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Health and Functional Efficiency

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This essay argues that what is central to Christopher Boorse's biostatistical theory of disease as statistically subnormal part function (BST) are comparisons of the "functional efficiency" of parts and processes and that statistical considerations serve only to pick out a healthy level of functional efficiency. On this interpretation, the distinction between health and pathology is less important than comparisons of functional efficiency, which are entirely independent of statistical considerations. The clarifications or revisions of the BST that this essay offers are friendly amendments that render moot some of the most prominent criticisms of Boorse's account.

Keywords: *Christopher Boorse, function, functional efficiency, health, pathology*

I. INTRODUCTION

Christopher Boorse's biostatistical theory of health (BST), which is embedded, with some differences, in Jerome Wakefield's harmful dysfunction view (Wakefield 1992, Wakefield 1999), seems to me close to the truth. It maintains that organisms are organized systems whose goals are survival and reproduction. Their parts enhance the probability of their survival and reproduction. There is a pathology when the functional efficiency of a part is significantly statistically subnormal in a reference class of an organism in a benchmark environment. Reference classes are distinguished by traits such as age and sex. Benchmark environments are *relevant* environments in the sense that the way that a part is able to function makes a difference to the systems to which the part belongs, and they are also common environments in which the species has sustained its population. Complete darkness is obviously not a relevant environment in which to consider the functioning of human eyes. Although environments completely lacking in vitamin C

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are relevant environments in which to assess the functioning of most parts and processes, they are not benchmark environments in which humans can thrive. There are other important details, but this is the gist of the theory. As Boorse insists (Boorse 1987, 365f), this is an account of the theoretical concept of health that is of concern to physiologists and pathologists, not an account of the concept of disease of concern to diagnosticians or therapists.

The BST seems to face serious problems. This essay responds to two of these. The first concerns Boorse's identification of survival and reproduction as the ultimate goals of organisms. What justifies this choice? Does it rest on a covert evaluation? What should one say when survival and reproduction conflict? What about pathologies that do not affect survival or reproduction?

Second, as Schwartz (2007) argues, the frequency of conditions seems to be irrelevant to whether they are pathological. Although Boorse has always noted the existence of a few pathological conditions such as tooth decay that are statistically normal, he treats them as exceptional cases. Schwartz argues that the difficulties with a statistical distinction between pathology and health extend beyond these few cases. On the one hand, there are many "common diseases"—that is, pathologies that afflict large minorities of reference classes, such as hip dysplasia in certain breeds of dogs or hay fever in humans. On the other hand, there are many conditions found in only a tiny portion of the population that are not pathological, even though they involve functioning that is worse than normal. Schwartz concludes that the distinction between what is healthy and what is pathological is neither arbitrary nor a matter of prevalence. He argues that this conclusion poses a challenge to Boorse's naturalism. It appears that the distinction between health and disease depends on an evaluation of the effects of the diminished functioning.

Answering these objections is not, however, the central aim of this essay, and it does not aim to convince those who have no sympathy for Boorse's account. It aims instead to establish that what is central to Boorse's account are comparisons of the functional efficiency of parts and processes and that statistical considerations serve only to pick out a healthy level of functional efficiency. The clarifications or revisions of the BST that I shall offer are, I think, friendly amendments, but I'll leave it for the reader to judge. Section II responds to the first objection. I argue that both the definition and assessment of the functions of a part of an organism must be relativized to the goals of the systems within the organism to which the part contributes. Section III develops the notion of functional efficiency and argues that it is central to the BST. Section IV clarifies Boorse's distinction between health and pathology and argues that the distinction is less important than comparisons of functional efficiency. Schwartz's observations about the distinction between health and pathology are correct, but they are not inconsistent with Boorse's views, as I interpret them in section IV. Section V concludes.

II. PART FUNCTION, REPRODUCTION, SURVIVAL, AND FITNESS

According to the goal-contribution view of functions to which Boorse (2002) and I subscribe, the functions of parts of some "directively organized" system consist of the contributions the parts typically make to the probability that systems of the kind to which the parts belong will achieve their goals. A system is directively organized if and only if it shows persistence in its pursuit of its goal, where that persistence depends on details of the structure of the system, not merely on natural law. Although a boulder rolling down a hill shows persistence in its voyage to the bottom, that persistence is not explained by details of the structure of the hill, and for that reason the hillside is not a directively organized system. It may be possible to ground the view of health I shall defend on an etiological rather than a goal-contribution view of functions, but I will leave that task to defenders of etiological views.

