Piero Mella

The Holonic Revolution

Holons, Holarchies and Holonic Networks
The Ghost in the Production Machine

Pavia University Press

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Preface

> Quod est inferius est sicut quod est superius, et quod est superius est sicut quod est inferius ad perpetranda miracola Rei Unius.
>
> That which is below is like that which is above, and that which is above is like that which is below, to make a miracle of the thing that is unity (Smeraldine Table of Ermete Trismegisto).

A minor conceptual revolution has been under way for less than forty years now, beginning in 1967 with the publication of Arthur Koestler's *The Ghost in the Machine* – a phantasmagorical book in terms of the breath and variety of its content – which formally introduced the concepts of *holon* and *holarchy* (the hierarchical ordering of holons).

Koestler's idea is clear and simple: in observing the Universe surrounding us (at the physical and biological level and in the real or formal sense) we must take into account the *whole/part* relationship between observed "entities". In other words, we must not only consider atoms, molecules, cells, individuals, systems, words or concepts as autonomous and independent units, but we must always be aware that each of these units is at the same time a *whole* – composed of smaller parts – and *part* of a larger *whole*.

In fact, they are *holons*.

By systematically applying the *whole/part* observational relationship, or the equivalent one of *containing/contained*, the Universe appears to us as a hierarchy of *holons*: that is, as a *holarchy* where, at each hierarchical level, the holons undergo the effects of the structural or operational variations of the subordinate holons and in turn produce variations in the behaviour of the superordinate ones.

The entire *machine* of life and of the Universe itself evolves toward ever more complex states, as if a *ghost were operating the machine*.

The concepts of holon and holarchy have since been used, especially in recent times, by a number of writers in a variety of disciplines and contexts, and these concepts are rapidly spreading to all sectors of research. Physics (Capra 1982), engineering (Babiceanu *et al*. 2005; Dani *et al*. 2004)), robotics, biology (Shafaei – Aghaee, 2008), organizational studies, management science (Zhang *et al*. 2003; Ng *et al*. 1996), business administration and entrepreneurship (Chirn – McFarlane 2001), production and supply chain systems (McFarlane – Bussmann 2000; Aktürk – Türkcan 2000; Amiri 2006). Connected to these ideas are those of holonic networks, holonic and virtual enterprises, virtual organizations, agile manufacturing networks, holonic manufacturing systems, fractal enterprise and bionic manufacturing (Chapter 5).

This short essay, written from an economic-business point of view, has four objectives.

The first (covering the first two chapters) provides the reader with a brief but precise *theoretical* framework for understanding the meaning of the new terms that increasingly come up in business literature (outside Italy as well) and which refer directly or indirectly to the ideas of holon and holarchy. Connected to these terms are those of holonic network, holonic firm and enterprise, holonic manufacturing systems, holonic production, bionic production, fractal enterprise, and virtual enterprise, to name but a few.

Since I have observed that often the term "holon" has been improperly used, without any reference to the original sources, leading to models and conclusions that are absolutely inappropriate, I feel it is useful to provide the theoretical framework within which these terms can be properly used, considering not only Koestler's definition but also the ideas of Ken Wilber, which are based on this notion.

I also feel it is useful to examine several fundamental classes of holarchies in order to show that the idea of a hierarchical order among classes of holons can be applied to a variety of contexts. In particular I have presented Koestler's *Self-organizing Open Hierarchical Order*, Wilber's *Kosmos* and Shimizu's *Autonomic Cognitive Computer* as applications that illustrate the concept of a holon.

The second objective (presented in Chapter 3) is to extend the notion of holon while respecting its original meaning, in order to apply it to organizations.

Starting from the definition of organizations as systems whose organs are composed of individuals or groups of individuals, I have attempted to demonstrate two interconnected aspects: on the one hand, that organizations are holons that derive from a holarchy of organs (from their functionalities), and on the other that organizations can be formed by other holon-organizations – which I have labelled *orgons* – that are connected in a holarchy that I have called an *orgonization*.

When we observe the functionality and the function of its organs we see that an organization can be thought of as a macro system whose purpose is the attainment of a macro objective. It immediately follows that it can be compared to an *Holonic Manufacturing System*, or to an *Autonomic Cognitive Computer*; that is, to a holarchy of operators at different levels – each included in the other, so as to form parts of ever smaller size – each capable of pursuing part of the macro objective.

When there is a larger objective to achieve, rather than add levels to the org*a*nization we can form an org*a*nization of org*a*nizations, that is an org*o*nization with unique characteristics.

The third objective is to show (Chapter 4) how holons can be connected not only in the typical hierarchical structure – the holarchy – but, by stretching somewhat the original meaning, also in a reticular structure in order to form *holonic networks* in which the vertical ordering (above and below) is replaced by a horizontal one (before and after).

Within the *holonic networks* the holons maintain their autonomy and their whole/part relationship, which together characterize holarchies. However, for this reason the dominant feature is their horizontal systemic interconnections; each holon becomes a node of input-output interconnections between holons that come before and those that come after in the structure.

I have thus discovered that even holonic networks can be made up of org*o*ns that form *orgonic networks*.

Since *holarchies, orgonizations, holonic networks* and *orgonic networks* are present everywhere – in firms and between firms, as well as in the economic system of which they are a vital part – it is useful to present a general survey.

Among the many types of holonic networks, I have chosen to examine the main sources of inspiration for those production systems referred to as the *Holonic Manufacturing Systems*, comparing these to those defined as *Bionic* and *Fractal Manufacturing Systems*. I have also considered the numerous *forms of Inter-organizational Networks as well as the Holonic and Virtual Organizations*.

The fourth objective (Chapter 5) is perhaps the most ambitious one, since I have tried to extend the holonic vision to the global production-economic system, or *Production Kosmos*.

Globally we are witnessing the continual and accelerated economic progress of mankind. There is an increase in the quantity and quality of needs that are satisfied and those still to be satisfied, and in the aspirations achieved and yet to be achieved. The increase in productivity and quality is unstoppable, and appears to guide the other variables in the system.

It is natural to ask who activates and governs such phenomena. The answer is that they are self-generated and self-organized in the context of *reticular holarchies* and *orgonic networks* formed by production enterprises – or production organizations – that comprise the integrated process of global production.

On a continental scale, it makes sense to consider production in terms of *networks* of *orgons* in which, by choice or not, every firm that produces final consumption goods is linked at several levels to a number of other suppliers of materials, components, machines and other structural factors. We can easily observe that the large continental production networks – in North America, China, Japan, India and Europe – are not yet integrated but are becoming larger and increasingly connected, while other local networks are developing in other countries.

In order to understand how things are evolving in a context where there is a connection between firm and production organization we need a conceptual framework that does not limit our observations to the single production units, searching therein for the laws of survival, but one which, at least in principle, is able to explain how the large orgonic networks internally produce self-organization and self-development.

The theory of systems provides two particularly interesting approaches: one that considers firms as *adaptive systems* that operate according to local rules and that spontaneously and inevitably generate production networks understood as *complex adaptive systems*, and that which considers production organizations as *holons* that, given their arrangement in a *multi-level holarchy*, generate the production networks in which progress appears as the inevitable consequence of the *holarchic* ordering of the Economic-Production Kosmos.

This essay considers the second approach, presenting the holarchic model of the analysis of production networks. It assumes that in an economy based on knowledge, where the limits of time and space are tenuous, production must increasingly refer not to a single firm but to a system of firms (a super-organizational network) or to operational units (inter-organizational network) conceived of as an operative, information or cognitive network.

It truly appears there is a Ghost in the Machine, whose invisible hand produces growing levels of productivity and quality, increases the quality and quantity of satisfied needs and aspirations, and reduces the burden of work, thereby continually increasing the level of progress in the entire Kosmos.

It is useful to conclude with a bibliographical note.

The conceptual revolution begun in 1967 has not yet led to a relevant number of monographs. On the other hand, there is a substantial bibliography containing journal articles, papers presented at congresses, and opinions and documents from discussion forums. The Internet has been crucial for gaining access to recent material.

In the citations I have indicated the page of the reference only for monographs and articles. Those citations from the Internet, even though in quotation marks, do not contain the page reference but only that of the author and of the URL of the site they were taken from.

NOTE. This book is the English version of «La Rivoluzione Olonica. Oloni, Olarchie e Reti Oloniche. Il Fantasma nel Kosmos Produttivo», published in Italian by Franco Angeli, Milan, 2005. The first four chapters are more or less unchanged, with the exception of some updated information and expanded treatment. Chapter 5, on the other hand, has been entirely rewritten to bring out more clearly the logic of the Production Kosmos.

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Chapter 1

Holons

> Parts and wholes in an absolute sense do not exist in the domain of life […] The organism is to be regarded as a multi-levelled hierarchy of semi-autonomous sub-wholes, branching into sub-wholes of a lower order, and so on. Sub-wholes on any level of the hierarchy are referred to as *holons*. Biological holons are self-regulating open systems which display both the autonomous properties of wholes and the dependent properties of parts. This dichotomy is present on every level of every type of hierarchic organization, and is referred to as the Janus Effect […] The concept of holon is intended to reconcile the atomistic and holistic approaches (Koestler 1967, Appendix I.1).

> The world is not composed of atoms or symbols or cells or concepts. It is composed of holons (Wilber 2001, p. 21).

1.1 The Holistic View and System Thinking

As we see from the two quotes at the beginning of this chapter, by holon we do not mean an object or concept but a way of connoting objects and concepts; it is not a thought but a *vision* of the world, the *holonic vision*.

Before presenting the definition it is useful to note that the notion of holon is connected to the *holistic* conception of "Reality".

"Holism" – from the Greek *holos*, which means *all*, in the sense of unity, whole, complete in all its parts, with reference to persons, things, events or phenomena – is a term introduced by Jan Smuts who – following Aristotle (Metaphysics) «The whole is more than the sum of its parts» – defined holism as «the tendency in nature to form wholes that are greater than the sum of the parts through creative evolution» (Smuts 1926).

Holism, which is typically evolutionist, contrasts with reductionism or molecularism, which are typical of mechanism, in that it focuses attention:

a. on the globality, on all (the whole), rather than on the particular or the part, considering the whole as characterized by emerging properties that are not found in its constituents, or in sub-wholes of the latter;

b. on the relations between parts and whole, and on the function of the parts in the whole;
c. on the context (or environment), which must be considered an essential element for understanding and analyzing any particular phenomena.[1]

Since by nature our mind conceives and observes individual structures, isolating these from the context – I conceive of the hand as distinct from the arm, and the arm as distinct from the bust, etc.; I observe the trunk as distinct from the roots and foliage, and a twig as distinct from the branch it is connected to, and the latter as distinct from the main trunk, etc. – operationally holism accepts the assumption that "Reality", at whatever level it is considered, consists of elementary structures (elements or modules) which, even though capable of being conceived of or observed autonomously, include structures which are less extensive but also recursively included in vaster structures (systems, networks, orderings, or hierarchies).

Every element in the reality can be described as a unity only if we ignore the aspects that connect it to the other objects to which it is recursively linked, thereby eventually forming the "Whole".

As a result: each *element* "exists", or takes on significance, only in a context of relationships with both the elements it is made up of and the structure it belongs to;[2] any event that involves an element produces a realignment, no matter how slight, in the entire structure; and, recursively, in all the superordinate and/or subordinate structures.

Thus, in its global, multi-layered and multi-leveled view of reality, *holism* assumes an elementary structure – a basic unit – that acts as a *component* in the observation of the "whole".

The *holistic vision* is typical of System Thinking (Mella 2007, 2008; Richardson 1999; Senge 1990) – which represents a necessary paradigm for business and management studies – according to which the basic unit of observation is a *system* (Gall 1978; Weinberg 1975), with each system having to be observed, *vertically*, in its interactions with super- and sub-system components; and, *horizontally*, in its

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[1] According the most famous Italian Dictionary, we find the following meanings:
1 TS biol., theory according to which every living organism has its own characteristics, which are not referable to the simple sum of its parts, and whose vital manifestations can be explained on the basis of the functional relationships among its constituent elements;
2 TS life sciences, any philosophical and sociological view according to which society is a whole that cannot be reduced to the sum of its individuals and their actions;
3 TS philos., in epistemology, the theory that considers scientific knowledge as a set of strongly connected propositions, so that it is not possible to empirically prove an individual hypothesis but only more or less extensive parts of the whole."

[2] «The set of properties that establish a holon as a self-defining group entity, are termed its 'Self-Assertive' properties. The set of properties that establish a holon as a dependent member of a group that makes up a higher-level holon, are termed its 'Integrative' properties» (Burns 2004).

interactions with other parallel systems, in order to form a network whose boundaries are given by the need for observation more than by the intrinsic limits of the system.

The holistic vision of System Thinking contains several general assumptions (principles):

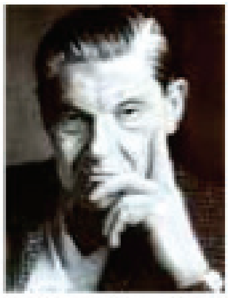
a. systems *are* everywhere (they are an objective reality), or can *be observed* everywhere (they are subjectively formed by an observer);
b. systems are characterized by a structure of interrelated elements – separate from an external environment – that, by changing their states over time, produce a network of processes that define the global process of the system (Sandquist 1985);
c. within the system the interdependence relationship (functional, temporal or spatial) predominates among the elements of the structure; there are no causal chains, only circular causal interconnections;
d. the systems are interconnected:
   1. external to each system is a vaster system of which it is an element;
   2. internal to each system are elements which in turn are themselves systems;
e. Reality is permeated by systems, of increasingly vaster dimensions, which form a global structure that produces a global process. Thus:
f. we can not be only on the outside or the inside of a system. Since a system is connected to others and includes others, an understanding of the inputs and the outputs makes no sense unless at the same time we also consider the feedback among systems and their processes; the idea of feedback is necessary for an analysis of systems from a holistic point of view;
g. in order to understand the behaviour of the system we must examine:
   1. from an analytical point of view, its structure and functioning; that is, the network of processes it can carry out;
   2. from a synthetic point of view, its function and functionality; that is, the global emergent process that is produced and the connections with the supersystem.

These premises make it easier to present the holistic view.

1.2 The Holon and the Holonic View according to Arthur Koestler

Holon – which derives from the combination of *holos*, whole, and the suffix *on*, which indicates the neuter form and means particle or part (as in prot*on*, neutr*on* and electr*on*) –

is the term coined by Arthur Koestler[3] in his fundamental works *The Ghost in the Machine* (1967) and *Janus; a summing up* (1978) to represent the *basic element* of a *particular holistic view* – called *holonic view* – which views as relevant not so much the *connection* between "elements" as their *inclusion* in others.


Arthur Koestler

Koestler saw the *holon* as a *whole* that is *part* of a vaster whole, and which at the same time *contains* elements, or sub-parts, of which it is composed and which provide its structural and functional meaning.

Each holon includes those from a lower level, but cannot be reduced to these; it *transcends* them at the same time that it *includes* them, and it has emerging properties (Edwards 2003b).[4]

With this term Koestler tried to interpret nature, the structure and the dynamics of autonomous biological and social systems (organizations) that always possess internal components but are also always components of vaster systems. Thus, the holon shows the tendency for both survival and integration:

> Every holon has the dual tendency to preserve and assert its individuality as a quasi-autonomous whole; and to function as an integrated part of a larger whole. This polarity between the Self-Assertive and Integrative tendencies is inherent in the concept of hierarchic order; a universal characteristic of life. (Koestler 1967, p. 343).

In this observational context a holon is viewed as an entity that is at the same time *autonomous*, *self-reliant* and *dependent*; *interactive* vertically and characterized by *rules* of behaviour.

Autonomy is revealed in the holon's structure and functioning, which must permit a dynamics that is distinct from the context and that refers to the holon-unit. The holon thus has a stable form that gives it vitality and allows it to survive environmental disturbances.

Self-reliance resides in its ability both to deal with contingent circumstances without requiring "authorization" or "instructions" from some superordinate unit and to control in some way the units it includes.

Dependence implies that the holon is subject to some form of "control" by the superordinate unit precisely because it has a role in the survival of the vaster structure that contains it. The superordinate structure can set the behavioural objectives of the subordinate structure, which transmits the results of its activities to the superior level.

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[3] There is a complete bibliography of the author at: <http://www.kirjasto.sci.fi/koestler.htm>.

[4] «In [complex] systems, the whole is more than the sum of its parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole. In the face of complexity, an in-principle reductionist may be at the same time a pragmatic holist» (Simon 1969, p. 68).

Interactivity is revealed by the two-way connection between the *whole* and the *parts* comprising it.

The *rules* represent the set of constraints on the actions of the holon due to its being both a whole and a part. The holon is defined by the position it occupies and by the direction of observation.

Thus for Koestler the holon is a *whole* characterized by a self-assertive tendency – which derives from its autonomy; by its ability to interact and coordinate with other superordinate and subordinate holons (*integrative tendency*) – which derives from its being at the same time both included and inclusive; and by its own dynamic ability for self-preservation, though in a context of vertical interrelationships.

Nevertheless this term is spreading to all types of disciplines, and indicates a systemic entity – conceptual or observational – that is both *autonomous* and *dependent*, since it is both a *whole* (autonomous and containing) and a *part* (dependent and contained) of a *nidified hierarchy* called a *holarchy* (for example, quark, protons, atoms, molecules, cells, tissues, organs, organisms, social groups, populations, federations, planets, solar systems, galaxies, galaxy clusters, etc.).[5]

In this sense, the holon is like a *double-headed Janus*: if it observes its own *interior* – that is, the lowest levels of the hierarchical structure – it considers itself a *whole* formed by (containing) subordinate *parts*; if it observes its *exterior*, it considers itself a *part* or *element* of (contained in) a vaster *whole* (Barlow 1991). If, however, it observes itself, it sees itself as an *independent (self-reliant)* and *unique* individual that must survive («Each holon must preserve and assert its autonomy»).[6]

Generalizing, according to Koestler the term "holon" indicates any object or concept observable on three levels: (1) as an *autonomous* and *independent* unit that acts according to its own behavioural "canons"; (2) as a *superordinate* unit, possessing emerging properties, with respect to the component parts that it transcends; and (3) as a *subordinate* unit in that it is part of a vaster whole that conditions it.

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[5] «At each level the system under consideration may constitute an individual organism. A cell may be part of a tissue but may also be a microorganism which is part of an ecosystem, and very often it is impossible to draw a clear-cut distinction between these descriptions. Every sub-system is a relatively autonomous organism while also being a component of a larger organism; it is a "holon", in Arthur Koestler's term, manifesting both the *independent* properties of wholes and the *dependent* properties of parts. Thus the pervasiveness or order in the universe takes on a new meaning; order at one system level is the consequence of self-organization at a larger level» (Capra 1982).

[6] «These sub-wholes - or 'holons', as I have proposed to call them - are Janus-faced entities which display both the independent properties of wholes and the dependent properties of parts. *Each holon must preserve and assert its autonomy*, otherwise the organism would lose its articulation and dissolve into an amorphous mass - but at the same time the holon must remain subordinate to the demands of the (existing or evolving) whole. 'Autonomy' in this context means that organelles, cells, muscles, nerves, organs, all have their intrinsic rhythm and pattern of functioning, aided by self-regulatory devices; and that they tend to persist in and assert their characteristic patterns of activity. This 'self-assertive tendency' is a fundamental and universal characteristic of holons, manifested on every level, from cells to individuals to social groups» (Koestler 1972, pp. 111-112).

This view produces an important methodological inversion: from the *holonic* point of view reality is not made up of *systems* or interrelated elements that form *structures* but of *relationships of inclusion* among structures or elements. What is key here is the notion of *inclusion* rather than that of *interconnection*. The holonic view considers each element as a member of a hierarchy of "Wholes" and "Parts". It views as primary the observation of the *whole/part* relationships, but it also believes it is fundamental to take account of the *feedback* among the various levels of the wholes and parts.

Koestler nevertheless observes that "Superior" and "Inferior", "Whole" and "Part" do not exist in an absolute sense but are instead defined by rules and observational strategies for those relationships[7] called observational *rules*. For example, if I observe a territory, I can divide it into areas, and these into sub-areas, and these again into sub-sub-areas, based on an observational strategy; if I observe relations of authority, that of a subordinate is included in the sphere of authority of a superordinate, which in turn is contained in that of its superordinate etc.; if I observe semantic relations, then each concept belongs to a concept that belongs to a concept, etc.; if I consider a project, then this can be broken up into sub-projects, which in turn can be broken up into sub-sub-projects, and so on until we arrive at unitary tasks that are no longer divisible. We can use a similar subdivision to divide complex machines into sub-machines and into sub-sub-machines, whose functioning (based on the whole/part relationship) is equivalent to that of the complete machine (as indicated below, par. 2.6).

1.3 The Holonic View and Ken Wilber's Classification "by nature"

Ken Wilber

Thirty years later, Ken Wilber (1995)[8] attempted to construct a holistic model to describe and understand – from a metaphysical and religious[9] point of view (*theory of self-transcendence*) – the dynamics of the entire universe – the Kosmos – by generalizing the concept of *holon*; on the one hand, he emphasized the latter's *relative* and conceptual nature (Kofman, 2000), and on the other its *unit/part/whole* properties as a component part of the Kosmos rather than the logical nature of *containing/contained*: «The world is not composed of atoms or symbols or cells or concepts. It is composed of holons» (Wilber 2001, p. 21).

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[7] «Whatever the nature of a hierarchic organisation, its constituent holons are defined by fixed rules and flexible strategies» (Koestler 1967, p. 55).

[8] A detailed biography can be found in Wilber's personal web page at: <http://wilber.shambhala.com/index.cfm/>. Wilber's vast work can generally be found in the original language at: <http://wilber.shambhala.com/html/books/kosmos/index.cfm/>. «It is not by accident, I believe, that the two founders of holon theory [Koestler and Wilber] have both come from outside of academia. One from the world of journalism and real politic [Koestler] and the other [Wilber] from the world of contemporary spirituality and the human potential movement» (Edwards 2003b). A rich collection of papers from various authors on the various aspects of Ken Wilber's vision is presented on the following website: <http://www.integralworld.net>.

[9] Wilber follows the schema and teachings of Eastern religions referring to Buddhist doctrine.

Wilber sees the Universe as moving towards ever higher states of self-awareness, and to take account of this he came up with the idea of a *holon* as a unit characterized in varying degrees by interiority and the awareness of an internal and external world[10] composed of sub-units and belonging to a vaster unit, typically though not exclusively along hierarchical lines (Battista 1985).

However it is viewed – at a physical-reactive, biological-active, human-cognitive, formal-logical level – the holon must have four fundamental features:

a. *Self preservation* (agency): the holon must possess the characteristics that permit it to maintain its structure "as such" (pattern) independently of the material it is composed of. In inanimate nature physical forces maintain the holon's identity; in animate nature autopoiesis intervenes, which allows the holon to maintain its organization over time, even if the structural components change (in the sense of Maturana and Varela, 1980); and in the world of logic it is the rules of combination and of derivation that preserve the holon's identity;
b. *Self-adaptation* (communion): since it is part of a vaster whole, the holon must be able to adapt and to link up with other superordinate holons; that is, to react mechanically, biologically or intentionally to the stimuli of the other superordinate holons;
c. *Self-transcendence*: the holon has its own new and emerging qualities which are not found in the holons that it includes. If all the holons have such properties, then not only is the universe dynamic but it is also "creative", since it causes new properties to emerge for the subsequent inclusion of holons in superordinate holons and also for the creation of new classes of holons;
d. *Self-dissolution*: the holons break up along the same vertical lines they used to form; the process of subsequent inclusion in an upward direction is transformed into a process of subsequent breakup or splitting.

In a coherent summary Wilber has introduced a classification *by nature* that specifies four types of holons according to whether or not they are (a) *sentient* or (b) *non-sentient*:

(a) *sentient* holons:

1. *individual holons*, or holons *in the proper sense*: these are *entities* that have a localized interiority or an objective consciousness that carry out

[10] «Conscious means 'having an awareness of one's inner and outer worlds; mentally perceptive, awake, mindful'» (Wilber 2004a, 2004b).

autonomous activities;[11] at each level the *senior holons* are composed of *junior holons*, but these in turn are constituent parts of higher level holons. The constitutive function of the holons of a certain level with regard to those of a higher level is the founding element of the individual holons. The holons are instantly defined, and at each subsequent moment the senior holon includes and transcends itself from the preceding moment (junior holon), thereby showing a continuous evolution;

2. *social holons*: these are *entities* represented by groups of individual holons that have *stable models of interaction* – and thus an autonomous existence – but which do not have localized interiority or objective consciousness, even if we can infer in them an intersubjective and non-localized consciousness with regard to the individual holons. Nevertheless the latter do not constitute social holons nor are they components of these; they are instead *individual members* based on a relationship of *belonging* though not a constituent one;[12]

(b) *non-sentient*, or pseudo holons:

1. *artifacts* or *physical systems*: these are entities produced by holons which, though presenting a stable organized model of the constituent elements, do not have an interior dimension[13] (machines and instruments created and utilized by sentient holons, including all types of language);
2. *heaps*: these are entities that have neither an interior dimension nor a stable model of organization or of observation.[14]

We must note that for Wilber only the *sentient* entities (atoms, cells, vegetables, animals and man above all) are typical holons. Strictly speaking, non-sentient entities (artifacts and heaps) cannot be considered holons, and thus there are no holarchies, even though the terms *artifactarchy* and *heaparchy* have been coined for *artifacts* and *heaps* (Smith 2004).

In particular, despite the fact the social component is implicit in each *individual holon*, the *social holons* not only represent a different class than the individual ones but appear to represent the highest level of observation of all the individual holons.

[11] «Individual holons are entities that have agency and localized interiority or consciousness—in addition to unified exteriority. (If the interiority was not localized or the exteriority not unified we would be talking about collective or macro, as opposed to individual or micro holons)» (Kofman 2000).

[12] «Social Holons are groups of individual holons that have a patterned mode of interaction. Social holons do not have localized interiority or consciousness; they have inter-subjectivity or non-localized consciousness. Social Holons do not have unified exteriors. They are composed of a plurality of individual holons and artifacts. For example, an ant colony (as a social holon) is composed of the ants (individuals) and the physical structure of the anthill (an artifact)» (Kofman 2000).

[13] «Artifacts are entities with no interior dimension. They are things that have been (instinctively or purposefully) produced by holons» (Kofman 2000).

[14] «Heaps are different than artifacts since they have no imprinted organizing pattern» (Kofman 2000).

The *sentient individual* is the holon at the highest level of the class 1) but, at the same time, it is the basic holon of the class 2); from this it follows that if we wish to extend the holonic view to levels higher than that of the individual holon we must enter the class of the social holons.[15]

If, on the one hand, this classification has the merit of demonstrating that we can imagine different species of holons, thereby extending the possibilities of the *holonic view* of nature (heaps that comprise heaps that, in turn, comprise heaps, and so on; artifacts that constitute artifacts that, in turn, compose higher level artifacts, and so on), on the other it is open to a number of criticisms due to the logical difficulties of identifying a clear-cut separation among the four classes (Jantsch 1980; Edwards 2003a; Smith 2004).

There are two important observations to make. First, precisely because Wilber's approach emphasizes the *holon-entity* view – giving secondary importance to the *containing/contained* relationships, which Koestler considered to be essential for describing holons – it is difficult to distinguish between *holons* and *individuals* (more generally, *structural entities*), and thus the two concepts overlap. Secondly, the Wilberian approach omits the idea of *organization* as a particular holon that cannot be absorbed by a social holon but that nevertheless appears like an entity, even though it is formed by a plurality of individual holons.[16]

Paralled to Wilber's interpretation, Andrew Smith classified holons into two classes: autonomous, or *fundamental* holons, which can exist independently of higher-order holons, and *intermediate*, or *social* holons, which can only exist within higher-order holons. The *autonomous* holons are, in turn, divided into *inert* holons, existing independently, and interactive holons, which associate with other holons to form intermediate holons.[17]

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[15] «The first problem is that "an individual" is not a well-defined holon. In order to define the holon, it is necessary to establish its "level" or "depth" of consciousness […]. The second problem is that "a group" is not a well-defined holon either. One needs to define the general level (or center of gravity) of intersubjective consciousness of the group to more accurately identify it […]. There is no higher "container" for evolution than the individual human being. As Wilber said in our conversation: *as far as we know, the individual body is the highest possible external surface of any manifest holon*». (Kofman 2000).
Smith (2000, 2004 and numerous other articles), after showing that the social holons are autonomous entities with respect to the individual holons, proposes a dynamic process for the Kosmos composed of the sequence: heaps, social holons, individual holons, heaps, social holons (but, as we shall see, he does not recognize the organizations in this dynamic process).

[16] For a discussion of these aspects, see below par. 3.1.

[17] «*Classes*. There are two kinds of holons, autonomous or fundamental holons and intermediate or social holons. Fundamental holons, including atoms, cells and organisms, can exist independently of higher-order holons as well as within them. Social holons exist only within higher-order holons. *Subclasses*. There are two kinds of fundamental holons, inert and interactive. Inert holons exist independently of higher-order holons. Interactive holons associate with each other and form all the higher stages (social holons) of their level of existence» (Smith 2000).

1.4 The Formal Characteristics of the Holon

We can generalize the notion of holon.

In its broadest formal significance a *holon* can be thought of as a *conceptual*, non-observable entity that functions as a *connective* or *intermediary element* among hierarchical levels of "Reality"; «the different levels represent different stages of development, and the holons […] reflect intermediary structures at these stages»: Koestler (1967, p. 61). The holon is a *point of reference* to give a *hierarchical meaning* to a reality, called a *holarchy*, that is interconnected through *inclusion* at multiple levels.

Thus, the holon does not correspond to any observational structure (observed or hypothesized). The holon is not *the* structure but *of* the structure, a center for the relationships with the other component, subordinate and composed, and superordinate structures (figure 1).

If we let $S_i(n)$ be the *i*-th autonomous structure or system (or an object of observation), observable at the *n*-th level – and deriving from a *Technical Description* (Mella 2009) – then we can view a holon $H_i(n-1, n, n+1)$ as the *Technical Description of* $S_i(n)$ integrated by the relations *Including* (composed of) the $S_{x,i}(n-1)$ – that is, all the structures *x* connected with the *i* of the level (*n*-1) and *included in* (composed of) $S_{i,y}(n+1)$; in other words, the structure *y* of the level (*n*+1) to which the *i-th* structure of the level (*n*) is connected; that is: $H_i(n-1, n, n+1)$ = *Including* $S_{x,i}(n-1) \rightarrow S_i(n) \rightarrow$ *Included in* $S_{i,y}(n+1)$ as shown in figure 1.

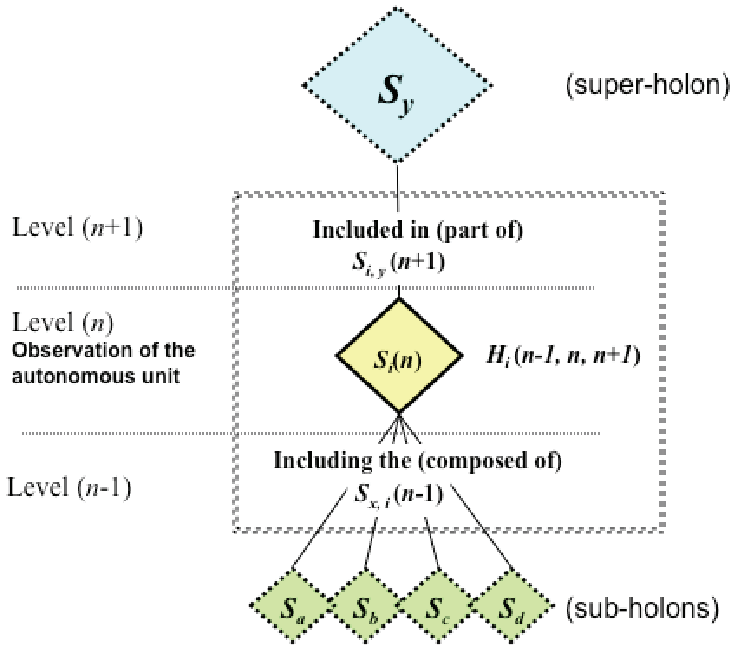

Figure 1. Holon H of the structure S.

From this perspective the *holon* is a *structuring* entity (it includes its own parts) as well as a *structured* one (it is part of another holon), and it is *not defined a priori*:[18] it is not a physical object, an individual or a system, but a particular view of these. From this holistic viewpoint everything can be considered a *holon* – a real object from a concrete system as well as a conceptual entity from a thought system – and the entire "Reality" must be observed in terms of holons and their vertical arrangement, which is defined by the connections of inclusion (figure 2).

