a higher level of Li+ in their drinking water [58]. In Texas, trace lithium in water was negatively associated with rising rates of AD, as well as obesity and type 2 diabetes, which are important risk factors for AD [59]. Previously they found lithium concentrations in tap water negatively associated with all-cause mortality and years of potential life span [60]. Other substances and above all heavy metals such as lead (Pb) and cadmium (Cd) negatively influence people's health: Cumulative lead exposure may adversely affect cognitive functions [61]. Additionally, high levels of manganese in drinking water in Bangladesh or Myanmar were shown to have neurotoxic effects and may lead to Parkinson's disease [62]. Long-term exposure to selenium through drinking water has been associated with elevated risk for several cancers and neurodegenerative diseases such as Parkinson's and amyotrophic lateral sclerosis [63]. However, results are ambiguous as high soil Se concentrations were also associated with a reduction in Parkinson's disease mortality rates in the USA [64]. Also for uranium (U), which seems to promote cancers as well [65], further investigations are needed. Altogether, while further research is necessary, studies thus far suggests that water consistency may have an impact on ARDs with especially heavy metals being detrimental and moderate doses of Mg, Ca and Li^+ being potentially beneficial for the process of healthy ageing.

Soil

Like water, soil can influence human health as it contains trace elements and may contain other, potentially harmful substances. Anthropogenic activities (industry, agriculture, mining etc.) significantly change the properties of soil. The quality of soil has an impact on human health, as through plants, water and animals it finds its way into the food chain and can directly be ingested by children as part of voluntary or involuntary geophagy. To date, there are only few studies on soil and its impact on ageing. Selenium (Se), a micronutrient of both natural and anthropogenic sources (e.g. fertilizer) was positively correlated with longevity index in China [66]. Consistently, some studies have demonstrated an anticarcinogenic effect of some organic forms of Se in regard to lung, colorectal and prostate cancer when taken in adequate dose [67] while others found a negative impact of Se on human health when taken in high concentrations [68]. Liu et al. found a negative correlation between barium (Ba) and nickel (Ni) with longevity indexes [66]. Both Ba and Ni are heavy metals, increased in soil through anthropogenic activities. Other substances, such as organochlorine pesticides, meanwhile banned in most developed countries, act as neurotoxins and have been linked to cognitive decline in elderly [69].

Recently, the effects of aluminum were brought into discussion: Aluminum is absorbed through food, water, drugs and the use of cosmetic products on the skin. While some studies pointed out a potential association between aluminum and AD and breast cancer, it remains controversial whether it contributes to the development of these diseases [70]. A high dose of aluminum as it may occur within dust exposure in specific workplaces may lead to severe critical adverse effects including specific encephalopathy, which is, however, not identical with the pathophysiology of AD [71]. Recently, an increasing trend to consume organic food, which is produced with restricted use of synthetic pesticides, is observable. However, environmental contamination occur in both, conventional and organic foodstuff since the proximity to traffic, chemical industries etc. determines the occurrence of pollutants [72].

Accordingly, a recent review concluded, that organic food might not necessarily be healthier than conventional food when exposed to indirect pollution [72].

Altogether, while further research is necessary to shed light on how the different components of soil may interfere with human aging, with regard to the principal of minimizing, exposure to potentially harmful substances should be kept as low as possible.

Man-made settings: built and social environments

The human imprint on the natural environment and its consequences for humankind are manifold, as it not only changes ecological patterns and systems, but also assets, economies, cultures and public health. Social and personal lifestyles arise from culture-mediated interdependencies and take place within natural settings changed by humans. There is, however, no strict dichotomy between natural environments and human constructs, since these dimensions are closely intertwined and influence the respective scenery. Individual health choices always take place within a society, where different policies shape with regulations, legislations and cultural norms the environments and health risk for populations [73]. People's health is strongly related to the environment they live in, but as the environment itself is complex and multidimensional rather than a single factor, the interaction of ecological, social, personal and cultural factors promotes the development of ARDs. The different bio-social dimensions are therefore to be understood in their interrelation, as multiple environmental exposures on different levels (e.g. air, lifestyle, socioeconomic background, working situation, nutrition, access to green spaces etc.) play together in the development of age-related phenotypes. Since these complex dimensions are important as they determine the risk of ARDs and longevity, the following section will give a tight overview about the most important aspects without illustrating them in its entirety.

