Animal capital: a new way to define human-animal bond in view of global changes

Cédric Sueur[1,2], Éric Fourneret[3], Romain Espinosa[4]

1 CNRS, IPHC UMR 7178, Université de Strasbourg, 67000 Strasbourg, France

2 Institut Universitaire de France, 75005 Paris, France

3 ETH+, ETHICS EA 7446, Université Catholique de Lille, 59000 Lille, France

4 CNRS, CIRED, Paris, France

There are approximately eight million animal species on Earth, and humankind directly or indirectly depends on 50,000 (according to IPBES)[1]. However, in their daily lives, humans only directly or indirectly **interact** (see the glossary for bold terms) with a dozen species at most, such as those involved in food production or kept as pets. The limited number of species with which we have direct contact greatly weakens the stability of our current civilizations, mostly the Western one. The concentration of our activities around a few species contributes to the decline of biodiversity, as it allocates a disproportionate share of resources to a very small proportion of species. This loss of biodiversity increases the risk of ecosystem destabilization[2,3], and is likely to lead to higher food insecurity and pandemic outbreaks in the medium term[4,5]. The current and global economic system fails to correctly value the direct and indirect benefits of biodiversity, which may result in suboptimal investment in animal protection[6,7]. Non-human animals are necessary for the survival of humankind, and it is important to recognize their social contribution, just as it has been done in the past for humans.

The capacity of a human being to contribute to the community is often discussed in economics by the term '**human capital**'[8] (see the glossary for bold terms). Improving human capital is one of the key objectives of economic transformations to ensure long-term economic development. Improving access to education or healthcare can benefit society in the long run by enhancing human capital. However, the contribution of an individual to society is not limited to their set of skills. For instance, Bourdieu highlighted the importance of considering how social and cultural activities also contribute to the health and wealth of humans[9,10]. While **social capital** and **cultural capital** is now well recognized for humans (e.g., UNESCO's list of Intangible Cultural Heritage), new voices are calling for similar recognition for animals (e.g., the concept of cultural capital has been extended to non-human apes[11]).

Similarly, the contribution of animals to society could also be discussed using the term 'animal capital'. Previous works have discussed the idea of animal capital, but have only referred to it as the contribution of animals to human society through forced animal use, such as food production, clothing, and animal experimentation[12,13]. However, the contribution of animals to society goes beyond the immediate material capital, and animals can benefit human society in numerous other ways, such as through natural, social, and cultural capital. Here, we propose to define the new conceptual framework of animal capital through four components and discuss how these dimensions can be used to deal with current global changes and a desirable future. We link each animal capital to the 17 United Nations Sustainable Development Goals (SDGs, table 1 and figure 1)[14]. This framework is the result of discussions between a biologist, an economist and a philosopher, all specialist in animal ethics.

Figure 1: Animal capital is subdivided in four capitals: material capital, social capital, natural capital and cultural capital. Each capital meets several United Nations Sustainable Goal developments (SDGs)

The Four Animal Capitals

Animal material capital. Animal material capital refers to the direct benefits that humans derive from animals when used as a product. Historically, animals have mostly contributed to human societies as material capital, and most of our current interactions stem from this type of use. Approximately 1,380 billion animals are killed worldwide each year to feed humans in farms or through hunting. However, their material contribution is not limited to meat, as numerous communities have been using animals as a sustainable source of clothing, such as wool, and other types of food, such as eggs (SDG 1-3). Milk consumption is one of the best examples of **gene-culture coevolution**[15], highlighting the importance of this behavior in the survival of some ethnic groups during severe droughts[16]. Wool production is also crucial for some populations living in harsh conditions where livestock is rarely killed for meat in these ethnic groups[17].