	DISCIPLINE SUBJECT	FIRST LEVEL	SECOND LEVEL	THIRD LEVEL
1	PHYSICS	Particles	Atoms	Molecules
2	CHEMISTRY	Molecules	Compounds	Bases
3	GENETICS	Bases	DNA	Genes
4	BIOLOGY	Genes	Chromosomes	Cells
5	ANATOMY	Cells	Organs	Individuals (Biota)
6	ENVIRONMENT	Biota	Ecological systems	Gaia (Earth)
7	ASTRONOMY	Earth	Solar system	Galaxy
8	SOCIOLOGY	Individuals	Families	Communities
9	ORGANISATIONS	Autonomous cells/ divisions	Firms	Keiretsu/groups
10	MONDRAGÓN CO-OP	Work groups	Social council	General assembly/ co-op
11	MONDRAGÓN SYSTEM	Co-operative	Cooperative groups	Mondragón Corporación (MCC)
12	VISA CARD	Geographic unit	Member bank	VISA International
13	GOVERNMENT	Communities/towns	Regions/States	Nations
14	ENGINEERING	Components	Sub-assemblies	Machine
15	SOFTWARE DESIGN	Sub-routines	Routines	Object-orientated programs

Figure 2. Holons everywhere. Examples of holons and of their levels: in nature (lines 1-7), social groups (lines 8-13), and engineering (lines 14 and 15) (*Source*: Turnbull 2001).

The preceding considerations allow us to sum up the characteristics of the holon as follows:

1. The holon is an independent conceptual entity, based on *self-assertive properties*, which gains significance from being at the same time a *whole*, a *containing* and a *contained* entity, in the context of a nidified hierarchical ordering of at least three (or, in particular cases, two) levels.

[18] «A Holon is a part of the universe which is complete and consistent in itself, but is also a necessary integral part of a greater system which encompasses it» (MacGill 2002).

2. A holon at level (n) is a *whole* that has unique characteristics, but it is also *double-faced*: it includes (contains, is composed of, recombines) other subordinate holons of level (n-1), or *sub-holons*, and is included in (comprises) a superordinate holon, or *super-holon*, at level (n+1);
   i) no holon of level (n) can be included in holons of level (n-1);
   ii) no holon of level (n) can at the same time be included in more than one holon of level (n+1);
   iii) holons from the same level cannot be included in each other;
   iv) two holons of the same level will always have a superordinate holon from level ($n+m$, $m \geq 1$) that includes both of them.
3. Each holon has three observational dimensions: absolute, internal and external, corresponding to the levels (n), (n-1) and (n+1), respectively;
   i) if viewed in absolute terms, with respect to level (n) it is an independent entity;
   ii) if viewed internally, with respect to level (n-1), its structure is formed by subordinate (structuring) holons;
   iii) if viewed externally, with respect to level (n+1), it is part of a vaster structure, or group, of holons at the same level that come together there, and of which it is a (structured) component.
4. A holon that does not include holons of level (n-1) is a *primal* or *bottom holon*; a holon that is not included in any holon of level (n+1) is a *final* or *top holon*;
   i) recursively, holons that are not primary contain all the subordinate holons, down to the primal holons;
   ii) recursively, the holons that are not final are contained in all the superordinate holons, down to the final holon;
5. The dimensions of a holon (however defined) cannot be less than the dimensions of the holons included in it;
   i) a holon can never have a dimension greater than that of the holon that includes it.
6. Each holon of level (n) produces a dynamic process and shows properties that are unique to it; these are *emergent* with respect to those of the holons of level (n-1) and *confluent* with those of level (n+1);
   i) the properties and dynamic process of the level (n) holon produce those of the level (n+1) holon, without determining them;
   ii) the final holon has a dynamic process and properties that transcend those of all the other holons.
7. [the numeration continues in par. 2.2].

1.5 Three Functional Interpretations

Even though "holon" refers to a conceptual entity, a means to denominate "nidified" structures that are part of multi-layered arrangements in several hierarchical levels (cell A part of-included in tissue X and including molecules Y; zone A part of-included in X and including Ys; component A of the subgroup X formed by the subcomponents Y; etc.), all the authors have usually, as we have seen, used the term to indicate those same *elements* (cell A, individual A, component A, etc.) as *entities objectively arranged in a hierarchy*, favouring the typical point of view of the single level (*n*), thereby ignoring, or implying, the hierarchical relation of *containing/contained* with the levels (*n*-1) and (*n*+1).

This viewpoint, focussed on the entity at level (*n*), leads to different interpretations, specifications and applications of the notion of *holon-entity*.

Considering the *function* and the *functionality* of the holons understood as *entities* arranged in a hierarchy, there are three that are particularly significant.

a. *Modular* interpretation: the holon represents a module in a vertical ordering of other, vaster modules that contain it; holons at the same level are similar and, by means of some form of composition based on specific rules (see below, par. 2.3), give rise to superordinate modules that are likewise similar (letters give rise to words, words to sentences, sentences to paragraphs, paragraphs to chapters, chapters to texts, etc.; quarks form protons, protons are holons for atoms; atoms are holons for molecules, etc.). The holons are uniquely and univocally defined, in terms of their structure and dynamic process, by their position, independently of what they represent and of how they operate;
b. *Cognitive* interpretation: the holon is viewed as an autonomous cognitive, sentient entity, and at higher levels of the holarchy as also equipped with awareness and consciousness. The holons of a given level are included in the superordinate holon that has cognitive capacities and autonomy, including those that characterize the component holons (micro-organisms and living things from the vegetable kingdom are sentient holons; the holons represented by the animal kingdom possess awareness; the holons represented by human beings or by cognitively autonomous groups of human beings are conscious entities). This is the typical interpretation by Koestler, Wilber, Smith, and all those who use the concept to investigate the dynamic process of interconnected reality in ever wider *observational spheres*;
c. *Operative* interpretation: the holon embodies an *operator* or an *operation* involving processing carried out *in parallel*, characterized by its own inputs and outputs; it can be a biological individual, a machine, or even an

> entire organization. Holons from the same level process, by means of their own procedures, elements or information from subordinate holons and transmit the results to those at a higher level for further processing; the processes originate from those of the subordinate holons and, carried out in parallel, shape those of the superordinate ones (Mesarovic et al. 1970).

This interpretation is typical of the biological analysis of cognitive processes (Bioholonics) and of the engineering analysis of the production processes (Holonic Manufacturing Systems), information processes (multi-processing), and the management processes (multi-agent decision making) carried out by decentralized, distributed, cooperative and negotiating agents (Chapters 2 and 4).

We must distinguish between these three interpretations, since different forms of holarchies and other interesting aggregations of varying significance derive from them, as we shall observe in Chapter 2.

1.6 The Holonic View and *Enkapsis*, or *Encapsulation*

Herman Dooyeweerd

The holonic view is not the only special form of the holistic view which is based on the *containing/contained* relation.

Back in 1953 the Dutch philosopher, Herman Dooyeweerd, came up with the theory of *enkapsis* – or *encapsulation* – taking the concept, as he himself acknowledged, from the Swiss biologist-anatomist, Theodor Haering.[19]

The basic idea is linked to the observation that some structures – conceived of as entities, or wholes – are in fact composed of incorporated or nested sub-structures that not only are parts but are, in turn, conceived of as entities, since they have their own structure and processes that cannot be found in the complete structure, although they contribute to the latter's creation.

Referring to living beings, Dooyeweerd acknowledges that their processes are produced by two forms of nested structures: those that derive from the *part/whole*

[19] «The term *enkapsis* was borrowed from the famous anatomist Heidenhain by Theodor Haering, who gave it a general philosophical meaning. Heidenhain used the term *enkapsis* or *encapsulation* to denote the relation between the separate organs and the total organism in the structure of a living creature. His scientific investigations had taught him that the organs of a living body such as the kidneys, the lungs, etc. are not simply "parts" of this body in the usual sense of dependent components, but that they are relatively independent individuals. Their growth proves to be a continuous self-propagation, a continuous self-division. On the other hand the total organism reveals itself as an individual whole of relatively independent individualities. […] This term "enkapsis" introduced by Heidenhain is used by Haering promiscuously with *Funktionseinheit* (functional unity) or *Ganzes mit Gliedere* (a whole and its member)» (Dooyeweerd 1953, p. III 634) (the bibliographical citations are from Dooyeweerd).

relation, which is applied to the biological sub-groups (cells, tissues, organs), and those that refer to *inert* structures (atoms, molecules). In particular, he has used the term *enkapsis* only in reference to the incorporation of *inert* structures in organisms formed by biological organs.

The organism becomes an *encaptor*, capable of incorporating structures that are not typically living in order to form and maintain the biological and living structures[20] in an autopoietic process (as it would subsequently come to be defined by Maturana *et al.* 1980).

Nevertheless, the term subsequently came to have a broader significance, and indicated all the forms in which the component structures appear *incapsulated* in the composite structure, just as organs appear incapsulated in the organism they are part of, or a statue is incapsulated in the block of marble from which it is created, or a cathedral in its host city.

By generalizing, Dooyeweerd in effect presents diverse forms of *enkapsis*, among which:

- foundational enkapsis (the statue is incapsulated in the marble);
- subject-object enkapsis (the oyster is incapsulated in the valve);
- symbiotic enkapsis (parasites are incapsulated in the host);
- correlative enkapsis (people are incapsulated in a community);
- *constitutive* encapsulation (two spouses are incapsulated in the couple);
- territorial enkapsis (the cathedral is incapsulated in its city);
- *functional* encapsulation (the water system is incapsulated in the city).

There are several important differences with respect to the holonic view:

a. *enkapsis* is not only a vertical relation between the whole and the parts (as in Wilber), between component and system, but rather it designates the whole as being composed of its interconnected parts (point of view of the entity) and the parts as being incapsulated in the whole (point of view of the parts);
b. *enkapsis* is not so much a simple *inclusion* (as in Koestler) but an *interlacement*, an *interwoveness*, a true *structural systemic interconnection* that transforms the parts into a whole with diverse and emerging properties. When the whole breaks up, the component parts regain their individuality; «In my opinion the term 'enkapsis' expresses much rather an interwovenness of individuality-structures that cannot at all be qualified as the relation of a whole and its parts» (Dooyeweerd 1953, p. III 636);

[20] «If a thing (e.g. a molecule) with a particular individuality structure functions enkaptically in a thing with a different (biotic) structure, this enkaptic interlacement always means a binding of the first (inert) structure. That is to say the molecule exceeds the boundaries of its internal structural principle in this enkaptic function within a living thing» (Dooyeweerd 1953, p. I 639).

c. *enkapsis* has a broader viewpoint than the holonic one, since it considers the holons as incapsulated in an operational environment that allows them to reveal themselves and to produce the dynamic process for the entire holarchy;
d. *enkapsis* does not limit itself to considering the relation of *inclusion* of holons of a certain type (atoms, words, components, individuals) in those of an including (encompassing) higher kind (molecules, sentences, subgroups, social groups), but recognizes the importance of the encapsulation of components of differing, though complementary, natures and qualities (a social group not only includes individuals but encapsulates a code of behaviour; a sentence not only includes the component words but encapsulates a semantic structure; an individual not only includes organs but encapsulates a system of knowledge; etc.).

Despite a different, though similar, underlying principle the *holonic view* is simpler in its conception and more effective in its application. It allows us to immediately perceive the logical interrelations between containing and contained, and the unlimited chain of these relations, rather than the physical encapsulation of the parts in the whole.

On the other hand *enkapsis*, precisely because it extends the containing/contained relation to heterogeneous entities, is more suitable to the systemic holistic logic than to the immediate perception of holarchies.

Chapter 2

Holarchies

> It is fashionable to feel that there is a 'bottom' line in fundamental physics; a basic collection of individual entities obeying a small number of mathematical rules in terms of which everything else can in principle be described. But the world may not be like this. Like a sequence of Russian dolls, there may be an unending sequence of levels of complexity, with very little (if any) evidence of the next level down displayed by each of them. (Barrow 1998, p. 99).

2.1 Holarchies

By definition the fact of being a double-headed Janus (par. 1.2) implies that holons *must necessarily* be included in other holons in a typical *vertical* arrangement, with progressive accumulation and forming a *nested hierarchical order* called a *holarchy*, which can be represented as an *arborised structure* (turned upside down to fit this particular context) whose branches become larger at each successive hierarchical level (figure 1).

Each holon becomes a *head holon* for the subtended branch and a *member holon* for the upper part of the branch it forms.[1]

In formal terms the holarchies begin with the lowest level holons – the *primal* or *base* holons – and end with the highest level ones – the *final* or *top* or *vertex* holon. They interconnect with the environment and by definition are open.

Because of the typical *whole/part* relation, each holon is connected to the higher level – *containing* – and the lower level – *contained* – ones, but not with those at the same level (Pichler 2000). Thus, holons from the same level can only interconnect[2] through the higher level holon. Horizontal relations are not considered in Koestler's model (even if some form of horizontal interaction is admitted in Wilber's conceptual

[1] «Every holarchy is composed of holons, each one simultaneously a part and a whole. As a part, we have called the holon a 'junior' or 'constitutive element'; other names we could use are 'primitive' or 'root'. As a whole, we have called the holon a 'senior' or 'holonic system'». (Kofman 2000).

[2] «A holarchy in the sense of Koestler can be classified as a multi-level system in a kind of a multi-layer system (in the sense of Mesarovic-Takahara 1970) with – as seen top-down – a graph-theoretical tree-structure» (Pichler 2000). A formal treatment of the Holonic Multiagent Systems and of the Holonic Organizations is presented by Fischer (Fischer *et al.* 2003).

framework), even though there is the implicit possibility for cognitive and operative holons to *interact* with their own micro environment (Mesarovich *et al.* 1970) and thus to *observe* holons from the same level.

The holarchy can arise out of a single primal holon by means of subsequent decomposition. In this case the holarchy is *descendant* (the base holons are at level (N); the final holon at level (0), as in the model in figure 1, or it can be formed by a set of primal holons through subsequent composition, thereby producing an *ascendant* holarchy (the base holons are at level (0) and the final holon at level (N).

The holarchy can be viewed as a *multi-strata* or *multi-layer* structure.

If we observe the *multi-strata* holarchy *bottom up*, then each level of the hierarchy always includes all the base holons; if observed *top down* it represents a form of segmentation of the final holon.

Each subordinate level constitutes a more minute representation of the superordinate holons (*reticulation effect*).

In the *multi-level* holarchy each head holon is broken down into the subordinate holons, though each level does not necessarily have to include all the base holons.

Each subordinate level represents holons which are less extensive and which are recompressed into the holons at the superordinate level (*arborisation effect*).

We indicate by $H_i(n)$ the *i*th holon of the *n*th level (n = 0, 1, 2, …, N-1) of a *descendant* holarchy (where the head holon is H(0) as in figure 1); based on the definitions in par. 1.4, a holon's interactions with the other elements of the holarchy must respect the following rules (figure 1):

1. at the subordinate level (n+1), each "whole" holon $H_i(n)$ is coupled with the component holons Hji(n+1), where "j", which depends on "i", is the countersign of the holons "j", which are part of the "i"th holon; thus $H_{ji}(n+1)$ indicates every holon included in $H_i(n)$ at level (n+1);
2. at the superordinate level (n-1), for each whole holon $H_i(n)$ of level (n) there is one and only one whole holon $H_{ih}(n-1)$ of which $H_i(n)$ is a part;
3. only holon $H_1(0)$ appears at the maximum level (level (0));
4. the holons $H_{i1}(1)$, which are part of $H_1(0)$, are indicated at level (1);
5. the holons $H_{ji1}(2)$, which are part of the holons $H_{i1}(1)$, are indicated at level (2);
6. the holons $H_{kji1}(3)$, which are part of the holons $H_{ji1}(2)$, are indicated at level (3);
7. and so on, recursively, until we reach the minimum level (N>1), where all the base holons which must be included in the higher level, (N-1), are contained; and so on, recursively, moving upwards in the holarchy to $H_1(0)$;
8. at the lower level all the base holons are connected to the environment in some way; thus, even the final holon must be considered linked to the environment from which the holarchy is isolated for observational reasons.

The *completeness principle* must apply in any event in the multi-layer holarchy: that is, all the holons of a certain level must be included in those of the higher level and include *all* the holons of the lower level.

As a result, each level of the holarchy includes, on the one hand, all the base holons, and on the other represents a segmentation into parts of the final holon.

In the multi-level holarchy the *congruence principle* must apply, in the sense that all the holons of the same level must have characteristics congruent with those of the superordinate holons, it being understood that all the base holons must be included in the final holon.

As shown in figure 1, a holon may be included in a particular level but not in the lower one, since it is not composed of parts, as we can see for the holons $H_{211}(2)$ and $H_{221}(2)$.

In order to respect the *principle of completeness* in the multi-layer order it is necessary to introduce *virtual holons* (the grey cells) in the graph, whose function is to bring to a lower level the non-decomposed holons, or to a higher level the holons which are not directly a part of this structure, as illustrated in figure 1.

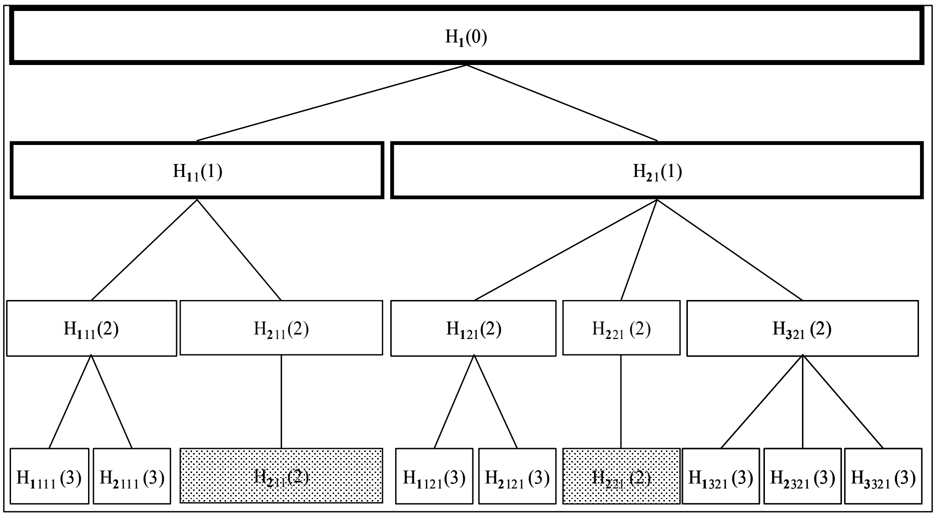

Figure 1. Model of a Holarcy (descendant). The holons in the grey cells are virtual holons. (*Source*: Presentation of Mesarovich's schema 1975).

The properties of the holons from a particular level are in any event emerging with respect to those of subordinate holons.

Independently of the nature of the holons, the relation between those at level (n) and those at level (n+1) can take on different forms that derive from the rules of composition used to include the holons of one level in those of a higher level. These rules are represented in figure 2, which is self-evident.

One thing to note: *holarchies are not holons* – or physical systems of holons – but *are conceptual arrangements of holons* that represent the *basic formal entities* for an holonic interpretation of the structures and dynamics of "Reality".

Their function is to underscore that the emerging properties of the holons from a particular level of the holarchy and the forms of self-organization can be understood only by knowing *both* the properties of the subordinate holons that form its structure *as well as* those of the superordinate ones of which they are structural elements; we cannot conceive of an individual animal as a super cell, an ecosystem as a super organism, or the ecosphere as a super ecosystem; these are different objects with their own characteristics which cannot be derived from those of the constituent holons.

From the definitions in par. 1.2, it follows that this is true recursively, in a top-down direction, all the way down to the primal holons, as well as a bottom-up direction, as far as the final holon.

2.2 The Formal Characteristics of Holarchies

From what we have said so far, in particular with reference to figure 1, Chapter 1, and figures 1 and 2, Chapter 2, we can derive the following principles (we continue the numeration from par. 1.4).

7. Holons are observed in holarchies:
   a. a stand alone holon is a final holon, or a base holon observed only at level (n);
   b. if characterized by several observational dimensions a holon can be part of several holarchies, even contemporaneously; there can be only one holarchy for each dimension.
8. Holarchies can be conceived of as *arborising structures* (upside down) composed of nested branches, with a *base* made up of the initial holons, and a *vertex*, the final holon (figure 1);
   a. the *extension* of level (n) (the number of holons at that level) cannot be greater than that of the holons of level (n+1);
   b. holarchies are open towards both the bottom and the top; their *depth* (number of levels) depends on the number of observations of the base and final holons;
   c. if we hold constant the number of base holons, then the greater the depth, the greater the reduction in the extension of each level;

   d. all the base holons are contained in the final holon, as well as in each level of the holarchy (including virtual holons).

9. There can be both *multi-strata* or *multi-layer* holarchies;
   a. *Multi-strata* holarchies abide by the *completeness* principle; at each level of the holarchy the holons include all those of the lower level and constitute all those of the higher level (figure 1, all cells);
   b. The *congruence* principle holds in the multi-level holarchies; assuming that all the base holons must be included in the final holon, the holons of a particular level include only those holons of the lower level whose features and qualities are congruent, and are included only in those holons of the higher level that they are congruent to (figure 1, white cells).
10. Holarchies are two-directional, but can only have vertical connections (ascendant or descendant) along the branches formed by the constituent holons;
    a. holarchies observed in an *ascendant direction* (bottom up) are *push holarchies*, since we can assume that holons of a given level create (push) the superordinate ones;
       i) in the *ascendant holarchies* the maximum level (N) distinguishes the final holon; the minimum level (0) distinguishes the base holons;
       ii) the holons of level (n<N) plan and control those of level (n-1);
       iii) the holons of level (n) adapt to those of level (n+1);
    b. the *descendant holarchies* (top down) are of the *pull type*, since it is natural to assume that the holarchy originated from the final holon that forms (leads) the subordinate ones;
       i) in the descendant holarchies the maximum level (N) distinguishes the base holons; the minimum level distinguishes the head holon;
       ii) the holons of level (n) plan and control those of level (n+1);
       iii) the holons of level (n) adapt to those of level (n-1);
    c. holons of the same level are not connected, unless through the superordinate holons; however, they "observe" one another.
11. The including/included relations imply that the properties of the level (n) holons are emerging; but, on the one hand, they depend on the properties of the subordinate level holons – which they transcend, by the integrative properties rule – and on the other they limit the production of those properties;
    a. the integrative properties rule for ascendant holarchies that include the following cases:
       i) *Union*: the level (n-1) holons merge with those of level (n), where they are no longer distinguishable (figure 2-a);
       ii) *Aggregation:* the subordinate holons join together, thereby losing

their individuality; however, they can still be traced to the superordinate holon (figure 2-b);

iii) *Interaction:* the subordinate holons interact according to a *model* – or schema – but remain disaggregated and distinctly traceable to the superordinate holon (figure 2-c);

iv) *Internal coordination:* the subordinate holons coordinate according to a stable model while remaining traceable to the superordinate holon; one of the holons serves as coordinator (figure 2-d); if there is no coordinator self-organization occurs;

v) *External coordination:* the subordinate holons are coordinated based on a stable model by means of a superordinate holon (figure 2-e);

vi) *Evolution*: the temporal reference of the level (*n*) holon is period (*t*); this holon results from the evolution of one or more holons from level (*n*-1) with reference to period (*t*-1); the levels correspond to successive time periods (figure 2-f);

b. the integrative properties rule for descendant holarchies involve symmetrical cases with the appropriate inversions.

12. It follows from the including/included relations that any change in the characteristics (qualities, processes, cognition, etc.) of a holon of a given level is transmitted to the lower- and/or superordinate holons;
    a. there is a feedback loop for holons with those at both a higher and a lower level;
    b. a holarchy is reinforcing if "small" changes of holons from a given level produce "large" changes in those at the other levels (amplifying the changes);
    c. in the opposite case the holarchy is balancing (dampening the changes).
13. Each final holon includes the entire holarchy;
    a. each level always includes the base holons;
    b. each *head holon* includes those of the subordinate branch;
    c. in the descendant holarchies the dissolution of the head holon leads to the dissolution of all the subordinate holons (for ex: with the elimination of the living forms, the tissues, organs and cells dissolve);
    d. in the ascendant holarchies the dissolution of a head holon leads to the dissolution of the superordinate holons (the disappearance of the cells leads to that of the tissues, the organs and the organism);
    e. the dissolution of the base holons leads to the disappearance of the holarchy.

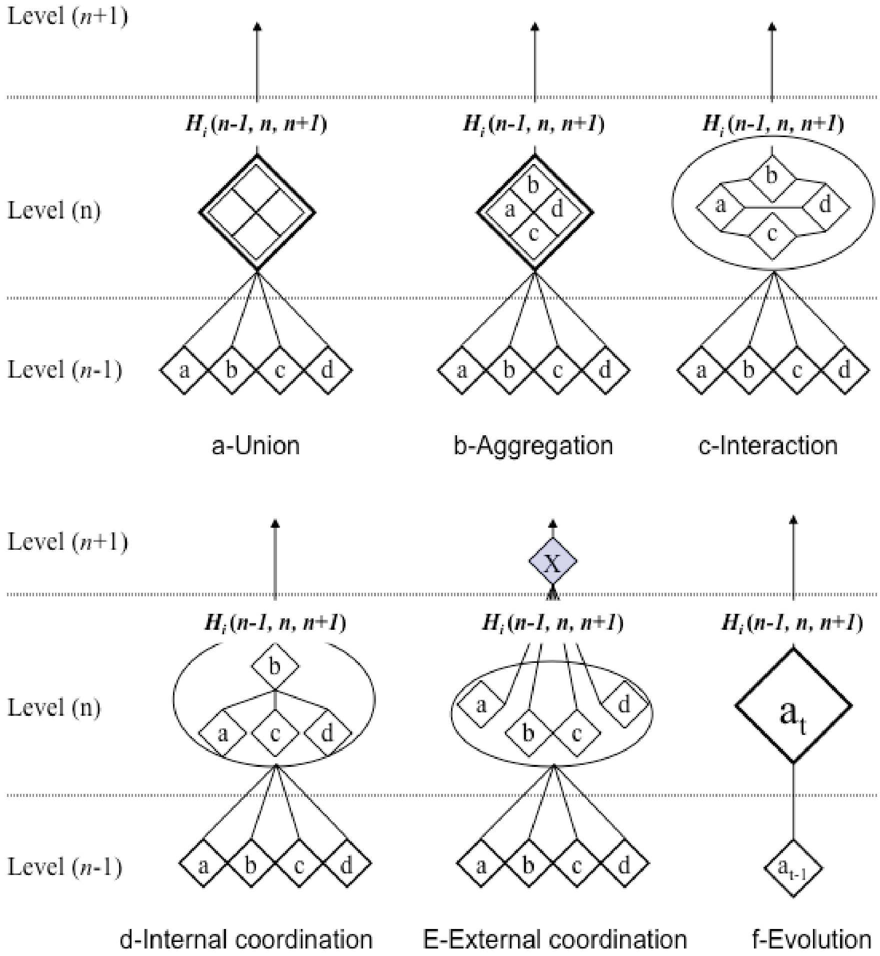

Figure 2. The integrative properties rule of holon.

14. Viewed in a dynamical sense, the holarchy usually evolves toward forms of ever greater efficiency of the component holons, thanks to the self-learning of the holons at the various levels;
    a. Particular types of *descending* reinforcing holarchies are the output holarchies (Koestler 1967, p. 344), which operate according to the *trigger-release principle*, where the top holon produces its processes thanks to the activity of the subordinate holons, which it coordinates by sending information about the activities they must undertake.
    b. Particular types of *ascending* balancing holarchies are the input

holarchies, which operate based on the *filtering principle*; these produce progressive syntheses from the subordinate to superordinate levels, as if, at each level, the holons filter or synthesize the inputs from the subordinate holons.

Many types of holarchies can be built with reference to the *holonic* view of reality; however, according to the various interpretations of holons the following three types can be identified:

a) *structural holarchies*: these derive from the arrangement of holons into subgroups of increasing size which are considered to be similar "modules" that form a more or less vertically extended structure; they represent the elementary idea according to which holons are considered uniquely for their qualitative and structural features and for their similarities of genus and species (Baldwin – Clark 2000);
b) *self-organizing cognitive holarchies* characterized by self-organization: these derive from the arrangement of holons in groups of increasing size considered as autonomous "cognitive entities", interconnected by means of relations of programming, coordination and control (typical of sentient, individual and social holons) in order to form larger entities (Smith 2000);
c) *operational holarchies:* these come from the arrangement of holons – sentient or artificial – in subgroups of increasing size considered as "processors" or "processes", interconnected in ever-larger operational structures through their inputs and outputs (Mesarovic *et al.* 1970).

Some of the more important cases will be presented in the following sections:

A. structural holarchies: *modular* holarchies and *fractal* holarchies;
B. cognitive holarchies: Koestler's *Open Hierarchic Systems* (OHS) (or *Self-organizing Open Hierarchical Order,* SOHO), Wilber's *Kosmos,* and Beer's *Viable System Model*;
C. operative holarchies: Shimizu's *Autonomic Cognitive Computer*, the *Holonic Manufacturing Systems,* and the *Holonic Control Systems* (HCS).

2.3 Structural Holarchies. Modular and Fractal Holarchies. Systems of Classification

The simplest form of structural holarchy is the *modular holarchy,* an ordered arrangement of holons conceived of as component *module-entities,* composed of smaller modules, that form larger modules.

In the case of these holarchies we are not so much interested in the nature of the modules as in their position, which depends on – and at the same time gives significance to – the structure and function of the base modules.

The typical modular holarchy has the form of a *mosaic*, however the latter is conceived. The mosaic is a unitary structure but is conceived of as the final holon of a holarchy in which the tesserae represent the base holons.

Each "tessera" is significant in that it is part of a form that, in turn, is part of a larger form whose significance depends in the end both on the component forms – thus on the base tesserae – and on the form it helps constitute; and so on, recursively, down to the final holon, represented by the entire mosaic.

For example, in the mosaic shown in figure 3 the triangular tessera that forms the right foot of the bird is important not for its shape – which is similar to that of the tessera of the beak – but because it is inserted in the claw, which in turn is significant because it is inserted in the foot, which is then included in the shape of the bird, which finally is part of the general form.

Figure 3. The mosaic as a modular holarchy. "Little bird on the branch"
(*Source*: Sant'Apollinare in Classe Basilica, Ravenna, Italy).

The containing/contained logic guides the holarchy of increasingly larger forms that, starting from the individual tesserae, go on to form the mosaic as the final holon of the entire holarchy.

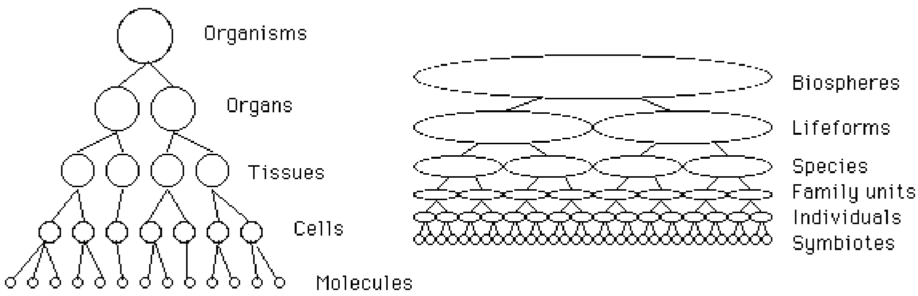

Figure 4. Examples of ascendant Holarchies as systems of classification.
(*Source*: Funch 1995).

The holarchies in figure 4 are also typical modular holarchies, to which we can add the modular holarchy represented by the interplanetary cosmos: the planets and their satellites make up the planetary system that, together with a star, makes up the stellar systems, which form the galaxies, which are included in nebulae and so on.

A similar observational strategy explains how a modular holarchy is formed from the decomposition of any physical body, down to the molecules, which in turn are composed of atom-elements that include even tinier elements.

Fractal holarchies are special forms of multi-strata modular holarchies. They are composed of similar elements that are arranged in levels that in the end form a fractal holarchy similar to that in figure 5.

Each element from a given level includes all those of the preceding level, to which new elements are added based on specific rules.

Or, as exemplified in figure 5, at each level the elements of the preceding level gradually increase in size, while maintaining the same structure, and include new elements in the same structure.

A third important form of holarchic arrangement are the *systems of classification*, whose aim is to separate out the elements of a group in order to assign these to some class of elements with similar characteristics in accordance with fixed cognitive objectives.

The logic behind classificatory systems is to identify a succession of classes whose properties are increasingly more specific.

Each class has its own content, but at the same time is also a subclass of a vaster class, and in turn contains other, less extensive subclasses.

