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The Human Condition for the Anthropocene: Being more-than-human

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Bioethics in the Anthropocene: A powerful tool for sustainable development and planetary co-responsibility

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Abstract: Bioethics is inherent to scientific work, and it takes on particular relevance in the Anthropocene, where the interaction between science, culture, and nature intensifies under conditions of global socio-environmental crisis. In this context, cultural diversity and the valuation of ancestral and local knowledge are fundamental dimensions for rethinking scientific



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and technological development from an ethical perspective. This review article analyses the coevolution between science and culture based on bioethics conceived as a reflective and integrative bridge, which is not limited to the formulation of normative principles, but rather guides the processes of deliberation and decision-making, reconfiguring scientific practices toward a more just, responsible, and contextualised scientific culture. From a perspective that moves from global bioethics to pluralistic and inclusive bioethics, the work examines the bioethical dilemmas inherent in scientific practice, understood as a situated, socially and politically engaged activity whose implications transcend traditional disciplinary boundaries. Similarly, it emphasises the importance of incorporating values of environmental responsibility, social justice, and planetary co-responsibility into the training of professionals in the natural sciences, as part of a transformation of worldviews that allows scientific knowledge to be aligned with the protection of biodiversity and sustainable development, from a bioethical reinterpretation in line with the challenges of the Anthropocene.

Introduction

Current scientific and technical challenges aimed at combining social development with care for the environment and nature force us to make decisions with an important modern ethical component: bioethics. It is generally accepted that this discipline emerged in 1971 with the publication of the book *Bioethics: A Bridge to the Future* by Professor Van Ressenlaer Potter, a researcher at the University of Wisconsin. However, it is known that Fritz Jahr, a German professor, Protestant pastor, and philosopher, was the first to use the term 'Bioethics' in an article published in 1927 in the prominent German natural science magazine, *Kosmos* (Saas, 2011), although apparently in a different context than its current meaning. Jahr extended Kant's moral imperative to all forms of life, turning it into a pragmatic model of balance between moral obligations, rights, and worldview: 'Respect every living being as an end in itself and treat it, if possible, as an equal.'

Philosophy continues to play a significant role in bioethics (Sandu, 2020; Blumenthal-Barby et al. 2022; Alvarez, 2022). The philosophical basis integrated into disciplines such as sociology, law, and biological sciences gives meaning to bioethics as reflective and critical; currently, bioethics does not only represent technically applied protocols and methodologies; rather, its conceptual structure comes from morality to refer to what is right. Although bioethics did not arise directly as a branch of the geological theory of the Anthropocene, it does appear as an ethical response to cultural and scientific and technical transformations that have modified the relationships between human beings and their environment (Boychenko, 2023; Osorio-García & Roberto Alba, 2023; Luna & Vásquez, 2022).

Co-evolution of science and culture in the Anthropocene

The term "Anthropocene" was proposed at the beginning of the 21st century to describe a geological era in which human activity has become the dominant force modifying terrestrial, climatic, and biological systems on a planetary scale, displacing the stable conditions of the Holocene that allowed the development of modern human societies (Crutzen & Stoermer, 2022). Although it has not yet been formally recognised as a geological epoch by all scientific communities due to technical stratigraphic issues, the concept has been widely adopted in ecology, conservation, and social sciences because it describes how anthropogenic transformations, climate change, biodiversity loss,

and alterations in the nitrogen cycle have placed human impact at the center of the Earth system's dynamics. In ecology and conservation biology, the Anthropocene is not only a marker of time but also an interpretive framework that requires a rethinking of the relationships between humans, other species, and ecosystems in terms of systemic complexity and irreversible consequences that challenge traditional paradigms of environmental management (Corlett, 2015).

In the Anthropocene, where human activities have altered ecosystems, bioethics emerges as a discipline where science, culture, and generational responsibility converge, giving rise to bioethical dilemmas that cannot be analyzed without considering the co-evolution between scientific knowledge and the culture of the communities that support or reject it. Bioethics, as a transdisciplinary science of complexity, seeks to understand the interconnections of humankind with the different levels of reality that coexist in nature and the cosmos. Coevolution is a process of feedback between species and their environment that modify each other (Collado, 2016). Bioethics is inherent to scientific work, and in this context, the focus on cultural diversity, together with science and technology, plays an important role in the Anthropocene, giving rise to the 'systems of systems' paradigm, which grants culture a systemic property in order to combine scientific and technological development with the appreciation of ancestral and local knowledge. In this context, cultural narratives cannot be fragmented, because doing so hinders the understanding of the anthropocentric world. Therefore, culture as a systemic property plays not only a relevant role, but also a necessary one for the development of society in the face of the global challenges it faces.

The systems of systems paradigm recognises that contemporary challenges, such as science, technology, and sustainability, cannot be addressed in isolation but rather as a heterogeneous and interconnected whole that interacts to give rise to emerging behaviors. This means that the challenges of the Anthropocene cannot focus solely on science or technology; rather, they require solutions that consider the complexity of the relationships between science, society, technology, culture, and history. In this sense, ancestral and local knowledge that is part of history provides a holistic, relational approach that does not always provide formal science, but complements and enriches technological information useful for sustainable solutions (Cavalcante et al., 2024; Ijatuyi et al., 2025; Araújo et al., 2025).

At the same time, bioethics has developed rapidly, especially in the field of medicine, with the aim, among others, to encourage the application of ethically appropriate behavior during the training of health professionals, thereby achieving more humanized patient care, which currently includes healthcare with applications that contribute to efficient monitoring for disease prevention (Lucivero & Jongsma 2018; Mendieta et al. 2021). However, the medical field is not its only area of action, as bioethics is of great importance in all biological sciences, which is , allowing us to visualize how the concept of the Anthropocene reflects a current and broad approach to bioethics (Donadoni & Ciliberti 2024; Anderson, 2023; Pratt, 2024), as well as the topic at hand in this article, which is shared responsibility for the protection of the environment, the biosphere, and biodiversity in the Anthropocene; that is, planetary co-responsibility, which was in some ways Potter's original proposal in his 'Global Bioethics,' by emphasizing bioethics as an interdisciplinary science, which is now reflected in the creation of ethics and bioethics committees in different institutions globally, whose work depends on their sphere of action; for example, in the health, academic, research, and governmental fields, whether at the national or international level (Goodwin et al. 2012; Wilches, 2014; Köhler et al 2020) to provide an ethical and bioethical approach to issues affecting humanity, promote social justice, and defend human rights, without neglecting the environmental context and giving rise to responsible decision-making in various areas such as the protection of biodiversity, the environment, science, and technology.

