Chapter 8

Stratified Cosmic Order: Distinguishing Parts, Wholes, and Levels of Organization

Jitse M. van der Meer

Introduction

Historically, stratification as a characterization of cosmic order issued from a response to the problem of change. Parmenides and Democritus reduced becoming to being. Plato and Aristotle tried to acknowledge both constancy and change, Plato by assigning them to separate realms of form and matter, Aristotle by uniting form and matter into concrete substance. Prime matter conceived as potential being becomes concrete actual being, that is a substance, when acted upon by the substantial form conceived as actuality. A substance can function in turn as matter in that it has the potential to become a higher substance under a different form. Actualization of this potential produces the Aristotelian levels of being: inorganic things, plants, animals, and rational beings.

Today we find a variety of different notions of stratified order. They are distinguished on the basis of the ordering relation between the components of the system (Table 8.1).[1] The problem to be addressed is the lack of a unified ordering relation in characterizations of the order of nature.[2] One of the two

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[1] The terms 'component' and 'constituent' refer to parts or subsystems that are interrelated regardless of the kind or strength of relation. Aggregates are excluded because their parts are not related.

[2] This problem has been addressed before by Mario Bunge, *Treatise of Basic Philosophy, vol. 4. A World of Systems* (Dordrecht, 1979); Marjorie Grene, 'Hierarchies in Biology', *American Scientist*, 75 (1987): pp. 504–10; Marjorie Grene, 'Hierarchies and Behavior', in Gary Greenberg and Ethel Tobach (eds), *Evolution of Social Behavior and Integrative Levels* (Hillsdale, 1988), pp. 3–17; Ernst Nagel, 'Wholes, Sums, and Organic Unities', *Philosophical Studies*, 3 (1952): pp. 17–32; Stanley N. Salthe, *Evolving Hierarchical Systems* (New York, 1985); Stanley N. Salthe, 'Summary of the principles of hierarchy theory', *General Systems Bulletin*, 31 (2002): pp. 13–17; Sytse Strijbos, 'The Concept of Hierarchy in Contemporary Systems Thinking – A Key to Overcoming Reductionism?', in Jitse M. van der Meer (ed.), *Facets of Faith and Science*, vol. 3. (Lanham, 1996), pp. 243–55; Jitse M. van der Meer, 'The Multi-Modal Hierarchy: Distinguishing Parts, Wholes, and Levels of Organization', in M.L.H. Hall (ed.), *Proceedings of the 40th Annual Meeting of the International Society for the Systems Sciences* (Louisville, 1996), pp. 507–18; Uko Zylstra, 'Living Things as Hierarchically Organized Structures', *Synthese*, 91 (1992): pp. 111–33; Uko Zylstra, 'The

Table 8.1 Main types of hierarchy in the literature

Sample relata in representative systems Type of ordering relation	Galaxy | Star	Organism | Molecule	Solar System | Gas Cloud	Commander | Soldier	Human Animal Plant Mineral
necessary but insufficient condition	✓	✓			✓
constitution, physical whole-part	✓	✓			✓
control	✓	✓			✓
lineage		✓	✓		✓
command				✓	
specification					✓
	(a)	(b)	(c)	(d)	(e)
Synchronic interpretation	✓	✓		✓	✓
Diachronic interpretation		✓	✓		✓

Notes: Lineage refers to causal chains of development such as in (b) molecule to organism, (c) gas cloud to planetary system, and (e) potential to actual existence. There is no lineage in (a) and (d) because stars are contained in galaxies, but do not develop into them, and soldiers do not develop into commanders. (b) has been interpreted synchronically as a non-evolutionary relationship between molecules and organism as well as diachronically as the evolution from molecule to organism. Likewise, (e) has been interpreted synchronically as the relationship of potential and actual existence (Aristotle) as well as diachronically in terms of evolution.

main contemporary ordering relations is the spatial whole-part relation. It underlies the constitutive hierarchy. The other is the relation between mutually irreducible and qualitatively different modes of existence found in the specification hierarchy (Figure 8.1).

My thesis is that there is a single stratified order of nature – the specification hierarchy. The specification hierarchy distinguishes between qualitatively different modes or levels of existence. 'Mode' or 'level' refers to the qualitatively unique way of functioning of entities, processes and events including their relations with other levels.[3] The spatial whole-part relation is one of these modes. This chapter starts with a description of the specification hierarchy. Then follows a description of the spatial whole-part relation and its limitations. The specification hierarchy is then used to resolve problems with level structures and to reduce

Influence of Evolutionary Biology on Hierarchical Theory in Biology, with Special Reference to the Problem of Individuality', in Jitse M. van der Meer (ed.) *Facets of Faith and Science*, vol. 2. (Lanham, MD, 1996), pp. 287–99.

[3] In this chapter, the term 'entity' refers to entities, phenomena and processes.