Each class thus represents a holon, since it is included in a wider class and includes smaller classes (for ex.: living, warm-blooded, mammals, humans, males, height up to X, age up to Y, living in Z, etc.).

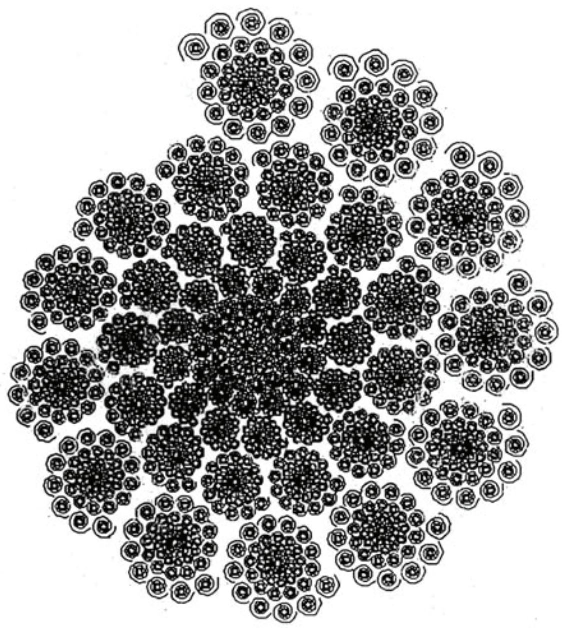

Figure 5. A modular holarchy with a particular fractal form.
(*Source*: Günther 2006).

2.4 Cognitive Holarchies. Koestler's SOHO

The concept of the *Self-Organizing Open Hierarchical Order* (SOHO) comes from Koestler, who also used the simplified term *Open Hierarchical Systems*.[3]

The author used this term to indicate a holarchy understood not only as an ordered arrangement of modules but as a vertical system of ever larger *cognitive units* possessing consciousness («Holons as an aggregate of consciousness working in some fashion as one unit»).

In holarchies the holon from a given level includes and coordinates, by means of its own cognitive processes, holons of a subordinate level, and transmits the information necessary to conform the superordinate holon, thereby producing an evolutionary dynamic process.

[3] The SOHO acronym is also interpreted as Self Organizing Hierarchical and Open systems, Self Organizing Holonic Organization, or Self-Regulating Open Hierarchic Order.

Koestler describes his evolutionary theory, which refers to social development, in an Appendix to his important work (1967) entitled *General Properties of Open Hierarchical Systems*, which sets out a succession of numerous interrelated principles that refer mainly to the domain of cognitive holons and of life.[4]

It is particularly interesting to note that after having proclaimed the relativity of holonic observations («Parts and wholes in an absolute sense do not exist in the domain of life») and defined holarchies as arborising structures, both downwardly and upwardly open-ended («The [holarchy] is open-ended in the downward, as it is in the upward direction»), he also acknowledges the possibility of the formation of horizontal networks among branches of parallel holarchies («Hierarchies can be regarded as 'vertically' arborising structures whose branches interlock with those of other hierarchies at a multiplicity of levels and form 'horizontal' networks»).

Not only does each holon in the holarchy tend to persist according to a canon («The canon of a social holon represents not only constraints imposed on its actions, but also embodies maxims of conduct, moral imperatives and systems of value»), it also shows a *natural tendency* to become integrated: that is, along with other holons of the same level to become a part of a higher-level holon.

There is thus a continual increase in the depth of the holarchies of life and of society, and we observe a continual tendency toward greater structural and operational complexity («Holons on successively higher levels of the hierarchy show increasingly complex, more flexible and less predictable patterns of activity, while on successive lower levels we find increasingly mechanised stereotyped and predictable patterns»).

Within this dynamic process *consciousness* is revealed as the emerging quality of high-level biological holons.

Consciousness increases complexity and flexibility, and thus the decision-making capacity and freedom for superordinate holons that emerges into free will.

In this sense the holarchy for Koestler must no longer be considered only as a conceptual model, useful from an observational point of view, but as a true *autonomous systemic entity* possessing order and its own dynamic process, as well as being open and capable of self-organizing its changes, whether casual or planned, at whatever level these are manifested.

The self-organizing dynamic process is no longer *in* the holarchy but becomes *of* the holarchy, which appears as the representation of a unit, of a whole, of a system, with its own dynamic characteristics and controls. In this sense Koestler's holarchy is an operative view that represented the starting point for Wilber's construction (par. 2.5).

By making local decisions for their survival based on their own *canon* holons send out and receive information along vertical lines, and adapt and evolve while maintaining

[4] Koestler underscores not only the cognitive aspect of holons but also their reproductive possibilities, with particular reference in this case to the sentient holons.

and gradually improving the entire holarchy, producing cognitive performances that are more relevant the more they are produced by superordinate holons.[5]

We can distinguish *input-holarchies*, or *push* holarchies – whose dynamic process is determined by the base holarchies that transmit their information and their states to the superordinates – and the *output*, or *pull*, holarchies whose dynamic process is determined by the final holon that, based on its operational and information needs, in some way spurs the dynamic processes of the subordinate holons.

The self-organization process of the SOHO is immediately evident as soon as we realize that modifying some property of a holon of a given level produces, as we have seen, effects on the properties of the superordinate holons. This effect spreads to the higher branches of the holarchy, and ends up by modifying the properties of the final holon.

These changes not only take place in an upward direction but can also show their effects in a downward one, due to the coordinating capacity holons of a given level have with respect to those composing the lower branch of the holarchy.[6]

The holarchy thus has numerous *feedback loops* that permit not only self-organization but also the gradual adaptation of the cognitive performance at each level. Advantageous changes improve the holarchy while disadvantageous ones are eliminated or mitigated. In the contrary case the branch of the holarchy where these changes appear are suppressed. Certain changes at a given level of the holarchy can even produce new branches.

2.5 Cognitive Holarchies. Wilber's Kosmos

Ken Wilber (1995) also adopts the holonic view in order to demonstrate the evolutionary path of "Nature" toward the consciousness that characterizes man and his social groupings. Precisely for this reason he has adopted a particular notion of holon – as an

[5] «These are hierarchies which model the overall system, where the components receive 'orders' from components above and transmit 'orders' to components on the next lower layer of the model.» (Pichler 2000). «The 'Janus face' of those holons, with respect to its looking 'up', can usually not be achieved by learning alone but needs a certain talent to build the proper reference system. On the other hand, holons which are situated on the lowest layer need for the 'down' looking 'Janus face' a skill comparable to handcraft, to realize and integrate the processes which define the lower boundary of the SOHO-structure. This skill can again be considered as a kind of art which can only be acquired by practical experience. From this point of view, the holons on the upper and lower boundaries in a SOHO-structure play an important role and deserve special attention. It is mainly their proper functioning which defines the quality of performance of a SOHO-structure.» (Pichler 2000).

[6] «Every sub-system is a relatively autonomous organism while also being a component of a larger organism; it is a 'holon,' in Arthur Koestler's term, manifesting both the independent properties of wholes and the dependent properties of parts. Thus the pervasiveness or order in the universe takes on a new meaning; order at one systems level is the consequence of self-organization at a larger level.» (Capra 1982).

entity that in varying degrees possesses interiority and consciousness (par. 1.4) – as an individual (*individual holon*), or social grouping of individual holons (*social holons*), which form a *qualitatively* defined holarchy (Ashok 1999) named as Kosmos.[7]

While Wilber's starting point is generally the same as Koestler's, his analysis of the dynamics *of* and *within* the holarchies is more coherent and detailed.

In order to carry out the connections among the individual holons (proper holons) – which are at the basis of Wilber's conception, with particular reference to the sentient holons – and the social ones, Wilber uses an *integral* method (or AQAL, which stands for All Quadrants All Levels). He reduces the various *dimensions* according to which the individual holons can be analysed (*interior/exterior* and *individual/collective*) to a single diagram, thereby developing an observational four-dimensional model (figure 6),[8] many of whose aspects have been criticized (Smith 2001, 2002, 2004; Goddard, online).

The schema in figure 6, on which Wilber's theory is based, must be interpreted as a *dynamic model* where each holon is defined as an *entity (unit) of awareness* that is present in an individual at a given *time* (senior holon) and which implies that the holarchies also include the holons from the same level that refer to previous *times* (junior holons) and to different degrees of awareness.

A holon is not an individual but the *temporally-specific awareness* of an individual or a group of individuals.

As a result, we can conceive of the awareness of a physical individual at a given moment as a senior holon that includes the junior holons defined in the *past history* of that individual.

In Wilber's Kosmos, artefacts and heaps are not proper holons, as they have no awareness.

In figure 6, quadrant I shows the holons in their *individual dimension* and *interior perspective*, each of which represents a transcendent unification (*prehensive unification*) of all the holons that preceded them, or are at a lower level in the holarchy, since they inherit the sensitivity and awareness of their predecessors and of their predecessors' components, with a continuity in the causal dynamics between past and present.

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[7] «Ken Wilber has raised a body of work (The Spectrum of Consciousness/1977, The Atman Project/1980, Up From Eden/1981, Eye to Eye/1983, A Sociable God/1983, Transformations of Consciousness/1986, Grace and Grit/1991, Sex, Ecology, Spirituality/1995, A Brief History of Everything/1996, The Eye of Spirit/1997, The Marriage of Sense and Soul/1998, One Taste/1999, Integral Psychology/2000 and A Theory of Everything/2000) that is a monumental discourse on consciousness and evolution and a dizzy feat of theory and vision.» (Ashok 1999).

[8] «The *four quadrants* are four of the basic ways that we can look at any event: from the inside or from the outside, and in singular and plural forms. This gives us the inside and the outside of the individual and the collective. These four perspectives are not merely arbitrary conventions. Rather, they are dimensions that are so fundamental that *they have become embedded in language* as pronouns during the natural course of evolution. These embedded perspectives show up as first, second, and third person pronouns. Thus, the inside of the individual shows up as 'I'; the inside of the collective as 'you/we'; the outside of the individual as 'it/him/her'; and the outside of the collective as 'its/them.' In short: I, we, it, and its.» (Wilber 2004b).

The holarchy thus becomes the model of the temporal continuity of the sensitivity of each individual holon and represents the basis for the formation of the individual memories; it represents the Karma («This is karma, yes?»*)*. However the awareness of each individual holon is characterized not only by its experience (the past) but also by the manifestations of its creativity, as an expression of liberty which, once produced, grows over time. This form of holarchy, says Wilber, is universally present in the Kosmos.

Quadrant II presents the *collective dimension* holons, and retains the *interior perspective*; here we have an intersubjective awareness – which defines a *cultural background* and gives rise to cultural memories and social histories – that represents stable models of reproductive and social behaviour. In this instance the holons modify themselves according to the same temporal rules followed by the holons in quadrant I («Individual holons and communal holons prehend their past»).

	INTERIOR	EXTERIOR
INDIVIDUAL	**I** Prehension Subjective Identity Agentic memory	**III** Autopoiesis Individual morphic resonance and formative causation Genetic inheritance
COLLECTIVE	**II** Habitus Cultural Memory Mutual prehensions Intersubjective background	**IV** Systems memory Ecosystem autopoiesis Chaotic and strange attractors Social autopoiesis Collective formative causation

Figure 6. Diagram of Wilber's four observational levels.
(*Source*: Wilber 2004b; I have added the Roman numerals).

Quadrants III and IV analyse the *individual* and *collective features* of the holons, but from an *exterior perspective*, where the holons are observed in the third person and no longer in the first person. This form of observation allows us to identify the structure and the exterior dynamics of the holarchies in terms of *morphic* structures and of *morphic* fields.[9] The *morphic structure* identifies a stable structure of holons, the stable models

[9] «That is a brief outline of *subjective* and *intersubjective* inheritance, the means by which the *felt dimensions* of the Kosmos reproduce themselves moment to moment, while still allowing creative emergence (which then itself becomes part of the inheritance future holons will transcend and include).» (Wilber 2004b).

that we can observe; a morphic field identifies the social superstructures that surround the holon. These models are always present in every holarchy and are subject to the same rules of temporal change that distinguishes all holons.

This representation implies that the holons are subject to unitary permanence at each instant, in a context that is also permanent but in continual *hereditary evolution* over time, and that they are conditioned by *creative mutations* that then spread throughout the entire Kosmos. They represent the *stable modules* that, interacting at each level of the holarchy, produce the dynamics of the Kosmos.

The Kosmos tends towards improvement, since the individual holons interact and evolve in order to pursue their *integral health* and their *essential health*, which translates into the awareness that the improvement in health is a positive factor.

In his "metaphysical" view of evolution Wilber presents 20 postulates (principles or dogmas) of evolution (the *Twenty Tenets*)[10] that are both parallel and complementary to the operational rules presented by Koestler in his Appendix (par. 2.4) (Leonard 2000; Smith 2000).

The two basic postulates are indicated in *Tenet* 3 («Holons emerge») and in the correlated *Tenet 4* («Holons emerge holarchically»), which state that in nature holons appear spontaneously in the form of a holarchy, as part of a chain of whole/part or containing/contained relations. In fact, there seems to be no doubt that after the big-bang inanimate nature was populated by ever larger holons, which were holarchically arranged in composite structures that then became part of larger structures, eventually forming

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[10] The Twenty Tenets are classified as follows (we must also take into account the sub-numeration)

«1. Reality is not composed of things or processes, but of holons, which are wholes that are simultaneously parts.

2. Holons display four fundamental capacities:
   a. self-preservation (agency)
   b. self-adaptation (communion)
   c. self-transcendence
   d. self-dissolution

3. Holons emerge.

4. Holons emerge holarchically.

5. Each holon transcends and includes its predecessors.

6. The lower sets the possibilities of the higher; the higher sets the probabilities of the lower.

7. The number of levels which a hierarchy comprises determines whether it is 'shallow' or 'deep;' and the number of holons on any given level we shall call its 'span.'

8. Each successive level of evolution produces greater depth and less span.

9. Destroy any type of holon, and you will destroy all of the holons above it and none of the holons below it.

10. Holarchies co-evolve. The micro is always within the macro (all agency is agency in communion).

11. The micro is in relational exchange with macro at all levels of its depth.

12. Evolution has directionality:
   a. increasing complexity
   b. increasing differentiation/integration
   c. increasing organization/structuration
   d. increasing relative autonomy
   e. increasing telos.»

macro molecules and organic molecules, and from these the entire holarchy that characterizes living beings (cells, tissues, organs, sub-systems).

The emergence of the holons appears not so much as the formation of ever larger structures but as the composition of structures that have new and emerging properties. [11]

Tenets 5 («Each holon transcends and includes its predecessors») and 6 («The lower sets the possibilities of the higher; the higher sets the probabilities of the lower») are equally relevant. These postulate that each holon includes all the subordinate holons (parts of parts of parts, etc.), while at the same time transcending these, even though deriving from them, in the sense that they produce emergent processes and qualities. The holarchically-ordered Kosmos has an evident, inevitable and useful asymmetry.

At each level of the holarchy the holons contain those of the previous level, but not vice-versa.

The range of possibilities of a holon at a given level depends on the range of possibilities of the subordinate holons, but it does not entirely derive from this; new possibilities emerge from the creative tendencies of the Kosmos. Reciprocally, the holon at level (*n*) maintains within its structure the lower-ordered holons, and to survive it must preserve and regenerate these. In fact, the destruction of these holons would imply that of the holon at level (*n*) – as stated in *Tenet 9* («Destroy any type of holon, and you will destroy all of the holons above it and none of the holons below it») – thereby making it more likely that the holons at levels below (*n*) will survive and be consolidated.

Due to the interrelation between *micro* and *macro*, between containing and contained, between whole and parts (*Tenet 11*) – in the sense that any improvement in a class of holon has repercussions for all the higher-ordered as well as the lower-ordered holons – and the natural co-evolution of the holarchies, the Kosmos itself displays an evolutionary dynamics that has directionality (*Tenet 12.a* to *12.e*), since the holons tend to increase in complexity, differentiation and integration, organization and structuration, as well as in their relative autonomy and *telos*.

The structure and dynamics of the Kosmos, as a holarchy of cognitive, individual and social holons, thus emerges.

2.6 Beer's Viable System Model

This section considers Stafford Beer's model, universally known as the Viable System Model, or VSM (Beer 1979, 1981), which interprets organizations as *viable systems* that are open, recursive and adaptable and, thanks to their cognitive and control structure,

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[11] «Reality, in the modern conception, appears as a tremendous hierarchical order of organized entities, leading, in a superposition of many levels, from physical and chemical to biological and sociological systems. Such hierarchical structure and combination into systems of ever higher order, is characteristic of reality as a whole and is of fundamental importance especially in biology, psychology and sociology.» (Bertalanffy 1976, p. 74).

which is capable of communicating with the environment (economic and non-economic), tend to have a long-term existence thanks to continual adaptation, even in the presence of disturbances that were not foreseen when the system was designed and carried out.

The organization outlined in Beer's model has all the features that represent a typical holon that is autonomous with respect to the environment and capable of maintaining its own autopoiesis.

The structure of the holon-organization in the VSM, which is summarized in figure 7, includes FIVE interconnected SUB-SYSTEMS (SS):

SS1: OPERATIONS. This represents the *operational units*, which in turn are viable systems whose purpose is the achievement of the operational objectives at the various levels by connecting with the environment, to which they are *structurally coupled*, taking into account specific and particular constraints, both internal and external.

SS2: COORDINATION. The operational units of SS1 – which employ common resources and are potentially in competition regarding the objectives – are *interconnected*, usually *interfering* systems that can thus produce, in their *local* values, an oscillatory dynamics that may cause inefficiencies. For this reason SS2 is charged with *coordinating* the interconnected operational units.

SS3: CONTROL. The operational units of SS1 each pursue *local* objectives. They must therefore be directed toward the achievement of the higher-order objectives, which refer to the organizational unit, based on a common *programme.*

The SS3 are charged with this function. Since it is capable of activating a *range* of control levers, SS3 is charged with formulating the utilization *strategies* of the levers for the various objectives. Nevertheless, SS3 cannot detach itself from subsystems 4 and 5, as it forms together with them a higher-order subsystem that carries out *cognitive activities* and represents the organization's *intelligence.*

SS4: RESEARCH OF INFORMATION ON THE ENVIRONMENT (INTELLIGENCE). The survival capacity and conditions of vitality of the organization depend on the latter's capacity to continually observe the environment and forecast its "future" state in order to allow SS3 to formulate programmes of action and adapt to these the units and activities of SS1.

SS4 represents the viable system element charged with proposing the vital objectives – based on foreseeable future scenarios – and translating these into programmes of action whose implementation it oversees.

SS5: POLICY. To complete the VSM, Beer has clearly observed how organizations tend to contemporaneously pursue numerous objectives. Thus the control lever *strategies* used by the lower-order subsystems are not sufficient; a careful assessment and rational ordering of the SS4 objectives is indispensable. SS5 is necessary precisely to guarantee that the organization will have a *unitary management,* an *entrepreneurial* along with a *managerial capacity* that can define the *policies* needed to achieve the vital objectives.

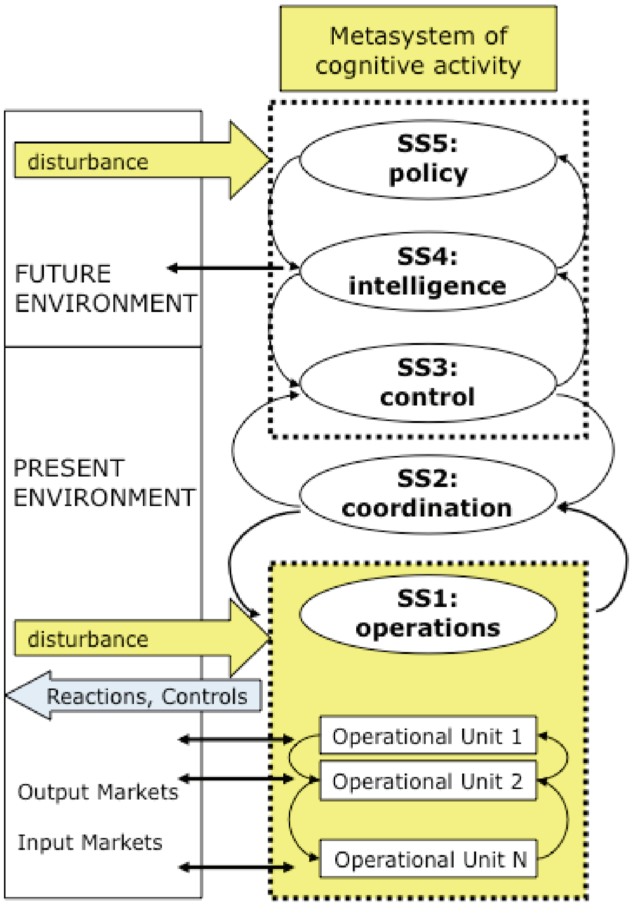

Figure 7. The Viable System Model in brief.

According to Beer, the VSM can also be applied to the organs, groups of organs, or operational units however defined, that compose the organization, which itself thus appears composed of lower-level viable systems. Moreover, every organization must always be viewed as part of a larger organization. Beer proposes the following "theorem" which, on the one hand, clarifies the holonic nature of every organization, and on the other highlights the recursiveness of the holarchies.

> RECURSIVE SYSTEM THEOREM
> In a recursive organizational structure, any viable system contains, and is contained in, a viable system.
> There is an alternative version of the Theorem as stated in *Brain of the Firm*, which expressed the same point from the opposite angle: 'if a viable system contains a viable system, then the organizational structure must be recursive'. (Beer 1979, p. 118).

It is thus immediately clear that the organization outlined by Beer is not only a holon but must be interpreted as a *cognitive holarchy* composed of sub-holons which are themselves viable systems.

2.7 Operational Holarchies. Finite State Machines

If Koestler's SOHO and Wilber's Kosmos view holons fundamentally as *cognitive entities*, particularly biological (or more properly, as levels of awareness of these cognitive entities), without distinguishing between structure, processes and results of processes, then we can imagine a third type of holarchy: that formed by holons understood as *elementary agent-operators* – physically observable or theoretically definable – which are vertically interconnected by means of their input and output flows, so as to form a multi-level operator system of nidified components of increasing size.

An *elementary agent-operator* can be defined as an entity – biological, mechanical or informational – capable of developing any type of process, at given performance and efficiency levels, under conditions of limited resources, by coordinating with other entities in an attempt to remain vital (for example, in the sense of Beer, par. 2.6 and of Maturana – Varela. 1980).

It thus presents the typical characteristics of the holon, since it is an entity that has autonomy and interiority, a *whole* but also a *part*, and since it is linked to lower- and higher-level entities in order to form an operational holarchy. The results of its processes combine those of the lower-level holons while contributing to achieve those of the higher-level ones.

Let us first consider the holarchy that forms from the decomposition of the *Finite State Machines* (of FSMs) into a ramified succession of parallel-operating machines arranged on different levels.

We can construct figure 8 starting from figure 1 (simplifying the notation), assuming that $H_1(0)$ represents a finite state machine that is decomposed into two parallel operating machines, $H_1(1)$ and $H_2(1)$. $H_1(1)$ is in turn decomposed into two parallel machines: $H_1(2)$ and $H_2(2)$; $H_2(1)$ is decomposed into three machines of a subsequent level; $H_1(2)$ is further decomposed into two component machines; and similarly for $H_3(2)$ and $H_5(2)$.

After the decomposition we can represent the hierarchy of machines as a holarchy by employing *holonic modules*.

We can define a *holonic module* of a given level as the holons of that level that are connected to the same holon of the level above. A module can be composed of a single holon or by any number of holons that *operate in parallel*.

Thus every holon of a given level derives from a lower-level holonic module. The holonic modules do not communicate with each other except through the superordinate holons, of which they are constituent elements.

Thus the operational holarchy of the FSMs can also be represented as a hierarchy of holonic modules holarchically interconnected – in a descending holarchy – such that at each stratum of the holarchy the modules always represent the entire machine, as shown in figure 8.

More generally, the *modular holarchies* represent the typical model of ramified sequential processes carried out by holons composed of *subsystems of agents* that operate parallelly – or of the *results* from combining the processes carried out by those same agents – grouped together in modules and arranged as a succession of strata to form a *Multi-Layer*, *Multi-Agent System*.

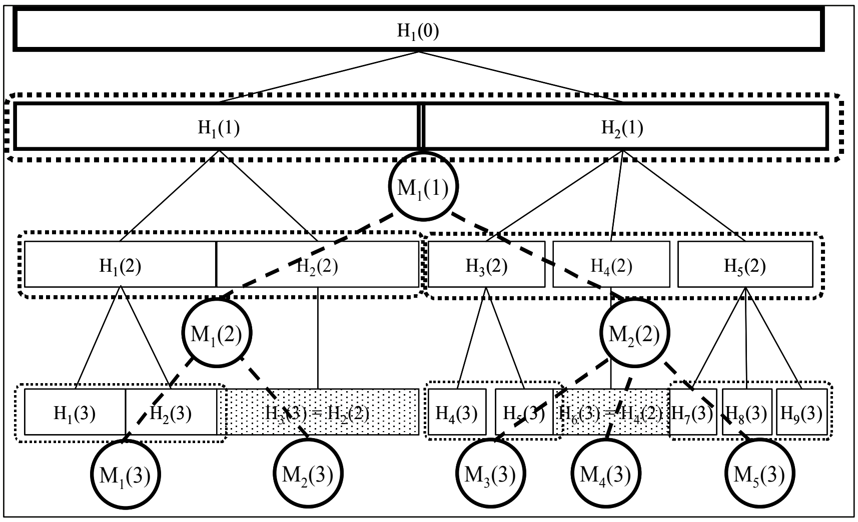

Figure 8. Multi-strata modular holarchy (derived from figure 1).

The modular holarchy is thus typical of both the vertical structures formed by human agents in organizations (see below, chap. 3) as well as those composed of the modular machines of production processes, with regard to both physical operations as well as the computations and sequential processing of data and information, stimuli and impulses (pumping networks in oil pipelines, modular networks, the nervous system, artery and vein structures, etc.).

The diagram in figure 8 can be generalized, as shown in figure 9.

Let us take any kind of system that can be represented as a finite-state sequential machine, $M(0)$, which, together with its structure and programme, can carry out the task, $T(0)$, (which can also be an objective, a project, etc.) with an appropriate succession of outputs.

If we assume that:

- $T(0)$ can be broken down into a hierarchy of sub-tasks $T_{ij}(h)$, where h = 1, 2, …, the hierarchical levels of the sub-tasks, so that $\bigcup_h T_{ij}(h) \Rightarrow T(0)$, where $T_{ij}(h)$ indicates the tasks *i* of level *h*, which are part of task *j* of level (*h+1*) and where "⇒" indicates the relation of *equivalence* (or of *parts/wholes*);
- that each sub-task $T_{ij}(h)$ can be carried out by sequential sub-machines of smaller size, $M_{ij}(h)$, so that we have: $\bigcup_h M_{ij}(h) \Rightarrow M(0)$;
- we can then, by adopting the notation of the holonic modules:
- construct the holarchy of the tasks, which has $T(0)$ as the final holon and the tasks that cannot be further decomposed as the primal holons;
- construct the holarchy of the machines that carry out the tasks, which has $M(0)$ as the final holon and the sub-machines that cannot be further decomposed as the primal holon*s*;
- consider the two holarchies to be holonically equivalent.

Figure 9 shows how the machine M=$M(0)$ has been decomposed into a multi-strata holarchy made up of 15 machines, which admit no further decomposition (grey background), by means of a certain number of intermediate machines, which are inserted at each level of the hierarchy. Superimposed on this is a multi-level modular holarchy (connected circles) built without the insertion of virtual holons for the machines M_2, M_{21}, and M_{23}.

In any event, the fundamental rules are respected, according to which the machines of every level must all be included in the higher level and all the primal holon*s* (grey background) must be included in the final holon.

The simplified representation of figure 9 offers additional interesting information: if we observe the superimposed modular holarchy we note, in fact, that for each level of the decomposed hierarchy the machines that cannot be further decomposed prevail operationally over the others, and are in fact final holons.

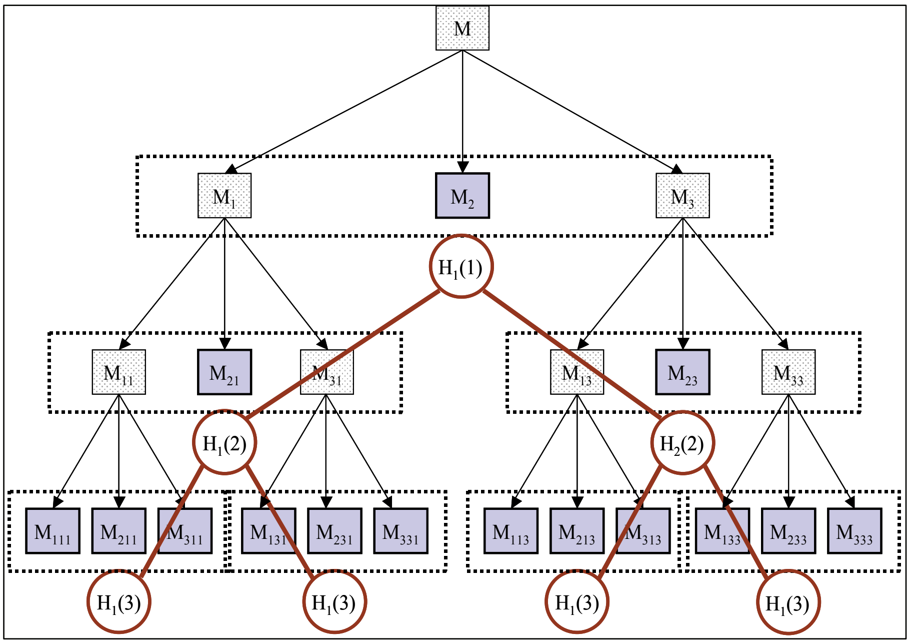

Figure 9. The multi-strata decomposition of a finite-state machine and its multi-level representation with holonic modules.

2.8 Shimizu's Autonomic Cognitive Computer

Another interesting multi-level operational holarchy where a complex task is decomposed into partial tasks, which are then carried out by operative elements that make up a complete machine, is that described by Shimizu (1987), who introduces the idea of *bioholon* and *bioholonics* as a discipline that studies holonic applications in biology.

Shimizu has theorized the construction of an *Autonomic Cognitive Computer* that can be conceived of as a holarchy of holons composed of modules that process information in parallel in order to carry out, through subsequent combinations, a complex operation that produces information at a final level of synthesis.

The function of holons at a given level is to combine the information processed by the component holons so that the *cognitive computer* can proceed to a more complex and organized synthesis of elementary information from the base holons (*microscopic level*), so that the final holon is then able to provide a *semantic* structure to the data from the final synthesis.

In simplified terms, an ACC is made up of a parallel set of processors which are arranged on various levels. A certain number of processors from *level 1* process basic information, with autonomous significance (for example, colored pixels), which are transmitted to a *level 2* processor for processing, thus leading to a synthesis of information that is significant in itself (for example, a letter of the alphabet); a certain number of *level 2* processors process the information previously received from the lower-level processors and transmit this to a *level 3* processor, which synthesizes this into new information (for example, a sentence); the information thus obtained is sent to higher level processors for further synthesis, and so on, until a *final level* processor is reached that processes the information from the immediately preceding level to obtain final information with autonomous significance (for example, a sentence, a concept, a story). The number of levels and the number of processors at each level obviously depend on the type of information to be processed and on the operative program of the ACC.

According to Shimizu's theory both holons and *processors* can be viewed as information.[12]

The stable holarchy of processors, which are viewed as *correlators* between signals from different levels, is an artefact in Wilber's sense if its construction, from higher to lower levels, is subsequent to the semantic structure of the *bottom holon*; or it is a proper holon if the higher-level processors are *spontaneously* created *by* the same lower-level modules.

The holarchy of processors produces different information holarchies that, by gradually reducing the complexity inherent in the elementary information, allows us to derive certain types of cognitive models, as appears to be the case in the evolutionary process from inanimate nature to intelligent life (from the macromolecules to the brain), or in the gradual hierarchization of political structures (from the city districts to the union of states).

The model in figure 10, which derives from figure 1, presents a simple holarchy of the processors that constitute a *cognitive computer* in Shimizu's sense, where the final holon *contains* all the lower level holons in terms of processors as well as the meaning of the processed information.

The task assigned to the final holon – to find the value of the final expression – is achieved by the holarchy of the processors that carry out the development by means of successive holonic components arranged in a holarchy.

[12] «In a cognitive computer elementary signals are related to each other to generate organized information. In this process, relevant correlations between elementary signals are discovered also with the neglect of some correlations. In other words, semantic correlations are found in the assembly of elementary signals. We shall call autonomic unit processors for elementary signals, or semantic correlators of elementary signals, 'holons'. The holons are local-rule generators.» (Shimizu 1987, p. 211).

