Health, Homeostasis and the Situation-Specificity of Normality

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Abstract

Christopher Boorse's *Biostatistical Theory of Health* has been the main contender among naturalistic accounts of health for the last 40 years. Yet, a recent criticism of this theory, presented by Elselijn Kingma, identifies a dilemma resulting from the BST's conceptual linking of health and statistical typicality. Kingma argues that the BST either cannot accommodate the situation-specificity of many normal functions (e.g. digestion) or cannot account for many situation-specific diseases (e.g. mountain sickness). In this essay, we offer further improvements in line with Daniel Hausman's response to Kingma's dilemma. We propose that recalling Boorse's specification that health is an intrinsic property of its bearers and explicating this intrinsic property in relation to the concept of *homeostasis* can illuminate how proponents of naturalistic accounts of health should deal with the situation-specificity of normal functions. We argue that, beyond what Boorse and Hausman have delineated, the situation-specificity of normal function cannot be fully captured in a simple dichotomy between normal and abnormal environment, or between relevant and irrelevant situations.

By bringing homeostasis to the fore of the analysis of health, we set out a richer picture of what the various situations which affect living organisms' functional performance can be. Accordingly, we provide a broader classification of these various situations which, we contend, better accounts for the main intuitions that philosophers of medicine have sought to accommodate than previous naturalistic theories of health.

Keywords

Health, normal function, homeostasis, self-regulation, Christopher Boorse, Elselijn Kingma.

Introduction

Christopher Boorse's *Biostatistical Theory of Health* (BST) [1, 2], which very broadly defines health as statistically typical functional performance, has been the main contender among naturalistic accounts of health for the last 40 years. This may partly be due to Boorse's impressive ability to deal with the various critiques addressed to his theory since he first expounded it. An important line of criticism which the BST has faced concerns its conceptual linking of health and statistical typicality—that is, its definition of health as the absence of disease, where disease is defined as "statistically species-subnormal biological part-function" [1, p. 4]. A recent criticism of Boorse's theory in this respect is the one presented by Kingma [3], who identifies a dilemma for the BST. Kingma argues that the BST, either cannot deal satisfactorily with the fact that the normal performance of many functions (e.g. digestion) is *situation-specific* in that it is normal for them to be performed only in specific and not statistically typical situations; or cannot account for many situation-specific diseases (e.g. mountain sickness). In this essay, we offer further improvements in line with Hausman [4, 5], who, in response to Kingma's dilemma, states that the BST's grounding of health in statistical typicality should be abandoned. We propose that recalling Boorse's specification that health is an *intrinsic* property of its bearers and explicating this intrinsic property in relation to the concept of *homeostasis* can illuminate how proponents of naturalistic accounts of health should deal with the situation-specificity of normal functions.

Although Boorse has acknowledged homeostasis as an implicit component of his account of health, he has never brought it to the fore of the analyses he presented. This paper argues that bringing homeostasis to the fore sets out a richer picture of what the various situations which affect living organisms' functional performance can be. We argue that, beyond what Boorse and Hausman have delineated, the situation-specificity of normal function cannot be fully captured in a simple dichotomy between normal and abnormal environment, or between relevant and irrelevant situations. As organisms maintain their functional abilities homeostatically, not all the cases where they fail to perform their functions in situations where the performance would have been relevant should be deemed pathological. Our proposal involves many deviations from Boorse's statement of the BST, but nevertheless, we think, remains faithful to the core of his account of health.

We elaborate our proposal as follows. In section 2, we summarize the main lineaments of Boorse's biostatistical theory and of Kingma's criticism, and conclude, following Hausman, that the definition of health in terms of statistical typicality should be abandoned in favor of an emphasis on health as an *intrinsic* property of its bearers. In section 3, we describe the notion of homeostasis and its role in a satisfactory definition of health. And in section 4, we derive consequences of the definition of health we propose in section 3 for the categorisation of organisms' life-situations which further improves upon Hausman's solution to Kingma's criticism.

1. Boorse's account and the situation-specificity problem

1.1 Boorse's account of health

According to the BST, health is the statistically normal functioning of an organism, that is, its capacity to perform every physiological function typical to a reference class at a minimal level of efficiency. Boorse states the elements of the theory as follows:

1. The *reference class* is a natural class of organisms of uniform functional design; specifically, an age group of a sex of a species.

2. A *normal function* of a part or process within members of the reference class is a statistically typical contribution by it to their individual survival and reproduction.
3. A *disease* is a type of internal state that is […] an impairment of normal functional ability, i.e., a reduction of one or more functional abilities below typical efficiency [...].[1]
4. *Health* is the absence of disease. [1, p. 7-8, 2, p. 562]

Kingma [3, p. 244-245] emphasizes four more or less explicit features of the BST that follow from this formulation and other precisions made elsewhere by Boorse. First, Boorse defines health in relation to function. As he defines it, the concept of function includes any part of an organism's contribution to survival and reproduction; and health includes only *normal* functions, that is, only those contributions which are statistically typical for a reference class to which this organism belongs. Second, the idea of statistically typical contribution involves two dimensions, a *qualitative* dimension, that is, the *type* of activity typically performed by the part; and a *quantitative* dimension, that is, the *level* of efficiency at which the activity is typically performed.[2] Third, health does not require the *actual* performance of normal functions, but rather the *disposition* to perform normal functions. For instance, an organism's incapacity to breathe on the moon does not reveal a pathology on its part. This dispositional aspect is reflected in Boorse's use of "ability" in the formulation of his third element (Boorse also speaks of the "readiness" of a part to perform its function [1, p. 8]). Although Kingma does not emphasize this aspect, the dispositional character of normal function follows from Boorse's specification that a disease must be an *internal state* of an organism (see the third element in Boorse's statement of his theory). Normal function is not a mere absence of performance due to some lack of relevant circumstance (e.g. not digesting when one has been fasting), but an absence of performance resulting from the organism's own inability. And fourth, in

[1] We remove the environmental clause from this third component of Boorse's statement of his theory because he decided to remove it in response to some criticism [1, p. 86]. He however added some specification to meet the challenge posed by environmental diseases [1, p. 84], which we will discuss in section 2.2.