Considering animals beyond our direct use allows us to fully benefit from their material capital by developing sustainable products that do not harm animals. Advances in agricultural yield over the past few centuries have enabled us to reduce the direct exploitation of animals (SDG 8-9). In terms of meat consumption, the development of plant-based alternatives, the rise of flexitarians, and the strengthening of legislation for animal welfare suggest that at least some Western people re seeking to replace, reduce, and refine animal farming, just as scientists are doing in animal experimentation with the 3R principles[18] (SDG 16-17). More recently, the development of cultured meat illustrates how humans can benefit from animal material capital in a less negative way for animals by producing meat without harming them and decreasing global warming[19,20] (SDG 11-15). Research shows that cultured-meat meets by its own the 17 SDGs[19].

Animal social capital. Social capital reflects the value of relationships[21]. Multiple studies have shown that friendships, shared values, and close and frequent contacts are important for humans to live longer in healthy conditions. The concept of social capital has been extended to include animals, mainly pets, for their influence on the physical and mental health of humans (SDG 3). Owning a dog has been shown to increase physical activity, make owners feel better, and expand their social networks[22], thus potentially decreasing the use of drugs expansive (SDG 10) and pollutant for the environment (SDG 6, 11-15). Pets also contribute to the development of soft skills, as children who have pets or are linked to animals have been shown to become more empathetic[23] and may play important role in education (SDG 4). More globally, a growing number of scientists emphasize that urban areas do not only include humans but also other animals whose interests should be integrated into urban design and politics as human-nature connectedness increases health[24] (SDG 11, 16). Humans and free-living wild animals may also coordinate their behavior to achieve a mutual benefice[25] as collective hunting (SDG 8, 10). In other words, animals with whom we share space are also part of our communities and thus constitute social capital that can be mutually beneficial and may decrease of engines use in agriculture as well as in urban environment (SDG 12-15). For instance, we can bring shelters, food, health to horses bringing us way to move on small distances and to farm.

Animal natural capital. Beyond their direct use, animals play an important role as part of the biodiversity of ecosystems[1,26], which is crucial for the survival of some ecosystems and human populations facing climate change (SDG 6-7, 11-15). The ecosystem services provided by wild fauna are considerable, but their scale is difficult to assess[27]. As a result, many NGOs are calling for the development of nature reserves free from human intervention. For example, the Half-Earth project, initiated by E.O. Wilson, proposes to set aside at least half of the planet as a reserve to save the living part of the environment and obtain the stabilization necessary for human survival[28]. The study of wild animals can also significantly contribute to the improvement of human societies. For example, understanding how bats can harbor multiple viruses without developing symptoms could pave the way for significant advances in medicine[29] (SDG 3, 9-11,17).

Natural capital includes all the ecosystem services provided by animals, such as bioindicators or pollination[30,31]. These services benefit not only humans but also other animals and plants by preserving life in local ecosystems. At the global level, ecosystem services contribute to maintaining the environment within planetary boundaries[32,33] (SDG 3, 6-7, 11-15). For instance, biosphere integrity is dependent on the stability of ecosystems, which relies on biodiversity and the pollination of plants and trees (SDG 2, 11-15). Climate change is also linked to biodiversity in that invasive species are favored by increasing temperatures, but their expansion is limited in stable and more biodiverse ecosystems[34]. Moreover, plants and animals store carbon, and the more there are, the higher the amount of carbon stored. For instance, whales or elephants are one of the most prominent nature-based solutions to capture greenhouse gas emissions[35,36] (SDG 13). Other issues such as biogeochemical flows, freshwater changes, or ocean acidification can be buffered by filtering species (SDG 6, 11-15). Protecting the natural capital of animals is therefore an essential condition for successfully combating environmental degradation.

Animal Cultural capital. Cultural capital refers to the accumulation of knowledge, behaviors, and skills that a person can use to demonstrate their cultural competence and social status. While some animal experts were historically hesitant to discuss animal culture due to the fear of anthropocentrism, numerous studies have now documented the existence of cultures among animal communities[37,38]. For example, the intergenerational transmission of tool use among chimpanzees illustrates the concept of cultural capital in the animal kingdom[39]. The need to protect local animal cultures is receiving more attention[40], as seen in UNESCO's recent call to protect the cultural behavior of apes. Animal local traditions are as important to preserve as human local traditions because this knowledge

goes beyond the economic benefits for human societies[41] providing education and innovation (SDG 4, SDG 9). Animal cultures are valuable for the animals themselves and can also help researchers better understand the evolution and origins of humankind (SDG 4, 5).