Given the theory of evolution, the highest-level goal of organisms is fitness—that is, the transmission of genes of the kind the organism possesses. Selection, not any human evaluative commitment, imposes this goal. To a first approximation, organisms transmit their genes if and only if they survive to reproduce, reproduce successfully, and survive to nurture their young. It is thus an excellent approximation to assert, as Boorse does, that the highest-level goals of organisms are survival and reproduction. But neither survival nor reproduction nor any combination of these is in fact the highest-level goal of organisms. Consider, for example, a prairie dog that gives a warning call that threatens its survival. Making the warning call lowers the individual prairie dog's probability of surviving and reproducing. Yet the prairie dog has no pathology. Its behavioral system is functioning as it should function and promoting its inclusive fitness.

Organisms are complicated systems made up of many subsystems that are directively organized to achieve specific goals. The kidneys, for example, have the goal of removing wastes from the blood. The goals of the subsystems within an organism typically contribute to the fitness of the organism. But there are exceptions. Some parts are redundant. Whether the left kidney is functioning may make no difference to fitness. Other systems within the organism may have no function. A benign lipoma contributes nothing to survival or reproduction (though one may question whether it is directively organized). Other systems within organisms, such as malignant tumors, may threaten survival or reproduction. The functional efficiency of a part with respect to one system to which it belongs may differ from its functional efficiency with respect to other systems in which it is contained. The blood vessels in a thriving lipoma in Martha's left arm are contributing to its growth. With respect to the growth of the lipoma, they may be functioning with high efficiency. But these blood vessels may not be contributing anything to Martha's fitness. The blood vessels within Morris's malignant tumor are contributing to the tumor's growth while cutting short Morris's life. Treatments of the malignancy may aim to induce malfunctioning in the tumor's blood vessels in the service of enhancing Morris's health.

By relativizing functional efficiency to system goals, one can understand how a malfunction, such as that induced by removing the optic nerves of a female octopus (that would otherwise starve itself tending to its eggs) can enhance survival. Even if the highest-level goal is fitness and, as is the case in the female octopus that has unhatched eggs, survival does not promote fitness, survival is also a goal, and the functioning of a part of an organism can be assessed with respect to that goal. Human bodies are structured so as to maintain life for many decades. That goal typically promotes fitness, but it remains a goal whether or not it promotes fitness, and the functioning of the parts of human bodies can be assessed with respect to the goal of survival as well as with respect to the higher-level goal of fitness and with respect to specific goals of subsystems to which the parts belong. So though not the ultimate goals (unlike inclusive fitness), survival and reproduction are not just approximations. They are goals themselves.

When a trait such as the functioning of the optic nerve in the female octopus enhances successful reproduction at the cost of survival or enhances survival at the cost of reproduction, then Boorse's theory does not say whether the trait is pathological. From the perspective of evolution, reproduction (conceived of as the survival of offspring to reproductive age) is what counts; but from the perspective of health, this weighting is questionable, and in many cases, it may be best to assess traits separately with respect to survival and with respect to reproduction and to be ambivalent about what is healthier overall.

Furthermore, insofar as traits of human beings (and I have in mind especially behavioral traits) have functions within supraindividual systems, assessments of functioning may be relativized to the goals of those systems. This possibility might help to resolve some of the puzzles attached to understanding mental illness. But I shall not pursue that thought here or say anything further about mental illness.

III. FUNCTIONAL EFFICIENCY

To help clarify his views, Boorse presents the following diagram:[1]

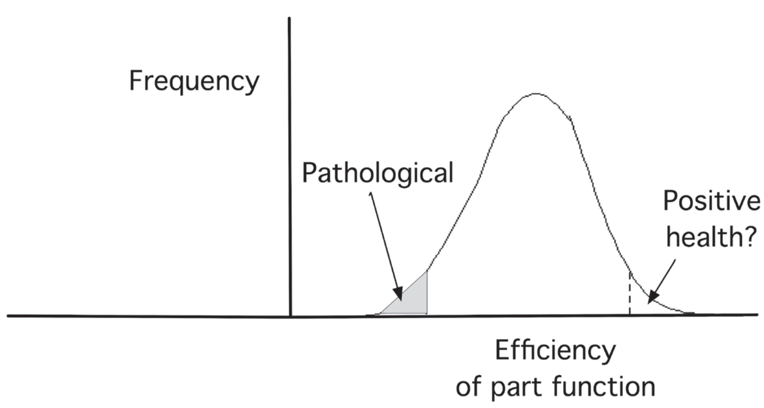

Fig. 1. Statistically subnormal part function (Boorse 1987, 370; Boorse 1997, 8).