Bioethics, institutionally articulated through ethics and bioethics committees, constitutes a normative and deliberative space that guides the decision-making process in contexts where science, technology, human rights, and social justice converge, guaranteeing respect for human dignity, equity, and the protection of biodiversity in the face of scientific and technological advances. According to UNESCO's Universal Declaration on Bioethics and Human Rights (2005), ethical decisions in science and technology must integrate psychosocial and cultural factors, emphasizing that cultural diversity is an indispensable common heritage for humanity and that ethical reflection must be an integral part of scientific and technological development to ensure justice, equity, and environmental protection.

Similarly, bioethics committees perform essential functions in evaluating ethical, legal, and social issues raised by scientific and technological research, formulating binding recommendations that integrate ethical theory, cultural values, and scientific practices. This integration is particularly relevant because culture influences how bioethical principles and scientific standards are interpreted and applied, for example, when defining who is authorized to make decisions, how justice is understood, or what values are prioritized over the protection of biodiversity and human rights, which requires ethical and bioethical approaches to be culturally sensitive in order to be legitimate and effective (Chattopadhyay & De Vries, 2013).

Bioethics in cultural context

From the above, it is undeniable that culture influences science when global challenges such as climate change, artificial intelligence, gender studies, among other research, give rise to questions that science formulates and that arise in a cultural, political, and ethical framework.

Although different cultures have different moral codes, pluralistic bioethics recognizes alternative ethical frameworks that allow us to understand how different cultures interpret these challenges, giving rise to bioethics that recognises cultural diversity (Mbugua, 2012). Science and culture influence each other and co-evolve in the human and non-human context.

Although different cultures have different moral codes arising from specific traditions, beliefs, cosmologies, and social conditions, which has been documented in studies showing that conceptions of health, life, and moral obligations vary widely according to sociocultural contexts, this does not imply that it is impossible to articulate bioethics capable of recognising and harmonising that diversity. Culturally situated morality generates profound disagreements even on fundamental questions of life and death, challenging the assumption of a uniform common morality in bioethics and requiring methodological approaches that recognize the plurality of values and ethical reasoning, such as approaches to value pluralism and moral diversity in bioethics. However, pluralistic bioethics does not seek to impose a single universal moral code, but rather to establish a space for intercultural deliberation in which alternative ethical frameworks can dialogue, confront each other, and, when possible, converge on contextualised ethical compromises, respecting the autonomy of cultures and avoiding both absolute relativism and moral imperialism. This is achieved through methodologies that allow for the articulation of shared ethical principles with cultural sensitivity, recognising both differences in moral codes and the possibility of normative agreements that address shared ethical responsibilities in issues such as justice, equity, and respect for life in global and local contexts (Turner, 2004; Marino, 2017; Gray, 2019).

Furthermore, continuing with the description of the emergence of bioethics, three years after Professor Potter's first publications, in 1974 the US Congress appointed a commission, later known as the Belmont Commission, with the aim of providing ethical guidelines to protect the rights of

people participating in scientific research. In 1978, this commission published the famous 'Belmont Report,' considered an important modern reference in the ethics of research involving human subjects. This report summarised three fundamental ethical principles in clinical research: (1) respect for people, (2) beneficence, (3) justice (Turner, 2012; Pose, 2020; Varkey, 2021).

As mentioned above, bioethics currently plays an important role in the practice of health professionals, seeking to balance values and principles in situations of conflict, which means that the weight of decisions falls on the physician or the patient depending on the various situations (Arroyo & Avilés, 2000; Arras, 2017).

The Belmont Report and its principles were historically developed to protect human research subjects and provide a framework for structuring ethical decisions; their value lies not in prescribed rules, but in offering principles that must be weighed in a contextualised manner in each ethical decision-making process in science and society. However, the field of bioethics has recognised that contemporary challenges transcend the boundaries of traditional clinical research and require a broader framework, as evidenced by the recent development of planetary ethics approaches that integrate human health with ecosystems and intergenerational justice. In this sense, concepts such as bioethics oriented toward planetary sustainability or discussions inspired by post-humanist perspectives aim to expand the object of bioethics to involve ecological issues, such as environmental degradation, global equity, and more-than-human relationships, and to reconfigure how ethical responsibility is understood beyond the classical anthropocentric paradigm, incorporating both scientific knowledge and social and cultural values to guide complex collective decisions (Nagai et al., 2022; Anderson, 2023; Wabnitz et al., 2025).

Clinical bioethics, which predominated in the early decades of the discipline, historically focused on ethical problems emerging within medical practice and, in the doctor-patient relationship, addressing dilemmas related to life and death, informed consent, confidentiality, and therapeutic decisions in specific clinical contexts. This approach was driven by the development of biomedical technologies and the need to regulate specific medical practices, contributing decisively to the institutionalization of clinical ethics committees and the use of principles such as beneficence and autonomy in healthcare. In contrast, global bioethics emerged in response to the limitations of bioethics focused on individual clinical cases, significantly broadening its scope to include ethical issues of a public, social, and planetary dimension, such as global justice, health equity, environmental rights, and the transnational effects of research and technology, recognizing that ethical problems are not confined within the walls of a hospital but are intertwined with inequalities, policies, and diverse cultural practices in a globalized world. This evolution implies a shift from localized medical ethics to a broader field that considers shared values, cultural diversity, collective rights, and socio-ecological impacts, requiring cooperative and multi-local ethical deliberation for problems that transcend professional and territorial boundaries (Gracia Guillen, 2002; Hellsten, 2018; Ten Have, 2022).

