Functional Anatomy: A Taxonomic Proposal

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Abstract. It is argued that medical science requires a classificatory system that (a) puts functions in the taxonomic center and (b) does justice ontologically to the difference between processes and enduring entities. Here we propose a formula for constructing such a system and describe some of its benefits. The arguments are general enough to be of interest to all the life sciences.

1 Traditional Anatomy and Functional Anatomy

The idea to be outlined in this paper is that there is an as yet unexplored taxonomical approach within the life sciences, in particular within medicine, which we call *pure functional anatomy*. Pure functional anatomy is complementary to traditional (structural) anatomy while at the same time remaining distinct from pure physiology. In our opinion, physicians as well as medical scientists are already working with a large amount of more or less implicit knowledge of functional anatomy. Our proposal is that this knowledge be made explicit and that it be carefully systematized in the form of a new kind of taxonomy.

Traditionally, anatomy has been said to describe only the structures of the body, functions and processes being left to physiology. The aim of anatomy has been to divide the human body into spatial parts only by means of physico-chemical compositions and spatial arrangements of these parts. Even for the first anatomists, it must have been apparent that bones, muscles, blood, and various organs such as the lungs, heart, and kidneys are composed of different kinds of material. And it was easy to turn the skeletal system into a spatial coordinate system in which all the other anatomical entities had their places.

Philosophers often say “no entity without identity.” Equally true, for entities in space and time, is “no entity without boundary.” From where, then, do anatomical entities get their boundaries? For many of them, for example the separate bones of the foot, the answer is that anatomists select a pre-existing discontinuity in the physico-chemical composition of reality – on the one hand is the material entity, and on the other hand is its surroundings (including a liquid medium). But when it comes to parts of entities made of homogeneous material, the boundaries must of course be constituted in some other way. They have to be in some sense a product of our demarcation. In other words, some boundaries are bona fide and some are fiat (Smith, 2001). Similarly, when a part of the body recognized by anatomists is made of non-connected parts (e.g., the endocrine system) then here, too, the boundary must be a product of our demarcation. Many anatomical parts such as the skull, the ribs, the chest bone, and the pelvis have a boundary that is partly bona fide and partly fiat. Often, such mixed boundaries are constituted by a large bona fide portion complemented by a small fiat boundary drawn at the point where organs are connected to conduits for the passage of substances in or out.

But there is also another way to create spatial boundaries. One can select boundaries in such a way that the entity delineated is a *function bearer*, that is, a unity which as a whole performs a specific function. The musculoskeletal system is not a unity from a structural point of view, but from a functional point of view it is. The muscles and skeleton are grouped together because their unity is what bears the function: to move the body. Of course, many functions are such that their bearers are single anatomical parts already discerned traditionally (the heart has the function to pump blood, the liver has the function to produce glycogen, and so on). Our point is that this is not the case for all functions.

There are thus two different kinds of anatomical parts in the body: spatial-structural parts and spatial-functional parts. Each can ground an anatomy of its own, notwithstanding the fact that some parts are simultaneously both spatial-structural and spatial-functional. We will call these anatomies *pure structural anatomy* and *pure functional anatomy*, respectively. Without arguing the case, our opinion is that many anatomical textbooks, old as well as new, cannot be conceived of as being purely structural. Some of the presumed structural-anatomical entities distinguished are instead functionally delimited. Is it for instance really the case that the heart muscle is regarded as part of the circulatory system instead of the muscle system only because of certain structural difference between this muscle and the other muscles?

The term “functional anatomy” is nowadays widely used. As this paper is being written (March 2004), Google™ lists more than 49,000 entries for this term. There are papers about the functional anatomy of limbs, of the knee-joint, of the hypothalamus, and many more. Thus far however there seems to exist no clear statement of the principles governing functional anatomy, nor any clear understanding of how functional and structural anatomy are to be distinguished.

