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The Copernican turn of biology in the early twentieth century

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The emergence of the term *Umwelt* within twentieth-century biological thought is reminiscent of the turn towards the "subject" in early modern philosophy. The term *Umwelt* originally had a spatial connotation, which explains why analysis reveals an interdisciplinary terminological connectedness transcending the confines of any specific scientific discipline. This interdisciplinary consideration opens the way for systematic perspectives developed against the relevant historical background, in particular the *Umweltlehre* of Jakob von Uexküll, who explicitly introduced the notion of a "subject" into biological research. His contribution is assessed in terms of multivocal spatial terms such as (bio-)milieu and (bio)-sphere and the subject-object relations found in nature (within the plant and animal realms). This highlights the inherent limitations of the *Umwelt* concept, also explaining why in its purely biological sense it cannot be applied to the domain of human experience.

Die Kopernikaanse wending in die twintigste-eeuse biologie

Deur te let op die wyse waarop die term *Umwelt* beslag gekry het binne die biologiese denke van die twintigste eeu word 'n mens herinner aan die Kopernikaanse omwenteling ten gunste van die "subjek" wat in die moderne filosofie ingetree het. Oorspronklik besit die term *Umwelt* 'n ruimtelike konnotasie. Daarom lê 'n analise daarvan 'n interdissiplinêre verweefdheid bloot wat die grense van enige spesifieke dissipline te bowe gaan. Hierdie interdissiplinêre oorweging open die weg vir sistematiese perspektiewe teen die relevante historiese agtergrond, spesifiek die *Umweltlehre* van Jakob von Uexküll. Hy het (in aansluiting by Kant) die nosie van 'n "subjek" in biologiese navorsing aan die orde gestel. Hierdie bydrae word beoordeel in die lig van terme soos bio-milieu and bio-sfeer in terme van die talle subjek-objek relasies wat in die natuur (beide binne die ryke van plante en diere) aangetref word. Hierdie oorwegings belig argumente op grond waarvan die ongekwalifiseerde toepassing van die begrip *Umwelt* op die menslike ervaring bevraagteken moet word.

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In their speculation about a world *logos* and a "chain of being" classical Greek and medieval philosophy adhered to an ordering outside and beyond the human subject.[1] During the late medieval transitional period a withdrawal from the concepts of God and a cosmic world-order began. Descartes merely drew the radical conclusion of this process when he postulated the "thinking I" (*cogito*) as the new source of certainty, using the apparent infallibility of mathematics to proclaim the sovereignty of human thought. In his *Prolegomena to every future metaphysics acting as a science*, Immanuel Kant said that it was David Hume who had liberated him from his "dogmatic slumber" and helped him to realise that "objective reality" ought to be understood in terms of the subjective categories of thought (cf Kant 1783: 260 *Vorrede*). This is known as the "Copernican turn" in the epistemology of modern philosophy. In a different context I have shown that Kant actually elevated human understanding, through its *a priori* concepts, to become the formal law-giver of nature (cf Kant 1787: 163; Strauss 1982). Having thus witnessed a return towards the subject in modern philosophy, I consider in this article a similar occurrence which took place during the early twentieth century within the field of biology.

1. Hierarchical concepts only?

Every scholarly discipline inevitably has to employ key terms which are constitutive of its theoretical endeavours. The special sciences tend to coin their own terms as distinct from those employed by other disciplines, often as a result of misguided attempts to elevate certain basic concepts to be more encompassing than they really are. According to Thure von Uexküll it was the intention of the German biologist Jakob von Uexküll to design a new method in the development of his *Umweltlehre* (*Umwelt* theory) with its own peculiar conceptual system

1 This article focuses mainly on the development of biology during the early twentieth century. Its primary purpose is to highlight the intersection of a powerful philosophical tradition with a significant historical development within the discipline of biology. At the same time the relevance of crucial systematic insights and distinctions are applied to the material under discussion — particularly the idea of elementary or analogical basic concepts and the importance of particular subject-object relations.

which it would not be possible to derive from any of the existing sciences. He did this by employing the idea of purposefulness (*Planmäßigkeit*) and natural plans (*Naturplänen*).[2]

Is it really possible to develop a conceptual system which does not have any links to other domains of knowledge? If not, can instances of partial overlapping in the terminology of different disciplines be accounted for only by means of categories with varying degrees of generality, as is assumed in the approach of William Catton?

Catton attempts to develop a truly naturalistic sociology but does not want to become a victim of reductionism. He believes that sociological axioms may be formulated which are parallel to the axioms of Newton. He dismisses the charge that they are metaphorical as irrelevant. The sociological concepts thus defined and their physical counterparts should be viewed simply as special cases of more abstract concepts generally applicable to all fields of (naturalistic) inquiry (Catton 1966: 237). In other words, in terms of the classical Aristotelian mode of concept formation (the classification of plants and animals), he appears to advocate a distinction between a general concept (*genus proximum*) and more specific concepts (*differentia specifica*). He writes:

> If a force is that which produces an acceleration, then a physical force is that which accelerates material bodies in physical space, and a social force is whatever accelerates social processes. It makes sense to use the term 'force' in both contexts because both physical forces and social forces are special cases of the general concept (Catton 1966: 233-4).

Clearly, Catton elevates the concept of force to the level of a *genus*, encompassing various species of this general concept as special cases. The crucial question, however, is the following: if physical forces and social forces are merely specifications of a general (*genus*) concept of force, what then is the original experiential domain of this "general concept" of "force"? As a *genus* it must transcend the diversity of properties we can experience. If it does not find an original "home" or

2 "Um den unbekannten Inhalt von Naturplänen zu erforschen, bedarf die Umweltlehre einer Methodik, die aus keiner der bestehenden Wissenschaften entliehen werden kann. Sie muß dafür ihr eigenes Begriffssystem entwickeln" (Thure von Uexküll 1970: xxvii).

"seat" within the physical aspect of reality, where else can we locate it? Perhaps an alternative approach is required.[3]

2. The formation of analogical concepts

Something very fundamental regarding the formation of scientific concepts seems to be at stake here. Although energy-operation — with its associated notions of cause and effect — pertains in a crucial sense to physical phenomena, this does not mean that physics has a terminological monopoly on energy and force — or that other disciplines may not use these terms.