The application of bioethics in the medical field is essential for properly assessing the consequences of a decision in both the professional and personal spheres. However, there are no differences between doctors and other professionals in the natural sciences, such as molecular biologists, in terms of the ethical considerations and bioethical principles applicable to these groups, as proposed by American bioethicists Tom L. Beauchamp and James F. Childress. According to Ebbesen & Pedersen (2007), in their study on the ethical reasoning of Danish physicians and molecular biologists, they report that the latter explicitly consider non-maleficence in relation to the environment, the health of the researchers themselves, and animal models. In contrast, the considerations of non-maleficence of oncologists refer to patients or human beings. Molecular

biologists consider the principle of respect for autonomy as a negative obligation, in the sense that the informed consent of patients must be respected. However, unlike molecular biologists, physicians experience the principle of respect for autonomy as a positive obligation, since the physician, in dialogue with the patient, offers a medical prognosis based on the patient's wishes and ideas, mutual understanding, and respect. This study concluded that these principles are applicable to both groups in their professional practice, demonstrating that each of the four bioethical principles of American bioethicists Tom L. Beauchamp and James F. Childress (respect for autonomy, beneficence, non-maleficence, and justice) are reflected in the daily work of physicians and molecular biologists in Denmark.

Approaching bioethics

The principles of bioethics can be influenced by different cultural contexts. Although proponents of global ethics may argue that these principles are universally generalizable, this is not always possible due to diverse cultural practices and understandings of what is considered 'good' (Chukwuneke et al., 2014).

This contribution analyzes the bioethical dilemmas involved in doing science through various examples and defines scientific practice as situated and politically active, which must therefore be guided by bioethical principles. It emphasizes values of environmental and social responsibility in the training of natural science professionals and analyzes the human condition as a relational figure to promote sustainable development and co-responsibility in the context of a transformation of worldviews based on a bioethical reinterpretation and of the human being as a node in the web of life, giving rise to ethical posthumanism with ontological responsibility, reintegrating it as part of a larger living system. Without neglecting the disruptive and cumulative changes in global ecological systems inherent in the Anthropocene, allowing bioethics to reorient the limits and purposes of scientific work towards planetary sustainability. Therefore, this article starts from the hypothesis that the incorporation of bioethics into the practice and training of natural science professionals allows us to face the scientific, cultural, and environmental dilemmas of the Anthropocene, promoting an ethical, pluralistic scientific culture that is co-responsible with the biosphere.

The objective of the article is to analyze and propose bioethics as an integrative framework that allows us to understand the co-evolution between science and culture in the Anthropocene and, from there, to guide responsible scientific and professional practices in the face of the global socio-ecological crisis. In this sense, the different emphases mentioned in the manuscript, the co-evolution between science and culture, planetary co responsibility inspired by Potter's global bioethics, and the application of an integrative bioethical approach in the work of the natural and social sciences—are not independent objectives, but rather complementary dimensions of the same analytical and normative purpose. Bioethics, understood as an interdisciplinary and reflective science, allows these dimensions to be articulated by offering a common language to link scientific knowledge, cultural values, socio-environmental justice, and decision-making in highly complex contexts characteristic of the Anthropocene. Thus, this article seeks to show that bioethics not only critically interprets scientific, technological, and cultural transformations, but also functions as a guiding instrument for planetary co-responsibility, integrating concerns for biodiversity, sustainability, and the ethical responsibility of professionals in scenarios where human action has become a determining geological and cultural force (Potter, 1971; Rockström et al., 2009; Dawson, 2019).

Methodology

The research was conducted using a qualitative documentary approach, with a theoretical-interpretative design based on hermeneutics and deductive analysis, aimed at critically understanding the conceptual evolution of bioethics in relation to science, culture, and the Anthropocene (Casas Martínez, 2008). This approach allowed the texts to be analyzed not as isolated empirical data, but as cultural and normative productions that express values, ethical frameworks, and conceptions about the relationship between humanity and the biosphere.

Search strategy and selection of reference sources

A critical review was conducted of scientific literature and normative documents retrieved from widely circulated and internationally recognized academic databases, including Scopus, Web of Science, PubMed, SciELO, Dialnet, and Redalyc, with a search period covering publications available up to July 2025. These platforms were selected for their relevance in the fields of bioethics, social sciences, and natural sciences.

Searches were conducted using standardized descriptors from the UNESCO Thesaurus. The main keywords included: *bioethics*, *global bioethics*, *environmental bioethics*, *Anthropocene*, *science and culture*, *planetary responsibility*, *biodiversity*, *ancestral knowledge*, and *sustainable development*. These combinations made it possible to identify works that explicitly addressed the interrelationship between bioethics, scientific practices, cultural contexts, and contemporary socio-environmental challenges.

Inclusion and exclusion criteria

The inclusion criteria considered:

- a) Peer-reviewed articles, theoretical essays, and relevant international declarations;
- b) Works published mainly in recent decades;
- c) Studies that developed an explicit ethical reflection on science, culture, bioethics, the environment, or the Anthropocene.

Publications of a strictly technical or descriptive nature that did not incorporate ethical analysis were excluded, as were documents that addressed scientific issues unrelated to bioethical or regulatory frameworks

Analysis procedure

The analysis was organized in successive stages. In the first phase, an exploratory reading was carried out to identify key texts and conceptual trends. Subsequently, an analytical and comparative reading was carried out, structured around previously defined conceptual categories, such as bioethics, global bioethics, science and culture, planetary co-responsibility, bioethical dilemma, and ancestral knowledge. These categories guided the interpretation of how these concepts have been formulated, discussed, and re-signified in different historical and disciplinary contexts, particularly in the natural and social sciences.

From the hermeneutic approach adopted, the texts were analyzed considering their normative assumptions, contexts of production, and horizons of meaning, allowing us to establish conceptual relationships, identify tensions, and develop theoretical inferences. To this end, thematic content analysis techniques were used to make analytical generalizations and critical reflections on the role of bioethics in the face of the challenges of the Anthropocene (Haggarty, 1996; Bardin, 2011).

Synthesis and Writing

Finally, the results of the analysis were thoughtfully integrated into the writing of the manuscript, articulating the theoretical contributions identified with the objectives of the study. This process allowed us to construct a coherent and well-founded interpretation of bioethics as a bridge between science and culture, oriented toward ethical decision-making, sustainability, and planetary co-responsibility.