The horizontal axis in figure 1 represents level of functional efficiency, while the vertical is the frequency of each level in a reference population. The discussion in the previous section suggests that the horizontal axis may be ambiguous, because the functioning of a part may have different efficiencies with respect to different goals of the organism or systems within the organism. There is no reason why the distribution of functional efficiency should be normal, continuous, single-peaked, or symmetrical. Some part of an organism might function at a small number of levels of efficiency or even at just two levels, "on" and "off."

Boorse maintains that the functioning of a part in a reference class is pathological if and only if its efficiency lies in the lower tail of the distribution of functional efficiency in the reference class. Exactly where to draw the line between low normal and pathological functioning is arbitrary. "Second, the lower limit on normal functional ability—the line between normal and pathological—is arbitrary. . . . The concept of a pathological state has vague boundaries—though the vast majority of disease processes involve functional deficits by any reasonable standard" (Boorse 1987, 371).[2] What, Boorse asks, apart from prevalence, would lead physiologists to conclude that 20–20 vision is healthy while 20–50 vision is not, rather than judging them both to be pathological as compared to the vision of an eagle (Boorse 2002, 102)? On Boorse's view, statistically normal functional efficiency defines "adequate" functional efficiency.

On one reading of Boorse's account, which seems to be implicit in Schwartz's criticism, and which I maintain is mistaken, one picks some low probability—that is, some small percentage of the area under the curve in figure 1 starting from the left and bounded by a vertical line. Whatever levels of functional efficiency lie to the left of the vertical line bounding this region are pathological, while whatever levels are to the right of boundary count as healthy. But, as Schwartz argues, with respect to conditions such as hip fractures or heart failure, *what determines whether a level of functional efficiency is pathological is its location along the horizontal axis, not its cumulative frequency in the population*. If Boorse distinguishes what is pathological from what is health by prevalence, then he is mistaken.

But there is an alternative and much more sensible interpretation of Boorse's view. On this view, the statistical distribution is relevant only insofar as the median level defines a level of adequate functioning. What distinguishes pathological from healthy functioning is then (as Schwartz maintains) whether the actual functioning or functional capacity is significantly worse than the median level. The only role for statistics is to identify the median level of functional efficiency, the adequacy of which natural selection will more or less guarantee in stable environments.

To clarify the role of statistical considerations, it is crucial to make clear what constitutes "functional efficiency." To judge how efficiently a (token) part is functioning is to judge how well the part is now able to serve the goals of the systems of which it is a part. What are the standards in terms of which parts differ in their capacities to function? Boorse says little about what defines efficiency and how its levels are to be distinguished, as they must be before one can talk about their frequency and draw a graph such as figure 1. In "Health as a Theoretical Concept" (1977) Boorse writes:

> To put it another way, the function of the thyroid is not merely to secrete hormones, but to secrete the right amount of them for current metabolic needs. For us there is no such thing as excessive function. But to keep the formulation unambiguous I use the term "efficiency"…. The population distribution to which the definition refers is the one for a function's efficiency. (1977, 559)[3]

In more recent work he says little more:

> …the function theory imposes a natural polarity on physiological processes…. The function of a physiological process is its contribution to physiological goals. By "deficiency" of function, then, I mean simply less function, less contribution to the goals, than average. This is an arithmetic[al], not an evaluative, concept. An easy example is homeostatic functions like regulation of body temperature…. *In general, whenever one knows the goal [function] of a process, one knows what is more or less function, and "deficiency," in the context quoted, simply means much less than average* (1997, 21; italics added).

These texts misleadingly suggest that one can simply read off functional efficiency from prevalence or measurement of some biological variable. Common capacities will typically be efficient within environments that are not changing rapidly, because natural selection promotes efficiency. This fact coupled with the frequent close correlation between functional efficiency and some biological indicator of functioning, such as ejection fractions or urea clearing rates, may explain why Boorse says so little about the assessments of functioning that are needed to define levels of functional efficiency. But comparisons of functional efficiency are (as the italicized phrase in the last quotation suggests) *evaluations* of functioning. Efficiency is not determined by prevalence: one needs to specify levels of efficiency before one can ask about their prevalence.