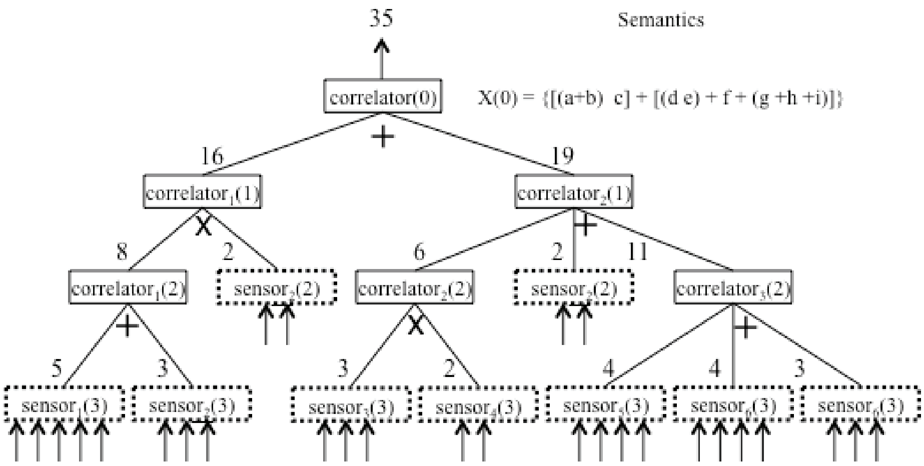

Figure 10. Example of Shimizu's Autonomic Cognitive Computer (derived from figure1).

2.9 The Holonic Interpretation of the Stock Exchange and of the Calculation of Production Costs with the MLCC and the ABCM

A simple and relevant holonic system, whose operational logic is similar to Shimizu's *Cognitive computer*, is the stock exchange, viewed not as a market for the exchange of securities but as a body that progressively combines the values of negotiations.

The stock listings summarize the quotations of the individual securities, which in turn reflect the quotations of the individual exchanges, considered as base holons, carried out by the stock exchange agents as processors.

The multiple informational feedback loops, shown in figure 11, produce the dynamics, often chaotic and explosive (speculative bubbles), that we frequently observe.

From a general point of view even *neural networks* can be viewed as a reticular variant of Shimizu's *Autonomic Cognitive Computer*. These are made up of artificial neurons (in a broad sense the theory can also be applied to the brain, which is formed by biological neurons) that are arranged in a directional reticular holarchy (Gurney 1997); input holons receive signals from a defined environment; intermediate holons process these according to given rules; final holons produce an output whose meaning derives from the semantic interpretation introduced by the network programmer (see below, par. 4.3).

Even the *Holonic Manufacturing Systems* (HMS) are operational reticular holarchies (Schilling 2000) that typically operate in the manufacturing or transport sectors (Kawamura 1997; Jacak 1999), where the holons are machines that make up increasingly larger structures (parts of successive structures) that carry out elementary processes which are often arranged in modules of identical machines (see below, par. 4.6).

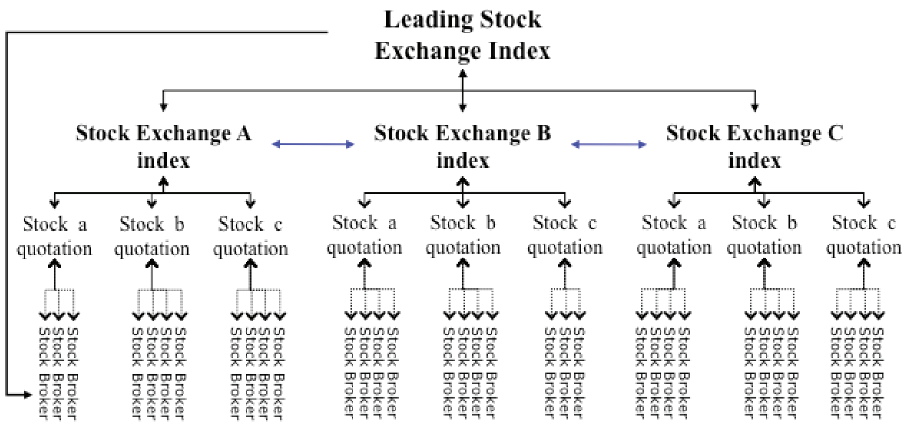

Figure 11. The stock exchange as an Autonomic Cognitive computer.

HMSs can be viewed as directional holarchies, since the input, intermediate processing and output holons are distinct (Seidel *et al.* 1994; Sugimura *et al.* 1997).

The holons of a given level carry out processes that derive from those carried out by the lower-level holons; these processes contribute to the functioning of the higher-level processes. At the top of the holarchy is the *automatic factory* (Talavage 1978), whose output is volumes of products or services.

For a complete analysis of these and other holonic forms of manufacturing systems, see par. 4.6.

An interesting form of holonic system, which is similar to an Autonomic Cognitive Computer, is the process that determines production costs through the gathering and subsequent accumulation of elementary costs into autonomous categories.

As we know, the calculation of production costs attributes the costs of productive factors used in obtaining given volumes of production achieved, programmed or variable (Kaplan – Bruns 1987).[13]

The factor costs are elementary costs, gathered by operative sensors, and can be compared to base holons.

Each subsequent grouping of elementary factor costs – for example, that which distinguishes between direct costs (for materials, components, services and labour) and indirect costs (for machines, plants and overhead costs) – generates higher-level holons; product costs represent further groupings that give rise to even higher-level holons.

The firm's total production cost can be thought of as the final holon of the process.

Between the base and final holons an expanding holarchy of intermediate and

[13] For more, go to: <http://www.accountingformanagement.com/>.

successive synthesis of costs is created.

The process for the calculation of production costs can be achieved in different ways; two which are particularly effective are:

a) the Method of Localization by Cost Centers, or MLCC;
b) Activity Based Costing Method, or ABCM.

The LCC Method (figure 12) assumes that factor costs are incurred not only to obtain the end product but also for the functioning of the operational centers that produce the services needed for the production: that is, to develop the production processes.

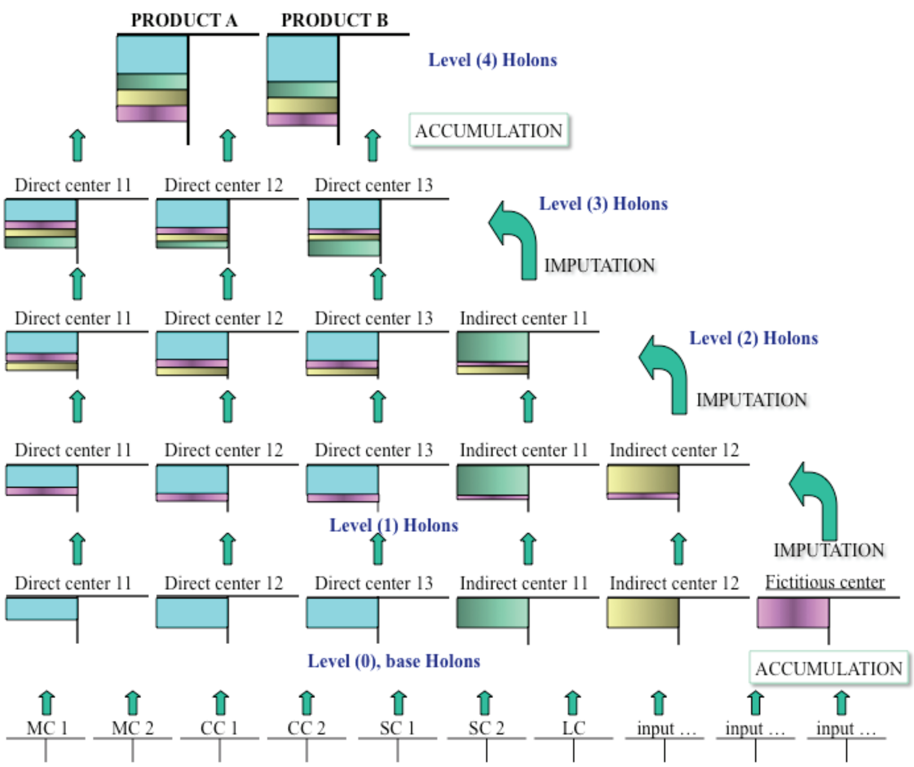

Figure 12. The holarchy showing the cost synthesis in the MLCC.

An *operational center* is *direct* if it represents an operational unit whose services are directly needed for the production process (press center, mill center, paint center, packing, etc.).

It must be autonomously observable and must:

- be autonomously equipped with instrumental factors, machines, equipment, etc.
- be autonomously equipped with workers,
- use typical resources and materials,
- manufacture in measurable units,
- have a person in charge of the activities, who coordinates with the other centers.

An *indirect* operational center is a production unit of *services* needed for the operation of the direct operational centers (maintenance center, administration center, etc.) and must also have the above-mentioned autonomous features.

1. The MLCC method for calculating costs is carried out through the gradual accumulation of elementary factory costs, as shown in figure 12:
2. the elementary costs for materials (MC), components (CC), services (SC) and labour (LC), considered as primal holons, are all attributable to a *cost center*, understood as a center for the accumulation of factor costs; if we assume the factor costs are level (0) holons, then the costs localized in the cost centers are level (1) holons;
3. the cost centers can be *direct* if they correspond to direct operational centers whose services produce products; or *indirect* if they correspond to service centers used by the direct centers; or even *fictitious*, or *conventional*, if they are merely *nominal* centers for accumulating costs to which there are no corresponding operational phases (center for administrative services, center for building utilization, etc.);
4. the costs of the *fictitious* centers are attributed to all the operational centers, both direct and indirect; this operation is called imputation (accumulation, distribution or shifting) costs from one center to the other centers, and it makes use of certain bases for shifting costs, or of *cost drivers* of the center;
5. the *indirect* costs of the centers, after having summed up the costs of the fictitious centers, are in turn *distributed* to the direct centers, through one or more *shifts*;
6. the costs of the *direct* centers, at the end of the shifting over from the indirect centers, represents holons of an even higher level; they are less numerous but combine greater volumes of costs;

7. the *final production costs* are determined by *imputing* the *direct* center costs to the volumes of finished products; these costs are holons of the penultimate level;
8. the sum of the product costs allow us to obtain the *total production cost*, which refers to the entire production organization; this constitutes the final holon (not indicated in figure 12), whose significance comes from the center costs, even though it transcends these, and it represents the final information synthesis of the process.

We can assume that each phase of cost calculation, at the various levels of the holarchy, is carried out through a similar process to that produced by a Cognitive Computer that provides successive syntheses of basic analytical data.

Thus, the holarchy represents the successive synthesis of costs with respect to expanding levels as well as the processors set up for the calculations.

Obviously at each level of the holarchy all the base holons are always included; in other words, each group of intermediate costs always sums up all, and only, the elementary factor costs.

ABCM differs from MLCC in that the elementary costs are reclassified according to centers of accumulation that are identified with the *activities* and the *phases* necessary to carry out the production processes (Cooper – Kaplan 1991).

This method is based on the realization that the elementary costs are in fact not incurred directly for production but rather in order to develop the production process that, through its own operations, leads to the final production and sales.

It is thus logical to attribute the factor costs to the production volumes by *gradually attributing these* to the *activities* needed to obtain those same volumes, and subsequently imputing the costs of the activities to the finished products through specific *cost drivers*.

ABCM, by *focussing* on the production process, assumes a complete, coherent, and thus meaningful identification of all the activities that go into the finished product, and thus into the results of the entire production organization (figure 13).

In order to apply this method, we must define *activity* as:

- a set of tasks, possibly composed of elementary operations, acts, or movements;
- carried out by an individual, or a group of individuals, supplied with specific equipment and machinery;
- based on a homogeneous set of know-how;
- that conform to a coordinated and coherent process in terms of costs and results.

A system of interdependent and interacting activities set up to achieve a unitary productive result is a *production process*.

Among the subsequent activities of a process there is a cause-effect link, while among parallel activities there is a relationship of interdependence.

The *cost of an activity* is the sum of the costs of the factors of production used to carry it out.

The *cost of a process* derives from the costs of all its component activities.

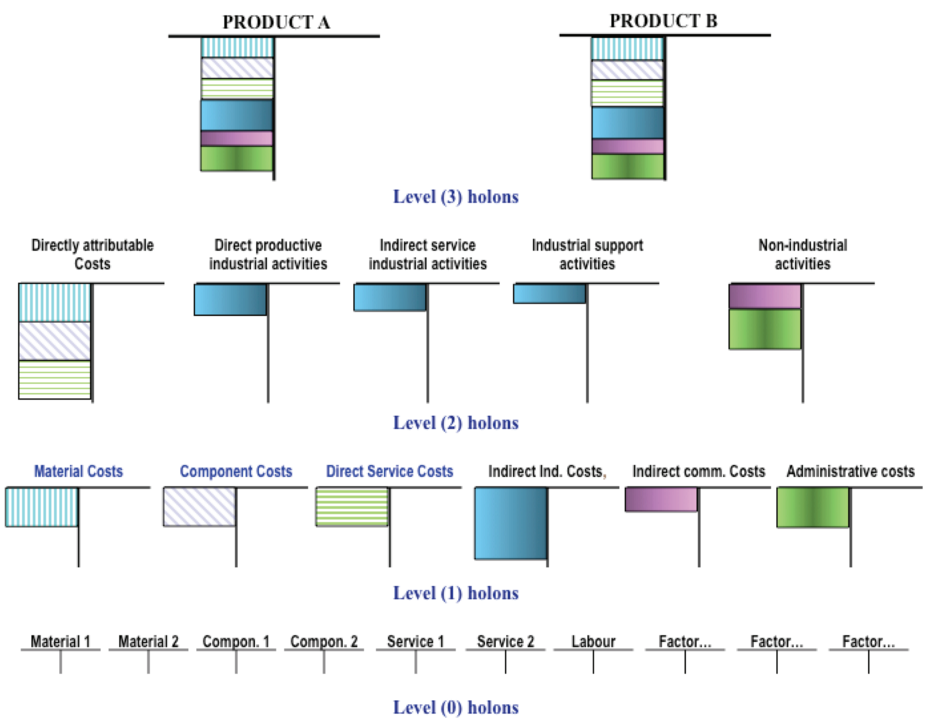

Figure 13. The holarchy showing the cost synthesis in the ABCM.

In relation to their role in obtaining the product, the *activities* can be divided into:

- directly productive, if they are part of the production and marketing processes of goods and services;
- productive of services which are instrumental for the direct production activities;
- support productive, if they are connected to the direct production activities but are not directly linked to the process that transforms materials into products: falling into this category are planning activities, production

engineering activities, programming, design, marketing, logistics, post-sales service, administrative services, and so on;
- various non-industrial activities.

We immediately see that the support activities are as necessary as the direct and service-related ones for carrying out the production and sales of goods and services.

Figure 13 shows the accumulation of costs in a holarchy with expanding synthesis, according to the ABCM:

a) the elementary costs, level (0) base holons, are classified above all according to their nature; from the synthesis we obtain the level (1) cost holons;
b) the elementary costs, level (0) base holons, are classified above all according to their nature; from the synthesis we obtain the level (1) cost holons;
c) the costs classified according to activity are then attributed to the product through appropriate cost drivers and form level (3) cost holons, to which could follow the final holon represented by the total production cost (not indicated in figure 13).

We can observe that, from a syntactic and formal point of view, the same set of base holons – that is, of factor costs – leads to the same final holon; the two methods, MLCC and ABCM, differ only in the different accumulation strategy used to form the intermediate-level cost holons.

Using the MLCC we build a spatial holarchy of the production processes; with the ABCM we structure a functional holarchy that reflects the structure of the cost generating process operations.

2.10 Holonic Control Systems

The process of control can be understood as the gradual approximation of the movement of a variable (under control) toward desired values (objectives), made possible by the action of one or more other variables (the control levers) whose values are recalculated, at every instant, in order to gradually counter any shifting away with respect to the objective.

In short, a dynamical system – logical or technical – where one variable is acted upon in order to force another to achieve an objective (a limit or a constraint) represents the most basic Control System, whose logical structure must always be represented by a balancing loop that tends over several steps to eliminate the distance (error) between the values of the controlled variable and the objective (Mella 2008).

Let us start with the idea that if the world is made up of recurring and recursive systems of variables then clearly (even for a casual observer) all the variables have some limits or some objective value – determined by man or by the natural characteristics of the world – toward which they tend and to which they return when some disturbance moves them away from these values (Mella 2007).

A world without objectives or constraints regarding the dynamics of its constituent variables would be without any control, dominated by chance, without any equilibrium or permanence.

When disturbances move the trends of the variables away from the objectives or constraints, the Control System is disturbed; if the action variables do not operate in an adequate manner, the system can also be irreversibly damaged.

Since the variables that make up the world are interconnected, by varying this context – zooming in or out – every Control System is interfered with by other systems, and the control must therefore also extend to these interconnected systems (Kusumi *et al.*1998).

At a given level of observation Control Systems are usually viewed as autonomous entities; however, apart from the specific interactions, we can view Control Systems as classes of observed entities placed at different hierarchical levels. This can easily be seen when we consider the fact that many Control Systems, though independent, are necessary for the functioning of others which, though independent, in turn permit others at a higher level to function. In other words, there appears to be a holonic hierarchy (holarchy) among Control Systems.

We can realize the different levels of Control Systems that exist as soon as we consider the fact that we can control our body's actions (movement, eating, etc.) because our organs function properly thanks to their Control Systems; and our organs, in turn, function correctly thanks to the cellular Control Systems that make up our tissue.

In living organisms the macro control of organs depends on the micro controls of the component cells. Each cell in the root produces a process that is controlled at the base level, but the Y variables of the Control Systems of cells are synthesized in the Y variables of the branches (which increase in size) of the roots, becoming in the end the variable T of the entire organ, which is represented by the roots as a whole. It is clear that the activity of the roots conditions that of the other parts of the plant; but it is also clear that objectives regarding the functioning of the roots and branches, down to the individual cells, do not determine the higher-order objectives, but instead derive from the nutritional and survival constraints of the plant as a single entity.

It is equally clear that I can control my fingers for typing this sentence because I control my arm, shoulder and entire skeletal muscle system; moreover, these words can flow from the keyboard because the neural system of the brain is under control; but this implies that the areas of the brain entrusted with the various cerebral functions are under control along with the individual neurons that have to control the impulses that arrive "upstream" in order to pass on other impulses "downstream".

It is also clear that the control of the direction and speed of our car is possible because the various car systems and components, the gas level in the tank, the turbo action, electrical system, tires, etc., are connected to specific Control Systems.

Even the Control System that tries to keep pollution emissions below certain thresholds implies, at the global level, the control of polluting companies, which limit individual emissions by controlling the energy consumption of their facilities and the maintenance state of their factories.

The control of global warming implies the control of emissions by individual countries, which conditions the control of individual areas, individual companies or families, and individual equipment and equipment components which produce substances that contribute to the greenhouse effect.

How can infant deaths be controlled if we do not activate controls on health structures (obstetric and neonatal wards) and families (hygiene and diet)? How can we control health structures or families without controlling the level of preparation and education of the personnel?

In short, without taking anything away from the circular interconnections among Control Systems, it is clear that every Control System of a certain level usually implies the existence of a lower level of control, which leads us to a new supposition.

Widening and generalizing these observations, we can conclude that the world can be viewed as a holarchy of Control Systems at various levels. The systems at each level have their own properties – new or emerging – but are influenced by those at a lower lever, while in turn influencing those at a higher level. Thus: the world can exist because it is made up of a holarchy of Control Systems.

It is clear that Control System holarchies are simultaneously input holarchies and output holarchies.

The close connection between Control Systems at different levels by means of the Y variables (ascending connection) and the objectives, Y* (descending connection), is a general feature of holarchies, and this connection fully reflects the general principle, clearly presented by Koestler, of greater complexity in the behaviour of holons the higher up we go in the holarchy: «Holons on successively higher levels of the hierarchy show increasingly complex, more flexible and less predictable patterns of activity, while on successive lower levels we find increasingly mechanised, stereotyped and predictable patterns».

From an ascending observational approach – gradually zooming out – we can see that a miniscule pixel functions because a micro Control System provides it with a certain state, since a superordinate Control System makes that state necessary in order to adjust the state of the monitor. But the state of the monitor derives, in turn, from the control objectives of the software that is operating at that moment, which in turn responds to the control needs of the operator who is using it, who in turn is influenced by the control needs of the group he operates in, which in turn is affected by the Control System represented by the operational center where the group carries out its activities; this is part of a larger Control System made up of the department, division and entire organization, which in turn is controlled by other superordinate systems.

The same applies for all organizations that can be considered not only as viable systems (par. 2.6) but also as Control Systems – with regard to the achievement of the institutional goals for which they were created – composed of nested control systems; the macro-level control depends on the control carried out by the organizational organs themselves, which depends on the control of the individual members, the processes, the operations, the movements, etc., which involves a descending observational approach that zooms in from a broader to a narrower perspective.

We must now ask if observing Control Systems from an holonic perspective enables us to derive the following hypothesis: the holarchy of Control Systems that make up our world produces a continuous improvement, allowing us to increase the variety and strength of the possible controls and the scope of the attainable objectives; the perpetual evolution of Control Systems permits the control of every micro and macro variable that make up our world.

We can view the holarchy of Control Systems as a Control System that produces progress.

There is no global desire to produce global progress; continuous improvement is not the result of decisions by some Supreme Authority but derives from the invisible hand of the unconscious action of Control Systems that improve other Control systems, which in turn improve other Control Systems as part of a circular causal chain that, in the end, produces the global improvement we are experiencing.

Echoing Koestler, we can thus consider the holarchy of Control Systems as an Open Hierarchic System, a machine that produces general progress in life through the two-dimensional improvement – upward and downward – in the holons-Control Systems.

Figure 6 shows a possible simple Control System arranged on three levels, in a typically holonic arrangement. The five Control Systems on the first level represent the base holons.

Level A represents an accumulator of the Y variables from levels A1 and A2, which in turn accumulate the values of the Y variables produced by the five base holons.

In the typical holarchy – from a bottom-up perspective – the values of the Y variables at level A derive from the values produced at the lower levels; moreover, these values – from a top-down perspective – are conditioned by the holons of the superordinate levels, since level A indicates the objectives to achieve at the lower levels, which for simplicity's sake are set equal to a proportional share of the level A holons.

The maximum objective, YA*=360, of the top holon is divided into two subobjectives, YA1*=180 and YA2*=180, for the intermediate holons. Holon A1 divides its objective between the two base holons as follows: YA11*=90 and YA12*=90. Holon A2 divides its objective between the lower base holons as follows: YA21*=60, YA22*=60 and YA23*=60. Other rules could be used to divide up the higher-level objectives among the lower-level ones, but the proportional division among the lower-level holons is logical, since it reflects the natural behaviour of these orderings.

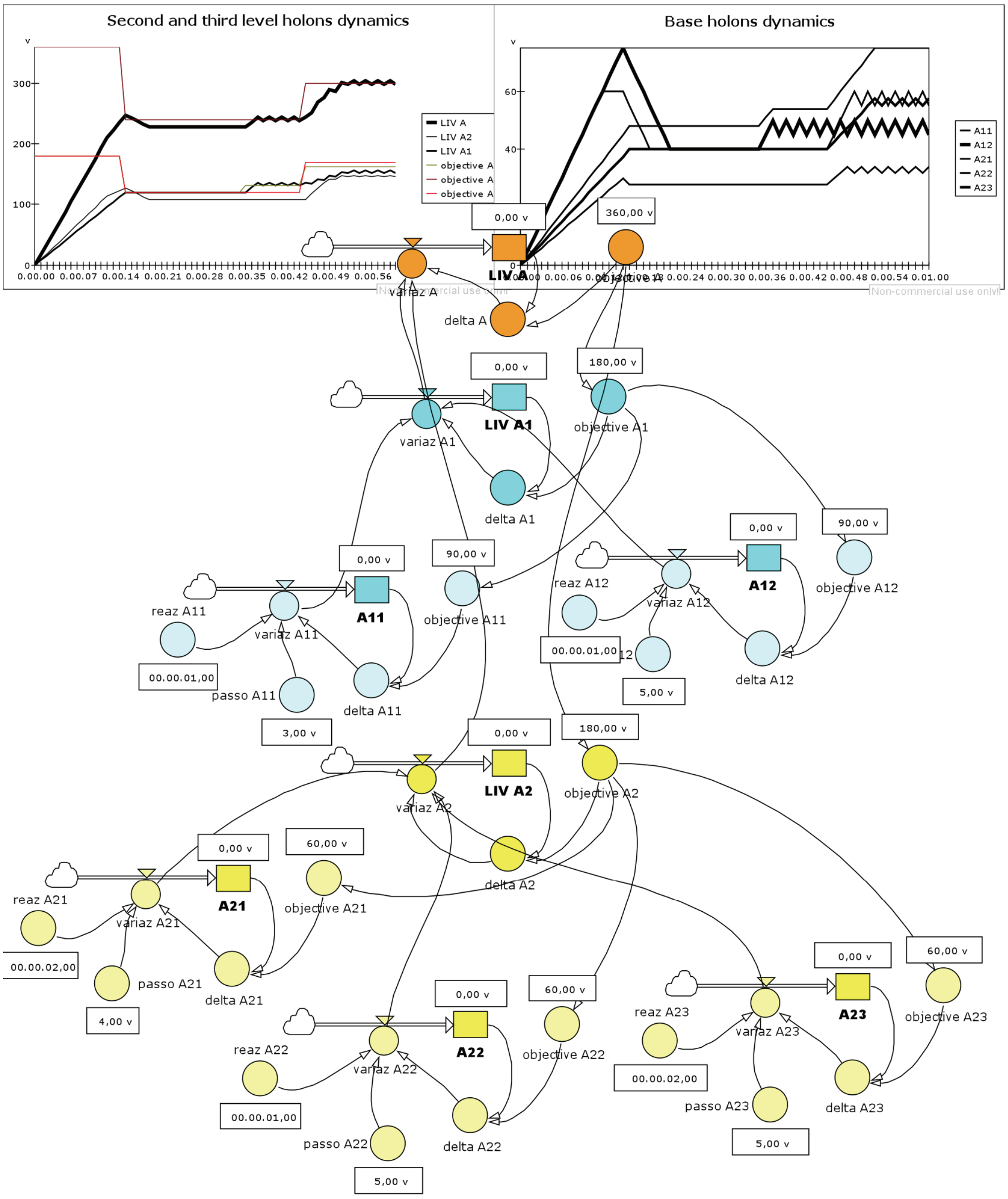

Figure 14. Control System on three levels with an holonic arrangement (*Source*: Mella 2008).

Chapter 3

Org*a*nizations and Org*o*nizations

> There once were two watchmakers, named Hora and Tempus, who manufactured very fine watches. Both of them were highly regarded, and the phones in their workshops rang frequently - new customers were constantly calling them. However, Hora prospered, while Tempus became poorer and poorer and finally lost his shop.
> The watches the men made consisted of about 1,000 parts each. Tempus had so constructed his that if he had one partly assembled and had to put it down - to answer the phone, say - it immediately fell to pieces and had to be reassembled from the elements. [...]
> The watches that Hora made were no less complex than those of Tempus. But he had designed them so that he could put together subassemblies of about ten elements each. Ten of these subassemblies, again, could be put together into a larger subassembly; and a system of ten of the latter subassemblies constituted a whole watch. Hence, when Hora had to put down a partly assembled watch in order to answer the phone, he lost only a small part of his work, and he assembled his watches in only a fraction of the man-hours it took Tempus. (Simon 1962, p. 90).

3.1 Not Only Holarchies. Organizations as Social Systems

The notion of holarchy permits us to interpret in a particular way the hierarchical interconnections of the containing-contained type among autonomous elements (modules, cognitive or operational entities) that we can observe in nature (from the quark to the ecosystem), that are human artifacts (from the individual PC station to the internet), or that we can imagine as logical entities (from the letter of the alphabet to all the letters of a given language).

"Reality" can also be observed from a different perspective, that of the *organization*, understood as a *social system*[1] that forms when a group of individuals (the personnel structure) accept, based on their *own motivations*, to become organs, or components of

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[1] The notion of organization corresponds to the more general one of organized system formed by human elements, or their groupings, that function as organs. «[Organization] derives from the Greek organon, meaning a tool or instrument. No wonder, therefore, that ideas about tasks, goals, aims, and objectives have become such fundamental organizational concepts. For tools and instruments are mechanical devices invented and developed to aid in performing some kind of goal-oriented activity.» (Morgan 1986, p. 21; see also Alter – Hage 1993).

organs – specialized according to *functioning, function, functionality* and spatial-temporal *placement* – of a larger structure, becoming members of the latter in order to achieve a *common goal* that cannot be attained by the single individuals or by partial systems.

As members of the organization they accept being bound by stable, horizontal and vertical structural relations (the organizational relations), which entail coordinated and cooperative behaviour; that is, they recognize and accept higher objectives, programs of action, rules of coordination and responsibility in order to carry out long-lasting processes aiming at the *common end*.

OBJECTIVES

FUNCTIONS	O_A	O_B	O_C
F_1	ORG_{1A}	ORG_{1B}	ORG_{1C}
F_2	ORG_{2A}	ORG_{2B}	ORG_{2C}
F_3	ORG_{3A}	ORG_{3B}	ORG_{3C}

Figure 1. Matrix of the objectives and functions in an organization.

The horizontal and vertical interaction of the element-organs produce *emerging* properties (a macro structure, a macro dynamics, a macro function, the achievement of a common institutional goal) that refer to the system and not to its constituent parts or its partial subsystems.

The organization's organs (ORG) can thus be thought of as *parts* of the *entire* system, necessary for and instrumental to the achievement of objectives, from which the institutional (constitutive) goals derive that refer to the entire organization as a "single unit".

The organs can be observed and ordered in a multi-level or multi-strata model – the *organigram* – according to different *points of view*, in particular by favouring the objectives or the functions needed to achieve these.

The objectives and functions are logically connected according to the matrix schema in figure 1, from which we immediately derive the two typical organizational structures illustrated in figure 2: the *linear* structure, which orders the organs in terms of the objectives, and the *functional* one, which focuses on the functions.

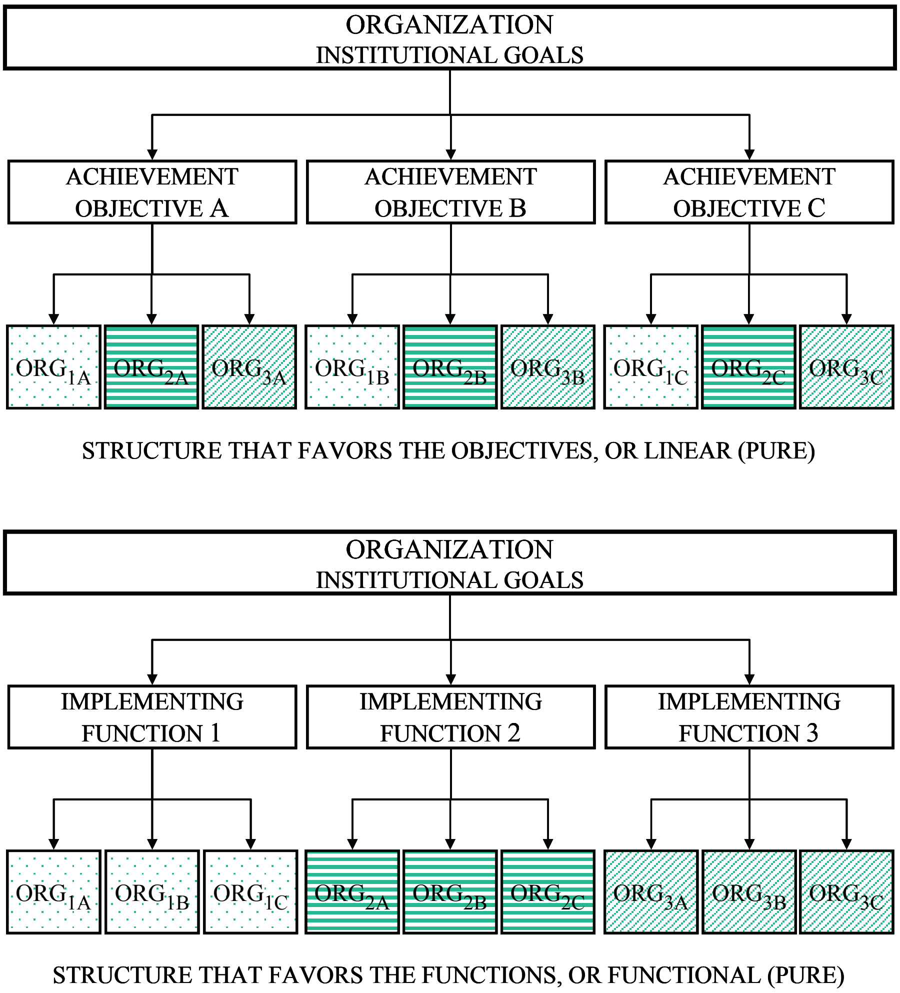

Figure 2. Typical organizational structures.