Critical review of current approaches

Science transforms culture

It is extremely complex to anticipate the bioethical problems that will have to be faced during this century, since the rapid development of emerging technologies, such as biotechnologies, and the axiological and social transformations that the world is undergoing, make it truly difficult to articulate a prospective view with minimal guarantees of success (Torralba, 2016), all this in the midst of a society of uncertainty, where 'the greater complexity of the world, the mistakes of scientists and experts, and the accelerated technology that creates new areas of ignorance, produce perplexity and confusion' (Innerarity, 2022). Nevertheless, they give rise to scientific theories that have transformed human understanding of everything around us on the planet. In this context, 'we can consider the environment as the result of a global system of decision-making architecture in which all kinds of actors, from consumers to large companies and the government, make decisions' (Thaler & Sunstein, 2018). From the perspective of cultural analysis, incorporating this approach into scientific research offers multiple ways to address the importance of culture as an integrating element of all areas of science and bioethics, because culture is all-encompassing, representing resources that are intertwined with or inseparable from power relations and, as such, cultural analysis requires new ways of approaching areas of interest to the researcher that reflect inter/transdisciplinary analysis. This is supported in the different areas of work represented by research projects in emerging disciplines from the point of view of the natural sciences, for example, bioprospecting versus the recognition of the values associated with ancestral knowledge and the distribution of benefits (Chenhall et al. 2014). Science generates knowledge that challenges deeply rooted cultural beliefs, while bioethics acts as a reflective bridge, seeking consensus, limits, and principles of justice in the face of change. Science develops and bioethics reflects on the possibilities, considers the risks, and presents proposals that, without being scientific, set the course for scientific development (Carvalho, A. S., & Ramalho-Santos 2013).

Additionally, scientific advances have given rise to new approaches to the need to protect the biosphere and all its components, such as technological developments that allow the environment to be monitored through eDNA, geospatial tools with artificial intelligence, clean energy production, genetically modified foods, gene therapies, nanotechnologies, pluripotent stem cells, and ecosystem restoration through bioengineering, among other examples. This allows us to pursue a dignified quality of life within the framework of a just society. These challenges are increasingly complex, as the behavior of the system is not determined by its elements, but by their interaction (Innerarity, 2022); this implies rational behavior for individuals or organizations, but which can be harmful to the environment. From the perspective of the role of bioethics in sustainable development, its integrative vision goes beyond the medical and biotechnological approach. Potter (1971) proposed global bioethics that includes the relationship between humans and the environment as a fundamental and basic dimension for the survival of humanity. Bioethics is an interdisciplinary

science that connects healthcare, philosophy, social sciences, economics, and environmental studies to address emerging ethical and al issues related to human life and the preservation of dignity within a context of global sustainability (Pavić, 2025). Environmental bioethics recognizes that the ecological crisis is essentially an ethical crisis arising from the links between science, society, and culture, requiring the integration of ethical values into the production, dissemination, and application of scientific knowledge within the social and natural environment (Sánchez et al., 2024). Additionally, personalist bioethics, as an interdisciplinary science, can address environmental issues to the point of articulating contributions from economists, lawyers, biologists, engineers, and other social scientists, with special attention to the most vulnerable, generating holistic and transdisciplinary knowledge (Luna & Vásquez, 2022). In this context of the Anthropocene, cultural practices such as researching, legislating, consuming, intervening in ecosystems, and managing natural resources cannot be understood as exclusively technical activities; they are deeply mediated by values, worldviews, and moral decisions. In this sense, the bioethical approaches presented allow us to interpret, evaluate, and reorient these cultural practices.

In the field of bioethics, the Anthropocene poses an epistemological and normative challenge by expanding the ethical object beyond exclusively human interactions toward an ethics that recognizes the profound interconnection between humans, other forms of life, and planetary boundaries. This implies that disciplines such as bioethics must broaden their traditional horizon, centered on clinical relationships between people, to include issues of inter-species and intergenerational justice, environmental health, and responsibility for global environmental damage. Recent literature shows that this expansion represents a paradigm shift: the Anthropocene demands bioethics that integrate not only human rights and social justice, but also the protection of ecological systems and equity in access to natural resources, recognizing that scientific and technological decisions have ethical impacts that transcend generations and borders. Therefore, discussing the Anthropocene in this article is the basis for connecting cultural-scientific coevolution, planetary co-responsibility, and ethical practices of professionals in the natural sciences, highlighting that the current ecological crisis requires transformative bioethics that articulates science, culture, and environmental policy (Donadoni & Ciliberti, 2024).

Thus, bioethics, as an interdisciplinary science, allows science and technology to be integrated into society and culture. In the Anthropocene, science not only describes reality but also actively participates in its transformation, which is why cultural practices associated with scientific research, biotechnological innovation, and environmental management require ethical criteria that guide responsibility, intergenerational justice, and planetary co-responsibility. Environmental bioethics, from a broad field of human life to socio-ecological systems, allows us to understand dominant cultural practices such as the overexploitation of nature and extractivism as a result of unbalanced relationships between society and the environment. Here, the cultural practices of the Anthropocene are collective ethical decisions that have prioritized growth, utility, and control of these resources to the detriment of their sustainability.

Personalist bioethics places the dignity of the person before their natural and social environment; therefore, in the Anthropocene, cultural practices are analyzed not only for their environmental impact, but also for their consequences among the most vulnerable populations, equity, and social justice. In this way, bioethics in relation to cultural practices is interpreted as co-evolutionary processes between science, culture, and ethics.

Challenges facing bioethics

Damage to nature, and therefore to biodiversity and its many habitats, is continually evident in different ways; For example, the Red List of Ecosystems (RLE) developed by the International Union for Conservation of Nature (IUCN), a global standard for measuring ecosystem health, reported that in the next 50 years, the mangrove ecosystems evaluated are at risk of collapse, classified as Vulnerable, Endangered, or Critically Endangered (Sievers et al. 2020).