[2] We will not discuss this aspect of Boorse's account in depth, although see Schwartz [6] and Hausman [5] for insightful discussions of issues related to the quantitative dimension.

accordance with their dispositional character, normal functions are only performed in specific situations. For Boorse, they must not be understood as statistically typical *in general*, but rather as statistically typical *in certain situations*. For instance, normal sweating and heart rate are situation-specific. Kingma highlights this as a logical consequence of the dispositional character of normal function which Boorse [1, p. 79] acknowledges but does not emphasize.[3]

1.2 A dilemma for the BST

Kingma however identifies a problem that arises from the situation-specificity of statistical normality in the BST. She argues that this specificity makes the BST unable to account for situation-specific *diseases*, that is, to account for the fact that many diseases are statistically typical in some situations. For instance, poisoning and drug overdose are statistically typical responses to situations where one has inhaled a high amount of carbon monoxide or ingested a heavy dose of paracetamol.[4] Given that it defines normal functions as situation-specific, the fact that these responses are statistically typical in the situations where they occur forces the BST to consider them normal rather than pathological. Boorse [1, p. 83-84] himself acknowledges this kind of problem in a discussion of criticism by van der Steen and Thung [9], noting the case of environmental diseases like mountain sickness, heat exhaustion and caisson disease. Since these states are statistically normal in some specific environments, the BST seems to have the counterintuitive consequence that they should be deemed normal rather than pathological. Boorse handles the problem of environmental diseases by making normal function relative to a statistically defined *normal environment*. This, Boorse maintains, allows for the inclusion among pathologies of bodily states that, although they are

[3] For extensive discussions of Boorse's theory of health, see Ananth [7] and Giroux [8].

[4] Like Hausman [see 4, p. 657n1], we keep with Kingma's use of "paracetamol," the British word for what north Americans call "acetaminophen."

statistically typical in rare environments, would be statistically subnormal if they occurred in usual environments.[5]

However, Kingma [3, p. 255-256] retorts that such solution will not do, for there is no strong connection between the rarity of environments and their harmfulness. On the one hand, as she remarks, there can be rare but non-harmful environments. For instance, "a rare-but-not-harmful environment is complete and utter pitch-black darkness (we are nearly always exposed to some light at least). The normal function of the eyes in this environment is to do nothing at all. This means that on Boorse's proposal eyes are diseased in pitch-black darkness."[6] This, as Kingma emphasizes, is a very counterintuitive consequence. Kingma also notes that there can be non-rare but harmful environments. For instance, for most light-skinned people, a "normal response to a couple of hours of summer sunshine is to burn quite badly [...] yet burns are undoubtedly a disease." And also, "a substantial part of the world population is exposed to harmful environments on a regular basis: those transmitting malaria or causing diarrhea, and those deficient in essential nutrients. [...] Although these are not *omni*present environmental factors, they are, unfortunately, not extremely rare either. According to Boorse's proposal they should therefore not cause disease". Again, these are very counterintuitive consequences. Thus, Kingma concludes that the normal environment in Boorse's amended BST cannot be defined statistically. After rejecting two other possible naturalistic ways to specify what normal environments are[7], Kingma [3, p. 258] formulates the problem in the form of a dilemma: "without situation-specific function, the BST cannot account for dynamic physiological function" that is, the fact that normal responses are situation-specific (Kingma's fourth feature

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[5] Here we adopt Hausman's [10, p. 661] interpretation Boorse's normal environment clause which, we think, better reflects what Boorse presumably meant. Boorse's own statement is: "a statistically species-subnormal function [...] is pathological if it results from an environmental factor outside an arbitrarily chosen central statistical range of that factor in the environments where the species lives." [1, p. 84]

[6] We leave aside Kingma's spermatozoon example as it becomes irrelevant in the light of Hausman's interpretation of Boorse's normal environment clause (see note 4).

[7] These two possibilities are normal environments specified as *non-adverse* and as *natural* environments.

presented in section 2.1), "but with situation-specific function, the BST cannot account for situation-specific diseases, i.e., diseases that are statistically typical in a certain situation or environment." Boorse's way out of this dilemma consists in making normal function relative to a normal environment, but this solution fails, as there is no successful naturalistic way to specify what a normal environment is.[8]

2.3 Situation-specificity and the intrinsicality of health

We agree with Kingma that proponents of the BST should give up attempts at defining normal environments. We also concur with Hausman's [4, p. 259-260] reading of the problem as partly one of making sense of the intuitive idea that functions need only be performed in *relevant* situations. The problem identified by Kingma, in essence, is that the BST, even the amended version, remains unable to demarcate two kinds of situation-relative non-performances[9]: (1) those which are plainly normal because they occur in situations where the performance of the function is not relevant, e.g. not digesting when one has fasted; and (2) those which signal a pathological state because they occur in situations where the performance would be relevant but is hindered by some interfering factor, e.g. not digesting because of paracetamol poisoning. Like Garson and Piccinini [12, p. 17-18], we think that some way out of Kingma's dilemma can be found by recalling that the BST defines health as an *intrinsic* disposition of organisms:

> One important question that arises when a trait is not performing its function is the following: is the trait, as it were, intrinsically dysfunctional or is it merely within an environment that is not conducive to the performance of the function? Suppose that a person is submerged in water. Clearly, the lungs cannot perform their function of distributing oxygen. However, at least initially (a short time after submergence), the lungs are not dysfunctional. This is because if they were transposed to the normal environment for their functioning (an environment replete with air), they would perform their function. Alternatively, imagine that someone's lungs are unable to perform their function of distributing oxygen because that person's chest was crushed in a stampede and the lungs

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[8] As Kingma notes, it is a requirement that normal environments be specified in a naturalistic way if, as Boorse wishes, the BST is to remain a naturalistic account of health.