3.2 The Holonic View of Organizations

We immediately see the close affinity between the *systemic* view and the holonic view of the organization.

Each member of the organization can certainly be considered a base holon (in both Koestler's and Wilber's sense) that, in turn, is a *part* for the organ to which it belongs, which is considered a larger *whole*.[2]

[2] «The choice of words which we use suggests to the reader the organizational structure of a country, a company, or a governmental administrative division as a valid example of a SOHO-structure.» (Pichler 2000).

If we leave aside its interpretation (module, cognitive entity, operational entity), then, to the same extent as the holon, an *element-organ* is significant only in its network of relationships with other organs; it is a whole, if observed as an organ, and a part, if observed as a component of a larger organ.

The four characteristics that distinguish organs (figure 3) – *functioning, function, functionality* and spatial-temporal *placement* – can be placed parallel to the *four dimensions* in Wilber's model in figure 6, Chapter 2.

DIMENSIONS	INTERIOR	EXTERIOR
INDIVIDUAL	**I** *Functioning* Internal structure Vital processes Cognitive activity Performance	**III** *Function* Activity Specificity of the functioning with respect to the other organs Role of the hierarchy
COLLECTIVITY	**II** *Functionality* Contribution of utility to the functioning of the structure Instrumentality for the other super- and subordinate organs Aim of the functioning	**IV** *Spatial-temporal placement* Vertical hierarchical relation of authority (top-down) and responsibility (bottom-up) Coordination along horizontal lines

Figure 3. The four observational levels of the organs
(*Source*: based on Wilber's model in figure 6, Chapter 2).

The *functioning* (quadrant I) refers to the internal characteristics of the element-organ; the *function* (quadrant III) defines its characteristics and specificity as an entity that necessarily differs outwardly from the other entities; the *functionality* (quadrant II) characterizes, from an internal point of view, the contribution of the element-organ to the constitution and functioning of the organization as a whole; finally, the *spatial-temporal placement* (quadrant IV), from an external perspective, characterizes the "topological" relations of the element-organ in the system's space-time dimension in terms of authority, responsibility and coordination.

In non-elementary organizations each element-organ can be placed in a *hierarchy* with other larger organs and can in turn be made up of smaller ones. Moreover, several similar elements can be included in *modules* that constitute larger organs, so as to form a modular systemic structure, or network of organs that form multi-level reticular structures.[3]

In particular, if we consider the organs as *mono-personal entities* or as *pluri-personal modules* made up of *agents* and their instruments, then the organization can be represented as a Multi-Layer Agent System as presented by Mesarovich *et al.* (1970); since the agents are grouped together into organs, this system becomes an Organisational Multi-Agent System (OMAS) (Ferber 1999; Hewitt 1989; Mathews 1996b).[4]

According to the holonic observation of organizations as systems, the *organs* can thus be viewed as holons that form an *organized holarchy*, since they present the typical vertical ordering (holarchy) while also being characterized by their differing specializations in the structure they compose (*organized*).

Based on the size observed (figure 3), there are at least four ways to consider the organs as holons arranged in organized holarchies: the structural, cognitive, function and functional view.

The *structural interpretation* stresses the *topological dimension* (quadrant IV in figure 3); the organs represent modules of *coordination* and form a *structural holarchy* in which they are holons hierarchically ordered in terms of *authority*, *responsibility* and *delegation* (Malone *et al.* 1994; Ferber 1999), as they are usually represented in organigrams, models that, in various forms, depict the formal hierarchical structure of the organization (Simon 1957).

In terms of *authority* and *responsibility,* it makes sense to affirm that the workers in an office are holons with respect to the office manager, who has authority over them; the office managers are holons with respect to the department head, who has authority over them; the department heads are holons with respect to the functionaries; the latter are holons with respect to the managers, who are holons with respect to the functional and/or product and/or policy director; the function directors are holons with respect to the general manager, who is a holon with respect to the managing director, who is a holon with respect to the board, which is a holon for the governance, in a typical structural holarchy where the authority and responsibility of each holon take on scope and significance in relation to the position in the holarchy.

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[3] If we focus our observation on the organs' operational instruments, then the organization can be viewed as a physical system processor in which the human elements are integral parts. This is the typical view of organizations as manufacturing systems (par. 2.5).

[4] «Agents, … can realize different organisational functions such as being a supplier (servicing customers), a mediator (managing execution requests), a planner (determining actions to be taken), a coordinator (distribution of actions and execution requests), a decision maker (taking the choice between different possible actions) or an executive (realizing actions). Such functions can also be observed for holons. A difference is, however, that the holons of Koestler are, according to their role in fulfilling an organisational function, hierarchically ordered, but the agents in an OMAS are seemingly all on the same level and they define as group-collections only virtual agents of the conceptual abstract kind on higher levels» (Pichler 2000; see also Beer's VSM, par. 2.6).

The *cognitive interpretation* focusses on the *functioning dimension* (quadrant I in figure 3); the organs are observed as cognitive holons that gather and coordinate information and make decisions (Fox 1981); they make up a *cognitive holarchy* where each organ/holon of a given level is an autonomous information and decision-making entity whose decisions influence those of the subordinate organ/holons, and include those of the higher-level organ/holons, following a *pull* or *push* approach depending on the type of organization.

From this perspective it makes sense to state that the decisions of the base operators depend on those of the office heads, which depend on those of the department head, and so on, up to the maximum level of the cognitive holarchy; and that, parallely, the information gathered at the base is analyzed by the higher-level holons that, in turn, transmit these to the superordinate holons, who analyze the information and transmit it further up the vertical path.

According to the *operational interpretation*, the organs are observed carrying out their *function* (quadrant III of figure 3). In this dimension, a *directional* holarchy is formed in the production organizations, usually in the form of an *output holarchy* of the *pull*-type, where the activity of the input and intermediate organ/holons is usually led by the activity of the output organs/holons (see above, par. 3.5).

In this representation we can thus state that the workers in an office play a useful role in allowing the departments to function correctly; the latter in turn are holons whose function is useful for the functional divisions, which are holons set up for sales, production, supply, treasury, finance, and so on, from whose functions derive those of the holons set up for the products, which produce the functions for the holons set up for business, and so on all the way to the Board of Directors, whose planning and control function is useful, in a top-down direction, for the functioning of the other lower-ordered holons that, in order to carry out their function, must plan the activity of the lower-level holons, and so on until we reach the base holons.

3.3 From Organizations to Holonic Organizations

Finally, we can consider organs in terms of their *functionality*, as *parts-holons* whose activity accounts for the *functioning* of the *entire* organization (quadrant II of figure 3), allowing the latter to reveal its own *functionality* as an *entity-whole* in the largest possible *environmental* supersystem so as to achieve its objectives, which are instrumental to attaining the common aim.

From this viewpoint, each organ/holon is not only a *linking element* between the levels of functioning, function and spatial-temporal placement of the organs but becomes a component of a holarchy (and/or an *holonic network*) of *functional holons* that make up the same organization and allow its functioning and existence over time.

Because the organization is composed of *functional* organs-holons and derives from the *functional holarchy* it forms, or from *objective-oriented* organs/holons, we can conceive of it as an *holonic organization*.

Nevertheless there is a basic difference between the holonic organization and the *holarchy of organs* that comprise it, which has not been fully exposed in the literature.

The holonic organization, as a system of organs, does not correspond to the holarchy of its own organs (not even with the meanings presented in the preceding section) but represents the *final holon in the holarchy* (figure 4).

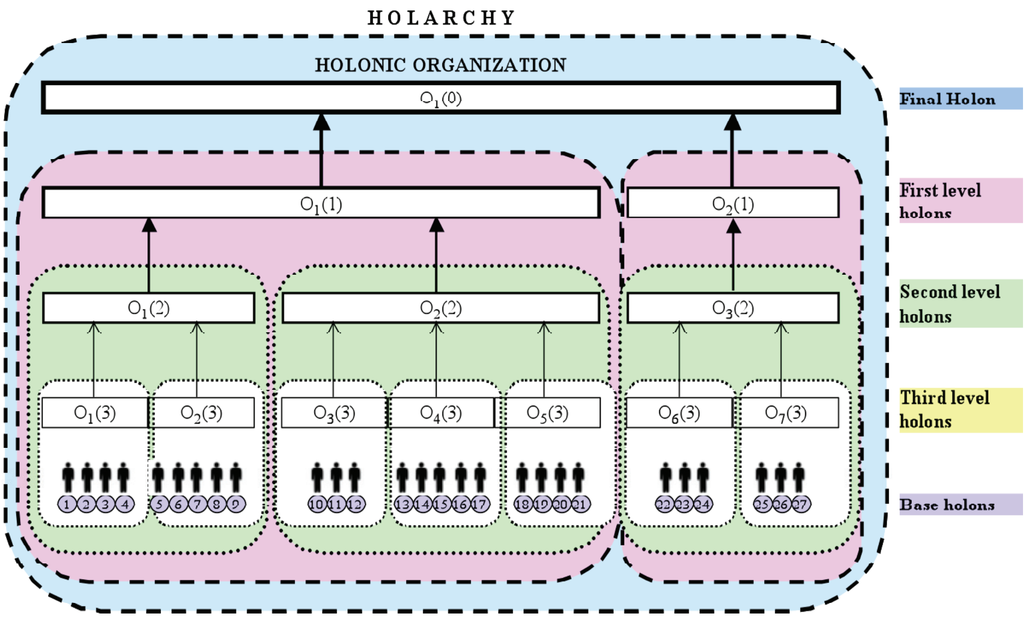

Figure 4. The holonic organization as the final holon of the holarchy (multi-strata) of the organs (27 base holons).

It is the final holon, which is composed of all the sub-ordered organs that are functional organs-holons of the lower levels, just as atoms make up molecules, and the latter the cells that compose the tissues that form the organs that make up the terminal holon: the *organism*; just as the base components constitute sub-assembled parts of other subsets that, at the end of the hierarchy, make up the final holon: the *mechanism*, keeping in mind that mechanisms, organisms and organizations are the three typical forms of organized systems, which are countered by the non-organized systems, which can be either complex or combinatory systems.[5]

[5] For learning more about Combinatory Systems, go to: <http://www.ea2000.it/cst>.

From this perspective it thus makes sense to say that in a *business organization* the base holons are functional for the office-holons; that the latter are functional parts of the department-holons, which are functional parts of the functional divisions-holons, which are functional parts of the business divisions, or sectors, that compose the holon-organization; in a government organization the *communal* holons are functional parts of the *province* holons, which are functional parts of the *region* holons, which are part of the *state* holons, which are part of the *federation* holons, which are part of the *continent* holons, which are part of the planet holon.

If we consider the organization from the *functional* dimension of the organs-holons we can identify several *principles* which can be inferred from those Koestler indicates for the SOHO (par. 2.4) and Wilber mentions for the Kosmos (par. 2.5):

1. *Emergence* (or effectiveness): *organizations* emerge in that they carry out a functionality (to reach an objective, undertake a task, carry out a project) that can not be achieved through partial groupings of lower-level organs-holons.
2. *Adaptation* (or contingence): both the organization and its component holons must adapt to the required functionality.
3. *Expansion*: organizations tend to grow, increasing both the depth of the holarchy of the organs as well as the number of base holons.
4. *Inclusion*: the organs-holons comprise all the subordinate organs-holons.
5. *Transcendence*: Although the function, functionality and functioning of a *holon-organ* depends on those of the subordinate holons, they do not coincide with any of them but are emerging.
6. *Self-preservation* (agency) (or conservation): each organ-holon survives by adapting to the higher-level holon and developing the vital capacities of the holons that comprise it («The egotism of the social holon feeds on the altruism of its members»; Koestler 1967, Def. 9.8).
7. *Well-being*: each organ-holon must be aware that its well-being depends on that of a higher-level holon and influences that of the lower-level holons.
8. *Utility*: each organ-holon must carry out *useful* behaviour for the lower- and higher-level holons.
9. *Efficiency*: each organ-holon must improve its performance to allow the higher-level holon to ensure it with better conditions for survival.
10. *Asymmetry*: the higher one goes in the holarchy of the organs-holons, the greater flexibility there is in the *function* and *functioning*; the lower down one goes the greater the inflexibility of the admissible behaviour.

We must now clarify the nature of the holonic organization, understood as the final holon in the holarchy of the constituent functional organs/holons.

If we refer to Wilber's classification of holons (par. 1.4) we can identify two interpretations based on the organization's formation process: (a) the organization is an artifact; (b) the organization is a social holon.

The organization is an *artifact*, without interiority (this is Wilber's view), if it is created through a *top-down* process by a generator holon that, in order to achieve its aim or carry out some activity which is beyond its possibilities, coordinates other agents, forming with them lower-level organs that are artifacts specialized by function and always controlled by a superior holon.[6]

In order to more efficiently carry out their function the lower-level organs in turn increase their size, coordinating other agents into organs that are artifacts at an even lower level, and so on. Thus at any hierarchical level the *organs* are *artifact-holons* made up of lower-level *artifact-holons* and constituting *higher-level* ones on which, as a result, their existence depends.

The generating holon can be external to the organization, which becomes an autonomous artifact (true artifact) created to satisfy its own general interests; or it can be a constituent element, *embedded* in the organization itself and controlling its performance levels. In both cases, *the organization is the instrument for realizing the supreme objective of the constitutor holon.*

The organization can also be viewed as a *social holon* formed by a group of individual holons, coordinated and cooperating to achieve a common objective.

Such a *social holon* possesses interiority, but with a vast consciousness, as it is composed of the base holons through a *bottom-up* process characterized by a gradual hierarchical ordering of the lowest-level holons into organs, thereby creating higher-level organs capable of carrying out processes and achieving a performance that is not possible for the individual base holons.

Under these assumptions the *organs* of a given level are social holons, since the lower-level organs delegate part of their autonomy to them but are not constituent parts of them; they simply participate along with them.[7]

As a result, at any level of the holarchy the existence of the *organs* depends on that of the *lower-level organs*,[8] since *the organization is the instrument through which the base holons realize their own special interests*.

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[6] «An organization is not just a physical artifact; it is also a conceptual one (legal, financial, etc.). From this perspective it makes sense to understand a hierarchical evolution of these artifacts congruent with the hierarchical evolution of the holons that design them. Commons and Richards trace the cognitive development of the individual from the capacity to grasp entities, to the capacity to grasp systems of interrelated entities, to the capacity to grasp systems of interrelated systems (of interrelated entities), to the capacity to grasp systems of interrelated systems of interrelated systems (of interrelated entities). Along this line, we can trace the development of organizational forms.» (Kofman 2000).

[7] «A company (as a social holon) is composed of the individuals (at the appropriate level of consciousness) that belong to it plus the production, management, information and all other systems (artifacts) that support the individuals' relational exchanges.» (Kofman 2000).

3.4 From Holonic Org*a*nizations to Org*o*nizations

There is a third possible interpretation: organizations are conceived of as *individual holons* characterized by persistence, internal consciousness and operational autonomy.

In fact, organization science now accepts that organizations – *companies* or *enterprises* – can be viewed not only as instruments of human activity in the economic field but also as *vital economic agents* that engage in *rational cognitive* activities in order to maintain their *autopoiesis* (Maturana *et al.* 1980; Mingers 1994; Uribe 1981; Varela 1981).

They are *economic agents* because they can generate a production activity of value that refers to the entire organization, and not to its organs.

They are *vital* agents since, in order to exist for a long time and adapt to changes and preserve their identity in a long-lasting autopoietic process, they develop a cognitive activity through their own organs that can observe the external environment and form representations and models of this that are turned into internal plans and programs, not ones imposed from the outside (de Geus 1988, 1997), and they exhibit a learning activity that does not refer to the individual or organs but to the entire organization (Senge 1990, Sterman 1989).

In this sense, Beer's viable system model is a typical example of an organization conceived of as an individual holon (par. 1.3).

They are *rational* agents in that the cognitive activity seeks to maximize the economic and financial *fitness* (in a broad sense), as indicated by a system of *performance measures* – analytic (the businesses, economic processes, organs) or synthetic (the entire structure) – that reveal the organization's capacity to maintain and improve the conditions for autopoiesis in a time horizon that is not defined *a priori*.

If we accept this view, it is clear we can consider organizations not simply as artifacts or social holons but as individual holons that possess *interiority* and *consciousness concentrated* in the maximum cognitive organs, which include and transcend the component *functional organs/holons* that, in turn, are at the same time units and parts at differing hierarchical levels, reaching all the way down to the base holons.[9]

This interpretation, which is neither mechanistic nor organic (Cummings 2002), can be applied to all long-lasting organizations that, however constituted, have become *autonomous* with respect to their governance – from the top (final holon) to

[8] In this sense the conception of an organization as a social holon created by the base holons has even greater significance than that which sees the organization simply as a SOHO. «In the organizational structure of a company, the people at the highest management level and the workers on the lowest level are in that sense critical holons, which realize the input/output processes on the interfaces of a SOHO-structure which is embedded in an environment consisting of the market.» (Pichler 2000).

[9] In this sense even Smith (2000) recognizes that the four classes of holons presented in Wilber's version are not enough to conceive of the Kosmos; nevertheless, the author does not explicitly consider the holons represented by the organizations.

the base (primal holons) – thereby acquiring their own vitality and undertaking cognitive activities.

An *initial objection* could be made with regard to this interpretation: organizations cannot be conceived of as individual holons, since they do not possess *localized interiority or consciousness*.

We get around this objection by considering that the consciousness of the organization, as cognitive system, resides in the governing organ, however this is defined, which appears as the final holon of the cognitive holarchy of the subordinate organs.

Moreover, even in individual human and animal holons consciousness can be located "in the individual", but it is still always the result of the action of the brain organ, connected to the rest of the holarchy of organs that make up the nervous system, which in turn is connected to the other sensory and effector organs, peripheral or internal, that constitute the individual.[10]

There could also be a *second* objection: the organization has no *precise spatial localization*; its elements and organs are spatially localized in different places.

This objection can also be overcome (Smith 2004) as soon as we consider the fact that the presumed cohesion and union of the elements that make up an animal or vegetal individual (like a composite artifact) simply derives from the nature of the structural ties, which define the topology of the organs (quadrant IV in figure3), and not from the organizational relations of *functionality* (quadrant II in figure 3) that characterize the view of the organization as an individual holon.

In holonic organizations the organs-holons can take on two extreme forms according to their *vital autonomy*; that is, their *capacity to have an autonomous existence with respect to the organization* and, in particular, to survive the latter in the event of its breakup:

a) as *member* holons with *reflex* vitality, tightly structured in the *top down* organization that justifies their existence, so that the breakup of the organization also implies the cessation of its organs/holons (for example, the local, communal and provincial offices of an association do not survive the closing of the regional and national offices, just like the organs of a biological individual do not survive the individual itself, if not artificially;
b) as *component* holons with *autonomous* vitality, capable of surviving as individual holons even if the *organization they belong to ceases to exist*; the

[10] «The concept of levels of organization makes it possible to consider the embedding of one level into another. In the same way that, in biology, a cell is considered as being an organization of macromolecules and at the same time an individual being for the multicellular organism of which it forms a part, we can similarly consider that an organization is an aggregation of elements of a lower level and a component in organizations of a higher level.» (Ferber 1999).

life and vitality of the organs/holons are crucial for the *bottom up* holonic organization viewed as a final holon.

This implies that the component holons, at levels above the base holons, must in turn be holonic organizations (for example, communes, provinces and regions can survive even if the state does not, just as an army or a convent can survive if the organization they belong to does not).

We now introduce the term *org-on*, or simply *orgon*) to denote an *org*anization-hol*on* that, in turn, is a *constituent member of a larger holonic organization*, that is a holarchy of org*a*nizations.

We can then call this larger holonic organization of *orgons* an *orgonization* (figure 5).

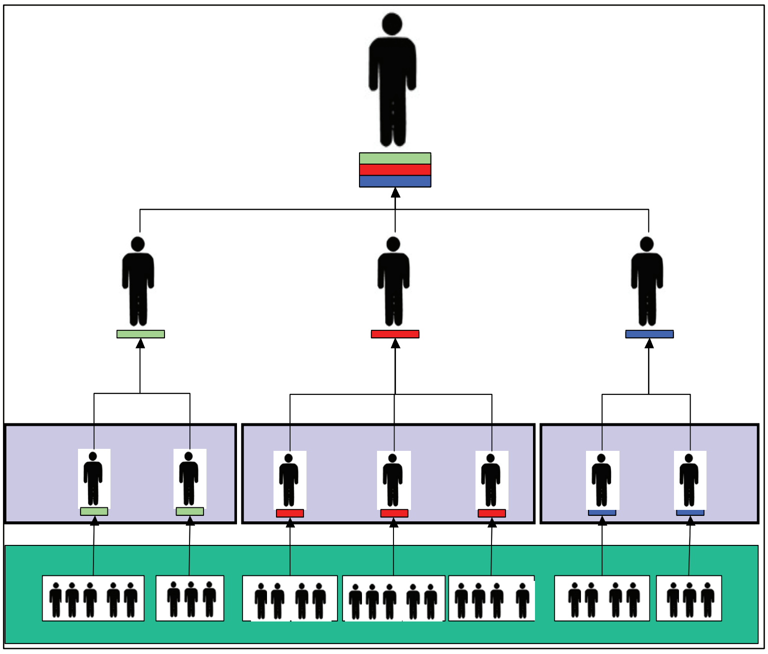

Figure 5. Org*o*nization (The underlined icon indicates an organization; in all other cases a primal holon).

In this sense the social and economic reality does not consist solely of individual holons and social holons but also of holons that are holonic organizations and, perhaps to an even greater extent, *orgonizations*, representing a *new species of holon* that comes about through a *functional integration* of the holonic organizations.

We should note that in Beer's VSM model (par. 2.6) the organization is not only an individual holon since, if we consider it to be composed of operational units that in turn are viable systems, then the organization becomes in all respects an *orgonization* of sub-units in the form of orgons.

3.5 Org*a*ns vs. Org*o*ns. Distinctive Differences

There are some important differences between organizations made up of *organs* and orgonizations made up of *orgons*; these differences involve aspects such as *functionality*, *function*, and the spatial and temporal *localization* of the constituent holons indicated in figure 3.

Among the main differences:

a) From a structural point of view organs are constituent, intrinsic parts of the organization. Orgons, on the other hand, as individual holonic organizations, participate in the orgonization but are autonomous in relation to it;
b) Genetically organs are generated with the organization and by the organization; orgons, on the other hand, being autonomous, can themselves generate the orgonization through the annextion of other orgons;
c) The functioning (structure, processes, flows) of organs is thus dependent and hetero-directed by superordinate organs. The functioning of orgons is self-directed and only coordinated by the orgonization;
d) Organs have a *reflex vitality* since their existence, their number and their articulation depend on the vital needs of the organization. Orgons are only coordinated by superordinate orgons and have an autonomous vitality;
e) Organs are functional for the organization; the orgonization is functional for the orgons it coordinates. The operativenes of the organs is based on their functionality. That of the orgons is centered on their function;
f) The spatial and temporal collocation of the organs is decided by the organization and represents one of their defining intrinsic dimensions. The orgons decide their localization autonomously, which moreover does not substantially affect the orgonization's functionality;
g) The cessation of the organization usually leads to that of its organs; the autonomy of the orgons means that they are vital even after the orgonization ceases to exist. The orgonization is more robust than the organization;
h) The autopoiesis of the organs depends on the organization. For the orgons autopoiesis is a necessary conditions for participating in the orgonization;

i) The organs' competencies are established by the organization. Those of the orgons are set autonomously and represent a condition for their participation in the orgonization;
j) The resources necessary for the functioning of the organs come from the organization, which "capitalizes" the organs based on their need. The capitalization of the orgons is based on the objectives and is normally autonomous and exogenous;
k) The primal holons that compose an organ also compose the organization and are recruited by request of the organ, according to need. The primal holons in the orgons are recruited based on objectives; they only make up the orgon, not the orgonization.

Orgonizations are quite common and are formed by means of various processes, among which we shall consider:

- strong strategic alliances;
- corporate groups;
- processes of organizational segmentation;
- privatization processes.

3.6. Orgonizations Everywhere. *Strategic Alliances*

Organizations-enterprises produce many forms of agreements and *alliances* (Mowery 1996) that are characterized by the heterogeneity of the object of the agreement, which can concern every organizational function: production, marketing, research, the development of new models or components, and supply.[11]

These alliances can be strong or weak. In their weak form they take the form of cooperation agreements,[12] based on (usually) short-term contracts between firms at the

[11] «Strategic alliances are agreements between companies (partners) to reach objectives of a common interest. Alliances are among the various options which companies can use to achieve their goals; they are based on cooperation between companies. […]
- Two or more organizations (business units or companies) make an agreement to achieve objectives of a common interest considered important, while remaining independent with respect to the alliance.
- The partners share both the advantages and control of the management of the alliance for its entire duration. As we will see, this is the most difficult problem.

The partners contribute, using their own resources and capabilities, to the development of one or more areas of the alliance (important for them). This could be technology, marketing, production, R&D or other areas.» (Pellicelli 2004).

[12] Chandler (1990) previously stated that the cooperation between companies… represents one of the most profitable and possible ways for modern capitalism to develop. Cooperative relationships between companies is meant to deeply modify the mechanisms of corporate governance, of the economic sectors (the markets in particular), by redefining their operations boundaries.

same level which nonetheless remain in competition with regard to all the other processes not included in the alliance.

Strategic Alliances are those that, independently of the formal contracts, either medium- or long-term, agree on common strategies to attain objectives involving the gaining or strengthening of competitive advantages; for this reason such accords call for not only the sharing of competencies, of management culture and instruments, but also the provision of substantial know-how, human and capital, in order to achieve the common strategic objective (Pellicelli 2004), which can be:

- to establish standard technologies in the production sector;
- to deal with threats from new competitors;
- to try to enter into a new market or sector;
- to overcome protectionist barriers or entry barriers;
- to share the risks from projects requiring high amounts of investment.

When there are binding strategic ties in the strategic alliances the organizations-enterprises create a higher-level organization to manage the alliance, assigning different functions to the companies, thus forming an *orgonization*, or an *orgonic network* (see below, par. 4.4), if the agreement provides for only horizontal ties.

3.7. Continuation: Corporate Groups

Closer in nature are the *orgonic ties in the organization, or corporate groups,* which represent an economic *entity* formed by a group of organizations or companies having their own "perfect" *legal form* but controlled by a single (group of) stakeholder(s), so that there is a unitary management of the group (Maclean 2005).

Depending on who exercises the unitary control, we can distinguish between (figure 6):

a) *proper* (or company) *groups*: here the unitary control is exercised by one of the companies (legal) that form the group, and which for this reason is called the group leader, parent company, or operating holding company; the others are the group entities, or subsidiaries;
b) *improper* (or personal) *groups*: here the control comes from outside, from a company that is not part of the administration of any of the group's companies; thus there is no group leader but only a company that controls the companies in a unified way.

A group formed by “legally” perfect companies can then be defined as an economic enterprise that carries out the unitary business, financial, economic and productive transformation – typical of a single company – by means of a group of operational units that are legally autonomous enterprises, all of which, however, are under a single management.

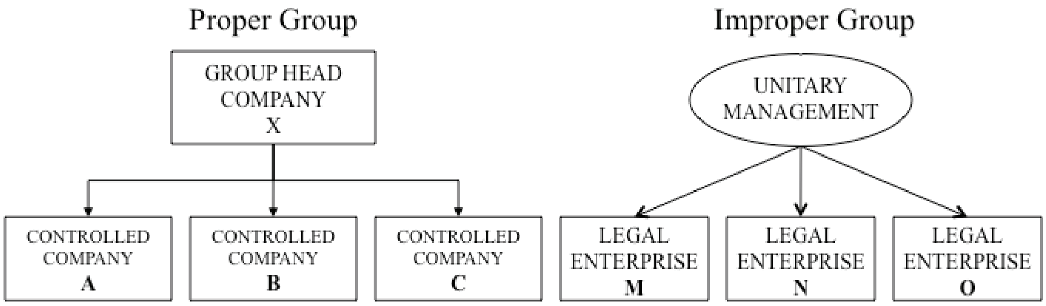

Figure 6. Proper and improper groups.

If we instead consider the means by which the unitary control is achieved, we can distinguish between:

1) contractual groups, when two enterprises, A and B, usually companies, stipulate a “contract” – of “subordination” or “control” – whereby they formally renounce their independence to form a group;
2) participatory groups, when an enterprise, A, is able to dominate B by “controlling” company B through the purchase of enough shares of B to control the company by controlling its assemblies. A thus becomes the group leader;
3) restricted groups, when A and B create commercial and/or financial relationships “restrictions” that are very important, intense and risky; if in order to stipulate the contract B is forced to accept control by A, then it becomes bound to, and dependent on A; between A and B a group is formed of which A is the group leader.

Groups can be formed both for economic-production aims as well as financial ones; we can thus distinguish between:

a. economic, or management, group if the control is motivated mainly by the need for a unitary and common operational management in order to produce synergies from a single central management that coordinates the specific management of the group's entities;

b. financial, or capital group, if the control is motivated mainly by capital needs, as regards both the investment of capital to obtain the highest return and the efficient raising of financial resources.

Since the capital relationships among the companies in the group result in hierarchical-vertical relations and the dependence of some companies on others – which translates into structures that are even highly differentiated (figure 7), though always under a superordinate unitary control – we can consider the group as a holon formed by subordinate holons, which in turn are composed of lower-level holons.

As each element of the group is an *org*anization-hol*on* (organization, company) that is formally autonomous, the group is an orgonization, where each orgon is characterized by the degree of control and coordination it exercises in a downward direction and by the control and coordination it is subjected to from above. If the group is not hierarchically structured but instead has a horizontal structure (chain- or star-shaped groups), or even a circular one (intercompany or circular investment), then we can even have an *orgonic network* (see below, par. 4.4).

In general there are two processes which give rise to orgonizations in the form of groups:

1. the integration process among autonomous companies; that is, the aggregation of several production units that unify their management control by handing this over to a central unit (which may or may not belong to the group) that formulates strategies and policies and guides both the exchanges within the group as well as the operational distribution of the processes; this genetic form can technically occur either through acquiring a controlling interest in already-existing companies or by creating new companies in which, from the start, the share subscriptions ensure control;
2. the process whereby a unitary company is split up, through enucleation, leading to the splitting off of operational units that are legally autonomous though economically arranged in a holarchy.

The typical form of splitting up a company can be seen in the common process of privatizations, which lead public authorities (organizations) to create orgons, autonomous but controlled, in order to produce specific services that previously were provided by the internal organs.

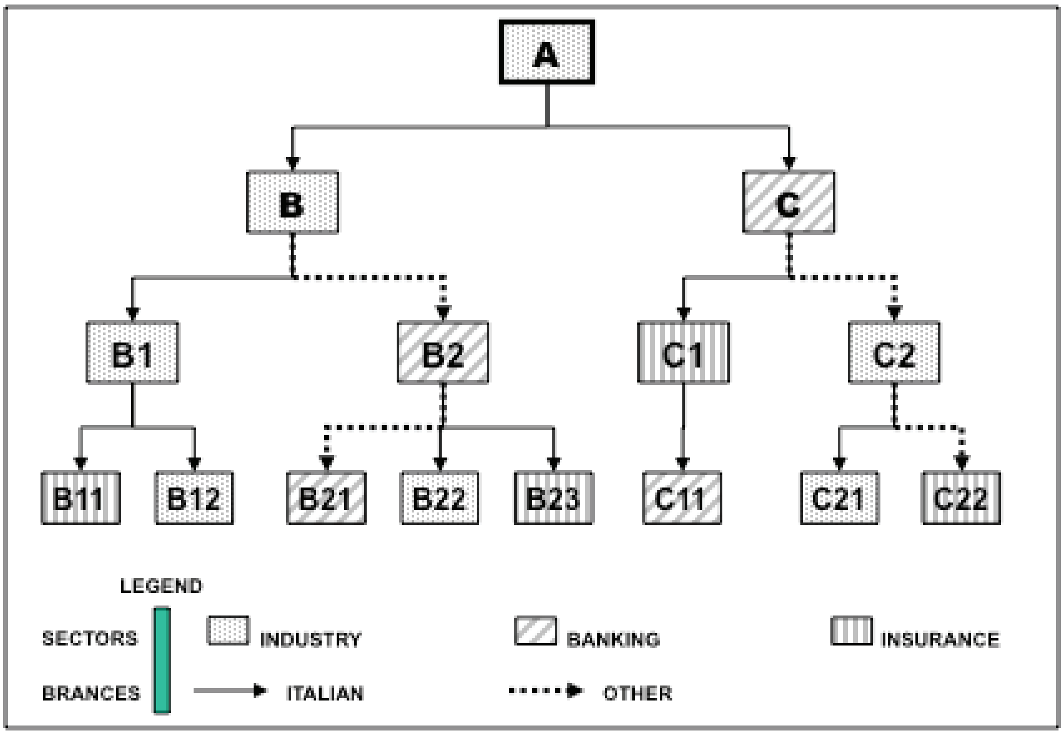

Figure 7. The corporate group as an orgonization.