The construction of a pure functional anatomy is of more than strictly theoretical-taxonomic interest. Such an anatomy can (a) facilitate medical teaching and learning; (b) be of help in supporting medical information science; (c) support the understanding and in principle also the cure of systemic diseases; and (d) make some tasks in medical technology more clearly visible. (Artificial body parts are meant to preserve an old function with the help of a new structure.)

2 Constituent Functions

Function talk seems to come naturally to people who know a lot about the human body and its parts. Many philosophers of science claim nevertheless that such talk should be reduced to talk of causality or natural selection (see section 6.2 below). We think, however, that such reduction is not possible, and that there is a primitive notion of function, which we will call *constituent function*, that can be used to denote an objective feature of the world. The notion we have in mind might also have been expressed by means of terms such as ‘component function’ or ‘part-to-whole function.’ What all these terms have in common is that they help us keep in mind that constituent functions are in every case relational in character.

As a point of departure for our taxonomic proposal, we have taken the human body regarded as a functional unit whose short-term function is: to preserve the life of the organism. With the function of life-preservation thus presupposed for the organism as a whole, most bodily functions are constituent functions, i.e., they are functions relative to this larger whole. Outside our framework fall functions responsible for reproduction, growth, and aging.

It should be noted that an entity does not have a constituent function in and of itself in the way in which, for example, mass is assumed to inhere in Newtonian corpuscles or human conscious intentions in persons. Functions that are monadic properties in this sense, we call *intrinsic functions*. If such functions exist, it is in principle possible for an entity to be the bearer of both intrinsic and constituent functions.

From the perspective outlined, the abovementioned function of the whole (living) human body may now be regarded either

(a) as a constituent function of a functional unit that is larger than the human body;
(b) as an intrinsic function of the human body; or
(c) as a projection, i.e., as a feature that is only projected onto the human body by perceiving and language-using human beings.

Unfortunately, each of these options is problematic. If (a) the human body has its function of preserving life only if it is itself part of some larger functional whole, then what about the function of the latter? An infinite regress that arises if one allows *only* for constituent functions. Therefore, it seems that at some stage we have to face a choice between options (b) and (c).

If we choose (b), we are confronted with the problem of how to make intrinsic functions consistent with natural science. If the human organism in itself, at a certain point of time, has the function to preserve its life for some time to come, then the organism must be able to be directed towards these as yet non-existing points of time. Ordinary vectors such as velocity and acceleration are not like this. They are directed only toward the very next instant of time, not toward anything more distant. Therefore, option (b) seems to make functions too similar to conscious human intentions to be parts of natural science. This problem of future-directedness does not appear in relation to constituent functions since the larger functional whole’s existence at the relevant future time points is simply taken for granted.

Third, if we opt for (c), we seem to license cultural relativity or even pure subjectivity to enter into science.

Quite a trilemma. How to choose between (a) an infinite regress, (b) an anthropomorphizing of nature, and (c) subjectivity? Our solution is simple, since it is of the cutting-the-Gordian-knot variety. We claim that, independently of whether or not the self-preservation of the whole human body is itself either a constituent function, an intrinsic property of the body, or only a projected feature, still all of the *constituent* functions of the body are objective features of the world. This move suffices to make functional anatomy a tractable scientific enterprise.

The most controversial part of this claim relates to case (c), i.e., when a constituent function is a function only in relation to a function that is projected onto the whole in question. But think of a house and the constituent function of its doors. In itself the house seems to be a pure material structure that lacks functionality; its functions are projected onto it by human beings. When it is regarded as a pure material structure its doors lack functionality, too, but when it is ascribed its usual house-function it is an empirical question whether or not also the doors have a function. Therefore, the constituent functions of the doors are not mere projections even if the function of the whole house is merely a projection.

Perhaps an analogy can give further credence to our view that constituent functions are objective. As an action can be objectively rational in its *relation* (as a means) to a pre-given end even if this end is itself completely irrational, so a spatial part can be objectively functional in its *relation* to an encompassing pre-given functional whole even if the function of the whole is only a subjective projection.