In fact, all behaviors are important in evolutionary research. By observing animals, we can learn not only about what they instinctively eat but also about their learning behaviors, such as how they learn from others, how they use plants to treat diseases and parasites based on knowledge passed down from past generations[42,43], how they live peacefully in groups or engage in wars by learning from pacifist individuals[44,45], and how they vote to move together and synchronize their activities[46]. Many animal behaviors are used as the basis for algorithms in robotics, which can solve human problems, and in artificial intelligence applied to human voting systems[46] (SDG 16). Animal behavior and culture are also crucial for ecosystem services, as imprinting and social learning help new generations to find their reproduction sites, learn how to extract food, and disperse and pollinate[47]. *Afromonum* species fruits are commonly ingested by chimpanzees, bonobos, and gorillas for their antimicrobial activity. These fruits are also sold in traditional markets and along roads in the Bwindi region for the treatment of bacterial and fungal infections, as well as anthelmintic medicine. The Navajos living in the southwestern United States attribute their knowledge of the antifungal, antiviral, and antibacterial properties of the umbellifer *Ligusticum porteri* to bears (SDG 3, 5, 10).

Preserving animal behaviors and cultures can also bring economic benefits to human societies[26] (SDG 8, 9). Humans enjoy discovering the specific behaviors of animals, such as whale watching, which contributes $2.5 billion to ecotourism. However, we need to respect certain rules to avoid disturbing them, such as maintaining a safe distance from their habitats. Thanks to technologies such as artificial intelligence, we have been able to discover the complexity of the sociality and language of these species. While researchers in animal behavior aim to avoid anthropomorphism, anthropodenial, and anthropocentrism, learning from distant but intelligent species such as cephalopods may offer new perspectives for applied and fundamental research in our societies[48].

Animal Capital Criticisms

There are three ethical and philosophical difficulties associated with the concept of animal capital that can be summarized in this way: 1) Animal capital can appeal to the notion of **utility** but shall not be in the only perspective of human beings. 2) However, only humans have **morality** principles towards other animal species. 3) Considering these first two points, the concept of **vulnerability** could be added to animal capital to adopt a more **ecocentric** approach of this concept as vulnerability can be seen less anthropocentric and more holistic than utility. Here we detail the three points.

1) First, our approach to animal capital proposes considering all the benefits that animals can bring to society, beyond the immediate material use by humans that is usually considered. It follows that our approach is not limited to the utility[50] humans derive from animals. On the contrary, our animal-capital approach seeks to go beyond **anthropocentri**c considerations and pleads for a broader consideration of interests (e.g. ecocentrism or **zoocentrism**)[51]. Leaving anthropocentrism behind raises important challenges in the valuation of animal capital. Whatever the set of interests that we consider (e.g., all sentient beings in a sentientist approach, or even ecosystems in the ecocentric approach), the concept of animal capital necessitates valuing animals' interests and contributions to the ecosystems beyond what is usually done. The second difficulty with the animal capital concept is that it may undermine the value of animals for their own sake. It is already difficult to assess human capital, especially immaterial components like cultural or social capital. Evaluating animal capital would be even more complex, as it is difficult to determine the value of animals in relation to other animals in their environment. While scientists know how species are important for ecosystem stability and trophic

webs, social and cultural capital also matter for non-human animals. For instance, spatial associations or group mixing between different species exist to avoid predation and share resource information[52]. Cultural transmission also occurs between species for predator and food recognition. There are even examples of friendships between isolated individuals of different species, which resemble social capital[53]. Therefore, it is essential to consider the value of animals beyond their instrumental usefulness for human beings and recognize their intrinsic value as well. However, only humans can do that, not other animals.

2) So, the second difficulty pertains to morality and raises a more intricate problem[54]. Only humans have developed a system of values and moral principles that lead to moral obligations and responsibilities towards other animals[55], even if they conflict with their own interests or consumption practices (e.g. moral, legal, and social obligations to protect the environment). Actually, humans are expected to act responsibly towards the environment and to change their behaviors not only to benefit from other animals, but also to ensure their right to live in their natural habitat.