Urban green

Humans act upon local ecology and create cultural and social identities through settlement into cohesive communities [25]. Throughout the process of civilization, humans have built artificial, non-natural environments to protect themselves from natural threats and created new anthropogenic threats to human health such as pollution, noise and crowding. By now, daily life for the majority of the world's population takes place in artificial built environments. While urbanization is clearly one of the leading global trends of the 21st century, humans display innate biophilic preferences [25]. There is a large body of evidence, that people prefer viewing natural over urban environments and that walking in nature is associated with increased wellbeing, cognition and fewer mental disorders among older people [74-78]. While on the one hand cities tend to be better equipped regarding access to healthcare infrastructure and greater educational opportunities, on the other hand they offer less interaction with natural vegetation, animals and sunlight. Residential green has been repeatedly associated with lower levels of cardiovascular diseases such as stroke [25]. Additionally, living within the proximity of greenspaces is associated with lower levels of stress, diabetes, with increased physical activity, better general health and social cohesion [75,79-81]. Within elderly people, urban green spaces seem to have a restorative effect [82] and can thus be considered both a protective factor against accelerated ageing and a therapeutic measure after onset of ARDs. Altogether, frequent exposures to landscapes with natural elements such as neighborhood street trees, small parks, or views of nature out of a window have a salutogenic impact on human health [83].

There are, however, rural-urban disparities regarding ARDs: Dementia appears to be more often diagnosed in rural settings [84]. It remains to be understood, why rural populations seem more susceptible to dementia and cognitive decline, however, educational opportunities and reduced public health supply may play a role [85]. For ARDs belonging to the cardiovascular cluster, particulate matter as it occurs in both urban areas and rural environments with intensive agriculture is a known risk factor. Several epidemiological studies examined the incidence rate of different cancer types, however, the results seem ambivalent [86]. Altogether, while further interdisciplinary research is needed, both rural and urban environments with its diverse environmental conditions poses positive and negative challenges onto human health.

Socioeconomic background

The sociocultural context of a person's life determines longevity and the individual risk for age-related diseases. The development of ARDs depend on exposure to harmful or protective environments, which in term are strongly associated with an individual's social status (e.g. working place, living conditions etc.). A well-described and significant socioeconomic gradient in health accounts for large differences in long-term health outcomes between people of different social backgrounds [87]. The higher individuals rise in social hierarchy, the better is their health. Since the "Black report" in 1988, a compelling body of studies from different countries has accumulated showing how social determinants shape health and promote or reduce healthy ageing [87,88]. By now, multiple studies have consistently shown that each grade of employment in industrialized countries has a higher level of morbidity and mortality than the one above it [89,90]. The improved health status in higher positions derives from increased human capital, better education, favorable living conditions, better psychosocial resources, higher occupational complexity, healthier lifestyle and better access to health care. Low education level and potentially modifiable risk factors account for almost half of all deaths in the USA [91] – findings, which have been mirrored in multiple European studies. The socioeconomic position defines not only the broader contextual environment with its diverse abiotic and biotic factors an individual lives in, but determines also which lifestyle behaviors are more likely to be adopted. All of these environmental conditions be it natural or social, exert ultimately an influence on cellular level and promote or reduce the outbreak of ARDs.

Social cohesion

Individuals are intertwined through social relationships. Deficits in social relationships such as social isolation or low social support can lead through chronic activation of immune, neuroendocrine, and metabolic systems to ARDs [92]: a representative longitudinal sample of the US population found that social isolation increases the risk of inflammation and promotes hypertension [93]. Moreover, social activities and religious involvement are associated with lower levels of allostatic load [94] and help to preserve cognitive function as people age [95]. Like most ARD-risk-factors, physiological vulnerabilities to social integration may be specific to life stage and seem to set the course early: Individuals who experience social deficits in early life are more prone to diseases in later life and have higher level of C-reactive protein in midlife [96]. Lack of social connections increases the odds of death by at least 50%, comparable to risk factors such as smoking, alcohol consumption, high blood pressure, physical inactivity and obesity [97]. As people age, the environment plays an increasingly important role and defines whether and to what degree an individual participates in social interaction, community engagement and physical activity [98]. Accordingly, geriatric depression is triggered by social and economic variables [99]. Research has found a strong correlation between social participation and positive health status in elderly among different communities in North America, Asia and Europe [96]. People, who regularly engage in social, cultural or intellectual activities built up a so-called "cognitive reserve" and are less likely to develop neurodegenerative disorders [97,98].