3 The Proposal Visualized

In this section we will present what a functional anatomy based on our principles may yield, and in the ensuing two sections we will present the principles themselves.

We grant that a functional unit may have more than one function. For instance, for the stomach we can distinguish at least: "Function 1: to break down the chyme" and "Function 2: to move the broken-down chyme into the duodenum." Other typical functions are: to store, to pump, to protect, to produce, to open, to close, to absorb, and to expel. To use the terminology of Function 1, Function 2, etc., however, does not imply any ranking of functions in order of importance.

We can distinguish a first level of functions part in the human body as in Figure 1.

The Human Body

Function 1: to preserve its life

Circulatory system	Alimentary system	Respiratory system
Senso-motoric system	Excretory system	Immune system
Musculoskeletal system	Vegetative regulation system	Integumentary system

Figure 1. Spatial-functional parts of to the human body

Starting from the partition in Figure 1, one can continue by zooming in on any of the spatial-functional parts represented. Figure 2 provides a correspondingly more refined partition of the circulatory system:

The Circulatory System

Function 1: to transport substances between bodily systems

Circulatory fluids	Vessel system	Heart

Figure 2. Spatial-functional parts of the circulatory system

We have identified only one main function of the circulatory system. However, we think that the alimentary system has at least two functions: "Function 1: to absorb nutrients from food" and "Function 2: to expel non-nutrients that come from food."

Zooming in on the vessel system and the heart respectively reveals:

The Vessel System

Function 1: to direct fluids in the body

Blood vessel system	Lymphatic vessel system

Figure 3. Spatial-functional parts of the vessel system

The Heart

Function 1: to pump blood through the blood-vessel system

Atria	Ventricles	Valves

Figure 4. Spatial-functional parts of the heart

By continuing to zoom in on ever smaller parts, one can zoom down, finally, to the cell and its major spatial-functional parts. Choosing some parts from the circulatory and alimentary systems respectively, we get the following spatial-functional hierarchies:

(1) human body → circulatory system → vessel system → blood vessel system → arterial system → macrovasculature → tunica intima → endothelial cells;

(2) human body → alimentary system → stomach → tunica mucosa → surface epithelium → endocrine cells.

Both the number of spatial-functional parts that a single functional entity has, and the number that there are *between* the human body as a whole and its cells, seem to be a mere contingent fact (which, by the way, may explain the difficulty of counting how many spatial-functional parts an organism has in total). At least, we have been working on the assumption that there are no general laws that predetermine such numbers.

All the main bodily systems, and all their consecutive spatial-functional parts, retain their identity through time. In philosophical jargon, they *endure*. So do the corresponding functions. Each person's circulatory system has at any moment in time the function "to transport substances between bodily systems," and the heart within it has at any moment in time the function “to pump blood through the blood-vessel system.” Neither the spatial-functional parts nor the functions spoken of have any natural or bona fide *temporal* parts. Of course, it is always possible to divide their lives into temporal parts by convention or fiat. Bona fide temporal parts, however, can often be found in the corresponding processes and temporally extended realizations of these functions, i.e., in their functional activities (or *functionings*). The cyclical functional activity of the heart affords us an example of such bona fide temporal parts. Each cycle contains two parts, the diastolic phase and the systolic phase. We regard the mentioning of such phases as an important element of our taxonomic proposal.

The kinds of temporal parts comprehended by any given functional activity are simply added to the relevant figure. In the case of the heart, the following should be supplemented:

Functioning of Function 1:

Diastolic phase	Systolic phase

Figure 5. Temporal parts of the functioning of the heart

Of course, many bodily processes, unlike the functional activity of the heart, feature actual rest phases (see end of section 4).