Globally, mangroves are estimated to contribute \$1.6 billion annually in ecosystem services and livelihoods. However, between 1980 and 2005, 807,030 hectares of mangroves were lost in Latin America (Sol-Sánchez et al. 2022). To cite a few examples, in countries such as Ecuador, the main causes are attributed to urban expansion, road and bridge construction, and the shrimp industry, which is one of the most booming productive sectors but generates the loss of large areas of mangroves and affects the ecological role of these forests. In other countries, such as Peru, shrimp farming has been one of the most important causes of destruction and changes in the use of mangroves, which has had a negative effect on the production volumes of other species (Sol-Sánchez et al. 2022).

On the other hand, mangrove forests provide ecosystem services such as provisioning, regulating, supporting, and cultural services, as they provide important natural barriers against coastal flooding, prevent climate change through carbon sequestration (blue carbon), act as biological filters, and contribute to the bioeconomy of community members through tourism and fishing. However, the clearing of mangroves is causing economic losses to artisanal fishing and affecting biodiversity. In this scenario, bioethics, understood as the science created to promote principles for appropriate behavior with respect to life, becomes relevant by offering moral guidelines for making the most appropriate decisions regarding the conservation of these important ecosystems, such as mangroves. In other words, managing mangroves from a bioethical perspective involves applying precautionary principles (UNESCO, 2005), with an emphasis on cases where there is no scientific certainty about the impacts that anthropogenic activities could have on these ecosystems. From a sustainable development perspective, SDGs 13 and 14, Climate Action and Life Below Water, respectively, provide the sustainability basis for mangrove restoration, with the application of ethical criteria (Ten Have, 2016) and the recognition of these ecosystems as common goods and shared natural heritage (Ramsar, 2021). Another example is the use of the sea, its planning and management, whether by the public or private sector. In this area, instruments such as Marine Spatial Planning (MSP), defined by UNESCO as 'the public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve economic, social, and ecological objectives that have generally been specified through a political process,' is an important tool for safeguarding the bioethical principle of beneficence () in these coastal marine ecosystems, which support the bioeconomic activities of coastal populations.

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) clearly states that human activities, mainly through greenhouse gas emissions, have unequivocally caused global warming of 1.5 °C. Some aspects of the ocean, cryosphere, and sea level in a changing climate, through paleo-reconstructions, observations, and mathematical model simulations, have been studied with the aim of improving the assessment of past changes, hypotheses, and processes over the last century (Reyes & Arenas, 2022). Simulators that predict future changes have also been used, providing improved projections and estimates of uncertainty regarding these changes by systematically using the data obtained and making other projections on ocean heat content, land ice loss, and sea level rise (Fox-Kemper, 2021). Therefore, transformative changes are needed in sectors

such as food, energy, transportation, industry, buildings, and land use (IPCC, 2023). We can cite various examples of the increasingly frequent and evident effects on the environment and of global efforts to address them. An important question would be: how can we generate tools that allow us to make the right decisions in this field? To make these decisions, we must consider our professional and even personal ethical principles, obviously combining them with the common good, which includes protecting all forms of life on our planet. The latter would seem an impossible challenge given the socio-economic factors that undoubtedly generate strong pressures. We can think of this situation as an analogy to the constant decisions, both professional and personal, that we must make and assume the consequences of.

In this vein, Ten Have (2016) proposes global bioethics that prioritizes solidarity, respect for the environment, and shared responsibility among different social actors. Similarly, he points to bioethics as a science that fosters an attitude of moral responsibility towards ecosystems, leading to the realization that human beings are not superior to nature, but rather part of an independent system (Ten Have, 2010). In this context, cultural development, together with the technological development offered by science, gives rise to co-evolution; that is, they change together in the face of current challenges. Science is no longer only objective, but also situated, responding to socio-ecological contexts from political ecology, ethnobiology, and environmental sciences, where the role of ancestral knowledge is recognized through worldviews that integrate the spiritual, community, recognizing the interdependence between species and ecosystems, gives way to bioethics as a space for dialogue between cultural traditions and science, promoting an inclusive ethic that recognizes the rights of nature and fosters co-responsibility (Chapman & Schott, 2020).

The affirmation that cultural development and technological development offered by science co-evolve refers to a systemic approach in which culture, science, and technology are not isolated spheres but networks of reciprocal interaction that transform each other over time. This type of co-evolution involves (i) multiple social and epistemological actors (scientists, technicians, local communities, regulatory institutions), (ii) conditions of possibility that include regulatory frameworks, cultural values, economic and historical structures of knowledge production, and (iii) modes of interaction ranging from technology transfer and social measurement to cultural feedback processes that reformulate scientific goals, expectations, and practices. Contemporary literature in the social studies of science shows that science and technology are imbued with cultural contexts that shape both research agendas and interpretations of results and social uses of technology (Jasanoff, 2004).

Furthermore, research on socio-technical innovation points out that technology develops in co-constitution with cultural values, norms, and repertoires, giving rise to technological trajectories specific to each society (Rip & Kemp, 1998). Finally, cultural biology and co-evolution theory have proposed that symbolic systems and human cultural practices interact with technological changes in feedback loops, shaping patterns of technological adoption, rejection, or reinterpretation that, in turn, reconfigure cultural imaginaries and social orders (Laland, Odling-Smee & Feldman, 2001). These approaches allow us to situate the co-evolution of science, culture, and technology as a dynamic process where historical conditions, plural social actors, and complex modes of interaction explain why culture, science, and technology do not simply juxtapose each other, but rather mutually transform each other in specific sociocultural contexts.

While the analysis of specific cases such as mangroves and marine areas, among others presented in this article, can illustrate how bioethical dilemmas manifest themselves in specific socio-environmental contexts, contemporary bioethics faces a much broader and more complexly interconnected set of environmental challenges that need to be addressed holistically. The literature

on bioethics and sustainability emphasizes that problems such as climate change, accelerated biodiversity loss, ecosystem degradation, and planetary health raise ethical dilemmas that go beyond individual local cases and require deliberation from a global, pluralistic, and systemic perspective, due to the interdependence between human, non-human, and environmental health. For example, research indicates that the climate crisis introduces ethical conflicts over equity, intergenerational justice, and responsibility for accumulated environmental damage that cannot be fully captured by studies focused on a single ecosystem, and that traditional bioethics needs to broaden its horizon to integrate these emerging areas of global ethical concern (Donadoni & Ciliberti, 2024).