Lifestyle: physical activity and nutrition

People in lower socioeconomic positions seem to adopt more readily and more frequent health-harming behaviors [88,100,101] such as smoking, sedentary behavior, poorer diets, lower therapeutic compliance [102]. The contributing factors are manifold and complex and include besides material factors, differences in knowledge and skills, in living and working conditions and cultural norms [103,104]. Moreover, people with lower educational status appear to be more pessimistic, put more weight into short-term gratification than into long-term outcomes and have a stronger belief in the influence of chance on health [102]. Most of these underlying behaviors do not follow free and individual choices but are rather a form of adaptation to the social, cultural and economic constraints.

Physical activity

The default mode for humans is to be physically active while inactivity is associated with a higher burden of disease in older age. Effectively, sedentary behavior is an independent parameter of mortality [105]. Several epidemiological studies have examined the association between physical activity and healthy ageing. The Harvard Alumni Study, the Whitehall Study and the Nurses' Health Study have consistently proved associations between physical activity and exceptional survival [106-108]. It is known that physical activity is a key element in predicting a non-disabled 65-year-old man's chances of surviving to age 80 and being non-disabled prior to death [109]. Health benefits of physical activity are even seen among individuals who became physically active late in life – suggesting that physical activity has both protective and restorative impact [110]. The underlying mechanisms are not fully understood, it seems, however, that aerobic exercise improves DNA repair mechanisms, is associated with an upregulation of protective proteins, has a positive impact on mitochondrial function and on telomere length and leads to a downregulation of negative regulator proteins of cell cycle progression [111]. Moreover, physical activity is beneficial for circulating concentrations of insulin, insulin-related pathways and inflammation [112]. Physical activity with its many effects on multiple organ systems is inversely associated with different cancer types such as breast [113], endometrial [114,115] and colorectal cancer [116]. In terms of prevention, a minimum of 2.5 h per week of moderate-to-vigorous physical activity led to a significant 13% reduction in cancer mortality [117]. Moreover, regular physical activity and elimination of sedentary lifestyle has been associated with a reduction of 15-39% of cardiovascular disease and 33% of stroke [118]. Additionally, physical activity is associated with a lower incidence of psychiatric conditions in older age such as cognitive impairment and dementia [119,120] possibly due to improved mechanisms of neural plasticity triggered by regular physical activity [121].

However, movement takes place where the physical environment allows it. The environmental influence on physical activity participation is well established: A high proportion of urban green spaces provides a venue for outdoor physical activity; cycling and pedestrian networks contribute positively to movement for those living in proximity [122]. Environment features such as destinations to walk to, fewer uncontrolled intersections and low traffic density are also associated with increased outdoor activity [123]. The concept of "walkability", as measure of the extent to which built environment allows physical movement and presence of people, is therefore of high public health relevance [124]. Eventually, socioeconomics define where and how people live. Accordingly, poverty may account for environmental barriers to physical activity. Besides, seasonality – as another strong environmental factor – has an impact on human movement. Both very cold and very hot weather is a barrier to physical activity participation [125]. In sum, physical activity is a key element for healthy ageing while it depends on a variety of personal, social, economic and environmental factors whether people engage in physical activity or not.

Nutrition

Additionally to physical activity, nutrition plays a major role in healthy ageing and has the potential to reduce the risk of several ARDs. While the debate on the optimal nutrition is ongoing, the Mediterranean diet, characterized by a balanced combination of fruit, vegetables, fish, cereals and polyunsaturated fats and reduced meat and dairy products is considered the optimal combination to preserve health and improve longevity [126]. This dietary pattern contributes with its anti-cancer, anti-inflammatory and anti-obesity properties due to its antioxidant elements, unsaturated fats and fibers to a risk-reduction of many ARDs [127]. Moreover, a moderate caloric restriction (i.e. restriction of proteins or other individual nutrients with respects to carbohydrates) positively affects lifespan and cognitive function [128]. The quality of people's foods depends, however, on its production. In any urbanized society, the majority of people eat food raised by others, which most often contain non-additional additives that may influence human health. Moreover, the socioeconomic background plays an important role in people's food choices, as higher occupational social classes are significantly associated with greater food expenditure, which in turn is associated with healthier purchasing. Altogether, energy-dense and less nutritious foods are often cheaper sources of calories while higher food quality is often associated with higher cost [129].