As in the case of our zooming in on spatial-functional parts, so also here: A zooming in on e.g. the diastolic phase of the heart’s functioning will reveal more fine-grained temporal parts of this phase.

4 The Proposal as a Taxonomic Formula

Let us introduce, by means of examples, the concept of a *taxonomic formula*. All the classical biological classification trees of sexually reproducing species that extend downwards from Kingdom via Phylum/Division, Class, Order, Family, and Genus to species might be said to be constructed according to the formula: “Define species by means of interbreeding, then order all the species by means of relations of similarity and dissimilarity into a hierarchy of taxa.” Similarly, a taxonomic formula for Mendeleev’s original periodic table of the elements might be: “The physical and chemical properties of the elements are in periodic co-variation with increasing atomic weights; order the elements on this basis into rows and columns.”

The presentation in section 3 is based on a taxonomic formula with two parts, one concerned with spatial-functional parthood relations, and one concerned with temporal parts of functionings.

The first part of the formula focuses on spatial-functional parts as they exist in a given human organism at an arbitrary point in time. Therefore, this first part might be called a SNAPshot taxonomic formula, or SNAP formula, for short. Since the second part of the formula takes account of time extension, it may be called a timeSPAN taxonomic formula or SPAN formula, for short. Their general forms are as follows:

SNAP

(a) In the functional unit A,
(b) one function of the spatial part and functional subunit B of A is,
(c) to V in relation to X, Y, Z, …;

SPAN

(d) This function (V) has in its functioning as temporal parts
(e) the phases P_1 to P_n.

This bipartite formula can be used both iteratively and recursively. That is, it can be applied iteratively to all the different parts of a functional unit that belong to the same level, and it can be repeated recursively in the sense that a subunit on level (b) in the SNAP formula is in the next cycle turned into the unit on level (a). Examples are:

(a) In the human body (A),
(b) one function of the circulatory system (B) is,
(c) to transport substances (V) between the bodily systems (X, Y, Z, …);

(d) this function (V) has in its functioning as temporal parts
(e) either fiat parts of the continuous fluid flow or bona fide parts in relation to the substances transported;

and:

(a) In the circulatory system (B),
(b) one function of the heart (C) is,
(c) to pump (V) blood (X) through the blood vessel system (Y);

(d) this function (V) has in its functioning as temporal parts
(e) the diastolic phase (P_1) and the systolic phase (P_2).

This formula reveals that nothing can be a constituent function if it is not the function of some part of a larger functional unit. (Intrinsic functions, whether they exist or not, do not fit the formula.) A recursive use of the formula does not imply that unit A disappears altogether; it only means that A leaves the linguistic foreground. B will always be a subunit of A; similarly, C will always be a subunit of B; and so on.

Our formula allows that some of the taxonomic paths between the main bodily systems and the cells will run through more levels of spatial-functional parts than others. In the general SNAP formula, line (c) says that the function of a certain entity is "to V in relation to X, Y, Z, …". Here, V is a variable for functions (depicted by verb phrases), and the variables X, Y, and Z range over entities on every possible level along any given taxonomic path. No level constraints are mentioned in clause (c). But if such constraints are found, the formula can easily be adjusted in this respect.

It should also be noted that the formula completely disregards *potential* functions. When, for instance during a heart transplantation, a heart is in a solution outside any bodily host, then it has its function only potentially. We can ignore such cases since the formula applies only to functions of entities that are already parts of a larger functional unit. In a living body, the heart always has its function actually. This would hold even if, counterfactually, its functioning, like the functionings of a number of glands, contained various kinds of *passive* phases such as rest phases, waiting phases, and guarding phases. It is one thing for a system to have a function only potentially and therefore not be functioning, and another thing for the system to have a function actually and to be functioning, but only in the sense that, so to speak, it is on duty without needing to do anything.

At any given time and for any given entity E and kind of function V, one of the following four possibilities has to obtain:

(i) E neither actually nor potentially has the function V.
(ii) E has the function V only potentially.
(iii) E has the function V actually, but V's functioning is in a passive phase.
(iv) E has the function V actually, and V's functioning is an active phase.