3) Ultimately, the importance of animals to humans is not solely based on the services they provide, but on the reality of human-animal interdependence. While humans rely on animals to enhance their well-being, more and more animals depend today on humans, particularly for protection from human activities and from suffering in the wild. For instance, without natural reserves creation, many animals as species and individuals would disappear mostly with great suffering. Vulnerability is a concept that can help redefine the notion of animal capital, emphasizing its relational nature in which the principle of utility is insufficient. Vulnerability[56] highlights the other side of animal capital, which requires revision, as it pertains to the individual exposed to harm and the role of their relationship with other living beings in mitigating that harm. The more an individual benefits from the capital of others, the less vulnerable it is. Moreover, one can say that animals are vulnerable because they don't have economical or political power to fight humans decisions, but the concept of vulnerability tries to go beyond a **liberal**[57] viewpoint. However, vulnerability transcends the hierarchy between species created by humans (**speciesism**) and the concept of utility, emphasizing the mutual dependence between humans and non-human animals[58]. The **One Health** concept is a contemporary example of this flourishing interdependence[59].

Conclusion

Today, the value of animal material capital, mostly in the form of meat, is declining as people begin to recognize the other forms of capital that exist in their relationships with animals. For example, rewilding predators can have significant socioeconomic benefits that outweigh the costs of farming[60], and elephants and whales play a crucial role in carbon storage[35,36]. People are starting to see that non-human animals have value beyond just their usefulness to humans, although there is still a debate between viewing animals through a lens of utility and vulnerability. Currently, one out of the estimated eight million species on Earth is at risk of extinction, meaning that one million species may not be able to contribute to the four forms of capital that they represent. To preserve animal capital and in line with the United Nations Sustainable Development Goals[14] and the IPBES Nature Futures Framework[61], there are four key societal actions that must be taken: 1) enforcing or establishing legislation to protect animals as species and individuals, 2) protecting animal behaviors, cultures, and languages, as well as rewilding habitats[36], 3) establishing social and economic mechanisms and policies to ensure animal welfare, and 4) uniting scientists, practitioners, and citizens to defend the rights of animals and their habitats. It is essential to work with animals to create a sustainable way of living, as without them, humans will ultimately become the vulnerable ones.

Glossary

Anthropocentrism: a concept that interprets or regards the world in terms of human values and experiences.

Capital: according to the World Bank, human capital consists of "the knowledge, skills, and health that people invest in and accumulate throughout their lives, enabling them to realize their potential as productive members of society."

Cultural capital: social assets of a person such as education, intellect, speech style, dress style, etc., that promote social mobility in a stratified society. Here, social capital is extended to assets from the group or society that benefit the group or society.

Ecocentrism: a concept that interprets or regards the world in terms of nature-centered values.

Gene-Culture coevolution: Evolutionary phenomenon where cultural processes (i.e., non-genetic) shape genetic evolution by modifying the selection of genes.

Interaction: By interaction, we mean different types of acts having effect on both actors, but these effects can be positive or negative for one of the actor. Cooperation and mutualism is beneficial for both actor. Predation is positive for one and negative for the other. Eating meat without killing animals is a predation interaction from humans towards animals with sharing of resources between humans after predating.

Liberalism: It is a political and moral philosophy based on the rights of the individual, and liberty and supporting private property, market economies, individual rights, liberal democracy, economic and political freedom.

Material capital: it refers to the direct benefits of human or animal production.

Morality: a body of standards or principles derived from distinguishing intentions, decisions, and actions between those that are proper (right) and those that are improper (wrong).

Natural Capital: the world's stock of natural resources, including geology, soils, air, water, and all living organisms.

One Health: approach that recognizes that the health of humans is connected to the health of non-human animals and our shared environment

Social capital: "the networks of relationships among people who live and work in a particular society, enabling that society to function effectively."

Speciesism: the idea that one species, especially human beings, is more important and should have more rights than another.