However, if different disciplines employed terms in the same sense it would be difficult to maintain that they were indeed distinct disciplines. It seems as if the only other option is to consider that each discipline uses the term "force" in its own peculiar way. But this raises the question: is there a primary or foundational use for such terms? If so, then other usages simply remind us of its original or primary sense while at the same time differing from its original meaning.

When one speaks about the "force" or the "validity" of an argument (employing the terms "force" and "validity" in a logical sense) the context evidently differs from that of a reference to physical forces. Likewise, the sociologist Robert MacIver in 1942 wrote a book dealing with "social causation", discussing all kinds of social forces. When economists analyse economic forces they do not use the term "force" in a physical sense either. But both social and economic forces cause certain changes within social and economic life revealing an unmistakable similarity to both physical forces and physical causes and effects (causation).

Yet social and economic forces are attributed to human beings or to societal institutions (collectivities) which are considered to be accountable in a normative sense (although they can also act in anti-normative ways, violating certain social or economic principles) which clearly indicates that there are also important differences between the various modes of forces.

3 We shall return to the concept of "force" in connection with Jakob von Uexküll's vitalistic orientation and the notion of a "vital force" in the theories of Hans Driesch.

It is precisely in the employment of the same term, "force", that the difference between the two universes of discourse becomes apparent. Another way of formulating this — and in doing so we call upon considerations which surfaced in medieval philosophy — is to say that in these instances the difference is shown within the element of similarity, or that the similarities are shown in the differences. These two formulations are alternative ways to define an analogy. Initially this term was used by mathematics in both an arithmetic (10-6 = 6-2) and a geometric (8 : 4 = 4 : 2) sense, with the combination giving birth to a harmonic connotation. In the transfer of meaning from the *genus* domain to that of the *species* (and *vice versa*) Aristotle used the notion of analogy to account for the lingual level of metaphor formation (cf Kluxen 1971: 214-27).

The interdisciplinary attempt to reflect upon the conceptual foundations of the term *Umwelt* soon reveals comparable considerations. It evinces particular connections to terms with spatial connotations. Within the context of a scientific study the term "space" can take on various different forms, more or less synonymous with "extension". Mathematics has struggled with this issue throughout its history, initially within Euclidean geometry and later in the context of analytic geometry and the more general discipline of topology. Mathematical space — or, as we might prefer to say, the original aspectual meaning of space — provides us with the most basic (foundational) sense of continuous (dimensional) extension. If this claim is sound, then other analogical usages presuppose the original spatial meaning of the term "extension" (and other analogically synonymous equivalents).

Catton (1966: 234) approximates this perspective when he remarks that one needs to use the adjective "physical" when physical force is intended "because physics got there first and has a prior claim on the word 'force'". Yet, in order to make this remark useful, Catton needs a theory regarding analogical linkages between various aspectual domains. Only then will it be possible to explain that the concept of force originally refers to the physical aspect or reality and can therefore only appear as a physical analogy in the social (and other non-physical) aspect(s). Any attempt to subsume analogical concepts under a highest *genus* concept must inevitably result in the eradication of the uniqueness of the different aspects of reality.

3. The initial meaning of the term *Umwelt*

An account of the first employment of the term *Umwelt* shows that it surfaced during the nineteenth century and subsequently developed in close connection to the notion of *milieu*. Müller (2001) refers to a contribution of Leo Spitzer (1948: 179-316) on "milieu and ambience" which appeared in his *Essays in historical semantics* where he points out that during the first decades of the nineteenth century the term *Umwelt* emerged as a newly formed (undefined and concept-free) word predominantly related to human beings in a topographical sense. The phrases mentioned are: the "surrounding world", "environment", "outer world" and "surrounding neighbourhood" (Müller 2001: 99).

Ernst Haeckel introduced the term "ecology" in 1866 (Müller 2001: 100). During the nineteenth century "milieu" was the term mainly used by biologists. A related term apparently referring to the same reality is "environment".

Since the rise of modern evolutionary biology the interaction between living entities and their *Umwelt* has given birth to the distinction between "phenotype" and "genotype". The latter expresses the inherent genetically determined potentialities of a living entity, while the former denotes how a living entity appears on the basis of its adaptation to the environment.

The fact that the further development of the term *Umwelt* was accompanied by a fundamental reassessment of "object" and "subject" is best demonstrated by considering the biological thought of Jakob von Uexküll.

4. The theory of von Uexküll

Jakob von Uexküll explored the concept of *Umwelt* in his biological thought. His views are explained in his general work *Theoretische Biologie* (1973) and also accessibly articulated in his work *Streifzüge durch die Umwelten von Tieren und Menschen: ein Bilderbuch unsichtbarer Welten; Bedeutungslehre* (1970).

Traditionally the academic disciplines dealing with various aspects of living entities encompass sciences such as physics, chemistry, physiology, anatomy, the study of the behaviour of animals (ethology) and

even sociology. Yet, as Thure von Uexküll (1970: xxiv) remarks, none of these disciplines gave an answer to the question of how the individual living being experiences the elements of its environment, how it orders these entities in its own world, or how this world is connected to the worlds of other living subjects. The greater the distance between human beings and animals becomes, the more problematic the answers provided by psychology.[4]

Jakob von Uexküll was critical of his age's dominant mechanistic view of the "organism" as a machine. Portmann (1970: x) points out that he respects the mysterious fact that the full-grown organism presents itself to us as a purposeful structured whole.[5] His theoretical biology, supported by extensive biological investigations, aims at substantiating certain basic features of Kant's philosophy (cf von Uexküll 1973: 12ff).[6]

Jakob von Uexküll introduces the notion of a "functional circle" (*Funktionskreis*) by means of which he intends to capture the structural coherence between the animal body and its environment — whether the latter is living or non-living, belongs to the same species

4 "Physik, Chemie, Anatomie, Physiologie, Ethologie und Soziologie, alte und neue Wissenschaften, Disziplinen, die auf den exakten Naturwissenschaften aufbauen, und solche, die andere Begriffssysteme verwenden, haben uns viele Antworten gegeben. Aber die Fragen, wie das einzelne Lebewesen die Dinge und Vorgänge seiner Umgebung erlebt, wie es sie zu einer Welt ordnet, in der es sich zurechtfindet — und wie diese Welt mit den Welten anderer lebender Subjekte zusammenhängt, diese Fragen finden im Kreis all dieser Wissenschaften keine Antworten. Sie werden von ihnen ausgeklammert, und die Antworten, welche die Psychologie zu geben vermag, die einzige Wissenschaft, in der Subjekte auftreten, die etwas erleben können, werden im Bereich der Tierwelt um so problematischer, je weiter wir uns vom Menschen entfernen".