[9] For concision, we speak of non-performance in a broad sense which includes not only absence of performance but also underperformance, which, for Boorse, itself includes what some often call overperformance (cf. Boorse [11, p. 371]).

> suffered gross structural damage. If that person's lungs (given the structural damage), were placed within the normal environment for their functioning (one without a stampede and without chest damage), they would not be able to distribute oxygen. It is for this reason that, in the case of lung damage following being trampled, the lungs are dysfunctional. They are not merely unable to perform their function due to an environment that is not conducive to performance.[10]

Fundamentally, then, Hausman's two kinds of non-performances can be contrasted by their effect on the *internal disposition* to normal function of the organisms involved. In the first case, this internal disposition is not affected while in the second it is. Seeking to locate this internal disposition, proponents of the BST should, we think, simply appeal to the role of the design of a reference class in their theory, and emphasize that this design determines not only normal functions *simpliciter*, but also the relevant actualization conditions for these functions. For instance, the normal function of the stomach is not simply to digest, but to digest *food*, and thus it is implicitly implied that its function is to digest *in the presence of food*. So, normal and pathological non-performances can be distinguished by paying attention to whether the non-performance occurs in a situation where the function is or is not designed to be performed.

However, defining the relevant situations for the performance of functions by appealing to the design creates a problem of circularity. This is so because in Boorse's theory, on the one hand, the functional design is what is manifested in the statistically typical performance of the members of the reference class, and on the other hand, as Kingma emphasizes (see section 2.2), this statistically typical performance must be indexed to relevant situations. This amounts to saying that a situation is relevant for a function to be performed just if the situation is one where the design of the reference class can be statistically observed, whereas a situation where the design of the reference class can be statistically observed is one which is relevant for the function to be performed. To avoid this conceptual circularity, we agree with Hausman's [5, section 2] suggestion that a naturalistic account

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[10] However, we do not follow Garson and Piccinini's solution to the situation-specificity problem in terms of "non-negligible contribution to survival or inclusive fitness." See section 3.2 below for our stance on the relation between health, reproduction, and evolutionary fitness.

of health should take more seriously Wachbroit's [13] distinction between *statistical* and *biological* normality. As Hausman notes, the relation between these two kinds of normality is contingent and empirical rather than conceptual:

> Although statistically normal functioning usually coincides with adequate functioning (lest organisms fail to survive and reproduce), the coincidence need not be perfect. Processes of selection and development are not flawless, and, even if they were, organisms can only be healthy in some environments. In an environment without essential nutrients, no one would be healthy. [5, p. 525]

Yet, given that evolutionary processes confer some robustness to the contingent correlation between statistical and biological normality, Hausman, following Wachbroit, proposes that the former can nevertheless play an *evidential* role in the discovery of the latter.[11] This proposal entails a stronger understanding of Boorse's idea that the inference of the design from statistical typicality involves a process of *idealization*. In such proposal, the design is always epistemologically underdetermined by what is statistically observed. The process of idealization then requires that some tokens be discounted as aberrant cases on the grounds of previous assumptions about what the normal design can or cannot be and about what situations are appropriate to observe it in. This may allow that some statistically typical traits, e.g. tooth decay, be nevertheless considered pathological (see Hausman's [5, p. 525ff] discussion of Schwartz's [6] cases of "common diseases"). Such an idealizing process still involves some partial circularity, but it is *epistemic*, not *conceptual* circularity; and as Nancy Cartwright [14, 15] has famously argued, partial epistemic circularity seems to be standard to scientific practice. Thus, we think that such circularity should be considered compatible with naturalism about health.

[11] For Boorse too, what legitimates the appeal to the notion of design is the effect of "normalizing selection," which, on shorter-than-evolutionary time-scales, maintains some significant degree of uniformity among members of a species [see 2, p. 557]. In section 3.2, we discuss the relation between designs of reference classes and evolutionary factors.

Boorse's appeal to the notion of design has of course prompted other lines of criticism[12]. We do not fully deal with these criticisms in this paper, although we will have a little more to say about designs in section 3.2. This essay instead focuses on some further subtleties regarding the situation-specificity of normal functions which, we think, have not been given sufficient attention in previous philosophical discussions of health. Considering them will be relevant to future attempts at dealing with issues related to the epistemology of designs and normality raised by Boorse's critics. So far, we delineated only two cases of non-performances: those which are entailed by the design and so are perfectly normal, and those where a performance is designed to be performed, but fails to do so because of some particular circumstance and so are purportedly pathological. Yet, it does not seem true that *all* such circumstantial non-performances are cases of pathologies. For instance, the fact that one cannot see clearly just after moving from a well-lit room to a much darker (though not pitch-black) one does not reveal one's eyesight to be in a pathological state, even though one's eyes are (presumably) designed to be able to see in such a situation (as is suggested by the fact that clear vision will normally be restored after a few seconds). Or the fact that one is out of breath and needs to stop after having run for a long time does not always indicate that one's lungs are in a pathological state. And recall Garson and Piccinini's example of the lungs' failure to distribute oxygen when one is in water, which, they emphasize, is no sign of pathology. This is so even though, as oxygen distribution is always necessary to maintain life, it is, presumably, not a function whose performance is *designed* as situation-specific. The lungs are intrinsically disposed to circulate oxygen in such situation (they are not designed to interrupt their performance), and the performance is suspended simply because a background condition necessary for it, namely the presence of gaseous oxygen, is not provided. There are many cases similar to these. Thus, it seems wrong to classify all non-performances which occur in performance-relevant situations as pathologies. So appealing to design-

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[12] See Kingma [16], Cooper [17, p. 266-267] and Ereshefsky [18, p. 222-223] for recent criticism related to the notion of design, and Ananth [7, p. 156-161] for a discussion of older ones and of Boorse's responses to them.

specified relevance conditions excludes only *some*, but *not all* cases of non-pathological non-performances.