Similarly, it has been argued that the field of bioethics is called upon to respond to multiple socio-ecological processes, including justice in biodiversity conservation, the environmental implications of biomedical practices, and the sustainability of scientific infrastructures, as part of a global bioethics that articulates ethical principles with responsible scientific policies and decisions. Recognizing the breadth of environmental challenges in the Anthropocene, the inclusion of illustrative cases alongside a broader conceptual analysis is justified, allowing for the presentation of both concrete examples and the ethical categories necessary to address problems affecting ecological and social systems at different scales (Cortez-Capano et al., 2022; Pratt, 2024).

Sustainable Development and Bioeconomy

Although it is not only the impacts on the environment, the biosphere, and biodiversity produced by anthropogenic activity that constitute a driving factor for decision-making framed within the principles of bioethics, there is also a current need to incorporate the participation of young human resources in order to apply creative and innovative solutions to the various problems we face as humanity. In this context, in 2021, the Food and Agriculture Organization of the United Nations (FAO) proposed ten principles for a sustainable bioeconomy and recognized young people as agents of change, considering that in the future they will manage the planet's ecosystems and agri-food systems through various efforts, including those framed within the bioeconomy, with the aim of ensuring inclusive economic development that is resilient to future crises and contributes to the achievement of the Sustainable Development Goals (SDGs). Consequently, youth has been integrated as one of the cross-cutting themes in the FAO's Strategic Framework as a key aspect of decisive importance for the 2030 Agenda, and has been considered a priority in all areas of work, with a particular focus on the interaction between the bioeconomy and young professionals in decision-making in this sector (Dietershagen & Bammann 2023), taking into account that the bioeconomy is one of the pillars of economic productivity, because the biological wealth of countries can be transformed into sustainable economic value if it is managed ethically and bioethically. Environmental sustainability, social justice, and young human resources are considered a potential source of innovative solutions to old problems, driving change in the global economy by becoming young bioentrepreneurs.

Therefore, intergenerational aspects of linking young people to bioethics for the generation of sustainable development involve training them by creating participatory and creative educational spaces for them to play their future role as ethical, critical citizens. It also involves empowering young people to be an active part of social and environmental change processes (Sachs, 2015). Therefore, the articulation of young people involves recognizing their role as active agents in the transformation of the relationship between science, culture, technology, and bioethics. In addition, they are active subjects with the capacity to make decisions towards the construction of more sustainable, fair, and ethically informed models.

Recent advances in science and technology have led to the discovery of new functions for biological resources (Hodson de Jaramillo, 2018), in which the participation of young people in decision-making is key to influencing the use of resources in a sustainable way. For example, to increase biomass production and the use of biowaste, which allows for the diversification of the value chain as an opportunity for the creation of bio-enterprises. This would be the appropriate scenario for applying the principles of bioethics in the sustainable management of natural resources. At present, the participation of youth groups in the process of formulating public policies to promote the bioeconomy has not been evident, due to the lack of education on these issues at the secondary level; if this is achieved, we will be well on our way to a more just society that allows for decisions aimed at strengthening and developing practices that benefit the care of the environment, the biosphere, and its biodiversity.

The bioeconomy, as it has been incorporated into international policies (e.g., FAO, EU Commissions, or OECD), is often understood as a paradigm that articulates the use of renewable biological resources and biotechnological technologies to achieve sustainability and economic growth. However, this dominant interpretation runs the risk of reducing the bioeconomy to superficial sustainability or 'green growth' that does not question the productive and extractive foundations of global capitalism, nor the practices of intensive exploitation of nature that have generated the current environmental crisis. A growing number of authors warn that the hegemonic discourses on the bioeconomy are ambiguous and can be used to legitimize models of intensive biomass exploitation without substantive changes in consumption patterns or power structures. This becomes particularly problematic when these policies ignore or subordinate traditional knowledge, environmental justice, and the biophysical limits of the planet, perpetuating harmful processes under the euphemism of 'sustainable bio-innovation.'

In contrast, critical approaches propose rethinking the bioeconomy not only as a technocratic strategy for replacing fossil resources, but as a platform for denouncing unsustainable practices, questioning power relations in the production and use of biological resources, and promoting profound socio-ecological transformations that integrate justice and real ecological limits. This critical shift implies, among other things, recognizing that the bioeconomy can be a field of dispute between models oriented toward economic growth and models that emphasize socioecological justice, the recognition of local knowledge, and the comprehensive protection of biodiversity versus the mere sustainable exploitation of resources (Meyer, 2017; Giampietro, 2023; Virgolino, 2025). Vidal (2010) emphasized the need to apply ethics to assess the impact of knowledge and technology on human, environmental, and social development. The use of biotechnology for technological innovation in sectors such as agriculture, health, and clean energy must be governed by ethical principles that guarantee transparency, caution, and equity in scientific and technological processes, in order to prevent negative impacts on the environment and vulnerable communities. Bioethics and its principles are valuable tools for responding to the various scientific and technological challenges that inevitably influence the environment, the biosphere, and the biodiversity that surrounds us; in this situation, we must seriously address the problem of climate change. Additionally, instruments such as the Sustainable Development Goals (SDGs) represent a clear example of an area in which it is vital to apply bioethics, as they are designed to contribute to a better, more just, and inclusive quality of life, avoiding damage to our environment. This allows for the combination of the socioeconomic advancement of populations with their protection, especially the most vulnerable. In this context, the work of global bioethics could lead to useful changes in decision-making by integrating the SDGs into economic decisions and public policy in countries, as they have a greater influence on decision-making (Gregg, 2022) and thus justify whether political economy should be a