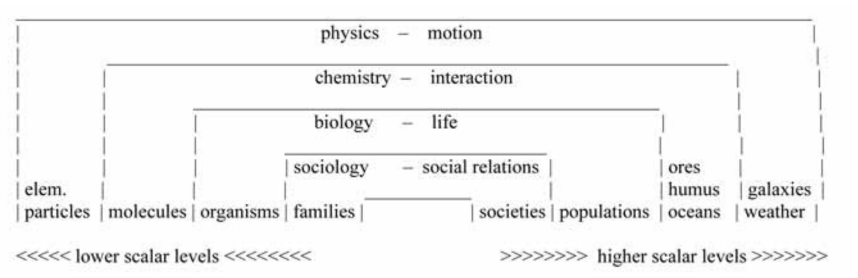

Figure 8.1 Entities, processes and phenomena ranked according to two ordering principles

*Note*s: Horizontal: entities ranked in levels of scale in a hierarchy of spatial constitution (composition, nesting). Smaller entities provide initiating conditions for larger entities. Larger entities provide boundary conditions for smaller entities. Vertical: entities ranked according to selected modes of functioning in a hierarchy of specification. For all modes of functioning see Clouser, R. A Sketch of Dooyeweerd's Philosophy of Science. In: Facets of Faith and Science, Vol. 2. J.M. van der Meer, ed. Lanham, MD: University Press of America. 1996: 81–97 (1996). Modified after Salthe, S. N. 1985. Evolving Hierarchical Systems. Columbia University Press: New York, Fig. 16.

the panoply of hierarchies to the specification hierarchy. Space prevents me from considering presuppositions of hierarchy theory, accounts of the unity of parts in a whole taken as an Aristotelian-Thomistic substance and the emergence of levels of organization.

The Specification Hierarchy

Distinguishing Entities and the Ways they Function

There are qualitatively different kinds of entities or wholes which function in qualitatively different ways (Figure 8.1). I distinguish entities from the ways they function.[4] For instance, we experience an elephant as functioning in a variety of ways or modes (Figure 8.2). It functions in a numeric way by having parts that can be numbered. It functions in a spatial way by being extended in space. It functions kinematically by having momentum, physically by having mass, biotically by being alive, perceptively by responding to stimuli, and socially by having a defined social organization. In sum, an elephant has numerical, spatial, kinematic, physical, biotic and social properties. Each category of properties describes a way in which the elephant functions. There are lawful relations among the properties within and

[4] This distinction was introduced by Herman Dooyeweerd, *A New Critique of Theoretical Thought*. vol. 3, (Nutley, 1969 [1935]).

self-reflective			object functions	subject functions
sensitive		object functions	subject functions	
biotic	object functions	subject functions		
physical	subject functions			
kinematic				
spatial				
numerical				
▲ properties and laws/entities ►	physical entities	plants	animals	humans

Figure 8.2 Distinction between kinds of properties and laws (vertical axis) and kinds of entities (horizontal axis).

*Note*s: Each kind of entity has subject functions (highest subject function listed) as well as object functions (lowest object function listed). Humans have no object functions. There are more kinds of properties than are shown. For instance, some animals function socially and the self-reflective functioning of humans issues into many other ways of functioning, ranging from the logical to the spiritual. For an exhaustive list and an explanation of the modes of functioning, see Clouser (1996).

between categories. These relations can be represented as laws of nature that are characteristic for entities functioning in the corresponding mode. Generally, each category of properties – numerical, spatial, kinematical, physical, biotic, perceptive and social – can be represented by a set of modal laws. The coordination of these functional properties into a coherent unity is itself subject to a separate category of laws that govern the entity.

Order of Succession in the Way Things Function

There is an order of succession in the ways entities function. Any given way is a necessary but insufficient condition for the possibility of the next way (Figure 8.1). Spiritual functioning requires self-reflection, self-reflection requires perceptive functioning, perception requires life, life requires matter, matter requires motion, motion requires space and functioning in space requires number.[5] This particular sequence defines the *level structure of modes of functioning* of a person. In general, the unique organization and behaviour of an entity are characterized by the highest modality in which it functions actively, the *qualifying function*. For an entity to function *actively* in a mode of existence means that it is subject to the

[5] My current level system is intended to be neutral with respect to dualism and non-reductive physicalism, though it is flexible enough to accommodate either should the evidence so demand.

ordering principle of that mode. For example, a pebble is qualified by its physical function, a plant by its biotic function and an animal by its perceptive function. Thus the level structure of modes of functioning can be used to rank entities according to their qualifying function and it turns into a level structure of entities (Figure 8.1). Aristotle did this with his levels of inorganic → plants → animals → rational beings. Each level is a set containing entities with the same qualifying function as its members. Therefore, the succession of modes of functioning is also a *level structure of qualifying functions*. This is the specification hierarchy because it specifies the qualifying function of any entity. The level structure of entities and that of modes of functioning are abstract representations of the same stratified ontological order because both are based on the properties of entities.

From the synchronic perspective of this chapter the specification hierarchy is a representation of a series of different modes of functioning in order of generality.[66] The order of succession of modes of functioning can be defined as an ontological relation between entities:

> Let E1 and E2 be two entities. Then E1 has a lower qualifying function than E2 if
>
> 1. E1 is necessary, but insufficient for the existence and proper function of E2, and
> 2. E2 is not necessary for the existence and proper function of E1.