5 "Von Anfang an lenkt Uexküll den Blick des Beschauers auf die übermaschinellen Eigenschaften des Lebensstoffes, auf die geheimnisvolle Tatsache, daß im reifen Organismus ein planmäßig gefügtes Ganzes vor uns ist".

6 In passing we should note that the recent project of Lakoff and Johnson, analyzing "conceptual metaphor," stems from the same Kantian legacy. They claim that the world as we know it does not contain any so-called "primary qualities" because "the qualities of things as we can experience and comprehend them depend crucially on our neural makeup, our bodily interactions with them, and our purposes and interests" (Lakoff & Johnson 1999: 26).

or not, or may even be dangerous. The "features" (*Merkmale*) of the environment are co-dependent upon the sensory organs (and neural structures) of animals — co-determine in advance the quality and intensity of the relationship between an animal and its environment. In attempts to penetrate an animal's experience (*erleben*), quantitative methods fall short. Suddenly the world of colours, forms, sound, and odours, with their joys and pleasures, appears as a worthwhile "object" of scientific biological research (cf Portmann 1970: xii).

With great care Jakob von Uexküll describes the introduction of the "subject" in biological research. He points out that although we do not know an animal's experiencing tone (*Erlebniston*) of elements in the environment according to their subjective quality, we can deduce their effects from the actions of animals. By highlighting this "toning" (*Tönung*) of "objects", biological thought is taken to its limits in the acknowledgement of an inner mood. Portmann (1970: xiii) remarks that the theory of Jakob von Uexküll on the peculiar *Umwelt* of every animal species did indeed become a chapter of modern biology. Whereas the science of ethology and physiology treat living organisms as "objects", his *Umweltforschung* focuses on animals as subjects.

Jakob von Uexküll constantly argues that we as human beings are never able to see, hear, smell or feel what a foreign subject sees, hears, smells or feels (Thure von Uexküll 1970: xxv). The relationship to the environment is given in an intricate and intimate connectedness, which causes Jakob von Uexküll to consider this reality in terms of a true totality (*Ganzheit*).

In addition to the *Merkwelt* of animals he introduces the notion of their *Wirkwelt* (action-world). The subject is endowed both with *Merkorgane* (organs receptive to noting "features") and with *Wirkorgane* (organs for taking action). The *Merkorgan* receives the features inhering in the bearer ("object") of such "marks" while through the *Wirkorgane* and the *Wirkwelt* the *Wirkmal-Träger* (the bearer of the effects of the actions of the animal subject) is affected. The "functional circle" (*Funktionskreis*) encompasses the coherence, adaptation and interaction of subject and object as a purposeful whole (*planmäßiges Ganzes*) (Jakob von Uexküll 1970: 11).

His classic example concerns the way in which an oak tree functions at once as the central reference point for various species of ani-

mals which disclose specific parts of the tree as constitutive of their life-world (*Umwelt*). In Chapter 13 of *Streifzüge* he discusses this issue under the heading: "The same subject as object in different *Umwelten*". The fox explores the roots of the oak tree in order to build its hiding place safely underneath the tree, which functions as its roof. The tree acquires a sole protective tone for the fox, which is similar to that of the owl. For the squirrel the tree has a climbing tone; for the singing bird that builds its nest in the branches it has a supportive tone. Jakob von Uexküll (1970: 98-100) writes:

> Each *Umwelt* isolates out of the oak tree a particular part whose characteristics are appropriate to be the bearer both of the properties and activities of their functional circle. In the *Umwelt* of the ant the whole of the oak tree diminishes [to] its crack-rich bark which, with its valleys and heights, becomes the hunting field of the ant. [...] In all the various *Umwelten* of its various inhabitants the same oak plays a widely diverging role, sometimes with particular and then again with none of its parts. The same part can be large or small, the same wood hard and soft, it can serve as a means of shelter or attack.[7]

As we have mentioned, although all these *Umwelten* in an objective sense coincide with the concrete multifacetedness of the tree and in this sense overlap, the *Umwelt* experiences of the various species of animals do not overlap.

If we invert the perspective and look at the animal subject in order to understand more about the way in which each subject "cuts out" what is required for its own *Umwelt*, the difference between our human *Umwelt* and animal *Umwelten* becomes more striking. For instance, the *paramecium*, as a unicellular organism, reacts only by fleeing (known as *phobotaxis*). Yet, in the absence of any specific sense organs, this reaction is sufficient to guide the animal to live in optimal conditions. Ludwig Von Bertalanffy (1973: 241) remarks:

7 "Jede Umwelt schneidet aus der Eiche einen bestimmten Teil heraus, dessen Eigenschaften geeignet sind, sowohl die Merkmalträger als auch die Wirkmalträger ihrer Funktionkreise zu bilden. In der Umwelt der Ameise [...] verschwindet die ganze übrige Eiche hinter ihrer rissigen Rinde, deren Täler und Höhen zum Beutefeld der Ameisen werden. [...] In all den Hundert verschiedenen Umwelten ihrer Bewohner spielt die Eiche als Objekt eine Höchst wechselvolle Rolle, bald mit diesen, bald mit jenen Teilen. Bald sind die gleichen Teile gross, bald klein. Bald ist ihr Holz hart, bald weich. Bald dient sie dem Schutz, bald dem Angriff."

> ... many things in the environment of the paramecium, algae, other infusoria, little crustaceans, mechanical obstacles and the like, are nonexistent for it. Only one stimulus is received which leads to the flight reaction.