In the following, we propose that the notion of *homeostasis*, which Boorse [1, p. 78-79] acknowledges as implicitly underlying the BST[13], can illuminate the kind of intrinsic disposition which health consists in, and provide some indication as to how to deal with cases of situation-relevant non-pathological non-performances like those we just mentioned. This proposal will partially diverge from the BST, but will remain faithful to Boorse's idea that normal functions are design-typical contributions to biological goals. We will indicate these divergences as we go.

2. Health and homeostasis

2.1 The notion of homeostasis

The term "homeostasis" was coined by Walter B. Cannon in 1926 to characterize the kind of dynamic equilibrium by which higher living organisms maintain their stability against the fluctuations of their outside environment [19, 20]. With this concept, Cannon was elaborating on a view of life set up by the 19th century physiologist Claude Bernard, according to which what distinguishes living and nonliving entities is the formers' ability to actively maintain the stability of their *milieu intérieur* (internal environment) through compensating responses [21, 22]. Whereas inert entities like rocks attain stability passively, living entities, Bernard remarked, achieve constancy through active regulatory mechanisms. By means of the concept of homeostasis, Cannon linked the phenomenon of regulation through compensating responses depicted by Bernard to the notion of negative feedback developed in the field of cybernetics, and thereby laid one of the main bases of

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[13] We follow Ananth [7, 36-37] and take as indications of Boorse's acknowledgment of homeostasis as a constituent of health his statements that "[o]bviously, no fact is more pervasive than what is often called the "dynamic equilibrium" of normal physiology: the normal functional variation within organisms acting and reacting to their environment," and that "[t]hough I did not stress the dynamism of normal physiology in presenting the BST, I always assumed it".

contemporary physiology.[14] Given the importance of homeostasis for physiology, we find it surprising that the notion was only rarely brought to the fore in analyses of health proposed by philosophers of medicine. Ananth's [7] and Bechtel's [26] evolutionary-homeostatic accounts are exceptions in this respect. In this section, we outline an account of health in terms of homeostasis, which will be used in section 4 to illuminate the way in which an account of health should deal with the situation-specificity of normal functions.

To spell out the place that the notion of homeostasis should have in a naturalistic account of health, it is helpful to start with Ananth's recent discussion of the link between health and homeostasis [7, 189-196]. As Ananth [7, 190-191] indicates, homeostasis involves five main components[15]:

1. **A regulated variable:** A variable kept constant, e.g. body temperature, blood pressure, concentration of particular nutrients in blood.

2. **A set point:** A quantitative range of value for the regulated variable, e.g. normal human body temperature varies between about 36.5 and 37.5 °C.

3. **Sensor(s):** A gauge which assesses the current state of the regulated variable, e.g. the anterior hypothalamus assesses the temperature of the body.

4. **An integration center:** A center which compares the current state of a variable with its set point, e.g. the hypothalamus compares the information it receives from temperature sensors with the normal body temperature.

[14] For detailed historical surveys of the origins and developments of the notion of homeostasis, see [23], [24] and [25].

[15] Ananth takes this characterization from Seidel [27].

5. **An effector:** An agent which adjusts variables deviated from their set point, e.g. the hypothalamus triggers sweat production when the body's temperature is over the set point, or increases cellular metabolism when it is under the set point.

Thus formally, homeostasis is the maintenance of a variable at a set point, through feedbacks generated by an effector, in order to compensate deviations from set points assessed by an integration center on the basis of information provided by a sensor. As Ananth further specifies, such homeostatic maintenance characterizes living organisms both at the level of the relation between organs and the intercellular environment and at that between the whole organism and its surroundings [7, p. 191-194]. Hence, following Ananth, we suggest that an organism's health is linked to its ability to homeostatically maintain the functions of its organs and its whole body.[16] As we will show, the fact that homeostasis involves the attainment and maintenance of stability through active responses has significant consequences for the appropriate way to deal with the situation-specificity of health. As these active responses necessarily occur through time, homeostatic

[16] For Ananth, homeostasis acquires its role as a component of health from its being a product of natural selection and from its contribution to an organism's survival and reproduction [7, p. 194-196]. Here he is sensitive to a remark made by Bechtel that some basis must be given for "why any premium should be placed on maintaining a system at its homeostatic equilibrium point," and builds on Bechtel's suggestion that evolution provides such basis [26, p. 151]. Hence, Ananth argues that what provides grounds for defining health in terms of homeostasis is the fact that living organisms' tendency to achieve homeostasis has an evolutionary origin and that such tendency, in turn, contributes to their propensity to survive and reproduce. It seems to us that such reasoning conflates *conceptual* and *causal* analysis. The fact that homeostasis has an evolutionary origin does not imply that it gains its conceptual relevance to the definition of health from this origin. In the same way, the fact that, by and large, the achievement of homeostasis by organisms contributes to their species' ability to persist and evolve does not imply that homeostasis is a component of their health in virtue of this contribution. The basis for a conceptual analysis of health in terms of homeostasis (or any other notion) should be found, not (to paraphrase Bechtel) in some premium placed on evolution, but in the analysis's ability to account for the terminological practice of medical theoreticians.

maintenance normally involves some time-lags between the moment when a performance is interrupted and the moment when full performance is reestablished. Moreover, as any homeostatic ability requires some background conditions to be actualized, homeostasis will unavoidably fall short of doing its work in situations when those conditions are not provided. This implies that these kinds of circumstantial performance interruptions are perfectly normal and should not be deemed revelatory of any abnormality on the part of an organism itself.