priority over the health and survival of humanity by offering bioethical arguments; considering that the priorities and practices of governments, responsible for the health and well-being of citizens, as well as industries and their leaders who have civic responsibility to their governments and communities (including consumers), are based on their greater control over the environment and the earth's resources; however, these social actors continue to fail to manage the for the benefit of the majority of citizens and consumers in countries that have even adhered to the agreements reached in the Glasgow Climate Pact, a key outcome of COP-26 in 2021, so there is little hope for health and survival in the near or distant future (Macpherson, 2022). Therefore, integrating the Sustainable Development Goals (SDGs) into economic decisions and applying the principles of bioethics offers benefits by ensuring that socio-economic development processes are carried out in a responsible, fair, and respectful manner towards nature, limiting utilitarian approaches to such development and promoting decisions towards sustainability. Bioethics is therefore becoming increasingly relevant as society advances, along with the instruments that humanity itself creates to establish a necessary social balance, bearing in mind that 'without consideration of the social, bioethics loses its true, totalizing, and general ethical meaning' (Gros, 2005). Bioethics also promotes participatory and democratic governance, where decisions on the use of natural and technological resources are made taking into account the voices of local communities and diverse actors (Sachs, 2015).

Bioethics and the professional training of biologists

In the bioethical training of biologists and other natural science professionals, it is relevant to refer to figures such as Kant, Hume, and Hans Jonas because each contributes fundamental philosophical perspectives that help structure the ethical analysis of scientific and technological action. Immanuel Kant offers a deontological foundation for bioethics by emphasizing the primacy of autonomy, human dignity, and moral duty as universal rational criteria that should guide professional and scientific conduct. This Kantian structure of obligation and respect for the ends of the subject has been used as a basis for discussing norms and rights in contemporary bioethics, including education in ethical values for researchers and health and biology professionals, for example, the idea of acting out of moral duty and not just for consequences (Rothhaar, 2010). David Hume contributes to the bioethical discussion by showing, from an empiricist perspective, that moral judgments, and by extension ethical dilemmas in science, cannot be derived solely from scientific facts but require reflection on motivations, affections, and social norms, which opens space for incorporating sociocultural dimensions into the ethical training of biologists, especially in contexts where scientific knowledge intersects with diverse cultural values and practices.

Hans Jonas, with his formulation of the principle of responsibility, takes bioethical reflection beyond the contemporary individual to future generations and the biosphere, emphasizing that professionals who work with life and nature have an extended ethical responsibility toward environmental sustainability and the endurance of human and non-human life. This perspective is especially relevant for educating biologists about the ethical challenges of the Anthropocene and the consequences of biotechnology and scientific research on complex ecological systems. Together, these philosophical perspectives provide solid conceptual frameworks for educational bioethics by integrating notions of moral duty, limits of knowledge, and responsibility towards others and the living world, which are not commonplaces but necessary epistemological foundations for training professionals capable of facing complex ethical dilemmas in the natural sciences. Thus, the incorporation of bioethics into the training of natural science professionals in the Anthropocene, not only doctors but also, for example, biologists, environmental engineers, agricultural engineers,

among others, and in the training of social science professionals such as specialists in environmental law, becomes essential because they must understand the dualisms of nature and culture, recognize and value local and ancestral knowledge, and understand that technological developments with AI, biotechnological techniques, or environmental law are cultural and ethical, not just technical tools. Likewise, it is essential to incorporate bioethical principles into the research carried out in these areas and to assume that scientific practice is situated and politically active, which must be framed within principles of co-responsibility. Therefore, those who conduct such research must be aware of bioethical aspects, as a reflective bridge associated with cultural and ecosystemic aspects, to be taken into account in their research work.

Immanuel Kant, in his work *Critique of Practical Reason*, argues that only through the principle of autonomy, free from all that is empirical and centered on objective reason (Fajardo, 2021), can we be guided toward a science with conscience. On the other hand, in global bioethics, it is necessary to take into account David Hume's first principle of morality, that is, the philosophical principle and the principle of responsibility postulated by Hans Jonas. the foregoing includes considering the responsibility that researchers and decision-makers must have to appreciate the value of nature, which leads to an environmental ethic that must start from a commonly accepted basis, which can be none other than respect for life (Burgui, 2015).

The notion of bioethical dilemma is not merely a rhetorical topic, but rather a central concept in bioethics that characterizes problems in which values principles, and consequences enter into irreconcilable conflict, requiring explicit and contextualized moral deliberation. In contemporary bioethics, dilemmas often arise when new technologies or scientific practices generate situations where it is not possible to simultaneously satisfy relevant ethical principles, such as justice, beneficence, or respect for life, without compromising one of them, which requires deep reflection rather than simplistic generalizations. Articles analyzing these cases point out that bioethical dilemmas are inherently linked to specific cultural, social, and environmental contexts, so that how they are identified, interpreted, and resolved depends on historical factors and the actors involved in each situation, including science professionals, regulators, and affected communities. For example, the anthropological approach demonstrates that bioethical dilemmas cannot be understood in a universalist way without considering local cultural norms and values, since what is perceived as a dilemma by some may not be so in other cultural perspectives, highlighting the importance of including epistemological and ethical diversity in science and bioethical practice.

Similarly, the literature shows that the concept of dilemma shifts in the context of *the Anthropocene* towards more complex socio-ecological situations where environmental impacts, intergenerational justice, and profound techno-scientific decisions confront scientific and ethical decision-makers with conflicts between scientific progress and environmental protection, requiring a bioethical analysis that goes beyond isolated clinical cases and articulates science with socio-environmental values. Finally, understanding bioethics in contemporary contexts implies recognizing that ancestral and traditional knowledge already contains forms of relational ethics towards the living world, which enriches the deliberation on bioethical dilemmas by providing holistic and long-term perspectives that question the separation between humans and the biosphere, promoting ethical and sustainable solutions in situations not resolved by conventional science (Sharif & Bugo, 2015; Botbol-Baum, 2015; Jessen et al., 2022).

The bioethical dilemma that arises, with greater emphasis among new generations of scientists, is fueled by conflicts in genetic manipulation, animal experimentation, and the use of artificial intelligence (AI) for information management, among others.