He points out that this example demonstrates how the organisational and functional plan of a living entity is decisive in selecting what can become a "stimulus" or a "characteristic" to which the organism will react in a specific way:

> According to von Uexküll's expression, any organism, so to speak, cuts out from the multiplicity of surrounding objects a small number of characteristics to which it reacts and whose ensemble forms its 'ambient' (*Umwelt*). All the rest is nonexistent for that particular organism. Every animal is surrounded, as by a soap bubble, by its specific ambients, replenished by those characteristics which are amenable to it. If, reconstructing an animal's ambience, we enter this soap bubble, the world is profoundly changed: many characteristics disappear, others arise, and a completely new world is found (Von Bertalanffy 1973: 241).

Jakob von Uexküll also portrays the world of a tick, which reduces its typical environment in an astonishing way. It hangs motionless at the edge of a branch in the bushes. By virtue of its nature it is capable of exploring the possibility of falling onto a passing mammal. No stimulus from the total environment is registered. Then suddenly a mammal approaches. The tick requires its blood for its offspring.[8] Something quite remarkable then occurs: of all the effects which proceed from the mammal's body only three are turned into stimuli, and in a determined order. From the majestic world surrounding the tick only these three stimuli are activated, like light signals from the dark, as guides for the tick, allowing it to reach its goal with certainty.

8 Of course it may happen that the tick needs to wait for quite a time before a mammal passes by. But it is equipped to cope with this problem, for ticks have been reported to exist for 18 years without food (cf Jakob von Uexküll 1970: 13-4). Von Uexküll adds that there is a difference between the *Umwelt* and the "environment" (*Umgebung*) of an animal. Whereas conditions in the former are optimal, the picture may be more negative (*pessimal*) in the latter. Yet, if this state of affairs did not prevail, the optimality of a specific *Umwelt* might serve to overpower other species (cf Jakob von Uexküll 1970: 13, note 3).

Its world is reduced to three characteristics and three actions (*Merkmalen* and *Wirkmalen*).[9]

Von Bertalanffy (1973: 241-2) captures the thrust of Jakob von Uexküll's example of the tick in a striking way:

> Von Uexküll has given innumerable examples delineating the ambients of various animals. Take, for instance, a tick lurking in the bushes for a passing mammal in whose skin it settles and drinks itself full of blood. The signal is the odour of butyric acid, flowing from the dermal glands of all mammals. Following this stimulus, it plunges down; if it fell on a warm body — as monitored by its sensitive thermal sense — it has reached its prey, a warmblooded animal, and only needs to find, aided by tactile sense, a hair-free place to pierce in. Thus the rich environment of the tick shrinks to metamorphize into a scanty configuration out of which only three signals, beaconlike, are gleaming which, however, suffice to lead the animal surely to its goal. Or again, some sea urchins respond to any darkening by striking together their [242] spines. This reaction invariably is applied against a passing cloud or boat, or the real enemy, an approaching fish. Thus, while the environment of the sea urchin contains many different objects, its ambient only contains one characteristic, namely, dimming of light.[10]

9 "Die Zecke hängt regungslos an der Spitze eines Astes in einer Waldlichtung. Ihr ist durch ihre Lage die Möglichkeit geboten, auf ein vorbeilaufendes Säugetier zu fallen. Von der ganzen Umgebung dringt kein Reiz auf sie ein. Da nähert sich ein Säugetier, dessen Blut sie für die Erzeugung ihrer Nachkommen bedarf. Und nun geschieht etwas höchst Wunderbares: von allen Wirkungen, die vom Säugetierkörper ausgehen, werden nur drei, und diese in bestimmter Reihenfolge zu Reizen. Aus der übergroßen Welt, die die [13] Zecke umgibt, leuchten drei Reize wie Lichtsignale aus dem Dunkel hervor und dienen der Zecke als Wegweiser, die sie mit Sicherheit zum Ziele führen. Um das zu ermöglichen, sind der Zecke außer ihrem Körper mit seinen Rezeptoren und Effektoren drei Merkzeichen mitgegeben worden, die sie als Merkmale verwenden kann. Und durch diese Merkmale ist der Zecke der Ablauf ihrer Handlungen so fest vorgeschrieben, daß sie nur ganz bestimmte Wirkmale hervorzubringen vermag. Die ganze Teiche, die Zecke umgebende Welt schnurrt zusammen und verwandelt sich in ein ärmliches Gebilde, das zur Hauptsache noch aus 3 Merkmalen und 3 Wirkmalen besteht – ihre Umwelt. Die Ärmlichkeit der Umwelt bedingt aber gerade die Sicherheit des Handelns, und Sicherheit ist wichtiger als Reichtum" (Jakob von Uexküll 1970: 12-3).

10 In terms of the idea of objectification discussed below, we can say that the milieu of animals is divided into whatever is objectified into their species-specific *Umwelt* and all the other potentially objectifiable entities belonging to their environment. The term *Umwelt* captures what has been objectified, while the term "environment" designates entities/subjects not objectified.

5. Thermodynamic open systems: transcending the vitalist legacy

Implicit in Jakob von Uexküll's account of the *Umwelt* of different animals is a new assessment of the importance of subjects in nature. Although the notion of a subject could be understood in the sense of activities, one cannot side-step the correlating concept of a law to which entities in nature are subjected. Physical entities are subject to structural physical laws and living entities to structural biotic laws,[11] while sentient creatures, such as animals, are subject to structural psychic laws.

The classical mechanistic point of view in biology believes that living entities (like plants, animals and human beings) are fully explicable in terms of non-biotic ("material") categories. In general the mechanistic standpoint rejects any "immaterial" force. Yet such an extreme materialism encounters severe difficulties with the ontic status of physical entities, which are supposed to be subject to physical laws — like those of thermodynamics — for these physical laws are not themselves material in nature.

Traditional vitalist approaches elevated the biotic aspect of living entities into an immaterial entity. The neo-vitalist biology of Hans Driesch extensively experimented with the phenomena of regeneration. Driesch accounted for the internal order and harmony displayed in the functioning of living entities (characterised by him as harmonic equi-potential systems) by introducing his notion of an immaterial vital force, an *entelechie* (Driesch 1920: 139ff), capable even of "suspending" physical laws, such as the second main law of thermodynamics, or the law of non-decreasing entropy (Driesch 1920: 434ff). He thought that *Entelechie* could account for the fact that living entities are apparently capable of increasingly creating internal order (an apparent decrease in entropy) in spite of the existence of the physical law of non-decreasing entropy. Driesch came to these conclusions after having shown convincingly that certain parts of living entities, after division, can function as immature wholes capable of developing integral maturity. In the case of a hydra, for example, a part as

11 Note that we do not speak of biological laws, since biology, as a scholarly discipline, is the product of human endeavours, whereas living (biotic) entities are not.

small as 1/200th can regenerate a whole new (freshwater) polyp. Yet, when no part is separated from an organism, the original living entity will mature normally without independently developing into more than one individual.