CONCLUSIONS

Guidance and norms, policies and legislation

Environmental health policies can be implemented from local to international levels. Accordingly, policies vary between regions and according to decision-makers. A recent approach at a global level to protect the environment and thus indirectly human health is the so-called "Paris Agreement", adopted under the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. However, by 2017 a study found that all major industrialized countries were failing to meet the pledges they made [130]. With regard to healthy ageing, the World Health Organization has adopted a "Global Strategy and Action Plan on Ageing and Health" in 2016, where the development of age-friendly and sustainable environments plays a central role [131]. Moreover, it is pointed out that more research is needed to identify the determinants of a long and healthy life including structural, biological and social determinants [131]. Thus, while the importance of environmental factors for healthy ageing is increasingly recognized, the consistent implementation of protective measures is not yet successful and requires both further scientific research and political efforts.

Further perspectives

As humans, we carry out our lives within a complex physical environment characterized by manifold biological and chemical systems that interfere with our health and wellbeing. With humankind constantly manipulating and acting upon the bio-social environment, it is of main public health interest to understand how these dimensions interfere with ageing and longevity. While it remains a challenge to associate environmental influences to specific age-related conditions due to the multifactorial etiology and the impossibility to exclude confounding factors in the chronic development of a disease throughout years and decades, epidemiological evidence thus far indicates that common ARDs such as cardiovascular and neurodegenerative diseases are driven by diverse environmental influences. Rather than one single causative factor a range of environmental, demographic, biological, behavioral and social factors determine the development and onset of the multifactorial diseases such as dementia and CVD. Exposure to harmful environmental conditions can alter biochemical pathways at the sub-/cellular level and therewith trigger the outbreak of age-related conditions. While further interdisciplinary research needs to be carried out and since the individual has only limited control over the exposure to environmental pollutants, policy intervention to reduce pollution are both urgent and necessary to allow healthy ageing on a global scale (Tab. I).

Altogether, while preventive strategies often aim at individual interventions, collective actions on the societal level such as restructuring cities regarding green and blue spaces and reducing anthropogenic air pollution, support healthy ageing and the prevention of ARDs. With regard to the complexity of the ageing process and the high emotional and economic burden ARDs pose on human societies, further interdisciplinary research needs to target potentially modifiable factors in order to structurally reduce harmful environmental influences on human health.

Table I. Preventive measurements on societal and individual level.

	Societal	Individual
Air	• Reduce emission sources. • Facilitate decision-making and implementation of laws to reduce air pollution • Exert regular control over the quality of air • Provide walkable infrastructures and bike lanes and reserve green spaces in urban and rural planning	• Susceptible individuals (e.g. elderly) should avoid acute and long-term exposure to polluted air • Regular physical activity improves heart and respiratory systems • Reduce outdoor activity on high pollution days • Use public transportation, carpool, and bike or walk
Climate	• Lower anthropogenic pollution leading to global warming and irreversible changes to the ecosystems • Improve management during heat waves: Allow transportation and access to cooling rooms for people • Help people with education and information to lower their “carbon footprint”	• Know your individual “carbon footprint” in order to lead towards a more sustainable lifestyle • Reduce, reuse and recycle • Conserve electricity, buy energy-efficient products, unplug electronics, consume consciously • During heat waves: Keep doors and windows closed, use blinds and drapes, drink enough water, wear light clothes, keep social contacts
Water	• Provide access to sanitation to prevent drinking water contamination from human waste • Exert regular control over the concentrations of different components in drinking water • Drinking water with high total hardness (TH) and Mg/Ca ratio might be good for the health. Heavy metals in drinking water seem to have health-damaging effects	• Avoid contamination of water with non-degradable products, medications, chemical cleaners or any other product with toxic ingredients • Stay hydrated especially during days with elevated temperatures
Soil	• Promote ecological complexity and robustness of soil biodiversity to suppress disease-causing soil organisms and provide healthy food • Avoid poor land-management practices • Control and restrict anthropogenic activities changing the properties of soil and increasing the accumulation of toxins such as heavy metals	• Keep exposure to harmful substances as low as possible • Avoid ingestion of possible contaminated soil • Buy local food from known and safe sources
Urban green	• Reserve green spaces in planning to improve physical and social activities of communities, reduce air and noise pollution, heat islands effects and provide refuge to disappearing species to support biodiversity	• Take benefit from the restorative effect of green spaces; visit them regularly for walks, social interactions, sports, relaxing time
Social and individual environment	• Close health gaps between higher and lower income classes • Improve and support the consumption of healthy diet • Provide safe spaces for physical activity and community interaction • Provide transport and education	• Mediterranean diet and caloric restriction positively affect lifespan • Regular physical activity decreases chronic inflammation and oxidative stress • Regular social interaction and community engagement improves wellbeing and preserves cognitive function

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