5 Special Aspects of the Formula

Some words about some of the specific features of the proposed SNAP-SPAN formula are necessary in order to avoid misunderstandings.

5.1 Sharing parts

In traditional species classifications and in structural-anatomical partitions it is usually required:

(i) that, collectively, the taxa on each level exhaust the domain captured by the genera on the next higher level;
(ii) that taxa on the same level be mutually exclusive, i.e., they should not share parts or taxa on some lower level;
(iii) that one taxon not belong to two or more taxa on an overlying level.

Let us focus on the last two requirements. When a purely conventional classification or partonomy is to be made, e.g., dividing a homogenous surface into surface parts, then it is an open question whether or not one should conform to these requirements. But in phylogenetic classifications of common species ancestors, an analogue of requirement (iii) represents an empirical hypothesis. Here, a classificatory "diamond" (Figure 6) would mean hybridization (which is normally assumed not to be able to give rise to new fertile animal species).

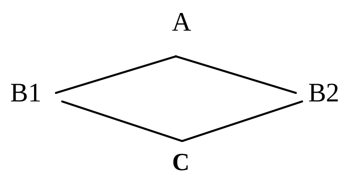

Figure 6. Classificatory "diamond"

Our taxonomic formula does not conform to requirement (ii), but it does conform to requirement (iii), and this means that it does not within its own special structure contain any cases where a taxon belongs to two or more taxa on an overlying level. It allows part-sharing, i.e., it allows one and the same entity to be a spatial-functional part of two or more larger functional units, but because of the specific features of our formula it does not contain diamond patterns based on subclass relations. For instance, for the oropharynx we get two different taxonomic loci:

(a)	In the **alimentary** system,	(a)	In the **respiratory** system,
(b)	function 1 of the *oropharynx* is,	(b)	function 1 of the *oropharynx* is,
(c)	to make possible food transport from the oral cavity to the esophagus.	(c)	to make possible gas transport between the nasal-oral cavities and the larynx.
(a)	In the **oropharynx**,	(a)	In the **oropharynx**,
(b)	function 1 of the *tunica muscularis* is,	(b)	function 1 of the *pharyngeal cavity* is,
(c)	to move food into the esophagus.	(c)	to direct the flow of air.

Figure 7. Taxonomic loci for the oropharynx

Another instance of this kind of part-sharing is afforded by the liver, which belongs to both the alimentary system and the immune system, and probably to some other systems as well.

Part-sharing allows for the easy integration of discoveries of new joint functions of already known spatial-functional parts. Also, the existence of as yet undiscovered systems in the body seems to presuppose or imply part-sharing since it is hard to believe that such systems should not use some already known parts.

5.2 Multi-Functionality Proper

It is sometimes taken for granted that nature has worked in such a way that one functional unit can only have one function. Our taxonomic formula has no such presumption built into it. It does not say "*the* function of E is," but rather "*one* function of E is." Even within one and the same functional unit a specific spatial-functional part may have more than one function. For instance:

In the **alimentary** system, function 1 of the *liver* is, to produce glycogen.	In the **alimentary** system, function 2 of the *liver* is, to produce bile.

5.3 Prototypicality

It is here taken for granted that instances of constituent functions can be functioning better or worse, but the functionings described are the well functioning cases. Thus the latter might be called prototypical. This does not mean that we think that degrees of functioning can be plotted along some single dimension; rather, we think that this is impossible. Nonetheless, in a loose sense one may speak of a “distance” between a certain functioning and the prototypical functioning. We do not regard the functional descriptions given under the heading ‘Function X’ to be the only possible prototypical descriptions. As one can measure the same distance with both a yardstick and a meter stick, so one can measure the distance of a certain functioning from different prototypes. There is a certain conventionality in the choice of standard units for the classical scales and measuring devices used in physics; similarly, there is a certain conventionality in the choice of prototypes in medicine. This is an innocent kind of conventionality. It does not imply that constituent functions are merely social constructions.