For example, molecules are a necessary, but insufficient condition for the existence of organisms but organisms are not necessary for the existence of molecules. Therefore, molecules function in a mode that is more general than organisms. The specification hierarchy can also be interpreted from a diachronic perspective as a sequence of qualitatively different modes of functioning that have emerged in succession from the physical mode of functioning by interpolation (Figure 8.1).[7]

Identifying Modes of Functioning

Initially a mode of functioning is identified empirically. But this leads to an endless proliferation of modes without order. Therefore, I add self-contradiction as an identifier. Conflating two qualitatively different modes of functioning, that is, applying epistemological reduction, results in self-contradiction.[88] For

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6 Stanley N. Salthe, 'Two Frameworks for Complexity Generation in Biological Systems', in Carlos Gershenson and Tom Lenaerts (eds), *Evolution of Complexity* (Bloomington, 2006), pp. 99–104.

7 Ibid.

8 Several authors have recognized epistemological reduction as the reason for contradiction: Timothy F.H. Allen and E. Paul Wyleto, 'A Complexity of Plant Communities', *Journal of Theoretical Biology* 101 (1983): pp. 529–40, see pp. 529–530; Dooyeweerd, *New*

instance, common experience leads one to distinguish the material and moral functioning of persons. The contradiction between moral freedom and natural (causal) determinism – known as Kant's Third Antinomy – is due to a denial of this distinction. Moral freedom characterizes the moral mode of functioning of people. Causal determinism characterizes the (classical) physical mode of functioning of humans as physical entities. A self-contradiction arises when classical physical causality is applied to moral functioning because it leaves no room for human responsibility with its own 'causality'. The criterion of excluded self-contradiction stipulates that there can be no contradiction between irreducible modes of functioning unless a boundary is ignored. In this case self-contradiction arises out of the failure to respect the boundary between the physical and the moral modes of functioning of human beings and the reduction of moral reasoning to physical causation. Similar arguments can be developed for distinguishing other modes of functioning between which there are differences of kind, not of degree.

Definition of Whole-Part Relation

The key to being a part of a natural whole is to be strongly integrated in the whole. This entails two conditions. First, the part must be a necessary but insufficient condition for the existence and proper functioning of the whole. Second, the part must be subject to the qualifying function of the whole it is a part of. If a whole W1 becomes part of another whole W2 that functions in the *same mode*, then W1 is an active part of W2. For instance, an atom in a hydrogen molecule is an active part of the molecule because both the atom and the molecule are directly subject to the same qualifying function of the physical mode which is physical interaction. Specifically, when an isolated hydrogen atom becomes a molecular hydrogen atom, its charge distribution, symmetry and nuclear magnetic resonance signal change. Due to quantum mechanical superposition, nuclear magnetic resonance cannot identify the part (H atom) in the whole (H2 molecule). But nuclear magnetic resonance can distinguish atomic hydrogen from molecular hydrogen. Thus one can infer that hydrogen molecules have hydrogen atoms as constituent parts. It is this changed molecular atom as opposed to the isolated atom that is an active part of the molecule. In becoming an active part, a whole – the isolated hydrogen atom – acquires new properties which we refer to as parts properties. But it also retains properties it has as a whole.

In contrast, a passive part is an entity which has become part of another entity that functions in *another mode*. Consider the spatial and the physical modes of functioning, specifically the space around the atom in which its electrical charge is distributed. The spherical symmetry of this space is an active part of the space

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Critique, vol. 2, pp. 38–41; Hans Jonas, *The Phenomenon of Life: Towards a Philosophical Biology* (New York, 1966): p. 132 n2; Howard Pattee, 'The complementarity principle in biological and social structures', *Journal of Biological and Social Structures* 1 (1978): pp. 191–200, see p. 193.

occupied by the atom because the symmetry is integrated in a spatial system and subject to the laws of geometry.[9] However, physical interaction between atoms changes their spatial properties. This influence on the symmetrical shape of the atom is indirect, mediated by the atom. Atomic symmetry, therefore, functions passively as an object of physical interaction. A spatial phenomenon such as atomic symmetry has two kinds of properties: those it has because it functions as a spatial subject itself (active properties) and those imposed upon it by the molecule of which the atom became a part, functioning as an object of physical interaction (passive properties).

Correspondingly, in the biotic mode, cells are active parts of an organism because cells are directly subject to the qualifying function of the organism. Both cells and organisms are alive. In contrast, a whole can also become a part of another whole which functions in a *different* qualifying mode. DNA has numerical, spatial, kinematical and physical properties by virtue of which it is actively subject to the laws of number, space, motion and interaction. These are its active properties. It is not actively and directly subject to biotic law because it is not alive. But DNA also contains and transmits genetic information – biotic properties it has by virtue of being produced by a cell. That is, DNA is a passive part of a cell because it is indirectly subject to biotic laws via the cell. Thus both DNA and cells have a function in the biotic subject (the organism), DNA as object, cells as subject. Further, DNA also has social and economic properties because it can function socially in the identification of criminals and economically in the production of proteins. But it has them passively by virtue of being used by wholes of a qualitatively different kind (humans). The order of succession of active functions determines the order of succession of passive functions. In sum, a whole such as DNA which functions as a part of a different kind of whole has two kinds of properties: those it has by virtue of functioning as a whole itself (active properties) as well as parts properties imposed upon it by the whole of which it is a part (passive properties).