3.2 Homeostasis, survival and design

A first deviation from the BST involved by our proposal consists in reinterpreting Boorsian functions as contributions to homeostasis rather than to survival and reproduction. Such reinterpretation, we think, remains faithful to the spirit of the BST. That this reinterpretation remains faithful to the spirit of the BST is fairly straightforward regarding survival, for what is intrinsic to an organism's propensity to survive is, arguably, its ability for homeostatic maintenance. In other words, to survive for a higher organism just is to maintain homeostasis. A reinterpretation in terms of homeostasis however is less straightforward regarding reproduction. Nothing in the notion of homeostasis itself involves actual or even potential reproduction. Thus, by downplaying reproduction, our reinterpretation diverges from the BST, which, as we have seen, ties health to the achievement of the biological goals of survival *and reproduction*. Yet, an objection to evolutionary accounts of health discussed by Bechtel [26, p. 152] pleads in favor of downplaying reproduction: "Conditions that afflict one after his or her reproductive years would not seem to reduce biological adaptiveness (propensity to reproduce) and so, within the evolutionary framework, could not count as diseases."[17] In a discussion of biological function, Schaffner [28, p. 388] raises a similar issue when he notes that, intuitively, we would ascribe functions to sterile organisms, while accounts of functions in terms of evolutionary fitness would not. Such cases support the downplaying of reproduction we are proposing. Hence, in the very spirit of Boorse's account, we suggest that health

[17] Bechtel acknowledges this objection as a problem which confronts the evolutionary account of health he is proposing.

should include the ability to reproduce only for organisms belonging to reference classes which normally reproduce—that is, whose design entails reproduction. Although this is a divergence from the BST, it may be a relatively slight one. Boorse [1, p. 90-91] himself downplays reproduction in his discussion of functional normality after reproductive age.

It must however be emphasized that although, as we indicated, Boorse acknowledges that homeostasis implicitly underlies the BST, he explicitly rejects it as a *sufficient* condition for health:

> Certainly many aspects of normal and abnormal physiology fit this model. Countless biological variables like blood temperature, acidity, speed of flow, and composition with respect to innumerable substances and organisms must be kept within narrow limits in a state of health.
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> Homeostasis cannot, however, profitably be viewed as a general model of biological function. Many life functions are not homeostatic unless one stretches the concept to cover every goal-directed process. Perception, locomotion, growth, and reproduction upset an equilibrium rather than maintain one. To say that their ultimate aim is internal equilibrium is unfounded; it is equally true, or truer, that the ultimate aim of internal equilibrium is perception, locomotion, growth and reproduction. Thus there is no point in trying to view corresponding diseases such as deafness, limb paralysis, dwarfism, or sterility as homeostatic failures. One can see why various equilibria are crucial to life without confusing homeostasis with the broader idea of normal functioning. [2, p. 549-550]

Moreover, in accordance with Boorse's [2, p. 548-549] response to Ryle's [29] account of health in terms of acclimation-adaptation, a miner's lungs deterioration resulting from his exposure to low levels of oxygen remains a deterioration. This is despite the fact that this deterioration favors his body's maintenance at the low oxygen levels his daily occupation exposes him to[18]. Thus, health cannot be the homeostatic maintenance of just *any* state. Some additional criteria must specify which states an organism's homeostatic mechanisms must maintain for it to be healthy. As we indicated, homeostasis requires a reference to some set points that an organism's compensatory responses are

[18] On Ryle's example and Boorse's treatment of it, see Ananth's [7, p. 25-27] illuminating discussion.

supposed to maintain, and these set points are not established by the notion of homeostasis itself but must be specified independently of it.

In the literature on functions, similar remarks have been made by Krohs [30, 31] in a critical discussion of organizational theories which seek to define normal functions in terms of self-maintenance, a notion closely related to that of homeostasis [32, 33][19]. As Krohs notes:

> [W]e find many biological functions that are not related to homeostatic self-regulation or that have even disastrous or lethal effects. In, e.g., fishes and octopods, biologists describe functions that terminate the life of an individual after propagation. […] If one does not want to marginalize non-homeostatic functions, one must at least admit other criteria for regulation than homeostasis. […] Biologists want to be able to speak about dysregulation, i.e., about malfunctions of regulatory system. So a norm is required that delineates proper from impaired regulation. Even if we regarded regulation as setting the reference for functionality, we needed to explain the norm for proper regulation. This means that we must accept norms above the level of actual regulation […] [31, p. 126].

Thus, as Boorse and Krohs emphasize, there can be normal functions which do not contribute to homeostasis or self-maintenance (e.g. growth and reproduction), and even abnormal ones which do. Thus, homeostasis is not a sufficient condition for health[20].

In response to the insufficiency of self-regulation, Krohs argues that normal functions should be defined in relation to the designs of what he calls “fixed types.” This proposal resonates with Boorse’s emphasis on the important role played by the designs of reference classes in a satisfactory account of health. In line with Boorse and Krohs, we think that homeostatic maintenance, although necessary, is not sufficient for health, and that an account of health should include a reference to a

[19] Related yet not identical because the organizational theory ties the idea of self-maintenance to that of organizational closure which requires that function bearers be both maintained by and contributing to the maintenance of the organized entity they are part of. See Mossio and Bich [24] on the relation between homeostasis and organizational theories of function, and Holm [34, 35] for an organizational account of health inspired from Mossio and colleagues’ work.