Utilitarianism: a family of normative ethical theories that prescribe actions that maximize happiness and well-being for all affected individuals.

Utility: a measure of the happiness or satisfaction gained from a good or service in economics and game theory.

Vulnerability: the quality or state of being exposed to the possibility of being attacked or harmed, either physically or emotionally.

Zoocentrism: expanding the circle of human moral consideration to include other non-human animals.

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Table 1: How the four animal capital meet the United Nations Sustainable Development Goals (SDGs)

Sustainable Development Goals (SDGs)	How animal capital meets SDGs
SDG 1: No Poverty	Sustainable material capital, such as cultured meat, releases space to grow vegetables. Social capital sets people free from expensive engines through collaboration with animals. Natural and cultural capitals set humans free from expensive drugs and products.
SDG 2: Zero Hunger	Sustainable material capital, such as cultured meat, releases space to grow vegetables. Integral protected areas contribute to sustainable material capital.

SDG 3: Good Health and Well-being	Natural and cultural capital set humans free from expensive drugs and products. Social capital increases health and prevents the need for medication.
SDG 4: Quality Education	Access to sustainable material capital, social capital, and natural capital can lead to better education about how to obtain and utilize these resources. This virtuous circle enhances the education quality.
SDG 5: Gender Equality	Sustainable material capital, natural capital, and collaboration with animals may decrease climate change and gender inequality. In addition, working with animals involves fewer funds, making it more accessible to women.
SDG 6: Clean Water and Sanitation	Sustainable material capital decreases pollution. Natural capital is important for filtering animals cleaning water and allowing for ecosystem stability and biodiversity.
SDG 7: Affordable and Clean Energy	Working with animals instead of engines saves energy and is not harmful. Some animals, such as bioluminescent bacteria, can also provide clean energy.
SDG 8: Decent Work and Economic Growth	Working with animals can be more gratifying and healthier than working with engines to achieve the same goal. Animal capital creates new jobs or makes jobs accessible to everyone.
SDG 9: Industry, Innovation and Infrastructure	Animal capital is an ecocentric way of living and leads to rethinking our habits with innovation. Lack of research in biomimicry, cultured meat, and zoo inspiration (learning from animal behavior) leads to innovation and new start-ups.
SDG 10: Reduced Inequality	Animal resources, regardless of the capital, are more equally distributed, reducing inequality. Non-private access to animal capital increases equality. Social capital increases health and decreases inequality. Sustainable material capital and natural capital also reduce inequality. Cultural capital leads to greater access to knowledge.
SDG 11: Sustainable Cities and Communities	Natural capital, including higher biodiversity and some animal roles, leads to more sustainable cities with fewer pollutants. Social animal capital increases mobility and social networks.
SDG 12: Responsible Consumption and Production	Sustainable material capital leads to responsible consumption and production. Social capital decreases the production of drugs. Natural and cultural capital lead to sustainable societies with fewer short-term products.
SDG 13: Climate Action	Sustainable material capital fights climate change. Natural capital maintains the environment within planetary boundaries, as in the case of pollination, ecosystem stability, and limitation of invasive species expansion.
SDG 14: Life Below Water	Life Below Water > Sustainable material capital contributes to the sustainable use of the ocean. Natural capital allows for ecosystem stability. Research on life below water will lead to an increase in cultural capital and natural capital.
SDG 15: Life on Land	Life on Land > Sustainable material capital contributes to the sustainable use of land. Natural capital allows for ecosystem stability.
SDG 16: Peace and Justice Strong Institutions	Peace and Justice Strong Institutions > Non-private access to animal capital increases equality and peace. Recognizing animal rights and respect strengthens justice and makes society more respectful of both animals and humans. Animal social capital increases empathy, leading to peaceful and collaborative societies.

SDG 17: Partnerships to achieve the SDG	Partnerships to achieve the SDG > Animal capital strengthens domestic resource mobilization. Endemic species should enhance international exchanges and diffusion of knowledge. Animal capital should increase macroeconomic stability and international policy coherence.

382