We can also observe the reverse processes, whereby an orgonization becomes an *organization* of production units, transforming orgons into organs.

The typical process is the *merger* (or *incorporation*), where several orgons are combined into a single entity of which the merged organizations become organs, thus losing their legal individuality to create a more comprehensive legal entity that includes all the preceding ones.

It is more difficult to characterize the *constellations*, due to the variety of existing types (informal, prearranged and programmed constellations) as well as their tendency to evolve toward the structure of the corporate group.

By observing this last type, we see that a leading company usually emerges that coordinates the others, thereby determining a "certain relational influence" (Bartlett – Ghoshal 2002). This group can thus develop along the lines of an orgonization and an orgonic network.

Finally, we can observe orgonizations in other less-evident circumstances, where various companies split up their organization into independent, though legally autonomous, units, as in the case of many companies where the divisions are managed with a high-degree of autonomy and are organized to cooperate together.

Chapter 4

Holonic and Orgonic Networks

> All the key objects of physics, biology, sociology, astronomy, atoms, molecules, cells, organisms, societies, planets, galaxies, represent systems. Outside of systems we have only the dispersion of particles. Our organized world is an archipelago of systems in an ocean of disorder. Everything that was an object has become a system. Everything that was even an elementary unit, including the atom, especially the atom, has become a system [...] Thus being human means being part of a social system that is contained in a natural ecosystem, which is within a solar system, which is in a galactic system; this is composed of cellular systems, which are composed of molecular systems, which are composed of atomic systems. In this chain there are overlappings, entanglements, superimpositions of systems. [...] This is the phenomenon we call Nature, which is nothing other than this extraordinary solidarity of entangled systems that are built one on top of the other, some by means of others, with others, against others (Morin 1994: 127).

4.1 Not Only Holarchies: Holonic Networks

The most *important merit* of the holonic view of "Reality" in terms of *containing/contained* – that of considering a holon as a significant entity only in the context of a holarchy, in which the holon of a given level acquires significance from the existence of lower-level holons, of which it is composed, and higher-level holons, which include it and justify it – is also an *important limitation*, since it assumes only a vertical, nidified interrelationship.

If we consider the broader definition of a holon as an entity that is part of a vaster whole, it intuitively follows *that the Janus-faced view does not necessarily have to be vertically oriented*. A holon maintains its characteristics as a conceptual entity characterized by unity, autonomy and interiority – which behaves like a whole that is part of a vaster whole – even if it is considered as a *subsystem* of a larger *system*, which in turn is composed of *subsystems*.

As a subsystem a holon can be viewed as an element (composite and component) of a *network of horizontal relations* – with holons of the *same level* – that can be called a Holonic Network, an instrument of the holistic view of reality typical of System Thinking (Mella 2007).

In the holonic network the holons are not arranged in a hierarchy with others and there are no vertical links, only relations among elements at the same level; we do not observe an *above* (containing) and a *below* (contained) but only – or also – a *before* (component, antecedent, constituent) and an *after* (composite, successive, constituted), in the typical relational observational variants of left/right, input/output, up the line/down the line, etc.

As with the holarchy, in the *holonic network* each holon is also a whole, an entity, whose existence, or meaning, comes at the same time from the connected elements that are observed as *antecedents* (before) and are *constituent* elements of the holon and by those that are observed as *successive* (after).

Nevertheless the holon *is not included* in those that follow it in the network and *does not include* those that precede it; it constitutes a *node* that composes (is inserted in) the holonic network and that possesses the functioning, function, functionality and spatial-temporal placement that justify it, and it acquires meaning from the network itself, that is by the antecedent holons and the successive ones.

An important point: like holarchies, the *holonic networks* are not holons but *conceptual entities* – horizontal or grid systems – whose nodes are holons which are interconnected according to their nature as entities whose meaning comes from their important horizontal interactions, in order to form a whole: that is, the holonic network.[1]

By definition holonic networks can be represented as *closed grids*, whose holons on the same level are connected in many ways (figure 1-a).

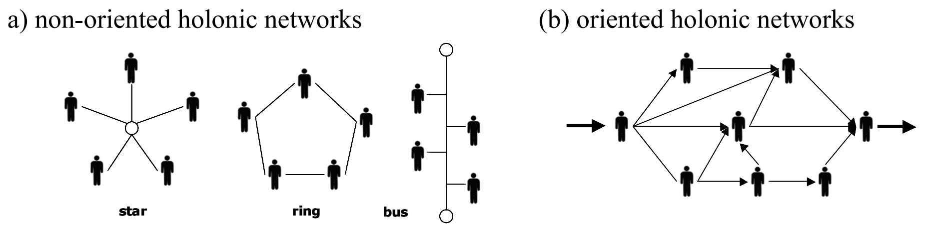

Figure 1. Forms of holonic networks.

Nevertheless we can also imagine *open*, oriented *grids* where some holons are primal holons and others final ones (in some way to be specified); between these are

[1] The study of actual organizational networks can be done using «Network analysis [that] is based on the intuitive notion that these patterns are important features of the lives of the individuals who display them. Network analysts believe that how an individual lives depends in large part on how that individual is tied into the larger web of social connections. Many believe, moreover, that the success or failure of societies and organizations often depends on the patterning of their internal structure» (Freeman 2004).

intermediate holons, though without any necessary hierarchical ordering or relations of inclusion (figure 1-b).

According to how we interpret the constituent holons we can configure – as already observed for holarchies – *structural* networks, *cognitive* networks and *operational* networks.

4.2 Features of Holonic Networks

We can formalize as follows the features of an holonic network:

1. holonic networks can be conceived of as a closed grid-like graph (with no beginning or end) whose nodes (vertices, points) are made up of same-level holons whose connections (lines, edges, links, ties) represent the horizontal relations (before/after) among them;
2. we can also conceive of open, oriented grids where some holons are primal and others final; within them there are intermediate holons, though not having any hierarchical ordering; only the relations of antecedence or succession have any validity;
3. each holon in the grid can have many/many connections, since it can connect to a multitude of preceding holons and a multitude of succeeding ones;
4. the grids can display chains (paths or routes), even ramified ones, along which the holons acquire significance only through their before/after connections with the other holons in the chain; the paths do not have primal or final holons; each holon in the path is the first with respect to those that follow, but the last of the preceding ones. Since each holon is a part of the whole, an holonic network can be configured as a holarchy with only two levels;
5. holonic networks (closed grids) can be laterally flexible; new holons or new paths can be added or pre-existing holons or paths can be eliminated;
6. holonic networks are two-directional but only have horizontal connections along the paths formed by the constituent holons;
7. non-oriented holonic networks can originate from an explosion or through implosion:
   a. *explosion* is the process that leads to the development of the holonic network by means of successive external connections to a nucleus of generator holons;

   b. *implosion* is the process by which the network develops by means of the gradual lengthening of the paths, or by the formation of new paths, within a primary generating network of generator holons;
8. the oriented holonic networks can be either of the push or pull type:
   a. the *push networks* are created by the primal holon, which connects to others that are down the line (to the right); the chains that start from the initial holons gradually expand;
   b. the *pull networks* start from the successive connections of the final holon with holons that are up the line (to the left); the chain behind the final holons gradually lengthens;
9. the subsequent holons depend on the characteristics of the preceding ones, but at the same time they direct the production of these characteristics;
10. each change in the characteristics of a holon of a given chain is also transmitted to the succeeding holons, and thus to the entire network;
    a. an holonic network is *strengthened* if small changes in the holons of a given position produce “large” changes in the succeeding holons (amplifies the changes);
    b. in the opposite case the holonic network is *balanced* (it dampens changes);
11. the holonic network usually evolves toward more efficient forms thanks to the self-learning of the interconnected holons.

4.3 From Holonic Networks to Reticular Holarchies and Orgonic Networks

The holons that compose an holonic network do not necessarily have to be *mono-level holons* (as in figure 1), but can also be final holons of an underlying *holarchy* or of an underlying organization. In the first case the holonic networks become *reticular holarchies* and take on the significance of *networks of networks* (figure 2-a); in the second, they are composed of *org*anizations-hol*ons*, and can more properly be called Orgonic Networks (figure 2-b).

The *holonic network* is flexible and can become larger and more articulated; in its general form it can be conceived of as a Multi-Layer Agent System (MAS), following Ferber’s (1999) and Mesarovich’s (1970) definition of the term.

4.4 Holonic Networks Everywhere

There are many examples we can imagine of holonic and orgonic networks, both *rational*, formed by a precise calculation of convenience, or *factual*, produced by the spontaneous aggregation of holons around an original nucleus.

Some rational networks, usually small in size, are formed voluntarily among organizations that decide to structure themselves according to this model in order to improve their performance, both by joining with other holonic organizations or by restructuring their internal processes, thereby transforming the organs-holons into orgons.

Independently of the *rational* networks – which we discuss in the following sections – on a larger scale it makes sense to consider production in the form of a *factual* production orgonic network, where, voluntarily or in point of fact, each company is connected to many others – suppliers of materials, components, machines and other equipment – thus forming a *necessarily integrated production system*.

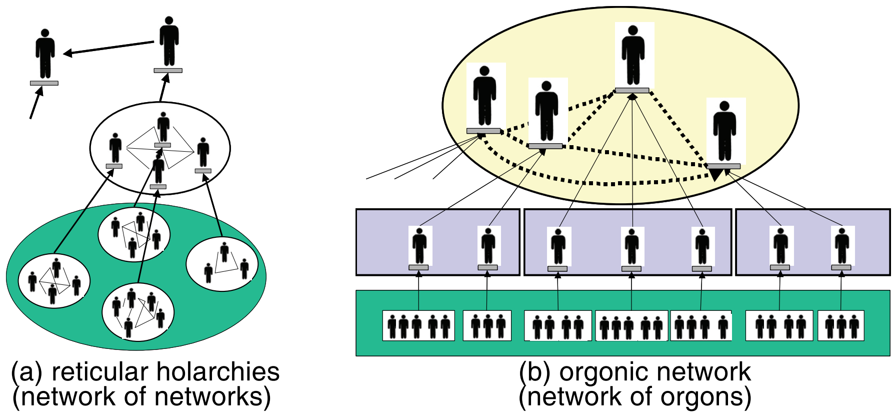

Figure 2. Models of holarchies as a multi-layer agent system.

Local *factual* orgonic networks are spreading in many countries and connecting up in transnational orgonic networks; the large trans-continental production networks (in North America, China, Japan, India and Europe) are orgonic networks that for the moment are not integrated, though increasingly larger and interconnected (see below, Chapter 5). We shall consider the following examples of rational holonic networks:

i) the Information Networks in a network, the Holonic Communications Networks, and the Responsibility-Driven Holonic Design,
ii) the information networks,

iii) the Holonic Manufacturing Systems,
iv) the Bionic Manufacturing Systems,
v) the Fractal Manufacturing Systems,
vi) the inter-organizational networks,
vii) the Virtual Organizations,
viii) the Localized Production Networks,
ix) the production Kosmos (Chapter 5).

The logic of these networks will become clear in the following sections.

4.5 Information Networks, Holonic Communications Networks (HCN) and Responsibility-Driven Holonic Design (R-DHD)

A certain number of *users* that are interconnected in one of the forms indicated in figure 1 form a cognitive holonic network where the *stock of information* of each user can be conceived of as a holon with its own individuality; this information acquires content and meaning from the connection with the information of all the other users, in a context of absolute informational parity and without any hierarchy.

In general even the *neural networks* (Gurney 1997) can be viewed as a reticular variant of Shimizu's Autonomic Cognitive Computer.

Two tendencies are taking hold in the engineering field.

In communications systems the holonic approach is developed by abandoning the technique of centralized control and creating *systems* composed of intelligent and autonomous *holon-connectors* capable of deciding which signals to "pass on" and where to direct them, according to the capacity of the lines, while also autonomously identifying and correcting errors.

In software engineering (Mathews 1996a) the holonic approach takes the form of *object-oriented* planning, which is translated into the so-called *responsibility-driven holonic design*, according to which each program is broken down into *sub-programs* in the form of *objects-holons* capable of carrying out specific functions on request; these parts are encapsulated in increasingly larger parts that make up the complete *holonic program*.

4.6 Holonic Manufacturing Systems

Holonic Manufacturing Systems (HMS) can be viewed not only as operational holarchies (see above, par. 2.9) but, more generally, as operational modular reticular holarchies. The holons of a given level carry out processes that derive from those undertaken by the holons that are arranged *before* or *below* and are functional to the processes of the holons arranged *after* or *above*.

In order to study the HMS an association has been created which has defined the technical, informational and operational specifications for a network of machines to be considered an HMS.[2]

The "specific techniques" of the HMS *Consortium* refer to a holon as a *block of a manufacturing system* which has specific attributes and is considered to be autonomous and cooperative (Adam *et al*. 2002) with respect to other *nuclei*, and which carries out processes involving the transformation, transport, conservation and control of physical or informational objects.[3]

The holon's *autonomy* is represented by its capacity to create operational plans and strategies and to control their execution. *Cooperation* refers to a holon's willingness to develop plans together with other holons and to jointly carry them out. In this sense the holons have external knowledge.

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[2] See: *HMS Consortium Web* Site, at: <http://hms.ifw.uni-hannover.de>. A Network of Excellence on Intelligent Manufacturing Systems (IMS NoE) has also been created; this is a world network of centres of expertise in the field of manufacturing that carry out an international research and development program on the next generation of technologies for industrial production and processes.
The main issues dealt with include:
- New models of production based on new global approaches ('Total-Life-Cycle'), networks of computerized production, and systems of production;
- Intelligent and sustainable systems of production, derived from biological systems (Biology-based Technology, Holonic Enterprise Networks);
- Innovations in the manufacturing process, flexible and widespread production systems, the improvement in the interactions among the production processes, the rapid development of new products;
- Scheduling and control in the extended enterprise and in virtual companies, the interaction between man and the work environment, the benchmarking and measuring of the performance of systems of production scheduling, the eco-compatibility and sustainability of products and processes, industrial services, the collaborative engineering of virtual products, the integration of the supply chain, and alliances and strategic networking.

[3] The association provides the following definitions:
Holon: An autonomous and cooperative building block of a manufacturing system for transforming, transporting, storing and/or validating information and physical objects. The holon consists of an information processing part and often a physical processing part. A holon can be part of another holon.
Autonomy: The capability of an entity to create and control the execution of its own plans and/or strategies.
Cooperation: A process whereby a set of entities develops mutually acceptable plans and executes these plans.
Holarchy: A system of holons that can cooperate to achieve a goal or objective. The holarchy defines the basic rules for cooperation of the holons and thereby limits their autonomy.
Holonic Manufacturing System (HMS): A holarchy that integrates the entire range of manufacturing activities from order booking through design, production, and marketing to realize the agile manufacturing enterprise.
Holonic Attributes: The attributes of an entity that make it a holon. The minimum set is autonomy and cooperativeness.
Holonomy: The extent to which an entity exhibits holonic attributes.

A set of *blocks* that in parallel produces materials or similar services forms a module; several modules can constitute a higher-ordered holon which in turn can be included in other blocks of even higher levels.[4]

Holons are characterized by technical and informational attributes that allow for the planning and execution of their functions as well as coordination with other holons.[5]

A holarchy is defined as a system of holons of various levels that, while autonomous, cooperate to achieve some objectives, even placing limits on their operational autonomy.

The blocks that carry out operations that are diversified, though all coordinated and necessary to obtain a result, make up a holonic network; holonic networks which are interconnected form a higher-level network that contains them; thus a more articulated reticular holarchy is formed.

The Holonic Manufacturing System is an oriented holonic network (reticular holarchy, or holonic organization) that, through its component blocks, integrates the entire range of manufacturing activities, from planning to supply, from production to marketing to logistics.

In its simplest configuration an HMS for a manufacturing company that is market-oriented includes three types of holons: the product holons, which indicate the products in the catalogue and their components (sub-holons); the resource holons, which specify the resources available for production; the order holons, which identify the market demand. These holons form an holonic network that is structured as an HMS, as shown in figure 3 and figure 4.[6]

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[4] For a survey on *block manufacturing* go to: <http://www.holobloc.com/>

[5] «[…] the three fundamental functions of a Holon. These are Planning, Execution and Monitoring. They have to be performed by all Holons in order to be able to act autonomously. Thus they have to be able to compile their own plans and execute them while monitoring their progress. […] Furthermore the functionality is attributed to the Holons, which also consist of the physical shop floor equipment and materials. Thus Order holons also have this functionality, which allows the planning of the production flow to be performed in co-ordination by both material and resources in contrast to traditional systems... » (Stylios *et al.* 2000).

[6] «For a minimalistic implementation of a manufacturing system, it suffices to have a holarchy consisting of these three basic holon types. For instance, assume the use of a heterarchical control approach, based on a market concept […]. In such implementation, product holons are created based on real or forecasted market demand. These product holons themselves determine how the product can be produced on the (dynamically changing) set of resource holons. They maintain all technical information needed for the fabrication of an instance of the product. When an order holon arrives in the system, it will first discover what it needs via the respective product holon. The order holon will negotiate with all relevant resource holons to have itself produced by them. As such, the order holon takes care of the logistical aspects (the resource allocation). When an operation starts, the order holon lets the product holon and the resource holons co-operate to perform the technical part of the operation» (Wyns 1996).
There are other models that imply a higher number of holons, as shown for example in: Kanchanasevee *et al.* (1997).

4.7 Bionic Manufacturing Systems

A *Bionic Manufacturing System* (Okino 1989; Tharumarajah *et al.* 1996) is a particular holonic network, or holonic organization, of production units (or of organizations, in the case of orgonic networks) similar to an HMS (of which it can represent a conceptual integration), but conceived of as an interaction of elementary *operator holons* that can be compared to the autonomous cells of a biological system.

The elementary operational units are grouped together in modules, which are similar to organs, and ordered on various hierarchical levels that form a holarchy that is similar to a biological organism. By means of the increasingly more articulated operational flows that take place at the various holarchic levels, the final holon is able to carry out some high-level operations, functions, or manufacturing activities, just like those specified in a *model* that "reproduces" the final result (the finished product represents the model "of itself").

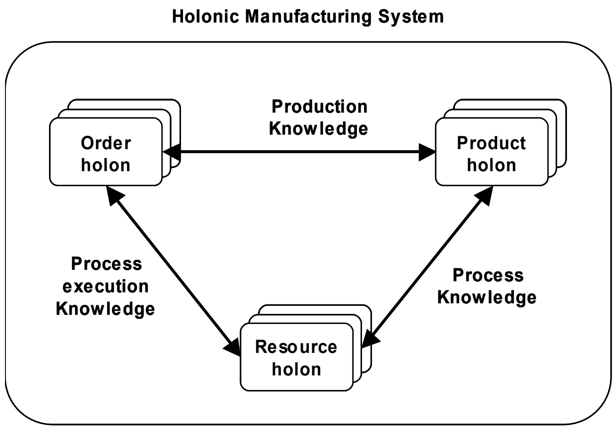

Figure 3. Base holons for an HMS
(*Source:* Van Brussel *et al.* 1998).

What distinguishes a Bionic Manufacturing System is the fact the operational units – or their groupings – are able to *autonomously decide* not only the processes to carry out but also the necessary inputs and the output volumes.

In order to present the holonic functioning logic of a Bionic Manufacturing System we must nevertheless refer not only to the *operational units* but also to the *information* that guides the activity.

The operational units make their decisions on the basis of two sets of information: the *primary information* is represented by the complete *part of the model* that must be

realized by each operational unit; the secondary information is composed of the state of the processes carried out by the production units at the same or a higher level.
The distinguishing holon of the organization or of the holonic network of a Bionic Manufacturing System is not so much the operational unit as the primary information on which part of the *model* to be realized; it is this information which also guides the activity. This *portion of the model* gains meaning from the parts that must realize the lower-ordered units, and represents in turn a part of the model to be realized by the higher-ordered operational units.

Thus the model to be created must be viewed in every respect as a holon; for this reason this *model/holon*, together with the entity that creates it, is called a *modelon*.

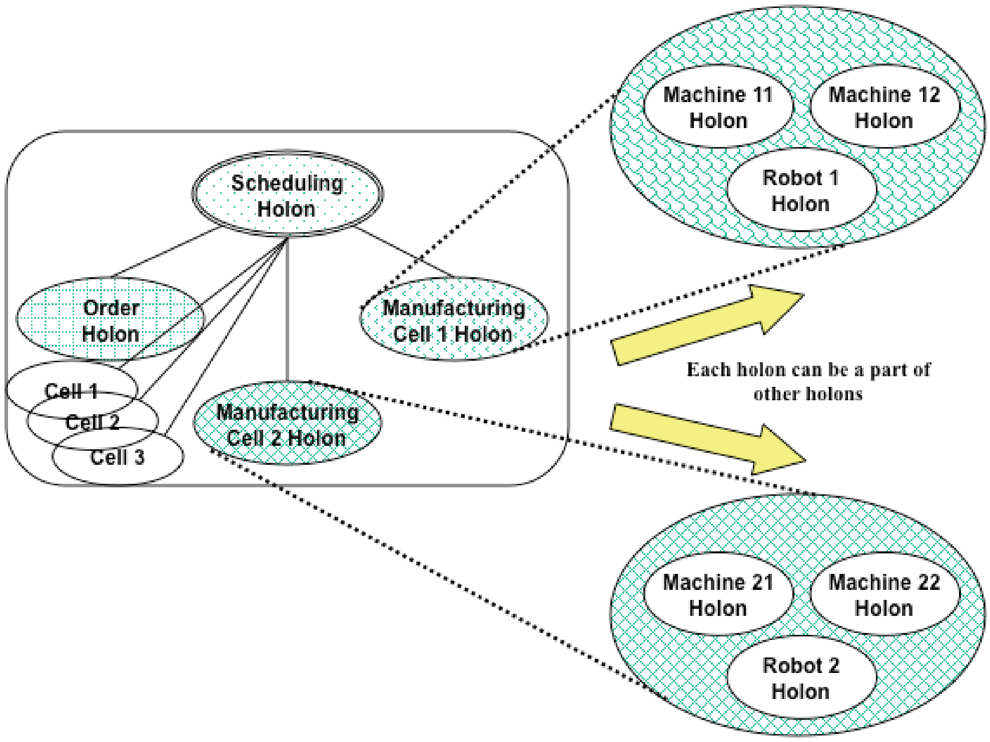

Figure 4. Holonic modules of an Agile Manufacturing System.

The Bionic Manufacturing System thus functions as a top-down holarchy that operates according to the logic of an Autonomic Cognitive Computer. The *final* or *parent modelon* is both the model to be created and the entire *Bionic Manufacturing System* (processor system) that produces the parent modelon, of which it represents the final semantic process; the *parent modelon* is divided into second-level *sub-modelons*, which in turn are divided into third-level *sub-sub-modelons*, and so on down to the *base modelons*, which are effected by elementary operational entities which themselves are considered as base processor holons (figure 5).

At the various levels the operational entities are coordinated by units of coordination that – by developing strategies, plans, programs and procedures to regulate all the production entities – function as enzymes (short run) and as hormones (medium run) do in biological systems.

In case of the need for strengthening, the *bionic system* can also develop further by annexing other entities with the same technical and functional specifications as the module units to be strengthened, or by creating smaller entities at a lower level in the holarchy, to which the same modelon and the same operational capacity as the original entity is passed on, with a mechanism similar to that of DNA transmission.

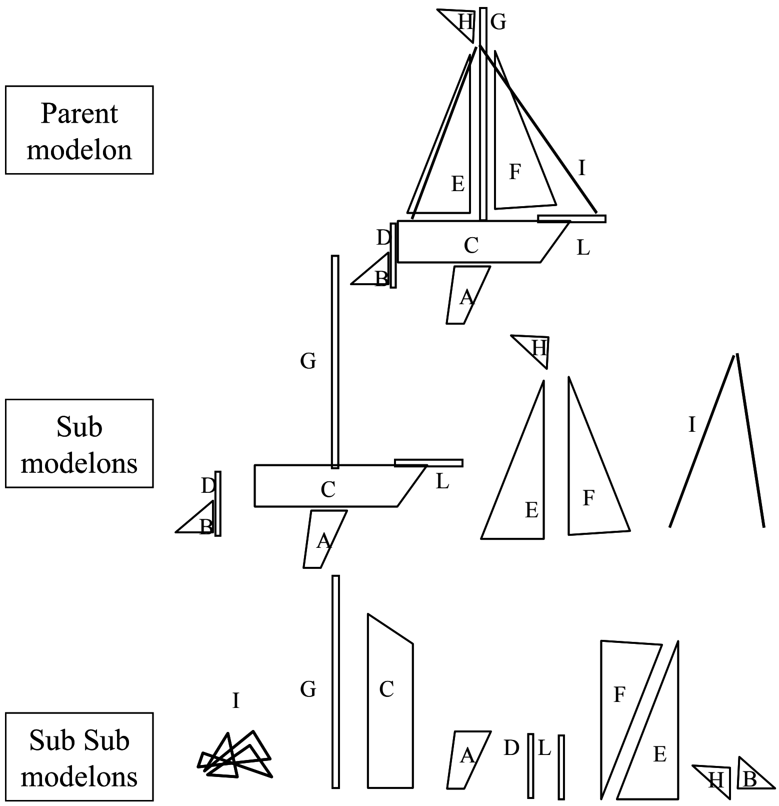

Figure 5. Holarchy of modelons in Bionic Manufacturing System.

4.8 Fractal Manufacturing Systems

A different type of holonic structure are the *Fractal Manufacturing Systems* (Warnecke 1993; Savage 1996), which are complex holarchies, typically *bottom-up*, formed by autonomous modules whose operational logic is repeated at various vertical levels, as a fractal holarchy (Chapter 2, figure 5), reproducing at each level the characteristics of the entire structure.

The *holonic* nature of these structures is not so much the processors (usually men or men-machine production units that self-coordinate) as the subdivision of *responsibilities* in terms of the objectives they must pursue.

All the high-level objectives – conceived of as final holons – are pursued through the recursive attainment of lower-level objectives, which are in turn subdivided into sub-objectives, down to the primary operational entities which are assigned smaller objectives, conceived of as primal holons.

At each level every operational entity is responsible only for the objectives of that level, and thus must coordinate with the other entities at its own level which, on the one hand, are set up to achieve the subordinate objectives, while on the other are components for the attainment of higher-level objectives.

An efficient information system must underlie the functioning of a Fractal Manufacturing System, since each fractal entity must be able to coordinate with the other entities, and this can be achieved only through monitoring in real time the state of attainment of the objectives of the other entities at the same level.

As *autonomous* and *self-organizing entities*, the fractal entities are more representative of orgonizations or orgonic networks than individual organizations are, in line with the typical logic of inter-organizational networks.

4.9 Agile Manufacturing Systems

According to the holonic approach, Holonic, Bionic and Fractal Manufacturing Systems are different forms of production organizations whose objective is to create agile manufacturing systems (Leitão – Restivo 2006); that is, automized, highly-flexible production systems – making wide use of machines, robots, work-cells and labour units – that are able to deal with the rapid changes that all the mechanized-production manufacturing enterprises, flow or batch order, must face: variety and uncertainty of demand, changes in tastes, reductions in the life cycle, and the need to reduce time to market (Mason-Jones – Towill 1999).[7]

[7] «Agile Manufacturing is primarily a business concept. Its aim is quite simple – to put our enterprises way out in front of our primary competitors. In Agile Manufacturing, our aim is to combine our organisation, people and technology into an integrated and coordinated whole. We will then use the agility that arises

The basic operational entities (machines, robots, work-cells, labour units, etc.) that characterize such Manufacturing Systems (figure 4) can be considered as *processor holons* that form a holarchy or an *operational* holonic network, but on the condition that their functioning is viewed as instrumental for the achievement of *information holons* of some type (models, objectives, decisions, responsibilities, and so on) that have a lot of variety and variability over time.

4.10 Interfirm Networks and Holonic Firms

In general terms the *interfirm networks* (*production* or *enterprise networks*) are holonic networks or orgonizations comprised of autonomous firms that are variously located – characterized by different roles and different operations (Grandori – Soda 1995; Gulati 1998; Dyer 1997), but integrated in terms of mission, vision and aim of their common businesses – and connected through a holonic network, real or virtual, often oriented,[8] in order to achieve a common objective through the sharing of resources, information and necessary competencies, without any hierarchical constraints of subordination (Goldman *et al*. 1995; Kinoshita *et al*. 1997).[9]

In the Japanese literature the holonic networks are also called holonic firms, and in North American terminology virtual firms.[10]

The connection among the various entities of the holonic network is carried out through a guiding firm (nodal firm), internal or external to the network, by means of agreements (generally not formalized) with the other entities (see above, par. 3.6).

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from this integrated and coordinated whole for competitive advantage, by being able to rapidly respond to changes occurring in the market environment and through our ability to use and exploit a fundamental resource – knowledge» (Kidd 2000; see also: Sanchez and Nagi 2001).

[8] «The network structure as a form of organization is different from a 'hierarchy' in which components are assumed to be invariably linked. It is also different from the 'market' as a form of organization that is generally assumed to be an atomistic structure in which all links between components are instantaneous and where few, if any, impediments exist to any of the components being connected to any another» (Håkansson – Snehota 1995, p. 40).

[9] Concerning the types of interrelations among firms, we can refer to Grandori (1997), who indicates four types of interrelations: 1) interdependence regarding the sharing of resources, 2) intensive interdependence regarding the firm's activities, 3) sequential interdependence, and 4) mutual and even circular interdependence.

[10] «We consider *Extended enterprises*, *virtual enterprises* and *supply chains* as very similar concepts, each of them being a *production network* formed from independent companies collaborating by sharing information, skills, resources, and having the same goal of exploiting market opportunities. A kind of production network focusing on collaboration between companies, is a *virtual enterprise*. If the collaboration network incorporates a dominant company imposing the rules of the information exchange, we call it *extended enterprise*. The alliance that focuses on the chain aspects is then the *supply chain*».
For more, visit the following site: <http://holonic.ailab.sztaki.hu/projects.htm>, which provides a vast list of other sites that specifically develop these concepts.

These firms also effect the coordination and the cooperation among the holonic components of the network:

> Organizational entities of varying size, large and small, are on the same level, and none have a special place due to its size or reputation. In an holonic network each firm, large or small, can exploit its fundamental capacities by connecting to other firms with complementary capacities.[11]

We must emphasize that the interconnected firms form a system, not an holonic network; in fact, the holons are not the interconnected organizations so much as the capacities (functionalities) that result from the stock of know-how, information, resources and competencies that they possess and that find common meaning and functionality precisely from the reticular interconnections.[12]

These holons are coordinated within the network and, if viewed as functional elements for carrying out some common business activities, can be conceived of as components of an holonic organization (firm), also known as a *virtual holonic enterprise* (firm) (Ulieru *et al.* 2002; Goranson 1999), precisely because it makes use of knowledge and skills to carry out processes which are in effect undertaken by the individual participating organizations (processors).

Thus an holonic firm is not a holon but an orgonic network that becomes an entity in a new business structure, which is neither formalized nor legally recognized but capable of effectively dealing with environmental change and rapidly attaining the best competitive positions.

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[11] At: <http://www.proxyma.it/olone.htm>.
«The notion of a network of firms, which is organizational in nature, includes four different types of situations regarding the firm, which depend on the type of control system. These obviously correspond to radically different economic and legal situations:
- 'hierarchical' network of firms, where the internal hierarchical structure dominates, but where there are also strong influence and negotiating relations with other small- and medium-sized firms (for example, large firms with a high level of decentralization);
- a network of firms whose "center of gravity" is concentrated on only one strategic agency with prevalent influence and negotiating relations (for example, systems regulated by financial holding companies, 'no manufacturing' industrial firms, hollow corporations, etc.);
- a network of firms with "multiple centers of gravity', where the system revolves around several and alternating strategic agencies, with quite complex and changing relations of influence (for example, association-type firms such as cooperatives) that cyclically revolve around an association or a large firm, or an informal 'union' of large firms;
- a network of firms without a center (for example, territorial-based systems such as districts, filiere, etc.)» (Butera 1990, pp. 58-59).