[20] Although see Saborido et al. [36] for a review of attempts to account for reproduction under organizational theories of functions and an original proposal.

design. As we indicated above, Boorse's appeal to designs and reference classes has prompted several challenges which this paper is not intended to fully answer. Nevertheless, Krohs points towards what we see as a promising way to deal with at least some of these challenges. As he [30, p. 70] points out, most philosophers (e.g. Kitcher, Millikan, Neander) who have linked the notion of function to that of design have conceived natural designs as the products of a selective history. This is also the case with Boorse who grounds the legitimacy of the BST's appeal to (statistical) designs in the effect of "normalizing selection" [2, p. 557].[21] Yet, Krohs [31, p. 129] argues that such grounding of design in natural selection may be too narrow in the light of recent developments in contemporary biology, such as the critique of adaptationism [37], and some new biological research programs like EvoDevo, EcoEvoDevo and epigenetics. Expanding from that narrow selectionist view, Krohs [30, p. 74] proposes to ground the designs of biological types in ontogeny rather that phylogeny:

> My answer to the question what a design is looks neither at the phylogeny of an entity nor at its organization alone, but at the description of its ontogeny, of the process that brings organization about. The question is how the relevant scientific theories describe that a component of a complex entity comes into place. With respect to some physical systems, such as atoms or solar systems, this question may be answered by a description of a process of self-assembly. […] With respect to biological organisms, descriptions of the ontogeny refer to genes coding for proteins, to gene regulatory networks influencing the transcription of these genes, to developmental systems, to external influences on developmental processes, etc. Biological descriptions of development include self-assembly but in addition refer to genetically, epigenetically or environmentally fixed structures.

This, as Krohs notes, does not reject selectionist accounts of designs altogether, but rather includes them into a broader picture. It retains from these accounts the general idea that the existence of designs in nature requires that some "type fixation" be at play, but recognizes that it is not the

[21] Such grounding of the appeal to design in past natural selection has led some to suggest that Boorse's account of health comes close to defining health in terms equivalent to Millikan and Neander's etiological account of proper function (e.g. Giroux [8, p. 81]) or to Godfrey-Smith's recent selective history account (see Krohs [31, p. 131]).

genome alone which fixes the designs of biological types. In accordance with Krohs's remarks, we think that it should be left open whether the designs of reference classes in an improved Boorsian account of health should be viewed as the sole products of "normalizing selection" or as type-fixed by other biological factors as well. Hence, Krohs's suggestion provides a further improvement upon what we observed above about the ontology of designs. Not only should biological normality (in accordance with Hausman's challenge to Boorse's appeal to statistically-defined designs) be distinguished from statistical typicality, but additionally, the former should be linked to a notion of design that encompasses more than what a narrow selectionist account embraces. Despite Krohs's refinements, some will possibly remain skeptical of appeals to designs in nature. However, we think that considerations of design are indispensable in the light of Boorse's and Krohs's remarks on the insufficiency of homeostatic regulation for health. And if all naturalistic accounts of biological design and types fail, the project of formulating a naturalistic account of health would most likely have to be abandoned[22].

Thus, although our account emphasizes homeostasis as a central constituent of health and involves a concept of design that is more robust than Boorse's statistically-defined notion, it retains central roles for the concept of design. First, as mentioned in section 2.3, the design determines the relevant conditions for the performance of functions (e.g. that digestion needs only occur when one has eaten). Second, it specifies the set points at which homeostatic responses are supposed to maintain the regulated variables. This role allows for the exclusion of cases of dysregulation like the Durham miner example from healthy states. And a third role must be added in the light of Boorse's and Krohs's indication of some functional performances which, like growth, perception, locomotion and reproduction, do not contribute to homeostatic maintenance. Although these functions are not means by which homeostasis is achieved, they are nevertheless capacities that a healthy organism

[22] Note however that the consequences of such abandonment would reach far beyond the philosophy of medicine, for as Krohs [31, p. 132-133] emphasizes, notions of design and types still hold important roles in many contemporary biological research programs.

(whose design includes them) maintains. Instead of being *means* to homeostasis, they are rather *ends* included in the design of a given class of organism, which a healthy member of the class maintains homeostatically. This constitutes a third role for the appeal to design in our Boorse-inspired account of health, namely that of specifying a set of end functions characteristic of a class of organisms, which are normally maintained homeostatically by members of this class. With this third role, our use of the notion of homeostasis turns out to be broader than the way it is commonly used by physiologists. Although physiologists usually restrict the scope of homeostasis to the regulation of vital functions (that is, to those which maintain the stability of what Bernard refers to as the *milieu intérieur*), we propose to expand the use of the notion to also include the regulation of non-vital functions, such as growth, perception, locomotion and reproduction. Such expanded use is, we think, justified by the fact that many non-vital functions are maintained through compensatory feedbacks which are formally identical to those which control vital functions. For instance, an organism's ability to see when moving from a bright to a dark place (or the other way round) is maintained through feedback mechanisms which contract (or dilate) the iris to let the right amount of light reach the retina. Or similarly, the ability of a male to reproduce is controlled by feedback mechanisms involving testicular hormones which regulate spermatogenesis.

To make explicit the role of design in our account, we propose that health should be defined not simply in terms of homeostatic maintenance, but in terms of *homeostatic maintenance of design*. This involves one further deviation from Boorse's account. Although we retain the two main components of that account—contribution to survival (and reproduction when applicable) and reference to a design—these components are reorganized in our proposal. Boorse identifies survival and reproduction as generic goals common to all species, and defines functions as contributions to these goals; and then adds the reference to a design to characterize *normal* functions. In our account, Boorse's two components are merged in that the goal of organisms is not generic survival and reproduction, but rather survival reinterpreted as homeostatic maintenance of design.

3.3 Homeostasis as an intrinsic disposition

To summarize our proposal introduced so far, we first reinterpreted the survival and reproduction components in the BST in terms of homeostatic maintenance. Second, following Boorse, we highlighted the insufficiency of homeostatic maintenance as an analysis of health and emphasized the complementary role of design in a more complete analysis. And third, we merged the homeostasis and design components into a single one defined as homeostatic maintenance of design. One last but important clarification must be made concerning a frequent ambiguity in the use of the term homeostasis. Sometimes it is used to refer to the *achievement* of the state in which an organism's functional abilities are fully maintained, and sometimes it is used to denote the process by which an organism reestablishes this state when it is disturbed. In this latter sense, homeostasis is not the achievement of designed functional abilities, but a *disposition* to reestablish these abilities. It is in this latter sense that our account conceives homeostasis as a necessary constituent of health. As we see it, an organism is in a pathological condition not merely when a functional ability regulated by its homeostatic responses is lost or diminished, but rather when it loses its *homeostatic disposition* to restore the lost or diminished ability.