The unsolved problems entailed in this vitalist position were effectively realized when Von Bertalanffy generalised the second main law of thermodynamics to open systems. The internal order built up by a living entity is not more than the chaos created outside it. Von Bertalanffy (1973: 132) generalised this law to include cases of a constant interchange between systems and their environments:

> Chemical equilibria in closed systems are based on reversible reactions; they are a consequence of the second principle of thermodynamics and are defined by minimum free energy. In open systems, in contrast, the steady state is not reversible as a whole nor in many individual reactions. Furthermore, the second principle applies, by definition, to closed systems only and does not define the steady state.

Von Bertalanffy's generalisation not only shows that living entities are thermodynamically open, but in the first place accounts for the numerous examples of physical systems that are also thermodynamically open, such as a glacier or a fire. This dynamic equilibrium, designated by the term *Fliessgleichgewicht* (steady state) by Von Bertalanffy (1973: 165), therefore concerns a physical feature of living entities, not a distinctive biotic one. In his work on the physical aspect of the cell Erwin Schrödinger speaks about negentropy in this connection (cf Schrödinger 1955).

That the physical aspect is foundational to the biotic aspect is even made clear by the term used by vitalism to account for something immaterial, for this is designated as a "vital force". In terms of our initial remark about original and analogical usages of the concept of force this designation actually begs the question. "Force" belongs first of all to the domain of physical phenomena. It is crucial to the physical aspect of energy-operation and it entails physical causes and physical effects.

The concept of a vital force simply reflects the unbreakable coherence between the biotic and the physical aspects of reality and cannot be used to support the idea of an entity-like immaterial "substance". Speaking about a vital force actually highlights a physical

analogy within the structure of the biotic aspect, similar to the way in which speaking about social forces reveals a physical analogy within the structure of the social aspect.

6. The original spatial foundation of a theory of an ambient (*Umwelt*)

Our exposition thus far has implicitly employed the intuitive idea of modal, functional aspects of reality pertaining to the "how" (mode of existence) of entities and not to their concrete "what". The quantitative aspect of numerosity enables the human being to ask questions about "how many?"; the spatial aspect of continuous extension enables us to ask questions about the dimensions and size of things, and so on (cf Cassirer 1969). Aspects relate to the *modus quo* of reality and are therefore also succinctly designated as modalities (cf Dooyeweerd 1997: vol 2). It is part of the classical heritage of philosophy and logic to distinguish between entities and their properties. Yet our intention is to argue for universal ontically given (functional) modal aspects. In their universality they co-determine the typical way in which concrete entities, processes and societal collectivities function within such modalities.[12]

Space in its original mathematical sense is characterised by continuous extension. The claim of modern set theory that it has succeeded in fully arithmetizing continuity entails an inherent circularity (cf Strauss 2002). Although the Greek atomists, Leucippus and Democritus, believed that there indeed are last indivisible units (which they called atoms) philosophy since Descartes has switched to the conviction that physical space is both continuous and infinitely divisible — a view already to be found in the thought of Anaxagoras and Aristotle. However, by the turn of the nineteenth/twentieth centuries it became necessary to distinguish between mathematical space and physical space. Physical space differs from mathematical space because it is a field, acting on physical subjects like electrons and atoms in an

12 For this reason we do not adhere to the nominalistic legacy which believes that number and other universals are mere modes of thought, as was asserted by Descartes (cf his *Principles* LVIII).

action which is intermediated by field particles such as electrons.[13] David Hilbert (1925: 164) points out that whereas mathematical space is continuous and infinitely divisible, physically extended realities such as matter, electricity and energy are not:

> In addition to matter and electricity, there is one other entity in physics for which the law of conservation holds, viz, energy. But it has been established that even energy does not unconditionally admit of infinite divisibility. Planck has discovered quanta of energy.

In his theory of relativity Einstein, too, has a clear insight into the way in which the original meaning of space (simultaneity) is relativised. Neither the spatial point at which something occurs nor the temporal moment in which it happens has physical reality. It is only the event itself which has physical reality.[14]

Although the meaning of space finds expression in its coherence with other aspects, the continuous extension at its core is indefinable. The same applies to our concept of number, where the intuition of a distinct multiplicity may be paraphrased but never "defined" in a non-circular way. This explains why modern axiomatic set theory, for example the system of Zermelo-Fraenkel, had to proceed from the acceptance of the undefined term "element of" (which is equivalent to the notion of a "set").[15]

Furthermore, the term "totality" (*Ganzheit*/*Totalität*) is merely synonymous with continuity. Whatever is continuously extended, such

13 I owe the formulation of this sentence to a critical remark from an anonymous reviewer.

14 The German text reads: "Nicht der Raumpunkt, indem etwas geschieht, nicht der Zeitpunkt, in dem etwas geschieht, hat physikalische Realität, sondern nur das Ereignis selbst" (Einstein 1982: 33).