In the philosophy of the natural sciences, if not in the natural sciences themselves, prototypical concepts have often been regarded as not being “mature” scientific concepts. Our proposal, however, is based on the assumption that prototypical concepts are just as indispensable to biomedicine as scale constructions and numerical concepts of magnitudes are to physics and chemistry (Johansson, 2004).

6 Background Ideas in the Life Sciences and in Philosophy

The taxonomic SNAP-SPAN formula we have presented has grown out of more general ideas that have been around for some time in minority circles in the life sciences and in philosophy. Some words about this, starting with the life sciences.

6.1 Three-Level Granularity

All of the life sciences contain, explicitly or implicitly, ideas about hierarchical systems, about levels of functionality, and about granularity, and some researchers have argued that in the life sciences one should always take three such levels into account:

> In the face of a potentially overwhelming complexity of transactions between entities at different levels we must seek to discover what might be the basic minimal set of relationships that would satisfactorily frame most (or the most important) relationships. A reading of some of the literature on systems reveals for us what that structure is. The smallest cluster of levels required to represent fundamental interactive relationships is a *triad* of contiguous levels, so that we can simultaneously examine some process (or the events it produces), the context of these events, and their causes. … Thus, three adjacent levels should provide for a minimal description of any complex diachronic system. (Salthe, 1985, pp. 75ff.; italics added)

Salthe (1985) argues that three levels are relevant in the analysis of hierarchical systems generally: the level of interests, or what he calls the focal level, plus one level above and one below. Here, the focal level is that of parts, the higher level is occupied by the organism as a whole, and the lower level by parts of parts, or subparts. Attention to level is crucial here in order to count parts in a consistent way." (McShea and Venit, 2001, p. 271)

Our proposal comes close to this idea. A constituent function (V) is always related to at least three entities. The smallest possible taxonomic unit in functional anatomy, we repeat, has the structure:

(a) In the functional unit A,
(b) one function of the spatial part and functional subunit B of A is,
(c) to V in relation to X, Y, Z, …

Here, what is designated by V is related to a functional whole (A), its bearer (B), and at least one entity in relation to which it causes something to happen (X). The variable B might be said always to designate entities that belong to a lower level than those designated by A, but we have not required that, similarly, entities designated by X belong to an adjacent level that is still lower. However, when in fact this is the case, then our formula conforms exactly to the three-level requirement asked for in the quotations.

6.2 Scientific Non-Darwinian Functions

In the wake of the rise of modern physics at the end of the sixteenth century, a general suspicion emerged about the use of teleological notions, e.g., functions, anywhere in the natural sciences. Philosophically minded biologists felt uneasy – until the Darwinian revolution, when design was replaced by natural selection. Nonetheless, biologists continued and have continued to speak of functions. This fact made a lot of twentieth-century philosophers of science uncomfortable. Their solution has been to claim that this modern function talk is innocent, because it can now always be translated into equivalent, but more cumbersome, talk about causes, dispositions, adaptations, and adaptiveness. They have argued about what the exact translations may look like. Classical "etiological analyses" include Wright (1973) and Millikan (1989); for an overview and a refinement, see Melander (1997). For a good criticism of this kind of reductionism, see Manning (1997).

In these etiological approaches, it is presupposed that all function talk is explanatory talk. That is, that the function of x is mentioned in order to explain *why* x *exists*. Our attempt at a rehabilitation of a non-reducible and non-Darwinian but natural-scientific concept of function, constituent function, rejects this presupposition. We think that a lot of function talk is purely descriptive. When one says that x has the function F, one is, whether or not one is also trying to explain the existence of x, describing a relational feature of x (Johansson, 2004). One is answering a question about *what* features x has. In spite of this fact, however, our view of functions comes close to one famous analysis in the modern philosophy of functions, namely Robert Cummins's (1975) so-called "intrasystemic role analysis." Cummins claims: "To ascribe a function to something is to ascribe a capacity to it which is singled out by *its role in* an analysis of some capacity of *a containing system*" (Cummins, 1984, p. 67; our italics).