Similarly, in the social mode, people are active parts of a society because they are directly subject to the social qualifying function of the social whole they are part of. They are related socially amongst each other. Individuals and societies are functioning actively in the same social mode. When an isolated unborn individual becomes a part of society his or her characteristics change. It is the socially developing person who is an active part of society. Likewise, a business is an active part of a society because both business and society are actively subject to social (economic) law. In contrast, the brain is not an active part of society – it is actively part of the organism because the brain is integrated in a biotic system and subject to its laws.[10] The brain does not actively and directly engage in social interaction, the human being does. However, social and cultural factors shape brain development. This influence is indirect, mediated by the organism. Like DNA as an object of organic formation, the

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9 Bunge, *Treatise*, vol. 4, p. 5.

10 Ibid.

brain functions passively as an object of social formation. Animals are also objects of socioeconomic activity. They are passively subject to socioeconomic law because they have monetary and aesthetic value. As socioeconomic commodities animals are actively subject to biotic laws. They are not actively and directly subject to socioeconomic law because they do not engage in business.

In conclusion, the active functions of an entity describe the properties it has by virtue of its own activities. Since these activities depend on nothing else, they define the entity. The passive functions of an entity describe the properties it has by virtue of the activities of another entity that functions in a different mode. Thus entities have active and passive properties. There is a corresponding distinction between active and passive parts. Active parts have active properties, that is properties due to the activities of their whole and, therefore, of the same kind as the properties of their whole. Wholes and their active parts have the same qualifying function and are subject directly to the same characteristic set of modal laws. Passive parts have both active and passive properties. Passive parts are wholes with a different qualifying function than the whole they are a part of. The active properties of a passive part are due to its own activities. The passive properties of a passive part are the combined effect of its own activities and those of the whole of which it became a part. When a whole Wn becomes a passive part of a higher-level whole Wn+1 or a lower-level whole Wn-1, the activities that qualify Wn+1 or Wn-1 direct the activities that qualify Wn such that Wn acquires new properties that turn it into a passive part that serves Wn+1 or Wn-1. That is, passive parts have properties that represent a propensity or potential to function as an object in a different-level entity. Thus,

Definition A: Let W have parts P_i (i = 1...n). Then P_i is a part of W if

1. P functions actively or passively in the mode of W, and
2. P_i is necessary, but *insufficient* for the existence and proper function of W, and
3. (P_1 ... P_n are jointly necessary and *sufficient* for the existence and proper function of W.

Definition B: P_i is an active part of W if P_i and W are subject to the same qualifying function.

Definition C: P_i is a passive part of W if P_i and W are subject to different qualifying functions.

Now that we have described the specification hierarchy let us look at its potential to solve the problems of the constitutive hierarchy.

The Constitutive Hierarchy

Definition of Whole-Part Relation

The constitutive hierarchy has the spatial part-whole relation as its ordering principle throughout. In the literature, physical inclusion is usually substituted for spatial inclusion because spatial inclusion has no causal efficacy. This is a problem of the constitutive hierarchy because spatial and physical reality each have their own ordering principles. This difference is acknowledged in the specification hierarchy which has spatial inclusion as a separate ordering principle that operates at only one level. Here I merely signal the problem. In what follows, physical constitution includes spatial constitution.

While spatial inclusion characterizes a separate level in the specification hierarchy, it recurs at higher levels without characterizing them. Rather, spatial inclusion at a higher level is characterized by the ordering principle of that level. For instance, atoms do not constitute molecules in the same way as cells constitute organisms, and cells do not constitute organisms in the same way as organisms constitute societies. Failure to recognize this produces confusion about the ordering principle being used in the constitutive hierarchy – physical constitution or biotic constitution or social constitution.[11] In contrast, the specification hierarchy describes such qualitative differences in modes of constitution. It uses the qualitatively different ways parts constitute wholes as so many ordering principles. This is possible because in a specification hierarchy lower-level ordering principles continue to apply at higher levels – a feature noted by Hartmann.[12] Thus the spatial part-whole relation is repeated at the physical level but in a modified way, as a physical part-whole relation. Both the spatial and the physical part-whole relations are repeated at the biotic level but again in a modified way, as a biotic part-whole relation. In this way, the specification hierarchy incorporates differences in modes of functioning of part-whole relations. The mode of functioning that qualifies each level also qualifies the kind of part-whole relationship that is causally relevant at that level such as the biotic and social part-whole relations distinguished by Bunge (1979).

In other words, at the physical level, atoms constitute molecules which constitute macromolecules which constitute stars which constitute galaxies (Table 8.1). At the biotic level, atoms also constitute molecules which constitute macromolecules, but they constitute cells which constitute organisms which constitute populations and so on. Again, at the social level, atoms constitute molecules which constitute

[11] In the literature on level systems 'constitution' is also referred to as scale, physical inclusion, composition, containment and nesting. These terms do not always refer to the same concept.