Having made this clarification, homeostasis can now be used to explicate the kind of intrinsic disposition which health consists in. Health, as Garson and Piccinini remark (see section 2.3), is an intrinsic disposition of organisms, but in contrast to Hausman's characterization, this disposition is not simply one to perform functions in relevant situations. Viewing health as the homeostatic maintenance of designed functional abilities implies that there can be cases of functional non performance in performance-relevant situations which are perfectly normal; cases when a functional ability is lost or diminished because of some interfering factors and the organism's homeostatic responses are working to restore it. Given that, as we indicated, a homeostatic response involves time-lags between the moment when a functional performance is disturbed and the moment when it is restored, an organism, in such a situation, is not pathological. In other words, in our account, health does not require that an organism always be able to fully perform its functions (even in performance-relevant situations), but rather, that the organism's homeostatic ability to maintain or restore those performances be intact. This implies that some situations can be challenging to an organism's homeostatic responses without being pathological. Pathology then, on our account, is the loss or impairment of an organism's homeostatic capacities rather than a mere disturbance of homeostasis.[23] And as Garson and Piccinini's lungs failure example illustrates, some situations can be challenging up to the point that they are overwhelming. As we remarked, any homeostatic ability requires some background conditions to be actualized. Even a normal organism has no homeostatic resources to restore a function in a situation which does not provide these background conditions. Thus, as suggested by Garson and Piccinini's example, it is perfectly normal for a non-amphibian organism not to be able to restore its full oxygen circulation in a situation where no gaseous oxygen is available. Such inability does not signal a pathology on the part of the organism, insofar as its intrinsic disposition to maintain and restore its full oxygen circulation in an oxygen-abundant environment is still intact. Indeed, in such situation, an organism may die from suffocation, but according to our homeostasis-based account, such death resulting from unsuitable background conditions is not death from pathology. Here, thus, we diverge from Boorse's [1, p. 69] contention that "death is the ultimate pathology."[24] In accordance with these elaborations, our proposal can now be formalized into the following statement:

(H) An organism is healthy if and only if it is intrinsically disposed to homeostatically maintain or restore its intrinsic disposition to perform its designed functions in relevant situations.

This definition somewhat complexifies the understanding of health as an intrinsic disposition of organisms in that it involves two layers of dispositionality. First, the dispositionality entailed by the

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[23] Here we diverge from Bechtel's [26, p. 149] view. Our view seems closer to Ananth's when he defines health as a *propensity* to secure homeostasis [7, p. 196].

[24] Considering overwhelming situations as pathologies would be inconsistent, for they are just extreme cases of challenging situations, and challenging situations are intuitively not diseases.

fact that the design specifies not only a set of functional performances, but also a set of conditions where the functional performances are relevant (this layer of dispositionality is the one highlighted by Hausman in his response to Kingma's dilemma, see section 2.3). And second, the dispositionality implied by the fact that healthiness requires a disposition to maintain one's designed functions homeostatically but not necessarily the *achievement* of this maintenance (so that a momentary interruption of homeostatic maintenance due to interfering factors or lack of necessary background conditions is not itself pathological). Disentangling these two layers might appear fastidious but, as we will show in section 4, it allows us to ground important distinctions concerning the situation-specificity of normal function.

4. Situation-specificity revisited

4.1 Varieties of non-performance

We can now describe how our account of health as disposition to homeostatic maintenance of design illuminates the situation-specificity of normal functions. It follows from our account that, relative to a given function, five different kinds of situations must be delineated:

(1) **Performance:** The function is designed to be performed in this situation and the situation allows both the disposition to homeostasis and the disposition to perform the function to be actualized. The function is performed.

(2) **Non-performance because the situation is not relevant:** The situation allows the disposition to homeostasis to be actualized so that the disposition to perform the function is present, but the function is *not* designed to be performed in this situation. The function is not performed but the non-performance is perfectly normal.

(3) **Non-performance because the situation is challenging:** The function is designed to be performed in this situation but the disposition to perform the function is temporarily lost because the organism's maintenance of this disposition is disturbed by some interfering factor

(although its homeostatic disposition to maintain it is not itself deteriorated). In this case, the disposition to perform the function should quickly be retrieved as homeostatic mechanisms operate. The function is temporarily not performed but the non-performance is not a pathology.

(4) **Non-performance because of pathological condition:** The function is designed to be performed in this situation but the organism has enduringly lost its disposition to perform the function because its homeostatic disposition to maintain it has been deteriorated. The non-performance of the function is a pathology.

(5) **Non-performance because the situation is overwhelming**: The function is designed to be performed in this situation but the disposition to perform the function is lost because the organism's homeostatic maintenance of this disposition is overwhelmed and unable to compensate for the intensity of the challenge (although the homeostatic disposition to maintain the function in a bearable situation is not itself deteriorated). In this case, the disposition to perform the function would be retrieved should the intensity of the challenge be decreased to a bearable level before the homeostatic disposition is also lost. The function is not performed and, if the intense challenge overwhelms a vital function, the organism may die, but *not* from pathology.

Among these cases, (5) is simply an extreme version of (3), and although only situations (4) are themselves cases of pathologies, situations (2), (3) and (5) can sometimes lead to situations (4). Situations (2) can lead to situations (4) if the non-performance of a function favors its atrophy, and situations (3) and (5) can prompt situations (4) if they last so long that they erode the homeostatic disposition to maintain a functional ability.