The challenge is to address these issues from the perspective of the biological sciences by applying a bioethical analysis method that makes it possible to reach a consensus on the limits of scientific research (Zemel et al., 2020) and, from the perspective of law, to give it the most appropriate legal form. This method of bioethical analysis combines the principles of ethics and legal bases with the assessment of the situation itself (Alvarado et al. 2016) to find fair answers and solutions to situations where science deserves to be considered for what it is: knowledge that enables the progress and development of society in a sustainable manner. This gives rise to the ethics of actions for sustainability (GBS, 2018) from an anthropogenic perspective, due to the urgency of meeting humanity's needs while conserving its environment, biosphere, and biodiversity. UNESCO (2005), through the Universal Declaration on Bioethics and Human Rights in Article 16, states that 'Due attention shall be paid to the impact of the life sciences on future generations, including their environmental and h y dimensions.' This implies adopting a long-term ethical and environmental vision within the academic curriculum, in training as a researcher, and in professional practice.

Discussion

Temporary tensions and debates in bioethics, science, and culture

The development of bioethics has not been without conceptual and methodological debates regarding its content, scope, and claim to universality. One of the central points of discussion is the tension between principled bioethics, formulated primarily from the Western biomedical context, and proposals for a broader, more contextual, and culturally situated bioethics. The principled approach, based on the principles of autonomy, beneficence, non-maleficence, and justice, has been widely disseminated and applied, but it has also been criticized for its abstract, individualistic, and limited nature in addressing complex socio-environmental and cultural issues (Beauchamp & Childress, 1994; Holm, 2018). From a critical perspective, various authors have questioned the claim of intercultural universality of classical bioethics, pointing out that the dominant principles reflect values specific to Western liberal societies and do not always adequately dialogue with community, relational, or non-anthropocentric worldviews present in other cultures (Engelhardt, 1996; Ten Have, 2016). In this sense, it has been argued that imposing a homogeneous ethical framework can render local knowledge, ancestral practices, and alternative moral systems invisible, especially in contexts of the global South and in socio-environmental conflicts linked to territory and biodiversity.

In response to the limitations mentioned above, proposals for global, environmental, and pluralistic bioethics have emerged that expand the field beyond the clinical and biomedical spheres, incorporating ecological, social, and cultural dimensions. Global bioethics, inspired by Potter's thinking and subsequently developed in academic and regulatory circles, proposes an ethics of survival that integrates science, values, and planetary responsibility, recognizing the interdependence between human and natural systems (Potter, 2012; Ten Have & Gordijn, 2014). This approach is not based exclusively on rigid universal principles, but on deliberative processes, intercultural dialogue, and ethical co-responsibility.

Similarly, non-principlist currents and narrative, hermeneutic, and care ethics approaches have contributed alternative visions that emphasize context, historicity, and relationships rather than the mechanical application of abstract principles. These perspectives are particularly relevant for addressing the dilemmas of the Anthropocene, where scientific and technological decisions have systemic, intergenerational, and cross-border impacts that go beyond the framework of individual ethics (Tronto, 2013; Rozzi et al., 2015).

Within this framework of theoretical plurality, contemporary bioethics is configured less as a closed normative body and more as a space for critical reflection and intercultural dialogue. Its strength lies not in eliminating moral differences between cultures, but in offering conceptual tools to understand and articulate them and to guide responsible decisions in contexts of high socio-environmental complexity. Thus, bioethics can operate as a bridge between science, culture, and politics, recognizing the diversity of values without renouncing the search for shared ethical minimums oriented toward sustainability and the care of life in all its forms.

Conclusions

a) The analysis developed in this article allows us to affirm that the Anthropocene constitutes a historical, scientific, and cultural framework that redefines the relationship between science, society, and the biosphere, placing human action as a determining agent of ecological and social systems. In this context, the coevolution between science and culture is not a linear or harmonious process, but rather a complex dynamic in which scientific and technological advances generate new forms of knowledge, while also producing environmental, social, and ethical impacts that challenge traditional regulatory frameworks. Bioethics thus emerges not as an external complement, but as a space for critical reflection capable of articulating scientific knowledge, cultural values, and planetary responsibility.

From the above, it is clear that we need bioethics capable of harmonizing ancestral knowledge with contemporary science, since local and ancestral knowledge provides relational, territorial, and long-term visions of the interaction between humanity and nature that complement and challenge the dominant techno-scientific approaches. Bioethics does this, and can deepen it, by promoting pluralistic frameworks for deliberation, intercultural dialogue, and ethical co-responsibility, integrating different knowledge systems into scientific and socio-environmental decision-making aimed at sustainability.

b) Throughout the manuscript, it is shown that the techno-scientific developments of the Anthropocene inevitably produce bioethical dilemmas, not only in the sphere of human life, but also in relation to biodiversity, ecosystems, and future generations. These dilemmas cannot be addressed exclusively from technical or economic criteria, but require contextualized ethical deliberation that is sensitive to cultural conditions and the plurality of knowledge, including ancestral knowledge. In this sense, bioethics is configured as an integrative bridge that allows for the interpretation of conflicts between scientific progress, planetary limits, and socio-environmental justice, expanding its scope from classical bioethics to global, environmental, and pluralistic bioethics.

c) At the same time, the work shows that bioethics is not limited to the formulation of abstract principles, but rather guides concrete decision-making processes, especially in scenarios of high complexity and uncertainty typical of the Anthropocene. Planetary co-responsibility, understood as a shared ethical commitment among scientists, professionals, institutions, and decision-makers, is presented as a central axis for preventing the irreversible deterioration of biological and ecological systems. From this perspective, bioethical values must form a cross-cutting basis for the design of public policies, sustainable development strategies, and regulatory frameworks that recognize both human rights and the rights of nature, as well as intergenerational responsibilities.

d) Finally, the article highlights the strategic importance of university education in training natural and social science professionals capable of addressing the ethical challenges of the Anthropocene. The incorporation of bioethics into educational processes, together with the protection of ancestral knowledge, community participation, and the integration of the Sustainable

Development Goals, is key to consolidating an ethical, critical scientific culture committed to the sustainability of life. In this way, bioethics is consolidated not only as an analytical framework, but also as a transformative tool aimed at caring for the planet, guiding scientific action, and contributing to a socially and environmentally just future.

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