[12] Nicolai Hartmann, '*Die Anfaenge des Schichtungsgedankens in der alten Philosophie'*, *Abhandlungen der Preussischen Akademie der Wissenschaften*, Phil.-hist. Klasse Nr. 3. (Berlin, 1943).

organisms, but they constitute societies which constitute nations and so on. At each level of the specification hierarchy, the entities have a definite order such that a part is a necessary, but insufficient, condition for the existence and proper functioning of a whole as in the constitutive hierarchy. But physical inclusion does not describe the qualitatively unique way in which parts at levels other than the physical level constitute a whole. Rather the physical part-whole relation is modified by the ordering principle characteristic for each higher level where it occurs. Thus, the part-whole relation can exist at any level. At a specific level, part and whole function (actively or passively) in the same mode at that level. At a different level they do so in a way characteristic for that level. In contrast, the part-whole relation in a constitutive hierarchy functions only in a single mode, that of physical constitution.

Scale

The phenomenon of scale illustrates the empirical inadequacy of spatial composition as a description of cosmic order. Spatial scale represents the magnitude of a particular space. The part-whole relation is a relation of small spaces enclosed within a larger space. But, whereas space does no causal work, physical scale is made to do such work in the constitutive hierarchy.

For instance, whether entities interact directly or indirectly depends on their combined difference in spatial and physical scale (size, mass and rate of change). Entities of similar size and mass have similar rates of change. That is, they complete their cycle of characteristic behaviour in similar time intervals and can, therefore, interact directly. For instance, the Brownian motion of a dust particle is caused by the random heat motion of molecules. Even though the size and mass of a dust particle is several orders of magnitude larger than that of molecules, the difference is not large enough to prevent causal interaction. Likewise, humans can hear sound below 20,000 Herz because the microscopic hairs on their auditory receptor cells can interact with the frequency of the sound waves below that level.

But if size and mass differ by too many orders of magnitude, large entities will change at rates far below small ones. As a result, a small entity will have completed its change before it can be affected directly by a change in the large entity in which it is contained. They have become causally isolated and interact indirectly. For instance, the Brownian motion of a dust particle in the Atlantic Ocean is not causally affected by the direction of the Gulf Stream. That is, Brownian motion continues in its own small-scale frame of reference while also moving in the large-scale frame of reference of the current. Likewise, humans cannot hear sounds above 20,000 Herz because the microscopic hairs on their auditory receptor cells cannot interact with frequencies of sound waves above that level. In sum, large entities interact with small entities contained in them indirectly, by setting limits within which the small entities can behave. Within those limits the smaller entities that function in the physical mode are free to differentiate into novel entities that function in the biotic mode. The biotic mode of functioning may have emerged by interpolation between large and small entities functioning in the physical mode (Figure 8.1).[13] These three levels make up the so-called basic triadic system. From a physical point of view this triad has three levels of physical constitution: the large-scale physical environment which contains the medium-scale biotic entities which in turn contain the small-scale physical constituents. From a functional point of view there are two modes of functioning: the physical and the biotic (Figure 8.1). Salthe offers the constitutive and the specification hierarchies as two equivalent perspectives on cosmic order.

I propose that the constitutive hierarchy represents only a single (physical) mode of functioning in the specification hierarchy. Physical composition is repeated in each of the modes of the specification hierarchy but, at each of its levels, the qualifying function overrides physical composition. Therefore, its multiple modes cannot be reduced to physical composition. As we have just seen, the relation of *physical* composition or inclusion entails differences in *physical* scale between larger containing systems and smaller component subsystems. The larger entity limits or constrains the smaller one. Such whole-part effects are typical for entities that function in the physical mode. But, I suggest, at every next level up a new kind of whole-part relation is added to the existing ones. The existence of qualitatively different whole-part relations entails qualitatively different kinds of scale and whole-part causation.[14] For instance, at the biotic level the cells lining the fruitfly intestine have a life span of about seven days. Individual members of the *Drosophila* species last in the order of eight weeks. The species as a spatiotemporal phenomenon may have a life span of several millions of years. Whole-part causation occurs in two steps both of which involve the flow of genetic information. The species has genetic boundary conditions for the reproduction of individual members such that genetic information can be transmitted to offspring within, but not between species. This transmission occurs by means of gene flow between populations of a species. But the species has no direct causal effect on the intestinal cells of individual members. Rather the individual organism controls the differentiation of intestinal cells directly during development by means of information-carrying molecules that move between cells within the embryo. Thus, whereas a physical whole affects its parts by force, a biotic whole does so by information.

In principle there are as many kinds of scale and kinds of whole-part causation as there are modes of functioning in the specification hierarchy. Each one of these is different from and added to the already existing scales and whole-part constraints characteristic for lower-level entities. The latter are overridden by the whole-part causation characteristic for the qualifying level. For instance, the flow of genetic information between generations characteristic for biotic entities occurs by physical means. But since physical scale differences *inside* biotic entities are

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[13] Salthe, 'Two Frameworks'.