So the problem with Boorse's way to spell out the contrast between situations where functions are normally performed and not performed is not only that its purely statistical character cannot single out situation-relevant and situation-irrelevant non-performances (case 2 vs. cases 3, 4, 5). It is also that a simple dichotomy between relevant and irrelevant situations cannot distinguish cases (3), (4), (5) from each other[25]. What allows our account to demarcate these three cases is its focus on homeostasis. By highlighting the fact that an organism's disposition to perform its functions is maintained homeostatically, our account can distinguish non-pathological cases of non-performances where homeostatic mechanisms are challenged or overwhelmed, from pathological non-performances where the homeostatic disposition itself is impaired.

4.2 Poisoning, suffocation, mountain sickness, sunburns, etc.

The following table classifies classical cases found in the philosophical literature on health and disease and new ones in the light of the above fivefold categorization (we add short explanations for cases which were not already explained in the above text). We contend that this classification accounts for the main intuitions that philosophers of medicine have sought to accommodate.

[25] Our distinction between what challenges the homeostatic maintenance of a function and what affects negatively the *ability* to maintain it has some familiarity with a possibility rejected by Kingma [3, p. 253] to demarcate normal functions from pathologies through a contrast between slow (or impossible) and quick reversibility. Our approach however, although it *implies* differences concerning the time required for the performance to be reestablished, does not *define* healthy and pathological states solely in temporal terms. Thus, we think, it handles Kingma's counterexamples to the reversibility/irreversibility demarcation criterion.

Classification of cases according to our account				
	States relative to oxygen circulation	**States relative to digestion**	**States relative to eyesight**	**States relative to UV protection**
(1) Performance	A standard amount of oxygen is circulated in the body by the lungs.	Digestion is normally performed.	Seeing properly.	Its current level of melanin protects the skin from damage caused by UV exposure.
(2) Non-performance because of non-relevant situation	Does not apply (oxygen circulation is always relevant).	Absence of digestion because of **fasting.**	Not seeing in **pitch-black darkness.**	The melanin does not perform any function because the skin is not exposed to UV radiation (e.g. when one is indoors under artificial lighting)[26].
(3) Non-performance because of challenging situation	**Altitude malaise** after gradual mountain ascension (normal acclimatization occurs so that the body can operate under lower oxygen levels). **Puffing after running** (normal levels of blood oxygen are retrieved as the person catch's her breath).	**Benign indigestion** after eating food that was too spicy, fatty or greasy, or after eating or drinking too much[27].	Not seeing clearly after **moving from a well-lit room to a much darker one.**	More intense UV exposure makes the current level of melanin in the skin insufficient for UV protection (the skin **tans** in response, to acclimatize to more intense UV exposure).
(4) Non-performance because of pathological condition	**Pulmonary edema** when one persists climbing despite mountain sickness (this state involves a loss of homeostatic ability to restore full oxygen circulation, so that descending will not be sufficient for retrieving full performance).	**Paracetamol poisoning**[28] **Non-benign indigestions** like gastritis, pancreatitis, etc (these states involve losses of homeostatic ability to restore digestive functions).	**Myopia, blindness, astigmatism, etc** (these states involve losses of homeostatic ability to accommodate for clear eyesight).	**Albinism** (this state is characterized by a partial lack or complete absence of melanin, and therefore involves a reduced or nonexistent ability to protect from UV exposure).
(5) Non-performance because of overwhelming situation	**Mountain sickness** resulting from too rapid ascension (one will recover shortly after descending). **Suffocation** when on the moon or in water (one will recover shortly when put back in an oxygen-profuse environment if the suffocation episode has not been long enough to kill the person or deteriorate her other functional abilities).	No case that we know of.	**Being dazzled** (in such situation the amount of light that reaches the eye lies beyond the range that iris dilatation can dim).	Too intense UV exposure overwhelms the body's ability to adjust the melanin level in the skin. **Sunburn** is likely to result[29].

[26] We thank an anonymous referee for pointing out this case.

[27] Physiologists consider vomiting as a reflex aimed at removing ingested toxic substances before they are absorbed, and nausea as aimed at preventing future ingestions of toxic food. Hence, they should be considered as homeostatic responses which indicate that the organism experiencing them retains its homeostatic ability to maintain or restore its full digestive abilities [see 38, p. 559].

[28] In accordance with Hausman's [4, p. 663-664] rejoinder to Kingma that, after such poisoning, one's "digestive system is no longer disposed to behave normally."

[29] Although on our account a person's developing sunburn does not indicate that her skin was in a pathological state before exposure, the resulting sunburn itself is indeed, as Kingma [3, p. 256] emphasizes, a pathological state. Sunburns cause DNA damages which affect the body's ability to regulate cell growth, and thereby increase the risk of skin cancer. This is an illustration of the possibility that a (5) situation prompts a (4) situation.

5. Conclusion

We first presented Kingma's demonstration that the BST faces a dilemma resulting from its statistical treatment of the situation-specificity of functional normality. We then followed Hausman's proposal that this dilemma could be avoided through a contrast between performance-relevant and performance-irrelevant situations, and suggested, in line with some remarks by Garson and Piccinini, the location of the relevance-conditions for normal functions in the intrinsic design of organisms. We then observed that, although this solution does some significant work in dealing with the situation-specificity of normal functions, it does not account for *all* cases of non-pathological performance-relevant non-performances. We proposed that defining health as organisms' homeostatic disposition to maintain their designed-functions allows us to account for these overlooked cases. We finally derived from this definition a fivefold categorization of health-related situations, and showed that it accounts for the main intuitions which philosophers of medicine have sought to accommodate. Thus, we presented a BST-inspired naturalistic account of health which deals more intuitively than does the original BST with particular cases of healthy states and pathologies. Although it deviates in many respects from Boorse's formulation, we think that our account preserves its major strengths and avoids its most significant weaknesses.

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