[12] «An Enterprise Network (or holonic system) is a strategic alliance among autonomous enterprises to become competitive on new markets and realise new products together. The term 'network' highlights the fact that the enterprises act like the nodes of a system, and establish relations to supply each other information, materials, components and products».
For more, see: <http://web.democenter.it/ucanet/virtualorganisations.php>.

Finally, we must mention the particular *holonic firms*, which represent an orgonization where the organs are orgons, since they have vast autonomy and are connected in a network entirely similar to that of an holonic enterprise.

These are divided firms that operate in various places through *branches*; they have economic, financial and organizational autonomy and operate in parallel or serially as components of a single production process, carrying out an autonomous local operational management, even if the strategic management remains centralized.

4.11 Agile Networks

Due to the flexibility that distinguishes them orgonic networks are also viewed as *agile networks*. These represent the most efficient means for creating an *agile manufacturing network*, an holonic production system (similar in inspiration to an Agile Manufacturing System) that is flexible and open to the needs of the market, able to plan, realize and market various product models to satisfy in real time the demands of clients from all the participating entities (Youssef 1992).

The various operational entities that make up the *manufacturing network* can, in all respects, be considered holonic organizations, or larger orgonizations, characterized by autonomy, consciousness, and the willingness to accept coordination.

In order to create an holonic firm it is necessary to carry out an organizational *re-engineering* process that can act in two directions:

a. *fragmenting* a unitary organization into flexible modules which are specialized according to their *core competencies*, thereby making its organs autonomous (McHugh *et al.* 1997);
b. *creating* a new organization by setting up lines of integration – even through recourse to outsourcing – among pre-existing firms, with a high degree of interaction, thanks to the support of powerful information systems, of uniform managerial systems, and of systems of shared values, in order to exploit the business opportunities that are presented; these holonic firms are also called *extended enterprises*.

In both cases the largest contribution to the creation of value in these new business models will depend on the logic of the client-supplier relations, according to a system of *comakership*, as well as on the speed with which processes for continual learning and the flow of knowledge among all the organization's units are activated (Merli 1991).

If the relations among the holons is achieved through an information network, then the organizational network will become a true *virtual organization*, in the form of both a *virtual enterprise* (firm) whose cognitive and operational boundaries are blurred and defined only by the interconnections (Davidow – Malone 1992) as well as a common network of competencies opportunely created by autonomous and independent holons that are virtually connected (Goldman *et al.* 1995).[13]

The current ITC illustrates networks that are solely informational (Rullani 1989), in which the component holons are connected by information flows and not by production flows. The network then becomes a communications network (D'Amours *et al.* 1999), similar to a *neural network*, which is able to produce knowledge that transcends that which is possessed by the individual connected entities and, probably, *consciousness, thereby favouring the development of the Networked-Digital Economy*.

[13] «A virtual enterprise is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation is supported by a computer network. A virtual enterprise materializes by selecting skills and assets from different firms and synthesizing them temporarily into a single functional business entity to respond to business opportunities. The cooperation among the enterprises involved in a virtual enterprise is supported by computer networks and other information technology tools. In fact, cooperation between enterprises is not a recent phenomenon at all. For instance, in the civil construction sector there is a long-standing tradition of cooperation in consortia to jointly develop large projects. The novelty factor introduced by the virtual enterprise paradigm is the strong use of computer networks and advanced information technologies to better support the cooperation among companies» at: <http://www.uninova.pt/~cove/motivation.htm>.

Chapter 5

The Production Kosmos as a Selfish Orgonic Network

> It does indeed seem there is a Ghost in the “Production” Machine, whose invisible hand produces growing levels of productivity and quality, increases the quality and quantity of satisfied needs and aspirations and reduces the burden of work, thus producing increasingly higher levels of progress in the entire Kosmos (see below, section 4).

5.1 A Change in Perspective

In this concluding chapter I will examine “complex production systems” – which produce the flows of goods and services on which the continuity of the «subtle film of material called life» (Brown 1954, p.3; Cipolla 1962) depends – from a typical holonic perspective, placing myself at a “sufficient height” (Senge 1990) to take in the macro and micro dimensions and, at the same time, their reciprocal interaction.

In order to understand the formation and development of a complex production system, simultaneously conceived of as a holarchy and an holonic network of holons-production units which are both autonomous as well as dependent, we must above all *radically modify* our ideas about the concept of production.

We are used to thinking about the production of a good or service as the result of the activity of a specific producer: clothes, perfumes, cold cuts, automobiles, films, cell phones, health services, university courses, etc., are always produced by some firm, organization or institution that is easy to identify. This is the *atomistic* way to conceive of production at the *micro level*. Is it the right way?

Things are not like this in reality.

Suppose I am wearing a double-breasted winter wool suit. I immediately realize, following a typical atomistic view, that in order to discover the producer I only need to read the label on the inside of the jacket. This is true. However, one thing is discovering the final producer – a firm or an enterprise; another is to understand the complex processes and activities that have gone into clothing manufacture in order to produce a continuous flow of analogous items.

We assume that the suit has only four components: the wool fabric, the internal cotton lining, the special sewing thread, and the buttons.

In order to have a continuous flow of wool fabric we of course need sheep farmers, and the sheep must be periodically sheared with the appropriate tools, which have been manufactured "who knows where and by who knows whom".

The raw wool must be collected, packaged and transported for washing, scouring, bleaching, carding and, finally, spinning; all these operations require machines of varying complexity produced by specialized firms that, in turn, need electric motors, steel and plastic components, cables, monitors, security systems, etc.

The spun wool finally reaches the dyeing stage, with colours that require producers of chemical components, metal or plastic packages, thinners and all kinds of accessories. The dyed wool, in skeins of wrapped around spools, produced "who knows where and by who knows whom", moves on to the weaving stage, with its modern robotic machines produced by super-specialized firms able to obtain fabric of any kind of weft and pattern.

Finally, the long rolls of fabric are packaged and bought by the clothing manufacturer, who then must cut and sew them with the appropriate specialized machines; the lengths are sewn with a special thread, after which the inside cotton lining is applied.

Here, too, we can imagine a vast and varied production network, if only for the simple fact that the cotton comes from cultivation and not animal breeding, and that the harvesting, spinning and weaving processes require completely different machinery and are in turn carried out by other firms. The reader can add to these two networks the one that provides the thread and the buttons.

What is the meaning of manufacturing and acquiring a suit? The article of clothing represents the single OUTPUT of a terminal process of several wideranging production networks that had to be active and activated for a period in order to provide the components for its manufacture.

Buying the suit means benefiting from a single OUTPUT of the entire *network*. The flow of suits – of which my personal suit is a component – is the OUTPUT of a complex network of production organizations, not that of a single production firm.

We need only visit a hypermarket to fully appreciate the number, variety, interconnection and complexity of production networks.

5.2 Production Networks

If we change our perspective, it is clear that any kind of production flow is obtained not from individual production organizations but from a more or less widespread *production network* of interconnected units located in different places and times, all of which, consciously or not, are necessarily connected, interacting and cooperating in a coordinated way in order to combine and arrange, step by step, the factors, materials, components, manpower, machines and equipment in order to obtain flows of products and to sell these where there is a demand for them.[1] We shall refer to this in general as a *productive network.*[2]

We can make a generalization: *all production networks represent an efficient holonic network of* "micro-local" *transformation and organization processes for resources for the purpose of producing flows of goods or services to satisfy the demand for final consumption goods, which represent the global* OUTPUT *of these processes.*[3]

The production units that carry out these processes are the nodes (or modules) of the network. The relations among the nodes take the form of *real flows* (goods and services), *economic flows* (values, costs and revenues) and *financial flows* (capital and earnings) from the exchanges and investments undertaken, more or less stably, among the various nodes (in order to simplify, we can consider the *information* as INPUTS and OUTPUTS that are included in the real and financial INPUTS and OUTPUTS).

There are no autonomous nodes: in the networks all the nodes are dependent on others (Barabási 2002) and form a holarchy of products and an holonic network of producers. If the producers are autonomous companies then they are orgonic, and the entire production network is, in fact, an orgonic network.

In fact, from a *pull*-type perspective, each product coming from the final producer is a holon that includes all the materials, components and sub-assembled parts that

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[1] The concepts of final good and component must be viewed in the widest possible sense: material and immaterial goods, and services; individual or collective consumer goods; goods to satisfy needs or aspirations, either individual or collective.

[2] «The term networks refers to exchange relationships between multiple firms that are interacting with each other» (Wilson – Möller 1995).

«The propositions of the network model refer to situations and cases in which the environment of the organizations is of a concentrated and structured kind […] As a result of an organization's interactions and exchange processes with any of these, relationships develop that link the resources and activities of one party to those of another. The relationships are generally continuous over time, rather than being composed of discrete transactions» (Håkansson – Snehota 1999, p. 23).

[3] «Once we admit that business relationships of a company are connected and that this applies for companies in general we have to consider possible chain dependencies between relationships. […] Generalized connectedness of business relationships implies existence of an aggregated structure, a form of organization that we have chosen to qualify as a network. Because of the connectedness a relationship is a part of a larger whole. Relationships are parts of the broader structure that links its elements – the actors (companies)» (Håkansson – Snehota 1994, p. 19).

«In order to obtain necessary resources, the organization is seen to develop relations with a number of other organizational units and thus it enters into a network of relationships. Two aspects of this network have mainly been studied. Firstly, the characteristics of the different organizations have been investigated as they relate to the other organizations within the same network. Secondly, the links between the units have been analysed in terms of, for example, formalization, intensity, and standardization. The parallel to these studies in the marketing area are those that form a 'distribution system perspective'. In this, the field is viewed as a system of interconnected institutions performing the economic functions required to bring about exchange of goods or services» (Håkansson 1982, pp. 11-12).

I have chosen to focus attention on the productive network rather than the distribution one, which we can think of as being included in – or a particular case of – the former.

represent the immediately preceding holons; each material and component that forms the final product includes, in turn, lower-level holons, and so on down to the base holons, which are the materials directly obtained without any transformation.

Production networks are found wherever man acts to satisfy his needs and aspirations. They concern not only production but also consumption; *there is no consumption without production, but at the same time there is no production without consumption* (par. 5.14).

A brief technical note.[4] The term *network* is correctly preferred to the term *system*, or *structure*, since it brings out three aspects. First, that among the nodes – that is, the production units – there must always exist necessary and stable connections, which originate from the exchange and information processes. Second, that the network functions if all its component-orgons act, according to their appropriate times and at an appropriate space, simultaneously and in a coordinated way, revealing a *selfish behaviour* aimed at its survival within the network. Third, that the network operates to produce flows and not individual products; thus, the unitary activity of the network must be observed over a *meaningful time span*, in which we can identify the flows of interconnection among the nodes and among the external reservoirs.

The demonstration of this assumption represents the heart of this Chapter.

5.3 Production Organizations as Network Nodes

The nodes of a production network are production organizations of some type, which can also be quite different in terms of legal status (public or private entity,

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[4] I define a *standard productive node* as an entity, or *operational module*, endowed with initial resources that, on the basis of requests from a given "reservoir of demand", transforms *external resources* – which have their own value, measured by standard procedures – into certain types of *production* – with their own value, measured according to homogeneous standard procedures – under the survival condition that the *value* of the output is not below that of the inputs; and, if it is below this, that the difference is not greater than the amount of the initial resource endowment (invested capital).
A *modular network* is defined as an organized dynamic system whose elements, or organs, are represented by input-output *modules*. The *operational modules* form the network in that they are interconnected by *organizational relations* that define the direction of the input/output interactions among the modules that compose the structure of the system.
Initial modules are those that receive external inputs, those that give off outputs to the environment are called *final* ones. The others are intermediate modules.
Associated with each connection between two modules is an *internodal indicator* that specifies a given condition necessary for the *downstream* module to produce its output after having received input from an *upstream* module.
We can assume that these indicators are *flow* requirements that specify to what extent the upstream module must contribute its output to produce that of the downstream module.
Networks can have an *invariable* organization or an *adaptive* one; in the former case the modules and their interconnections are stable, with only the *internodal indicators* changing; in the latter the nodes and their connections can vary as well.

association, individual company, professional group), size (large- and small-sized companies and craft companies), organizational structure (unitary, divisional and group structures), management approach (business and non-business, for-profit and not-for-profit organizations), and location and area of operation (local, regional, international, global).

The economics literature gives various names to these entities, adopting terms widely used in business terminology: production units, organizations, firms, corporations, etc. I prefer the more general term *production organizations* since, apart from their formal and managerial characteristics, the network nodes are still stable organizations that possess at least the following characteristics:

1. spontaneous genesis: they arise spontaneously – based on a decision by some person or group – when they can link up with some "demand reservoir", which already exists or is created by the same organizations; I define demand reservoir as a number of entities – individual or organizational – which, as a whole, represent a potential demand for goods;
2. autonomy and durability: through their own management they produce cognitive processes aimed at survival; once created, the production organizations tend to remain viable indefinitely by modifying their production processes in order to satisfy demand or by looking for other forms of demand; in this sense, they are viable systems according to Beer's definition (Beer 1979, 1981; Espejo – Harnden 1989), and autopoietic systems as defined by Maturana and Varela (1980);
3. need to connect: their natural tendency is to link up with other production organizations when this is deemed necessary or useful for survival; the connection occurs through real or monetary flows. I will consider as prevalent the real connections in terms of relatively stable flows of material, labour, services, and other goods;
4. specialization: they tend to specialize their productive transformations and their products (Snow *et al*. 1992), limiting the range of possible processes and adopting only those required by the production network, of which they represent one segment of the overall process; the production units linked to the consumption reservoirs are terminal production nodes; the others, linked to these in an instrumental and specialized way, are intermediate nodes.

As we observed in section 2.5, Wilber postulates that holons form spontaneously and order themselves naturally in a holarchy or an holonic network. In Tenets 3 and 4

Wilber clearly states: «3. Holons emerge. - 4. Holons emerge holarchically». These postulates are linked to the fundamental characteristics of every orgon.

5.4 The Holonic View of the Production Network. Orgons

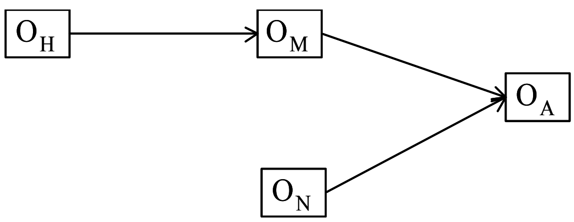
If we accept these *minimal properties* then we can acknowledge that the network nodes have a double meaning: on the one hand, they are *autonomous units* that carry out a specific process in order to obtain the finished products, and on the other they are *interconnected parts*, in that they are linked to other *antecedent* nodes – on which they depend – and to *successive* nodes, to which their production is aimed.

Thus if we fully consider the nodes from the holonic perspective, we can immediately conclude that the nodes of any production network are holons arranged in *levels* and interconnected in a hierarchical ordering that can be vertical (that is, a *holarchy*), or horizontal (that is, an *holonic network*). A network composed of more limited networks is a *reticular holarchy*.

Since the vertical and horizontal hierarchies, while different in structure, can be considered equivalent in their operational logic, I propose to use the term *antecedent* to O_A (or "connected before" or "upstream" to lower-level holons) for the holons O_M and O_N, and, similarly, for the holons O_H relative to O_M (see the following diagram); obviously O_A is *subsequent* to (or "connected later", "downstream", or at a higher level) O_M and O_N.

If we assume that the small network/holarchy is complete [Model 1], then the holons (or orgons) O_H and O_N are base, or primal holons. O_A is defined as a *terminal*, or *top holon*. O_M is an *intermediate* holon as well as the *head holon* of the branch [$O_H \rightarrow O_M$]. Obviously, not only the holons that are directly connected *before* but all the branches that are subtended to these are considered as occurring *earlier in the process*.

[Model 1]



5.5 The Minimal Structure of Orgons

If "node A" represents a generic "orgon A", or even "O_A", we can represent an orgon, viewed as an autonomous and vital node, by the simple *standard module* in figure 1.

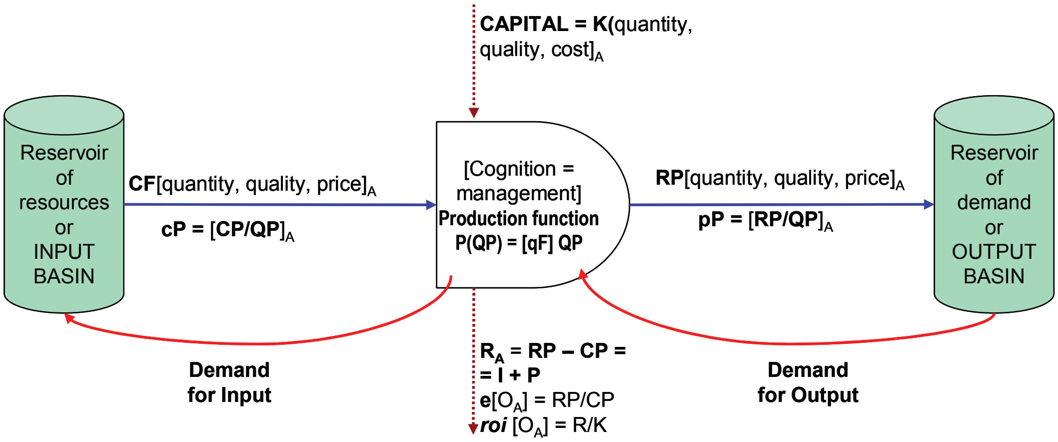


Figure 1. Orgon (standard module).

As a production organization, the orgon transforms factor or INPUT costs, CF, that form the cost of production, $CP = \Sigma\ CF$, into OUTPUT values, or revenue, of the production RP, according to given levels of economic efficiency **e**$[O_A]$ (naturally we must specify a reference period, T). R_A represents the operating results, while I and P indicate interest and profit, as a return on K.

The factors and the production are represented by vectors that show the quantity, quality and price for factor INPUTS and for each production OUTPUT. cP and pP express, respectively, the average unit cost and the average unit price for the volumes Q in period T.

K indicates any capital necessary for the investment needed to start up and actively maintain the production processes; this capital can be both monetary, as in the modern economies, and non-monetary, in the form of advances regarding various types of factors.

More elaborate models of orgons are possible, but the simple one proposed above serves our purpose in showing all the main variables in the transformation processes of a production organization considered as an orgon.

In primitive economies, where self-production prevails, as well as in *non-business organizations*, the value of production is equal to its *utility* for the final consumer or user; thus pP = 0 and CP is always the responsibility of the entire organization.

In business organizations, pP represents a price.

For-profit organizations or companies seek the maximum differential between price and average unit cost of production; or equivalently, the maximum economic efficiency, or the maximum R_A.

Non-profit organizations, on the other hand, seek the minimum gap between pP and cP, which is equivalent to producing an R_A that tends to zero.

Capitalist companies are characterized by an INPUT of Equity (E); in non-capitalist companies, like those composed of pure labour – cooperatives, professional offices – E tends to zero and K is mainly composed of Debt (D).

The capital, K, has a return of R_A = (RP-CP) = I + P, based on the level of financial efficiency expressed by *roi* = R_A/K and by *roe* = P/E.

Thus capitalist companies not only must tend in general to having a (pP – cP) = max, but also a *roe* ≥ *roe**, where *roe** is the return on E deemed just or desirable for keeping the capital invested and enabling the orgon to exist (for more details: Mella 2005b).

5.6 Selfish Orgons. The First 5 Rules of Selfishness

In the diagram of the standard module in figure 1, I have generically included the *cognition processes*; that is, the processes involving decision making, planning and control that characterize all organizational activities and which represent the "engine" behind all the flows.

It is not necessary to look further into how the orgon produces these processes, but at the very least we must assume that management, following its tendency to strive for *self-affirmation* and *existence*, must necessarily follow the *selfish rules* indicated below.

RULE 1) – *Reservoir of demand*: the orgon seeks (identifies or creates) a reservoir of demand compatible with its OUTPUT vector (volume, quality and price of the resulting production) and connects with this in order to transform production into OUTPUT, under the condition that it maintains the minimum level of economic efficiency deemed to be appropriate.

RULE 2) – *Increase in size:* if it succeeds in connecting with a given reservoir of demand, the orgon tries to attain the maximum size; that is, it tries to satisfy all the possible demand by increasing its production processes in line with its INPUT vector (volume, quality and price of the utilized factors) and the available capital.

RULE 3) – *Readjustment of its* OUTPUT *vector:* if it cannot connect to a reservoir of demand – or if the reservoir to which it is connected is no longer compatible with the processes carried out – then the orgon, in order to continue to survive, must try to modify its OUTPUT vector by adapting its internal processes, in accordance with the INPUT vector and the available capital.

RULE 4) – *Productive efficiency*: in any event, the orgon must *always* try to improve its INPUT vector in order to reduce the cost of production – by increasing productive efficiency – and/or to increase the quality of the factors. Figure 1 clearly shows that the reduction in the unit cost of production implies, on the one hand, the continual search for higher technical returns from the factors and from labour productivity – in particular in order to reduce the unitary INPUT – and, on the other, the search for new *resource reservoirs* in order to reduce unitary prices of factors and/or increase their quality.

RULE 5) – *Extinction*: if the management (cognition activity) cannot connect the orgon in a convenient manner to a reservoir of demand or modify its internal processes to the extent necessary to repeat its autopoietic processes (due to a lack of sufficient capital, technical reasons, or constraints of varying kinds), the orgon is extinguished.

RULES 2), 3) and 4) produce a *physiological improvement in performance* and are the logical consequences of RULE 1), which states the tendency toward autogenesis and the survival of any kind of orgon; in particular, RULE 4) lays out a basic principle: the orgon must try to achieve a continual adaptation of the cost of production independently of the need to connect with the reservoir of demand. This is true for any type of orgon, from those created for self-production to those that follow a *no-profit* logic, and even more so for the *profit-oriented* capitalist firms.

5.7 The Reservoir of Demand and the Resource Reservoir

With regard to what is stated in RULES 1) and 2), rather than simply refer to the traditional notion of *demand* for a given good I will propose the concept of *reservoir of demand*, which better represents the idea that the potential consumers or users can also have a geographic reference rather than a merely quantitative one, and that the orgons may have a tendency to connect with the reservoir rather than simply satisfy a certain stock of requests.

The *reservoir of demand* can be represented by a trapezoid similar to the one in figure 2; the horizontal axis indicates the volume of potential demand (P_{max}) of the reservoir for the good produced by the orgon at a value between a maximum and a minimum, with the quality level (qlP) assumed constant.

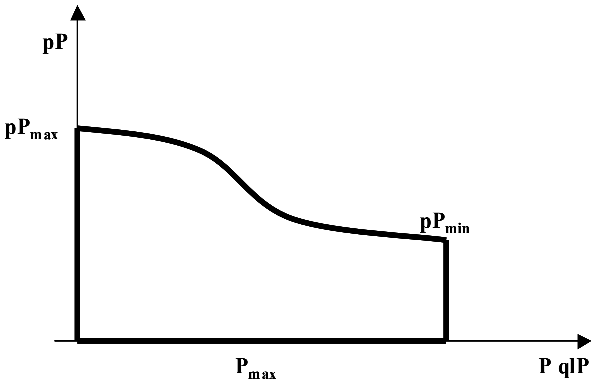


Figure 2. Reservoir of demand.

Each reservoir of demand – let us assume reservoir β for product A – is thus characterized by the vector $\beta_A = [P_{max}, pP_{max}, pP_{min}, qlP]_A$. In order for the orgon O_A (I have used the same notation as that for the product) to be able to connect with β_A, the quantity in OUTPUT to discharge (sell) must not be greater than P_{max} and must be offered at a value between the admissible minimum and maximum for β_A.

It follows that if the orgon identifies a reservoir of demand in which other orgons already discharge their OUTPUT, for example O_M and O_N (figure 3), then it must sell its production at a value no greater than that of the orgons that have preceded it, obviously for the same level of quality and with any other discriminating conditions being equal. However, it is possible that the amount produced by O_A exceeds P_{max} of β_A. In this case the orgon can, and must connect with other reservoirs.

Price competition appears to be a necessary factor for RULES 1) and 2). Clearly it is possible to consider tendencies toward monopoly positions and multiple pricing policies, but I do not feel it appropriate to go further into these aspects, since they are well described in the literature.

The idea of a reservoir of demand requires additional comment.

a. the reservoirs of demand do not correspond to reservoirs of needs or aspirations; the presence of needs must correspond to the ability of potential consumers (without considering any specific geographic reference) to acquire the goods of the orgon at a significant value or price;
b. a reservoir of demand does not necessarily concern final consumption products; for a component-producing orgon, the reservoir of demand is represented by other orgons that use those components for their products;

c. while in most cases the reservoirs of demand predate the orgon that wants to connect to them, in other cases it is the orgon itself that creates, or develops a reservoir of demand;

d. the concept of the connection of an orgon to a certain reservoir of demand does not also imply, except in particular cases, the physical location of the processes in the attracting areas; instead, the contrary is usually the case;

e. nor does this necessarily imply a direct connection, as occurs in the case of the "travelling salesmen", factory outlets or e-commerce; most of the time other orgons downstream arise to create the most appropriate distribution channel formed by commercial firms specialized in distribution.

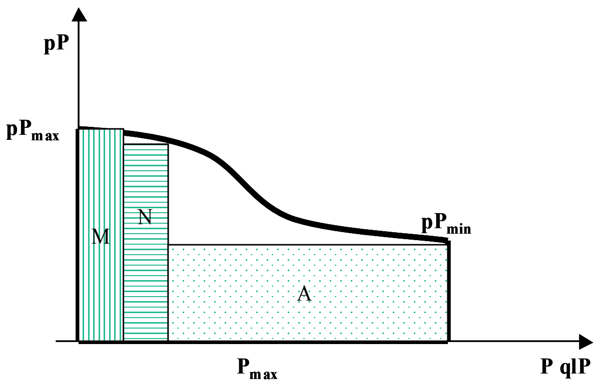


Figure 3. Reservoir of demand to which orgons are connected.

We can consider the concept of resource reservoir as being symmetric to that of a *demand reservoir*, with the difference that we can consider a resource reservoir both as a *site* where resources are present – a stretch of sea rich in tuna or seals, or an area rich in oil, water, gold-bearing metals, etc. – and as a *set of* orgons earlier in the process that can supply, competitively or as an alternative, materials, components and structural factors.

A particular resource reservoir is represented by a *reservoir of labour*, which can be understood as an area with a certain quantity and quality of manpower availability at a given unit cost.

Referring by analogy to figure 1, we can characterize resource and labour reservoirs by a vector that indicates the availability, unit value and quality of the available resources.

RULES 3) and 4) require the orgons to identify the resource and labour reservoirs and to connect with those that promise an improvement in their INPUT vector.

5.8 The Formation of Orgonic Networks

An Orgonic Network forms when several nodes connect to one another through their INPUT and OUTPUT according to the RULES of *selfish survival*.

In this sense the following analyses refer to *real* or *factual* productive networks and are not limited to *rational networks* that derive from voluntary agreements among firms to pool together resources and skills in order to form *holonic*, *virtual or extended enterprises*.[5]

The holonic nature of the orgon means that, for all orgons which are not primal and final holons, each OUTPUT of an orgon is at the same time an INPUT of some other orgon.

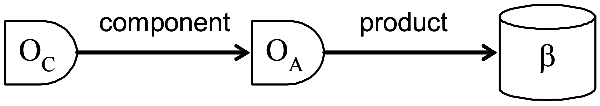
Only the chain of connections – more generally, the *network* – takes on full significance as a system for the production of goods.

The history and direct observation of primitive economies clearly shows that the first orgons were final holons, spontaneously arising from *self-production* by seeking and transforming resources through the labour provided by the consumers themselves.

RULE 3) guarantees that even these elementary production organizations manifest the continual search for higher levels of efficiency through the progressive learning on the part of the organization.

This spontaneous genesis makes it likely that, external to O_A, a new orgon, O_C, will be created, capable of producing with greater efficiency, and thus at a lower cost, some components (materials or equipment) already internally produced by O_A. It can then be convenient for O_A to connect *serially* to O_C to obtain the factors it needs at a lower cost or at a higher quality [Model 2].

[Model 2]



O_A is connected to the demand reservoir β, but at the same time it represents the demand reservoir for O_C.

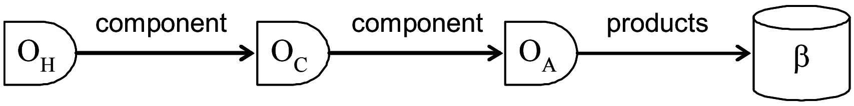
[5] Real productive networks have been the subject of a number of studies. For example, Michael Porter's work on the Value Chain, where it is easy to discern the vision of the productive network when he considers the inevitable relations between different Value Chains (Porter 1985, pp. 11-15; Powell 1990); or the related studies on Supply Chain Management (Mentzer 2000; Copacino 1997). More recently, though also from the managerial point of view, we have the studies on inter- and intra-firm holonic networks, where the holonic network is viewed as a new form of productive organization, voluntarily formed to manage complex businesses under conditions of extreme environmental variability and managerial complexity (Grandori – Soda 1995; Gulati 1998; Goldman *et al*. 1995; Kinoshita *et al*. 1997).

The OUTPUTS of O_C are INPUTS that O_A combines with other internal resources to obtain products.

The process can repeat itself serially or in parallel.

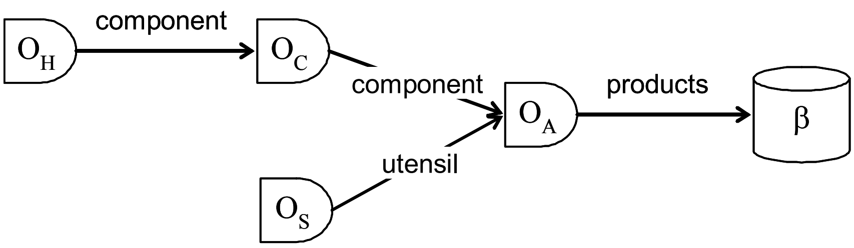
If a new orgon, O_H, should more efficiently produce several components needed by O_C, then the branch may lengthen (serially) [Model 3].

[Model 3]



If an orgon, O_S, produces a high-quality utensil, tool or machine useful in the production process of O_A, then we can have an enlargement in parallel of the Orgonic Network, with a ramification [Model 4].

[Model 4]

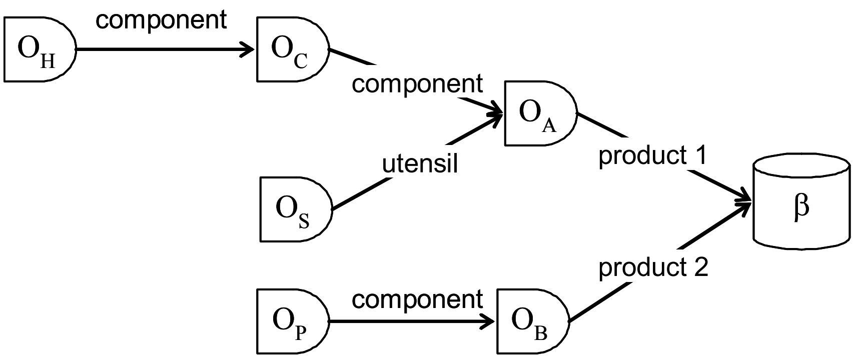


If O_A produces various products, P_1 and P_2 for example, it may be convenient to generate a specific autonomous orgon, O_B, parallel to O_A, for production P_2, thus creating two independent branches of the overall network [Model 5].

O_A and O_B connect to the same demand reservoir, creating *collaboration*, or *compete* with each other for connection to β.

In fact, according to RULES 3) and 4) each producer orgon must always, when it has to evaluate the adequacy of its own INPUT *vector* – that is, the quantity, unit value and quality of the productive factors – decide whether or not to *make* or *buy*.

[Model 5]



If the decision is to *buy*, then some specialized orgon must exist *upstream* and connect with one *downstream* to supply this with the materials, components and machines it has given up producing internally.

There is also the reverse case: according to RULE 2), each orgon must always evaluate the adequacy of its own OUTPUT vector, and it may be convenient for it to modify its own connection when this brings an improvement in the volume and/or in the unit value of the products.

Let us suppose [Model 6] that O_N, previously connected (downstream) to O_A, disconnects from O_A to connect with O_B.

This decision can be considered as the shifting from O_A to O_B not only of O_N but also of the entire branch below it.