15 Kurt Gödel (1964: 262, note 14) highlights the circularity entailed in the attempt to "define" a set: "The operation 'set of x's' (where the variable 'x' ranges over some given kind of objects) cannot be defined satisfactorily (at least not in the present state of knowledge), but can only be paraphrased by other expressions involving again the concept of set, such as: 'multitude of x's', 'combination of any number of x's', 'part of the totality of x's', where a 'multitude' ('combination', 'part') is conceived of as something which exists in itself no matter whether we can define it in a finite number of words (so that random sets are not excluded)".

as a straight line, coheres in the sense that all its parts are connected. With disconnected parts it would not be continuous. But if all the parts are present, then the line is given as a whole, in its totality. The whole-parts relation is therefore derived from the core meaning of continuous extension. It should not surprise us, therefore, that it is precisely this totality feature of continuity which forms an obstacle in the attempt to completely arithmetize continuity. Paul Bernays, the co-worker of the foremost mathematician of the twentieth century, David Hilbert, aptly writes:

> The property of being a totality undeniably belongs to the geometric idea of the continuum. And it is this characteristic which resists a complete arithmetization of the continuum.[16]

In a discussion of the foundational issues of mathematics Hermann Weyl also alludes to the irreducibility of continuity. In following the Dutch intuitionist, L E J Brouwer, it is the conviction of Weyl that mathematics should acknowledge the crucial whole-parts relation whenever it deals with continuity. He says that the fact of having parts is a fundamental property of the continuum. The "atomistic" understanding seriously violates this intuition, as is emphasised by Brouwer.[17] It is of the essence of every continuum to permit of infinite division: every part allows for an unlimited number of further subdivisions (Weyl 1921: 77). Mathematical analysis which tried to side-step this crucial aspect of the whole-parts relation in treating issues of continuity had to employ the notion of an environment (*Umgebung*):

> In order to account for the continuous coherence of points, contemporary analysis, which indeed broke apart the continuum into isolated points, had to take recourse to the environment concept.[18]

16 "Und es ist auch dieser Charakter, der einer vollkommenen Arithmetisierung des Kontinuums entgegensteht" (Bernays 1976: 74; cf also Strauss 2002).

17 "Daß es Teile hat, ist aber die Grundeigenschaft des Kontinuums; und so macht die Brouwersche Theorie (im Einklang mit der Anschaunung, gegen welche der heutige 'Atomismus' so arg verstößt) dieses Verhältnis zur Grundlage für die mathematische Behandlung des Kontinuums" (Weyl 1921: 77).

18 "Um den stetigen Zusammenhang der Punkte wiederzugeben, nahm die bisherige Analysis, da sie ja das Kontinuum in eine Menge isolierter Punkte zerschlagen hatte, ihre Zuflucht zu dem Umgebungsbegriff" (Weyl 1921: 77).

In spite of the fact that mathematics did not explore a third option — as opposed to the arithmeticism and geometricism which have dominated the history of mathematics (cf Strauss 2001: 17-51) — namely to acknowledge number and space in their uniqueness (irreducibility) and their mutual coherence, this insight proves useful in assessing atomism and holism.

7. The one-sidedness of opposing "element" to "totality" (*Ganzheit*)

Jakob von Uexküll constantly argued against the atomistic assumptions of the prevailing mechanistic trend in biology. From the time of Democritus atomism had acquired two senses, one indicating the attempt to explain the material world in terms of final indivisible elements ("atoms") and the other a broader conception using the term to designate different forms of pluralism.[19]

In opposition to both mechanistic monism and vitalistic dualism as biological theories the term holism was introduced by J C Smuts in 1926. In this narrow sense it aimed at a dialectical synthesis which might do justice to the imagined highest concrete totality (*Ganzheit* in the case of Adolf Meyer 1964). An expanded connotation is given to holism when it is used in the sense of a universalism which, in opposition to (sociological) individualism, attempts to account for the meaningful coherence and mutuality within societal institutions, ie for wholeness/totality as an essential trait of societal collectivities.[20] In his *Ontologie des Lebendigen* the German biologist, Richard Woltereck, a contemporary of Jakob von Uexküll and Othmar Spann, also develops a position which emphasises wholeness and *Ganzheit*.[21]

19 In the case of human society the final units were seen as the individuals. From 1825 Saint-Simon and his followers (among them Comte) employed the term "individualism" to designate the social philosophy of the eighteenth century as a whole — the view in which society was fragmented into isolated individuals (cf Strauss 1999).

20 Introduced by the German philosopher, sociologist, and economist, Othmar Spann, in the 1920s and also applied in his nature philosophy, cf Spann 1937.

21 Cf Woltereck 1940 and his reference to Spann on page 476, note 13.

From a theoretical point of view one may say that atomistic (individualist) stances in philosophy over-emphasise the explanatory potential of the quantitative mode of reality (or analogies of it in other modalities),[22] whereas holistic (universalist) orientations do the same with the spatial mode and its inherent whole-parts relation (or analogies of it in other aspects of reality).

Living entities integrate the multiplicity of their vital functions in order to continue to exist. They function in a unified way, thus exhibiting a function within the quantitative aspect of our experiential horizon. Note the subtle difference at stake in the distinction between the concrete function of a living entity within the numerical mode of reality and the inter-functional connections between the biotic and the arithmetical modes as expressed in the numerical analogies within the biotic aspect. A living entity is a biotic unity in the multiplicity of its vital functions. This state of affairs is well reflected in the uniqueness of biotic growth phenomena, for if a living entity does not continuously succeed in integrating its vital functions, it disintegrates and dies.

Within the discipline of physics we encounter the concept of "mass". It represents a numerical analogy within the physical aspect since it relates to a "quantity of matter". Similarly, a biologist may speak about "biomass". Jones (1998: 54), for example, refers to the fact that plants constitute 99% of the world's biomass, while fungi are estimated to have twice the total biomass of animals.

But living entities certainly also function within the spatial mode of reality — they are spatial subjects and they are related to other (surrounding) spatial subjects (ie those in their environment which

22 Organicism as a theoretical position does not necessarily need to be holistic because one can just as well explore the numerical analogy in the biotic aspect instead of the spatial whole-parts relation. Herbert Spencer, for example, advocates an organicist view but clings to an individualist perspective. Spencer speaks repeatedly about an organic aggregate which is fundamentally the same as a social aggregate. But he loads his conception of a biotic organism with an atomistic (individualist or aggregate) perspective in order to be consistent with his individualist liberal political convictions. He comments, for instance, on the decrease of authoritative control in society: "A more pronounced individualism, instead of a more pronounced nationalism, is its ideal" (Spencer 1968: 22).

share in the mode of being spatially extended). Even the smallest independent "unit of life" — the living cell — exhibits a remarkably constant proportionality in respect of the ratio between the nucleus and the cytoplasm.[23] The size and shape of living entities (a manifestation of their concrete function within the spatial mode) provide a foundation for the inner coherence between the spatial aspect and the biotic aspect, captured in the well-known expression "bio-milieu" and the equally familiar concept of the "bio-sphere".