Why, then, have we not used his analysis? Answer: (i) Cummins is a reductionist who tries (mistakenly) to do away with the concept of function (though he still employs a concept of "role," which obviously is a kind of function concept itself); (ii) he writes as if he is still concerned only with explanations; (iii) he has not noted the trilemma mentioned in section 2; (iv) per Cummins, any item that causes an effect in any putative system can be said to have a function in that system, whereas our analysis is limited to the functions of biological items; (v) Cummins seems now himself, as noticed by Arno Wouters (2003, p. 233), to have in any case abandoned his own earlier analysis.

Recently, it has been claimed that it can be doubted whether philosophers' "function concept has anything to do with function talk in biology and psychology," and that philosophers "may easily end up with a theory that is philosophically well-founded but gives us no insight whatsoever into the practice of inquiry" (Wouters, 2003, p. 233). Such an accusation cannot truly, we think, be made with regard to the new philosophical concept of constituent function.

6.3 Bipartite Taxonomy

Our taxonomic formula consist of two parts, one for functions and one for functionings. This idea relates to discussions between philosophers and information scientists about so-called "top-level ontologies" within information science; a top-level ontology contains a classification of the most general types of entities and relations in reality. As of today, from the point of view of a realist philosophy, most such ontologies seem not to do justice to the difference between enduring entities and processes. Enduring entities exist as wholes in a single instant of time but processes cannot. Enduring entities can exist from one moment to the next; processes unfold in successive phases (they can be segmented into parts along the temporal dimension). Both enduring entities and processes belong to one and the same reality, our world; but they might nonetheless be said to constitute two different, albeit related, ontologies, which have been termed SNAP and SPAN, respectively (Grenon and Smith, 2004). In line with this duality, our taxonomic proposal presents functions (as enduring entities) as part of the SNAP-ontology, and function*ings* (as processes) as part of the SPAN-ontology. Conversely, the structure of our proposal supports the view that the difference between SNAP-entities and SPAN-entities is far more radical than any difference within either of these ontologies. In our proposal only the SNAP formula features a hierarchical nesting of its own, and one might even say that the SPAN formula is parasitic upon the SNAP formula. But both formulae are needed.

7 Concluding Remarks: Possible Modifications of the Formula

It is easily seen that the proposed taxonomic formula allows for various kinds of modifications.

7.1 Substitute Functions

It is well known that when certain bodily organs are injured in such a way that they are no longer capable of performing their function, then some other spatial-functional part will take over. After a splenectomy, for instance, the liver takes over some of the spleen’s functions. In order to integrate such data, the original formula can, and must, be amended with the addition of the concept of substitute function.

7.2 Information Transmission and Regulation

Our formula has been worked out with the classical bodily systems in mind and using functions such as to transport, to direct, and to pump. For the time being, the transmission of information and regulation, such as signal transduction and cell-to-cell communication, are beyond our focus. The formula can, however, in principle be extended to allow for functions of these sorts also. Probably, such an extension is necessary in order to take care of all spatial-functional parts of the immune system.

7.3 Disease Taxonomies

As we said in section 5.3, every actually existing constituent function’s functioning can be more or less prototypical. But a constituent function can also be mal-functioning. All somatic diseases consist either in a malfunctioning or a complete loss of at least one of the body’s constituent functions. Since every possible taxonomic formula for malfunctionings and every possible formula for loss of functions refer to a corresponding constituent function, all diseases can be related to the formula we have put forward. Perhaps such a disease taxonomy would bring new order into the multifarious world of diseases.

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