[14] Synonyms for whole-part causation are: top-down causation, downward causation. Synonyms for part-whole causation are: bottom-up causation, upward causation.

small compared to those outside, their role is taken over by scale differences characteristic for the biotic mode of functioning. Only outside biotic entities are physical scale differences relevant. Likewise, the ‘diffusion’ of knowledge in a society depends on social relations, not on the physical carrier of the knowledge and its scale of operation. Again, the communication of spiritual meaning in a religious ceremony depends on the meaning of symbols, not on the physical carrier of the symbolic meaning. Generally, whole-part relations in any mode of functioning higher than the physical mode are ultimately mediated physically, but inside the entities functioning at these higher modes the role of physical scale is taken over by whatever whole-part relation characterizes the higher mode of functioning. Therefore, the perspective of physical composition is not equivalent to the perspectives represented by all the other modes of functioning in the specification hierarchy. This means that the interaction of *physical* initiating and boundary conditions that produced the biotic mode of functioning must be replaced with the interaction of biotic initiating and boundary conditions as a model for the emergence of entities functioning in the next higher sensitive mode of existence.

Confusing Parts and Wholes

Bonner (1969) presented his level structure as a level structure of composition.[15] From a spatial perspective it is a perfectly consistent hierarchy. Every entity spatially contains lower-level entities and is contained in a higher-level entity. Stars occupy space in galaxies and communities occupy geographical areas on the earth’s surface. Yet his level structure is empirically inadequate because it does not distinguish between two kinds of physical entities – those existing independently of organisms (wholes) and those produced by organisms (passive parts). For instance, a macromolecule can be an independently existing physical entity such as a macrocycle.[16] But it can also be an entity such as DNA whose existence depends on an organism. This depends on whether the entity has passive parts properties. A macrocycle may or may not find itself spatially inside an organism, but only DNA is biotically integrated in it. It is a passive part.

The implications of mistaking a part for a whole are significant. For instance, genes have been treated as molecular level wholes rather than cellular level parts.

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15 John Tyler Bonner, *The Scale of Nature* (New York, 1969).

16 The International Union of Pure and Applied Chemistry defines a macrocycle as ‘a cyclic macromolecule or a macromolecular cyclic portion of a molecule’ (see ‘*Structure-based nomenclature for cyclic organic macromolecules (IUPAC Recommendations 2008)’, Pure and Applied Chemistry*, 80.2 (2008): pp. 201–232. Organic chemists define it as any molecule with seven or more atoms. Coordination chemists define it more narrowly as a cyclic molecule with three or more potential donor atoms that can coordinate to a metal centre. My point is that macromolecules produced by organisms need to be distinguished from those that exist independent of organisms.

	Universe
Superclusters	
Cluster of groups	
Group of galaxies	
Galaxy	Galaxy
	Star (system)
	Planet
	Earth's surface
	Community
	Population
	Organism
	Organ
	Tissue
	Cell
	Macromolecule
	Atom
	Elementary particles
(Silk 1980)	(Bonner 1969)

Figure 8.3 Consistent level structures in which the whole-part relation is characterized by interaction (left column) and inconsistent level structures in which relations of interaction and information flow occur in the same hierarchy (right column).

This was to legitimize the application to genes of thermodynamics which requires genes to be homogeneously distributed, freely diffusible molecular wholes.[17] These conditions only apply under specific circumstances such as genetic recombination, random mating, random combination of gametes, unrestricted gene flow and a population-level time scale. Otherwise, genes or their activities are not free to diffuse because they are integrated passive parts of cells.[18]

Further, if interpreted as level structures of evolutionary lineage, the system of Bonner would be inconsistent because organs do not develop into organisms. This inconsistency arises because, instead of treating organs as parts, they are treated as wholes evolving into other wholes.[19] Consistent level structures require

[17] Michael Conrad, 'Biological Adaptability: The Statistical State Model', *Biosciences* 26 (1976): pp. 319–24; David Hull, 'Individuality and Selection', *Annual Review of Ecology and Systematics*, 11 (1980): pp. 311–22; Charles J. Lumsden and Edward O. Wilson, *Genes, Mind, and Culture. The Coevolutionary Process* (Cambridge, MA, 1981).

[18] Jitse M. van der Meer, 'The Engagement of Religion and Biology: A Case Study in the Mediating Role of Metaphor in the Sociobiology of Lumsden and Wilson', *Biology and Philosophy*, 15 (2000): pp. 759–72.

[19] Bonner, *Scale of Nature*.

the same criterion throughout for their construction. For instance, Silk consistently uses physical composition or constitution (Figure 8.3).[20]

Sometimes a part is mistaken for a whole and treated as a hierarchy itself. Ernst Mayr (1982) introduces, among others, a distinction between inclusive and exclusive hierarchies. In an inclusive hierarchy subsystems, for instance people, constitute the systems, for instance societies, that are members of the next level up. However, in an exclusive hierarchy the subsystems, such as soldiers, are not constituents of the system, say the commander. Allen and Star (1982) and Grene (1988) refer to the latter as a command hierarchy.[21] The relationship between a commander and his soldiers is designated as a separate kind of hierarchy because soldiers are not constituents of a commander. But the distinction between entities and their functions makes it possible to view an army as a social part or product with a specific function, like factories, hospitals and schools. Like other modes of functioning, the social mode of functioning is distinguished from other modes by the social relations between the components of a society (Table 8.1). The relation of authority and command is part of a spectrum of social relations that characterize the social functioning of people. In sum, the concept of a command hierarchy is superfluous because an army is an active part of a society. To take an army as a whole is to confuse an active part of a hierarchically organized entity with a hierarchy itself. That is, it is to confuse a part with the whole.