The way in which living entities are adapted to their environment received a specific designation in the holistic biology of Adolf Meyer. With the aid of extensive empirical information Meyer (1964: 59-60) formulated a "basic typological law":

> There is no group of existing organisms belonging to any taxonomical category of the Natural System, whose members possess all group characters in their most primitive or in their most progressive phases only. Rather are primitive, intermediate and progressive character phases thus combined with each other in each real member of a group that an organismic holism suited for living in any real existing ecological biotope results from it. Forms which possess all their morphological characters in their primitive or in their progressive phases only are neither living holisms nor suited for existence in ecological biotopes and are, therefore, but purely ideal constructions.

Yet one should question the mode of speech advocated by Jakob von Uexküll when he attributes the feature of being a true totality (*Ganzheit*) to the subject- and object-encompassing nature of an *Umwelt*. The various entities involved in these interrelations are indeed, in their own right, genuine totalities (wholes) which escape any atomistic attempt to reduce them to final constitutive elements ("atoms"). But in their interrelations these entities do not terminate their wholeness, however intimate their interwovenness with other entities may be. The Dutch philosopher, Herman Dooyeweerd, employed the term *enkapsis* (borrowed by Theodor Haering from the German anatomist Heidenhain) in order to explain the interlacement intended in these instances. This term aims to account for the maintenance of the internal structural properties of an entity even when it is intertwined

23 Richard Hertwig speaks about the "nucleoplasmic index" which is equal to the volume of the nucleus divided by the volume obtained when the volume of the nucleus is subtracted from the volume of the cell (cf West & Todd 1962: 208).

with other entities — like the atoms bound through chemical bonding into the enkaptical whole of a molecule. A similar interlacement is present when the relationship between physico-chemical constituents is explained as foundational to the typical vital functions of living entities. A living entity necessarily functions on the basis of material configurations (largely macro-molecular in nature), but the phrase "living organism of a living entity" should actually be reserved for the biotically characterised dimension of a living entity which is alive through and through. Consider, for instance, the organelles present within the organism of a living cell: lysosomes, mitochondria, ribosomes, and so on are all alive. The same could not be said in respect of the living entity as a whole, because the atoms, molecules and macro-molecules as such (in which the functioning of these organelles are founded) is not alive although they are also present within the total existential form of the living entity.[24]

8. Objectification in living and sentient creatures

Hans Jonas (1973: 23) aptly describes the underlying assumption of a pan-mechanistic approach in considering pan-mechanism and the problem of life:

> Life as a problem here indicates a recognition of its strangeness in the mechanical world, which is the real world; to explain it means – on this level of the universal ontology of death — to deny it, reducing it to a variant of the possibility of the lifeless.

Compared to the mass of *unbelebte* matter in the universe, living entities indeed appear to be a negligible layer at most.[25] Yet living entities ensure that the earth is kept in a dynamic state and not in chemical equilibrium (recall Von Bertalanffy's concept of *Fliessgliechgewicht* = "steady state"). It is worthwhile to pause for a moment to consider some of the most remarkable facts regarding the "life-controlled" condition of the earth:

> Through the key processes of respiration and photosynthesis (the world's most important redox reactions!), organisms entirely renew the carbon dioxide in the air every few years, and even the much larger volume of oxygen is renewed in about 2000 years. Most incredibly

24 Cf Dooyeweerd 1997, 3: 634ff.

25 Von Weizsäcker prefers to refer to physical entities — cf Weizsäcker 1993: 32.

> of all, even the 1.5 billion, billion metric tonnes of water on the Earth are eventually split and reconstituted by the activities of living things. It would seem incredible, because the biosphere is such a very thin film on the Earth's surface (it is spread throughout the oceans of course, but incredibly thinly). Compared with the depth and volume of the atmosphere, hydrosphere or crust, the biosphere is insignificant. For every atom in the biosphere, there are about 700 in the atmosphere, 400 000 in the hydrosphere and 2 000 000 in the crust! Yet this insignificant 'scum' maintains most of the rest of the world in a steady state adjusted optimally to its own needs. So accurate is the biosphere's system of balances and adjustments that, for example, the oxygen concentration in the air has not measurably varied during the 80 years for which accurate measurements have been available (Jones 1998: 42).

Biologists tend to explain this reality by using the term "adaptation." This practice may easily lead to a disregard for the guiding and qualifying biotic activities involved — as if the environment fully determines what happens to biotic subjects. Such an understanding loses sight of the fact that while the organic function of living entities is surely dependent upon environmental conditions — the legitimate side of the meaning of "adaptation" — that this is not sufficient to explain their guiding and determining role in respect of inorganic surroundings. The splitting and reconstituting of the earth's water, mentioned above, can only occur when living entities absorb water in their life cycle. Through their enkaptic bonding within living entities, water molecules are structurally objectified within the biotic aspect of reality, ie they function in service of the biotic needs of living entities.

Similarly, in the life of animals, the surrounding physical environment becomes partially objectified into the *Umwelt* of animals through and under the guidance of subjective animal functioning. Objectification as such is always the activity of a subject.[26]

What should be borne in mind is that Jakob von Uexküll's *Umweltlehre* finds a solid basis in the fact that each specific species has its own *Umwelt*. However, his attempt to expand its scope in order to incorporate human beings does not withstand critical scrutiny. Just as

26 An interaction with the ideas of Lakoff & Johnson (1999) briefly referred to above, which naturally falls outside the scope of this article, would have to introduce this view of objectification and its implied subject-object relations.

he expanded his *Umwelt* theory to human experience, we may consider the way in which the oak tree is opened up through human acts of objectification (cf von Uexküll 1970: 94ff). The human experience of the oak tree transcends the natural aspects of reality to which animal experience is restricted. Animals experience reality exclusively out of their natural inclination, directed at what is physically, biotically or sensitively important to them. They experience reality in terms of what is accessible or not accessible, edible or inedible, of the same sex or the opposite sex, and comforting or alarming (endangering).