As a result [Model 6], the branches of the network can vary their connections both *upstream* and *downstream*.

Obviously the connection of O_N to O_B causes problems in the production process of O_A; if O_A is not able to replace O_N, then it must modify its INPUT or OUTPUT vector; if this does not work, then O_A must disappear, with consequent difficulties for the entire antecedent branch formed by O_H and O_M.

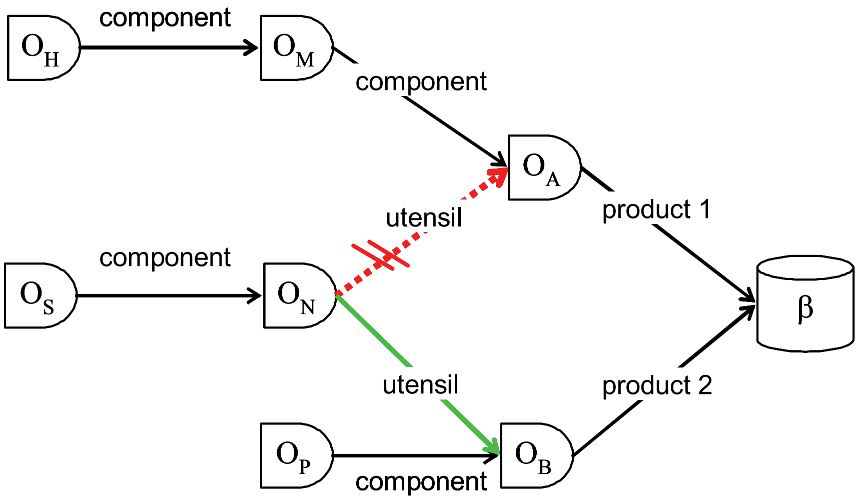
The genesis of new orgons capable of increasing the efficiency of the processes carried out by other already-connected orgons enables the Orgonic Network to develop and extend itself in terms of size (parallel orgons that connect to the same demand reservoir) as well as depth (specialized orgons that connect serially).

It is also possible for orgons to merge in order to create a larger orgon.

Finally, let us consider the more complex case that occurs when, due to the specificity of its production, an orgon employed in the production processes of several orgons or networks is connected at the same time to a number of other orgons *downstream*. Such an orgon can be fully considered as a *hub* (Lorenzoni – Lipparini

1999), in that it is the center of connection for many other organs and branches that are variously situated in the network or that even make up different networks.

[Model 6]



The more numerous are the *hubs* between different Orgonic Networks, the more these networks become integrated, to the point of becoming a single network.

Precisely due to the presence of *hubs*, the Orgonic Network can also become a complex behavioural network, since some orgons can have circular connections and generate dynamic or stable loops, even giving rise to evident paradoxes. This makes observation and modelling difficult; but this does not mean the orgonic network loses its features as a modular system.

The presence of *hubs* should not be considered a special case but rather the norm; according to RULE 2), each production orgon must try to connect to the largest possible number of other orgons *downstream*, since these represent its demand reservoir.

5.9 Five Additional Rules of Selfish Behaviour of Orgons as Janus-faced Holons

In the progressive expansion of orgonic networks, it is not difficult to perceive the economic dynamics of mankind.

The competition between orgons that produce the same good leads to improvement in the manufacturing process and thus to an increase in the quantity and quality of the final goods, as part of a natural *selection process* that – while displaying the clear differences due to the typical nature of orgons – presents principles similar to those of Darwinian evolution: *the network is an environment that produces* selective tendencies *in the* orgons *that spontaneously arise; requiring ever greater efficiency, the network favours random* creative mutations *in the production processes that raise the level of efficiency*.

It is even more evident today that there is a tendency for modern economies to move toward production specialization and the expansion in network connections (Dyer 1997): each Orgonic Network which is not too elementary will be composed of orgons *specialized* in the production of materials, components, services, energy and machinery orgons, all aiming at the production of final consumption goods.

From a "sufficient distance" the Orgonic Network thus appears as an entity with a dynamic structure, whose branches continually remodel their connections as a consequence of the cognitive activity that is rationally undertaken by the management of the *nodes*, which can be viewed as egotistical or opportunistic entities that tend to survive, according to Richard Dawkins' analysis:

> An entity… is said to be altruistic if it behaves in such a way as to increase another such entity's welfare at the expense of its own. Selfish behaviour has exactly the opposite effect. "Welfare" is defined as "chances of survival", even if the effect on actual life and death prospects is small […] It is important to realize that the above definitions of altruism and selfishness are behavioural, not subjective (Dawkins 1976, pp. 4, 5).

In order to survive, the orgons that make up the network must continually maintain or improve their performance by remodelling their connections according to a few additional simple *rules of selfishness* that can be summed up as follows (the numeration follows on from above).

RULE 6) – *Serial connection*: the orgon $O_A(t)$, at time (t),[6] appropriately connects to the orgon $O_M(t)$ to form, at (t+1), the chain $[O_M(t+1) \rightarrow O_A(t+1)]$, if at the same time:[7]

I. $e[O_A](t+1) \geq e[O_A](t)$,
II. $e[O_M(t+1) \rightarrow O_A(t+1)] \geq e[O_A](t)$,
III. $e[O_M](t+1)$ satisfactory for O_M.

Condition I. means that the *serial* connection must improve the economic efficiency of the orgon *earlier in the process*, O_A; at the same time condition II. requires[8] that the

[6] The time reference "t" must be appropriately specified in the various networks.
[7] I have used the following symbols: "→" indicates a *serial* connection; "‖" indicates a *parallel* connection; "→O" indicates an orgon which is a head holon of an *antecedent* branch; "O→" indicates an orgon which is a primal holon of a *successive* branch.

connection produce a chain $[O_M(t+1) \rightarrow O_A(t+1)]$ where overall economic efficiency is greater than O_A's would have been if the chain with O_M had not been created. Condition III. specifies that O_M, which was spontaneously created, must assess whether its own economic efficiency is at satisfactory levels. If O_A should see its economic performance worsen, then the connection would not be advantageous and it would probably be convenient for O_A to *make* and not to *buy*, or even to seek a connection with another orgon that can offer it more adequate INPUTS. If the conditions for economic efficiency were not satisfied but O_A had been created through a contribution of capital, then the connection could still be convenient for O_A if the decision to *buy* should reduce the amount of its own invested capital, thus allowing for an improvement in roi_A.

RULE 7) – *Parallel connection*: it is convenient for the orgon $O_A(t)$ to split in two orgons $O_P(t+1)$ and $O_Q(t+1)$ if:

I. $e[O_P](t+1) \geq e[O_A](t)$, and also:
II. $e[O_Q](t+1) \geq e[O_A](t)$, and subordinate to this:
III. $e[O_P(t+1) \parallel O_Q(t+1)] \geq e[O_A](t)$.

This rule states that the break up is advantageous above all if it improves the economic efficiency of both the orgons that result from the disjunction; if one of the two orgons should have an economic efficiency below that of $O_A(t)$, then the disjunction would still be advantageous if, on the whole, the two orgons that are placed parallel to each other, though considered as a unit, have an overall economic efficiency greater than that of the original orgon. This rule is followed when it is necessary to assess the advantages of a break up of firms and the formation of a corporate group; even if some units from the break up have a lower economic efficiency, the break up would still be convenient if the entire group maintains its economic efficiency unchanged or improves it, as if it were a single orgon.

RULE 8) – *Connection and disconnection of branches*: the preceding rules can also be applied, with appropriate adaptations, to understanding the reconfigurations that follow from changes in the connections among branches in the Orgonic Network. Since

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[8] «[…] increased specialization within a production network cannot be achieved without a cost. When transactors make investments in specialization, transaction costs arise because of the fear of opportunism. A central premise of transaction cost theory is that transaction costs increase as transactors make greater asset-specific investments. The standard reasoning is that as asset specificity increases, more complex governance structures (i.e., more complex contracts) are required to eliminate or attenuate costly bargaining over profits from specialized assets (O. E. Williamson, The Economic Institutions of Capitalism, Free Press, New York, 1985). Thus, transaction costs are presumed to increase with an increase in asset specificity» (Dyer 1997, p. 535).

each branch is connected or disconnected depending on whether or not its *head orgon* is connected or disconnected, the preceding rules apply in the sense that the operation must, in any event, improve both the performance of the head orgon that is reconnected and that of the orgon that enables the *successive* connection. According to RULE 6), the orgon $[\rightarrow O_M(t)]$, at time t, and thus the underlying chain, appropriately connects to the orgon $[O_A(t)\rightarrow]$, and thus to the successive chain, in order to form the new chain $[\rightarrow O_M(t+1) \rightarrow O_A(t+1)\rightarrow]$ if at the same time:

I. $e[\rightarrow O_M](t+1) \geq \rightarrow e[O_M](t)$, and also:
II. $e[O_A](t+1)\rightarrow \geq e[O_A](t)\rightarrow$.

RULE 9) – *Incorporation and merger*: the preceding rules can also be inversely applied to justify the incorporation and merger among orgons or branches. The incorporation transforms the chain $[O_M(t+1) \rightarrow O_A(t+1)]$ into the single orgon $O_{[M\&A]}(t+1)$. The merger transforms the parallel orgons $[O_P(t) \parallel O_Q(t)]$ into the unitary orgon $O_{[P\&Q]}(t+1)$. Mergers and incorporations imply an increase in the economic efficiency of the new and larger orgon with respect to that of the incorporated or merged orgons, considered individually or together.

RULE 10) – *Competition and collaboration*: the preceding rules, with appropriate adaptations, are valid for the *competitive* and *collaborative* behaviour between orgons and the *antecedent* subtended branches. In principle $[\rightarrow O_A]$ and $[\rightarrow O_B]$ *compete* if, having the same potential demand reservoir, under RULE 2) they want to increase their size in order to maintain or increase their economic efficiency; they *collaborate* if, based on RULE 4), the collaboration improves their INPUT vector by increasing productive efficiency. We can also imagine a collaboration between $[\rightarrow O_A]$ and $[\rightarrow O_B]$ to improve their OUTPUT vector (which also appears as part of the INPUT vector of *successive* orgons), but this collaboration would not be easily accepted by the *successive* orgons, since RULE 4) states that they would not accept a worsening of their INPUT vector.

5.10 The Holonic Nature of Production Networks

Following the holonic view, a *production network* thus has all the features that, in theoretical terms, distinguish every holarchy, as indicated in Chapter 2, to which I will now refer, limiting myself to the more immediately applicable principles.

Wilber calls the Kosmos the general holarchy that makes the universe evolve toward self-awareness; by analogy I propose to refer to the entire production system as the Production Kosmos (PK), which is included in the vaster *Kosmos* (according to Wilber).

At the *global level* the *Production Kosmos* appears as the largest production orgonic network and can be viewed as:

a) Koestler's Self-Organized Holonic Organization, whose function is to carry out, *by means of continuous local adjustments* – involving individual nodes and network paths – the optimal matching of available labor and capital, on the one hand, to the needs and aspirations of mankind on the other;[9]
b) an Autonomic Cognitive Computer, in the sense that the PK, through parallel processing by cognitive orgons, produces a progressive synthesis of components and values to produce the final product flows and their values;
c) a vast Holonic – and Bionic – Manufacturing System – whose blocks are production organizations-enterprises – that produces a cyclical process to transform labor provided by the base holons, the workers, into the production necessary to satisfy the needs and aspirations of mankind (figure 1).[10]

Of particular interest is the viewpoint indicated in point b). Observed from a sufficient distance, a *production network*, defined by a certain basket of OUTPUT goods, must not be considered only as a *global producer* composed of interconnected orgons that selfishly try to maximize their internal efficiency, but appears as am *Integrated Production System* that operates according to the logic of an *Autonomic Cognitive Computer*, carrying out progressive syntheses of labour and value (figure 4) through its

[9] «Change in the substance of any of the relationships affects the overall structure. Since a change in any relationship affects the position of those involved, the whole set of interrelated relationships is subject to change and that has consequences for the outcome of a relationship for those involved. A dyad, a relationship, is a source as well as a recipient of change in the network. […] The essence of the network function of business relationships is that as they arise they form a structure of actor bonds, activity links and resource ties where third parties are integrated. How the relationships develop and unfold is important for the features of the actors' organization, activity pattern and resource constellation and thus for the properties of the networks structure, such as its stability. The emergent structure has in any given moment a limiting effect on its actors at the same time as it provides the base for future development» (Håkansson – Snehota 1994, p. 41).

[10] If we ignore the holonic arrangement of organizations and only consider the local interactions, then the Production Kosmos could also be viewed as a Complex Adaptive System along the lines of Axelrod (1997), where the individual firms interact by adapting reciprocally in order to remain vital, thereby maintaining the global system vital, even if the idea of progress is not explicitly considered in the CAS (Goldspink 2000; Holland 1995; Mella 2002; Mitleton-Kelly 1998).

successive connection with a *demand* reservoir for final goods, which satisfy needs and aspirations, and its *antecedent* connection with a *labour* reservoir.

As we know from Chapter 2, the ACC leads to two interesting productive applications in organizations that carry out complex processes: the Holonic Manufacturing System (HMS) and the Bionic Manufacturing System (BMS).

If we adopt the holonic vision of production networks – whose logic is the development of multi-level processes that integrate in order to produce finished products (final processes or final modelons) – then we can immediately interpret these as ACCs, and in particular as HMSs or BMSs.

In this sense the Production Kosmos (figure 4) – as an Integrated Production System acting according to the logic of an HMS or a BMS – is capable of:

a. locally perceiving the needs and aspirations in the demand reservoirs,
b. determining the labour availability in the labour reservoirs,
c. carrying out successive syntheses through a parallel information processing that extends vertically and horizontally through the entire orgonic network,
d. finding the best dynamic pairing between the demand for goods as information input, on the one hand, and consumer satisfaction and labour employment as an operational output, on the other.

5.11 The Operational Program of the Production Kosmos

We can theorize the functioning of the Kosmos (figure 4) as an ACC**,** and in particular as an HMS or a BMS, by using the following operational program:

A. the orgons that produce final consumption goods act as *sensors*, in that they are matched with consumers that declare their needs and aspirations, in particular the desired minimum quality levels;
B. the production orgons are also matched to the base holons – the workers – who state their availability to work, specifying the quantity (the length of time of the work) and the quality (skills, specialization, responsibilities, etc.);
C. the ACC "knows" the productivity levels (π) of the individual firms in the production network and calculates the production volumes obtainable with the available labor;
D. the ACC "knows" the consumption rates of consumers and thus determines the needs and aspirations that can be satisfied with the goods obtained from the available labor; or the quantities (and qualities) of labor required to produce the goods needed to completely satisfy the needs and aspirations;

E. the ACC, as a global correlator, tries to obtain an equilibrium between the stated needs and aspirations and the available labor, allocating the labor among the needs and aspirations according to the following rules:
   1. if the labor that is declared to be available is below that required in terms of quantity/quality, ask for more labor; or increase the productivity levels of the individual orgons in the network;
   2. if the declared needs and aspirations exceed those that can be satisfied by the available labor, try to reduce the needs and aspirations; or increase the productivity levels of the individual orgons in the network;

F. when the firms in the network increase the quality of their production and the productivity of their processes – either based on a request from the orgons up the line or through creativity – this improvement has repercussions for the entire branch of the network;

G. a feedback loop of support is created: the increase in the needs and aspirations that are satisfied leads to an increase in the stated needs and aspirations;

H. this forces the firms in the network to increase their demand for labor, with a consequent increase in employment or an increase in productivity.

As Wilber explicitly notes (Tenets 9 to 11), the bi-directional influence of the holons, the interrelation between *micro* and *macro*, between *all* and *parts*, produces the basic *property of continual improvement* that distinguishes each production network.

As this characteristic derives from the *rules of selfishness* that characterize the cognitive behaviour of the orgons, there is no need for further consideration; nevertheless – leaving a more in-depth treatment for the next section – I would like to observe how the technological, technical and scientific progress of mankind is the consequence of the *triggering effect* of the holarchy – the process of rapid diffusion of innovations along the orgonic chain – in cases where an innovation improves the INPUT vector of *successive* orgons and the OUTPUT vector of *antecedent* orgons, expanding in both directions of the branches in question, often with a *reinforcing loop*.

The cognitive capacity of the orgons thus becomes fundamental; the orgons must also continually develop *creativity* and undertake research and development. Important challenges today involve new materials, nanotechnologies, and alternative energy sources to oil, as well as progress in the fields of biology and genetics.

Each orgonic network, thanks to its *hubs*, with their *feedback loops*, enhances *self-organization* as well as a rapid and widespread *performance improvement* for orgons at every level.

The changes that improve the holarchy are egotistically preserved and diffused, and they can also generate new branches; disadvantageous ones are eliminated or mitigated. In the contrary case, the branch of the holarchy in which they occur is eliminated.

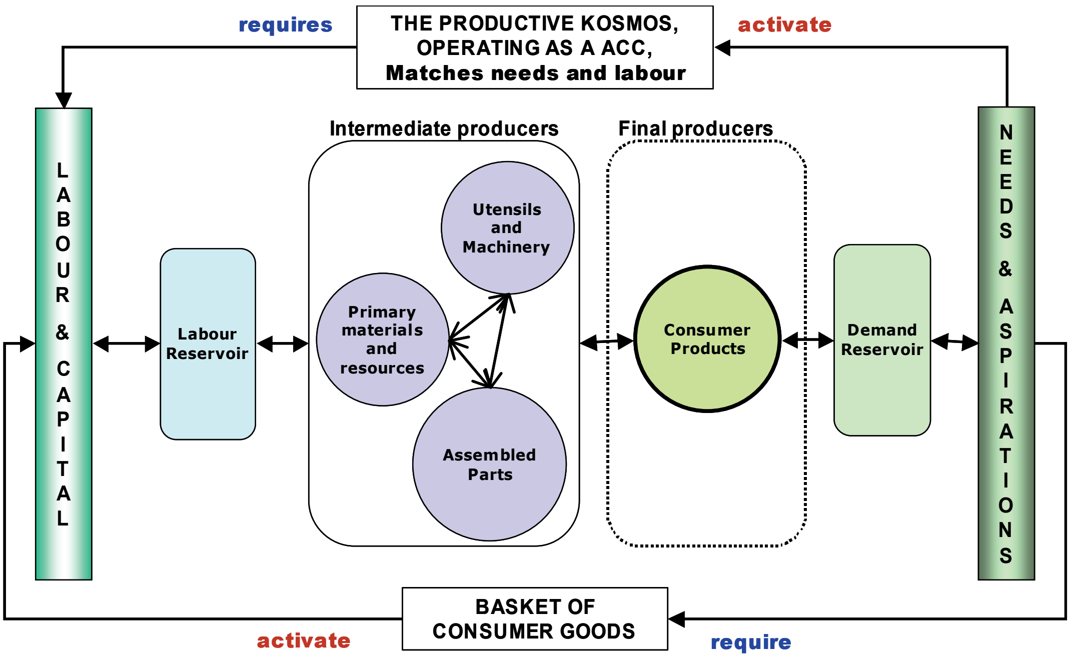

Figure 4. The productive network constituting the Production Kosmos (*Source*: adapted from Mella 2006).

5.12 Three "Laws of Production Networks". FIRST LAW: Expansion

The *cognitive* and *creative* processes that characterize orgons do not allow us to predict the actual evolution of production networks; nevertheless, if we assume that orgons – consciously or not – follow the selfish RULES of behaviour 1) to 10) above, then we can deduce several typical trends, or behavioural schema – perfectly in line with the laws of holarchies – which I have called *laws of networks*, in order to highlight their apparent inevitability and cogency.

The First Law predicts that Orgonic Networks *tend to expand*, that is, to increase in depth (vertical expansion), in width (horizontal expansion), and in their ramification.

The law is supported by the characteristics of the orgons – spontaneous genesis and tendency to connect – as much as by the basic RULES of behaviour: if at any level of the network the orgons try to enlarge their demand reservoir, improve their own INPUT vector and increase in size, then we can always assume an increase in connections both along the boundaries of the network as well as internally, with the formation of increasingly more connected branches at ever greater levels of productive specialization.

The expansion occurs in three ways:

1) the network expands its own boundaries and new links are added to the borders to enable connection to new demand reservoirs for final products;
2) the network adds more levels; productive specialization, creativity and research lead to the spontaneous creation of orgons whose outputs are the specialized inputs of successive orgons; the orgonic chain becomes longer as well as wider. Today, in modern economies, it is easy to recognize that even the smallest components of a product are acquired externally from ever new and specialized orgons;
3) two or more networks merge; many networks arise independently to produce distinct products aimed at differentiated demand reservoirs. When several final products are complementary and are obtained in an integrated manner from a single orgon; when an autonomous product becomes a component of a final product; or when several intermediate processes are centered on antecedent hubs, the networks can also be considered merged.

We can outline a dynamic trend by considering the gradual expansion of the networks to take on increasingly larger dimensions:

LOCAL MICRO NETWORKS that characterize production in families, in villages, in cities, and in small regions, since the *demand reservoir* and that for *resources* and *labour* are located in a single limited territory. Knowledge develops through observation and imitation.

LOCAL MACRO NETWORKS that extend to increasingly larger territories: the countryside, provinces, regions, which, in any case, are characterized by production from local resources of goods and services destined for local consumption. Physical markets arise as places for the concentration and supply of output of products to sell; production knowledge is accumulated and passed on orally as well as through apprenticeships.

BIPOLAR MICRO NETWORKS that expand beyond the original territory in order to seek resources in other territories: *consumption* and *production* refer to a given *demand reservoir* located in a territory, but the resources are imported by *resource reservoirs* situated in others. According to the RULE for the improvement of economic efficiency, *production* becomes increasingly separated from *consumption* and joined to *resources*. *Production* and *resources* are located in a territory; consumption remains in another territory.

MULTIPOLAR NETWORKS, where resources, production and consumption are in separate areas, which, however, are interconnected through a dense network of exchanges carried out by other connector orgons. Not only are the *production* processes separated from *consumption* and *resources*, but *production* itself is segmented into thousands, millions of specialized productive processes located in very diverse areas. Multipolar networks become *a-spatial* and *a-temporal*.

INTERNATIONAL AND GLOBAL NETWORKS that derive from the multipolar networks when the latter extend their links to different countries. Today these networks dominate the international economy and expand thanks to the *connection* process of the national networks.

5.13 SECOND LAW: Orgonic Networks tend to increase the quality of their performance through a non-linear cumulative process

This law derives from the tendency of orgons to improve their INPUT and OUTPUT vectors and from the general property of holonic networks to spread their individual improvements.

The network improves its performance even if a casual improvement occurs in the performance of only a single orgon; but RULE 3) leads all orgons, in order to improve their INPUT and OUTPUT vectors, to produce innovations and to make discoveries and inventions that, if useful, spread simultaneously to all branches of the network, though with differing intensity, thereby involving the most distant and unforeseen ramifications.

This law supports an important *corollary*: the improvement in the quality of the network's performance is *permanent* and *cumulative*, thus *path-dependent* and *non-linear*, and in general exponential, producing an increasing return (in the sense of Arthur 1994) regarding the network's economic efficiency.

In fact, as the improvements are transmitted to the network branches they not only spread but, until substituted by other improvements, are *preserved in time and space*, producing a cumulative effect that leads to an acceleration in the progress of each sector. Each improvement derives from a creative or rational action based on a previous improvement. If this were not the case then we could not explain the monumental and accelerated progress in electronics, telecommunications, transport, war production, and biology.

There is no "natural" turning back from progress!

And even if Stanley Kubrick's prophecy in the prologue *The Dawn of Man*, which opened his famous film *2001: A Space Odyssey* (GB 1968) – with the splendid fade-out "bone-spaceship", which embraces the entire parabola of mankind – should come true; and even if the following words from Albert Einstein prove true: «I don't know which arms will be used to fight World War III, but the fourth will be fought with a club»; there is no doubt that, having returned to Kubrik's bone and Einstein's club, after a suitable period of evolution we would attain a state of progress similar to the present one.

5.14 THIRD LAW: Orgonic Networks are resilient networks that tend to continue on as if they were living entities

This law is explained by the natural tendency of the orgons, as well as the branches that spread out from them in a *forward* direction, to survive through the adaptation of the INPUT and OUTPUT vectors, when this is necessary for their autonomy.

Thus, when an orgon is destroyed the entire successive branch – which remains functional for some time – tries, in order to avoid extinction, to adapt by connecting to another orgon; if this is not possible, the pressure to restore the antecedent branch is so intense as to make it likely that other orgons will be spontaneously created to substitute the destroyed one. If this spontaneous genesis does not occur, and if the *successive* orgons are also not able to internally produce the missing INPUTS, then it is likely that the INPUT vector will be modified so as to substitute various components for the latter. If this, too, is not possible, then the network will be broken.

As a result, production networks are *resilient*; they can withstand damaging events and a lack of resources. They replace nodes with other ones and repair the damage (natural calamities cause damage that is immediately repaired to restore the functionality of the destroyed links);[11] they replace parts that do not improve (inefficient orgons that cease their activities and others that are created and produce patents, inventions and know-how); they are strengthened through the creation of political and legislative superstructures that favour their existence, improvement and expansion. In other words, they try to survive.[12]

It is precisely this feature of networks to preserve and remodel themselves in order to survive, restoring any gaps in their links and replacing old links with new ones, that allows us to conceive of them as *Complex Adaptive Systems* in the economic environment (Gell-Mann 1995/96; Holland 1995).

Brian Arthur (Arthur *et al.* 1997) has identified *six* properties that characterize all economies: (1) widespread interactions, (2) the absence of a centralized and global control, (3) transversal hierarchical organization, (4) continual adaptation of the agents, (5) continual innovation and (6) dynamic progress far from the equilibrium.

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[11] Resiliency is the capacity of a material to resist deformation or dynamic breakage, or the capacity of yarn or fabric to return to its original form after deformation.

[12] «We define survivability as the capability of a system to fulfill its mission, in a timely manner, in the presence of attacks, failures, or accidents. We use the term system in the broadest possible sense, including networks and large-scale systems of systems» (Ellison *et al.* 1997).

More than any other structure, Orgonic Networks present these properties since orgons, viewed as autonomous entities in terms of their cognitive function, represent a collectivity of agents that interact and exchange information with their environment in order to maintain over time their internal processes through adaptation, self-preservation, evolution and cognition, making individual and collective decisions as part of a network of micro behaviours (Allen 1997).

We must also point out that networks also are able to survive because the orgons they are made up of not only produce the OUTPUT that is used for *successive* orgons but, through their production activity, maintain and continually regenerate the network of reticular relations that account for their existence. Orgonic Networks, viewed as structures that are self-contained within their self-organization – even if continually adaptive – can thus be conceived of as *autopoietic and living systems*, since they fall entirely within the basic definition proposed by Herberto Maturana and Francisco Varela (1980).

In particular, the Production Kosmos is in every respect an autopoietic machine; that is:

> … a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network (Maturana – Varela 1980, p. 131).

The orgonic networks that make up the PK tend to endure for a long time by continually regenerating the *processors* (orgons) and the *network of processes* that produce the production and value flows. Since no input comes from outside, the PK is *organizationally closed* and regenerates itself thanks only to the cognitive activity by the orgons that produces the cognitive activity of the entire orgonic network as the emerging effect of the activity of the individual nodes.

> An autopoietic system is operationally closed and structurally state determined with no apparent inputs and outputs. A cell, an organism, and perhaps a corporation are examples of autopoietic systems (Varela).[13]

> The autopoietic organisation can be characterised in terms of three types of relations between components and production processes: specificity (what), constitution (where), and order (when) (Mingers 2002, p. 294).

[13] At: <http://en.wikiversity.org/wiki/User:Jtneill/Autopoiesis>.

5.15 No Production without Consumption

Productive networks are found wherever man acts to satisfy his needs and aspirations. They represent the system for the efficient transformation and accumulation of resources in order to obtain goods and services to satisfy a demand for final consumption (Thorelli 1986; Powell 1990). As a result they concern consumption as well as production; *there is no consumption without production*; but, conversely, *there is no production without consumption*. The flow of consumption which provides an "outlet" for the production network, thereby allowing it to regenerate the production flow, is an integral, not disconnected, part of the Production Kosmos.

Paraphrasing Koestler (1967), it seems there truly is *a ghost in the production machine* whose *invisible hand* – acting on the individual nodes of the productive network – determines increasing levels of productivity and quality; increases the quality and quantity of satisfied needs and aspirations; and reduces the burden of labour, thereby producing ever higher levels of progress in the entire production Kosmos.[14]

This is clearly observable in all advanced economies, where, as Adam Smith observed, the dynamic trends are caused by the production organizations which, due to their constant self-interested effort to gain the most advantages for themselves, behave as if they were directed by an "invisible hand" in order to reach increasingly higher *standards:*

> It is not from the benevolence of the butcher, the brewer, or the baker, that we can expect our dinner, but from their regard to their own interest. By directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention. Nor is it always the worse for the society that it was not part of it (Smith 1776, p. 456).

There is nothing metaphysical about this evolution: it is produced and governed by *selfish* orgons and by the laws of Orgonic Networks.

Thus, I propose the following general conclusion: the *function* of each *Integrated Production System* is to maximize the efficiency of the process that transforms labour into the basket of final goods; the *functionality* of this system is to allow consumers to maximize the satisfaction of their needs and aspirations.

That is why *we need production networks*.

But it is also clear that the *networks need us*, our consumption, our labour and, above all, our *faith in the future*, which leads us to consume more, to shorten the

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[14] The invisible hand also, and perhaps prevalently, operates among holons of the same level that can form Combinatory Systems of varying size. For more on this, see the Combinatory Systems Theory site at: <http://www.ea2000.it/cst>.

utilization time of goods, to replace goods that are still efficient with newer ones, and to invest our lives in education and our capital in new productive links.

Consumption and *production are inseparable*, but one thing is certain: the networks can guide consumption, but only *faith in the future* can feed the necessary flow of consumption to maintain and expand the production networks.

Some final thoughts. Will networks always expand? Will they cover the entire globe? Will they employ robots?

In principle, we can assume from the THREE LAWS OF NETWORKS that the answer is inevitably: "YES".

This "YES" contains the true significance of economic globalization, which has brought forth apocalyptic visions.

We must be optimistic and trust in man's capacity to self-regulate his activities, since the *rules of selfish behaviour* of the Production Orgonic Networks indicate there is no other way:

> The development of a people does not derive primarily from money, nor from material aid or technology, but rather from the formation of consciousness, from the advancement in intelligence and morals. It is man who is the main protagonist in development, not money or technology (John Paul II, *Redemptoris Missio*. N. 58).

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(Note: all the sites mentioned have been visited in November 2009)

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5 – The Production Kosmos as a Selfish Orgonic Network

Piero Mella is Full Professor of Business Economics and Control Theory at the Faculty of Economics, University of Pavia. In the past he has been the Dean of the Faculty as well as the Director of its Department of Business Research. Author of dozens of publications (among which a treatise entitled *Amministrazione d'Impresa* [Management of the Firm], UTET Press), for years he has researched systems theory from multiple perspectives. His recent essays about Systems theory include: *Guida al Systems Thinking* [A Guide to Systems Thinking] (Il Sole24Ore, Milano, 2007) and *Sistemi di controllo* [Control Systems] (Franco Angeli, Milano, 2008). He has developed the Theory of Combinatory Systems (www.ea2000.it/cst); he is editor of the journal «Economia Aziendale on-line» (www.economiaaziendale.it).

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A minor conceptual revolution has been under way for less than forty years now, beginning in 1967 with the publication of Arthur Koestler's *The Ghost in the Machine* – a phantasmagorical book in terms of the breath and variety of its content – which formally introduced the concepts of holon and holarchy (the hierarchical ordering of holons). Koestler's idea is clear and simple: in observing the Universe surrounding us (at the physical and biological level and in the real or formal sense) we must take into account the whole/part relationship between observed "entities".

In other words, we must not only consider atoms, molecules, cells, individuals, systems, words or concepts as autonomous and independent units, but we must always be aware that each of these units is at the same time a whole – composed of smaller parts – and part of a larger whole.

In fact, they are holons. The entire machine of life and of the Universe itself evolves toward ever more complex states, as if a ghost were operating the machine.

The concepts of holon and holarchy have since been used, especially in recent times, by a number of writers in a variety of disciplines and contexts, and these concepts are rapidly spreading to all sectors of research. In particular these concepts are more and more frequently found in the literature of physics, biology, organizational studies, management science, business administration and entrepreneurship, production and supply chain systems. Connected to these ideas are those of holonic networks, holonic and virtual enterprises, virtual organizations, agile manufacturing networks, holonic manufacturing systems, fractal enterprise and bionic manufacturing.

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