The main reason for the confusion of parts and wholes is that the *physical* whole-part relation is applied to non-physical modes of existence. Physical inclusion applied at higher levels overlooks the part-whole relation characteristic for higher levels. Thus the relation of a passive part to a whole, such as that of DNA to a cell, seems no different than that of physical whole in a biotic whole, such as a macrocycle in a cell, because both involve physical inclusion. Wholes end up looking like parts when they are not. But we can avoid this confusion. When a whole becomes a part – whether passive or active – it undergoes changes while maintaining its identity. So we can tell parts and wholes apart. Moreover, the changes that make it possible to identify a part as a product of a whole are specific for the qualifying mode in which the whole functions in the specification hierarchy. Physical wholes have physical parts, biotic wholes have biotic parts and social wholes have social parts. Thus, by distinguishing between wholes and parts as well as between kinds of parts, we can avoid taking macrocycles as parts of cells and organisms as evolving from organs (Figure 8.3: Bonner). Moreover, whenever a whole becomes a part it establishes strong integration. By this we can distinguish a whole included, but not integrated in another whole, such as water in a cell, from a part included as well as integrated in a whole, such as DNA in a cell.

20 Joseph Silk, *The Big Bang: The Creation and Evolution of the Universe* (San Francisco, 1980).

21 Allen, Timothy F.H. and T.B. Starr, *Hierarchy: Perspectives for Ecological Complexity* (Chicago, 1982); Grene, *Hierarchies and Behavior*; Mayr, Ernst, *The Growth of Biological Thought* (Cambridge, MA, 1982) p. 206.

Finally, we can avoid the use of parts as yet another source of hierarchies, such as the command hierarchy.

Failure to distinguish between modes of constitution is one of the main sources of confusion over the nature of hierarchical systems. The confusion arises easily because *spatial* constitution is repeated in *physical* constitution – when a part physically constitutes a whole it is also spatially included in it. Likewise, both spatial and physical constitution are repeated in biotic constitution. The biotic parts of an organism are also physically and spatially enclosed in it. In general lower-level modes of constitution are repeated in higher-level modes.[22]

Confusing Qualitatively Different Wholes

Another manifestation of the same problem is that Bonner's hierarchy does not distinguish between spatial and physical constitution. For instance, from a spatial perspective communities occupy space on the earth's surface. But from a physical perspective, the surface of the earth is constituted by continents and oceans, not by communities. Bonner's notion of the earth's surface is ambiguous. Nor does his hierarchy distinguish physical from biotic constitution. For instance, from a physical perspective a planet is constituted by a core and a mantel, not by communities and populations. The specification hierarchy avoids these confusions because it distinguishes between qualitatively different modes of existence – in this case the spatial, the physical and the biotic modes.

Such qualitative differences in the way entities function are acknowledged by Sewell Wright (1953, 1964) in the fact that his hierarchy has branches (Figure 8.4). Wright wanted to provide 'a subdivision of the field of biology, based primarily on level of organization'.[23] He aimed at a classification of the biological sciences based on ranking entities according to the criteria of composition and complexity.[24]

On the left is the main hierarchy of physical entities. It is constructed on the basis of physical composition. Larger entities physically contain smaller entities. In the middle, 'The hierarchy of biological entities may be looked upon as a continuation of the physicist's hierarchy: ... [which is located] to the side of the main physical hierarchy.'[25] The biotic hierarchy is based on biotic composition. It has two branches: on its right is a hierarchy of social composition and on the left a hierarchy of logical composition (classification).

Physical, biotic, social and logical whole-part relations involve qualitatively different kinds of integration. Wright reduced them to a single kind by asserting

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22 Hartmann, 'Anfaenge'.

23 Wright, Sewell, 'Gene and Organism', *American Naturalist* (1953): pp. 3–18, see p. 11; Wright, Sewell, 'Biology and the Philosophy of Science', in William L. Reese and Eugene Freeman (eds), *Process and Divinity: The Hartshorne Festschrift* (La Salle, 1964). Also in: *The Monist*, 48 (1964): pp. 265–90, see p. 268.

24 Wright, 'Biology and the Philosophy of Science', pp. 268–9.

25 Ibid., p. 275.

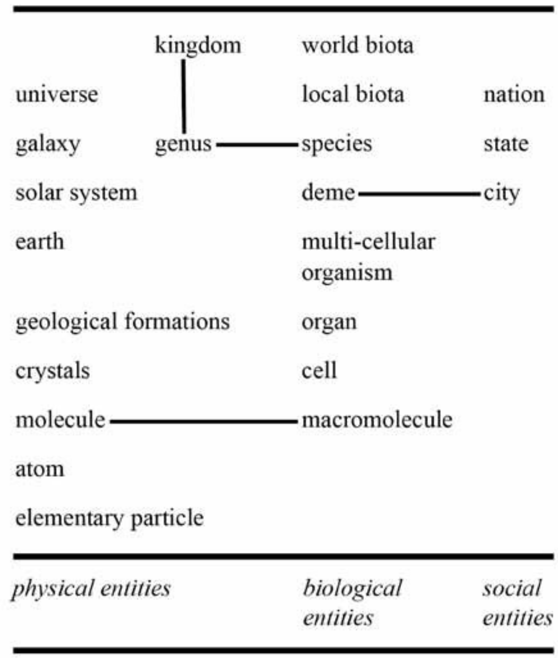

Figure 8.4 Reconstruction of Wright's hierarchy

Source: Based on Wright (1953, 1964).