The human experience of a tree opens up vistas beyond the grasp of animal capabilities. The natural scientist sees the tree as an object of analytical study, the hiker as something with a particular aesthetic attraction, the criminal as a hiding place from the law, the woodcarver as material from which to make furniture, and so forth. This human experiential perspective with its rich variety is linked to a cultural calling which enables a person to be variably settled in any environment by means of cultural formation. But in the case of human beings none of these domains of objectifiability is exclusive. Human beings share all of them and it is precisely in so doing they differ fundamentally from animals with their non-overlapping *Umwelten*. Adolf Portmann (1970: xiv) notes this shortcoming in mentioning that Jakob von Uexküll neglects the fact that all these different *Weltansichten* (world perspectives) share a communal species-world which enables mutual understanding as well as interaction on the basis of opposing views. The communal world in which human beings live constitutes a shared domain which is not fragmented even by the most severe differences in potential or cultural traditions. Poetry thrives on differences in world perspectives but depends on a final horizon of mutual understanding. The term *Umwelt* should be reserved for the distinction of the different worlds of animal populations; it should not be applied to the various ways in which human beings view the world,[27] and it should also be distinguished from the biotic envi-

27 "Diese Gemeinschafts-Sphäre der Menschenwelt, in der die Eigenwelten — deren Kontraste wir ebenso groß sehen wie Uexküll — eingebettet sind, dieses Umfassende der grundsätzlichen Verstehensmöglichkeit schafft die besondere humane Situation. Wie groß wir auch die durch Anlagen-Unterschiede oder durch Tradition entstehenden Gegensätze menschlicher Welten ansetzen, sie

ronment of plants. Portmann (1969: 86) is convinced that animals are actually determined by their instincts and that they are restricted to a particular ambient. The way in which animals experience the world is completely determined by their natural dispositions. They are only concerned with what has a direct physical, biotic or sensitive meaning to them. Consequently, they experience reality in terms of places suitable for walking or flying (physical accessibility), in terms of sex partners and other animals belonging or not belonging to the same species, in terms of what can be eaten and what not (biotic interest), and in terms of things or events which cause anxiety or which may be comforting (sensitive concern) (cf Landmann 1969: 162ff).

Gostonyi (1976) attempts to account for the difference between animal *Umwelten* and the domain of human experience in terms of the opposition between constancy and dynamics (change). He holds that the *Umwelt* of animals is largely stabilised through processes that are directed by instincts which cause them by and large to be unchanging. By contrast, as an effect of the *Instinkt-Ungebundenheit* of human beings (the fact that they are not determined by their instincts), the "world" of human beings is subject to continuous change, being constantly broadened and transformed. The animal is born as a part of its *Umwelt*, while the human being "conquers" its "world".[28]

liegen alle in einer Sphäre. Alle Dichtung lebt von der Darstellung solcher verschiedenen Weltauffassungen und ihrer Begegnungen — aber gerade die Dichtung beruht auch auf dem Grunde letzter Möglichkeit des Verstehens der Andern. Die Trennung tierischer Artwelten als gesonderte Sphären soll im Worte 'Umwelt' festgehalten und betont werden — gerade darum müssen wir aber diesen Begriff für die Kennzeichnung menschlicher Gegensätze des Weltbildes ausschalten" (Portmann 1970: xiv).

28 "Der entscheidende Unterschied zwischen der menschlichen 'Welt' und der Umwelt der Tiere ist — vereinfacht formuliert — der, daß letztere durch weitgehend gleichbleibende, weil von Instinkten gesteuerte Verhaltensabläufe stabilisiert und somit im großen und ganzen unveränderlich ist, während die 'Welt' des Menschen — dank seiner Entwicklungsfähigkeit und seiner 'Instinkt-Ungebundenheit' — ständiger Veränderung, Wandlung, d.h. Erweiterung und Umstrukturierung unterworfen ist. Das Tier wird in seine Umwelt hineingeboren, der Mensch 'erobert' sich seine 'Welt'" (Gostonyi 1976: 902).

9. Concluding remarks

The term *Umwelt* emerged and eventually found application mainly within the domain of biology and the discipline of animal behaviour. Given its original spatial connotation, an account of its meaning had to consider the interconnectedness of terminology transcending the confines of a single discipline. This interdisciplinary insight opens the way for the systematic considerations which we have developed in confrontation with the relevant historical perspectives.

Although we have argued that animal subjectivity is presupposed in every animal process of objectification, our subsequent argument relativised the "Copernican turn" by reverting to the acceptance of ontically given modal aspects of reality which ultimately condition every kind of animal (and human) subjectivity.

The merit of Jakob von Uexküll's *Umweltlehre* lies primarily in its aim to give animal subjectivity its due place. His understanding of the *Funktionskreis*, which highlights the interdependence between animal subjectivity and whatever is objectified by animals into their respective *Umwelten*, indeed reveals the constitutive domain of objectification underlying the very existence of living entities (in a biotic sense) and animals (as sentient creatures).[29] Although this subjective capacity to objectify also inherently belongs to human beings, it was necessary to point out that applying the *Umwelt* concept in Jakob von Uexküll's sense to the human domain neglects the mutuality of human understanding.

In order to come to a more systematic account of the original and analogical meaning of spatial (and numerical) terms we addressed related issues, such as the uniqueness and mutual coherence between number and space as well as the analogical concepts found in other disciplines, as being based upon the inter-modal connections between various modal aspects of reality.

These ontic modalities turned out to be not merely functional conditions for concretely existing entities, since they also serve as modes of explanation within different but mutually cohering scientific universes of discourse. Through the inter-modal coherence between

29 Portmann (1969: 86) characterises animals as milieu-bound and secured by their instincts ("Umweltegebunden und Instinktgesichert").

the spatial aspect and other aspects we are fully within our epistemic rights when we employ (analogical) concepts of space in diverse disciplines. Although we have highlighted some of these analogical phrases — such as physical space, biotic space (bio-sphere, bio-milieu and so on), and sensitive space (the content given by Jakob von Uexküll to his notion of an *Umwelt*) — there are still many others not considered in this study. Some of these unexplored contexts are: logical space (Rudolph Carnap [1922] wrote a work in which he reduced space to so-called formal space), lingual space (also encompassing theories regarding the semantic domains of words), social space (consider notions of social stratification and social distance), and jural space (intricate legal questions regarding the location of a legal fact).

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