that 'The universe as a whole is the all inclusive organism.'[26] Further, he postulated that 'The concept that organisms are composed of sub-organisms has become one of the most significant principles of biology.' Thereby, he replaced different kinds of part-whole relation with a single kind.[27] Differences between physical and biotic entities, such as the role of purpose and the flow of information through hereditary lineage, are ignored. This generalization forces him to homogenize relations between the entities in this cosmic organism. Homogenized relations differ in degree, but not in kind.[28] On the whole Wright cannot decide whether relations between entities differ in kind or in degree.

One complication of ignoring different kinds of whole appears in Wright's attempt to see the entire hierarchy as an evolutionary process.[29] The level structure of biological entities (without the organ level) can be interpreted as *a level*

[26] Wright, 'Gene and Organism', p. 7; 'Biology and the Philosophy of Science', p. 275.

[27] Wright, 'Biology and the Philosophy of Science', p. 269.

[28] Ibid., pp. 275, 284.

[29] Ibid., p. 271.

structure of biological lineage (Figure 8.4). In it, the relation between entities is one of biological descent between parents and offspring or between species and demes. But a crystal does not descend from atoms in the same sense that offspring descend from parents. Nor are macromolecules the biological descendants of molecules or organisms of organs. One cannot apply the notion of ancestry to a chemical reaction by designating the reactants as the ancestors of the products.[30]

The second reason for inconsistency is the combination of concrete and abstract hierarchies into a single hierarchy of spatial and physical constitution. In a *level structure of classification* taxons are conceptual entities that are related by the criterion of generality or logical subsumption. There is a relation of class inclusion or logical inclusion, but not of physical composition or evolutionary lineage. Wright worked before phylogenetic systematics (cladistics) were introduced in 1950 and became dominant in the 1990s. For Wright, evolutionary lineage does not extend beyond the species or, perhaps, the genus. He does not consider higher taxons as natural entities.[31] Therefore, his level structure of classification is a logical system that does not belong in a hierarchy of physical constitution.

In sum, Bonner, Wright and others overlook differences between wholes and parts, between different types of wholes and between concrete and abstract hierarchies. These problems disappear when the qualitative differences between modes of existence of entities are considered.

Hybrid Entities

The different modes of existence also underwrite the distinction between the active and the passive functioning of entities. This makes it possible to interpret the hybrid nature of such things as shells, nests, DNA, protein fibres, bark and systems of classification. The hybrid nature of a shell, for instance, refers to the fact that it has physical and biotic properties. A shell is actively subject to physical law. But, even though a shell is not alive, it passively obeys the laws of biology such as when its opening is determined genetically to be on the right or on the left.

Similarly, a classification is actively subject to logical law in that lower taxons are logically included in higher taxons. But though a classification does not actively engage in social relations, it is passively subject to the laws of society because the criterion of classification – Linnean, numerical, phylogenetic – is the result of social agreement among taxonomists. Physical inclusion is empirically inadequate to deal with hybrid entities because shells are not physically included in snails and a classification is not physically included in the social group of taxonomists. Treating them as actively subject in a lower mode of a specification hierarchy and passively subject in a higher mode solves the problem of how to interpret hybrid entities. Finally, social authority structures such as an army do not require separate representation in a different kind of hierarchy when seen as social products.

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30 Bunge, *Treatise*, vol. 4, p. 33.

31 Wright, 'Biology and the Philosophy of Science', p. 273.

The key to interpreting hybrid things is the distinction between active and passive functions. Passive parts are not only directly subject to the rules of their own lower-level characteristic mode of functioning, they are also indirectly subject to the rules for the higher-level subject in which they function. Active parts are subject only to the laws characteristic for their own mode of existence.

Conclusion

I have suggested that the part-whole relation that defines the constitutive hierarchy is conceived in spatial and physical terms. Such a hierarchy is an empirically inadequate description of cosmic order because it fails to distinguish between qualitatively different modes of existence, both material and nonmaterial. Differences between wholes and parts, between different types of wholes and between concrete and abstract hierarchies are suppressed. The constitutive hierarchy is also logically inadequate because it produces self-contradiction by ignoring boundaries between modes. These problems disappear when the qualitatively different kinds of properties of entities are distinguished. Further, the specification hierarchy distinguishes between active and passive properties of entities. This accounts for the hybrid nature of entities. Finally, spatial and physical whole-part relations occur at all levels but are overridden by the whole-part relation characteristic for the higher level. This means that the interaction of *physical* initiating and boundary conditions that produced the biotic mode of functioning must be replaced with the interaction of biotic initiating and boundary conditions as a model for the emergence of entities functioning in the next higher sensitive mode of existence.[32]

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