Assessments or evaluations of functional efficiency, rather than statistical considerations, are crucial to determining whether and to what extent there is a pathology. Consider Boorse's own example of thyroid function. Among the thyroid's many effects are the regulation of the body's sensitivity to other hormones and the body's overall use of energy. The thyroid accomplishes this regulation mainly through the production of the hormones triiodothyronine (T_3) and thyroxine (T_4). The hormone output is in turn regulated by a pituitary hormone, TSH. The statistically normal levels are 0.8–1.8 μg/l of serum T_3 and 46–120 μg/l of serum T_4. Levels that are higher or lower than these lead to goiters, which can make it hard to breathe and swallow. High levels of T_3 and T_4 also lead to diarrhea, muscle weakness, and weight loss.

Low levels lead to obesity, fatigue, weakness, and fainting. How well the thyroid functions—that is, its functional efficiency—diminishes (other things being equal) as it produces levels of T_3 and T_4 that are increasingly above or below the normal ranges. The effects of levels that are too high or too low (goiters, difficulties breathing and swallowing, weight loss, diarrhea, obesity, fatigue, muscle weakness, and fainting) interfere with the functioning of other parts, processes, or systems, or they directly diminish the probability of survival and reproduction. These effects of high or low levels of thyroid hormones also diminish well-being (with the possible exception of weight loss in a world where it is easy to overeat), and people have reasonably taken the harmful consequences as evidence of shortfalls in functional efficiency. But in Boorse's view and my view, what defines functional efficiency is goal contribution, not normative judgment.

To speak meaningfully of the efficiency of hormone output, one needs to assess it. The standards in terms of which physiologists and pathologists evaluate the capacities of a part are determined by the goals of the systems to which the part contributes or by their bearing on fitness. Neither statistics nor arithmetic tells physiologists what are appropriate levels of the thyroid's responsiveness to TSH. Levels of T_3 and T_4 above or below 0.8–1.8 µg/l of serum T_3 and 46–120 µg/l of serum T_4 would have the effects that they do regardless of their frequency. It is no more than a fortunate contingent fact, explained by evolutionary processes, that thyroids typically work as they should work. Statistics do not tell pathologists whether the "efficiency" of Jack's thyroid, which is hyperactive, is greater or less than the "efficiency" of Jill's thyroid, which is hypoactive. To gather any statistics on how the levels of functional efficiency of the thyroid are distributed (as opposed to gathering statistics on levels of T_3 and T_4), physiologists and pathologists need to know whether one pair of T_3 and T_4 levels is *better* or *worse* than another with respect to the achievement of specific system goals. Such knowledge is not easy to come by when, as in the case of the thyroid, there is no single quantitative variable whose value correlates with functional efficiency. Moreover, because the thyroid plays a role in many bodily systems and has many goals, the extent to which a given level of functioning meets the thyroid's goals is ambiguous. The levels of T_3 and T_4 output that are optimal for protein synthesis, for example, may not be the levels that are optimal for energy use or for fitness.

A further complication lies in the fact that high or low hormone levels may be due to a pituitary malfunction rather than any shortfall in the thyroid's functional efficiency. What one needs to assess is how the thyroid responds to levels of TSH, not its output of T_3 and T_4—although because pituitary glands typically function as they should, the output of T_3 and T_4 is a good indicator of whether the thyroid is responding as it should. In judging the functioning of one part or process, one judges how it is disposed to respond to the functioning of other causally independent parts.

How well a part is capable of functioning also depends on the external environment. Someone with mild hyperthyroidism may be healthier overall than someone with a normal thyroid in an environment overpopulated with fast-food restaurants. Although they may not be explicit about doing so, physiologists and pathologists accordingly relativize their assessment of the functional efficiency of parts to the environment in which the organism lives, whether or not that environment is a benchmark environment—provided that it is a relevant environment in which the functional efficiency of the part matters. It is often the case that a given capacity of a part has much the same level of efficiency across common environments. When there is such uniformity, it is harmless to leave the relativization to environment implicit.

The functioning of a part of an organism also depends on what I call the external "circumstances." Circumstances may change from minute to minute, unlike the environment, which I take to be relatively constant over the lifetime of an organism. (The onset of a rainstorm or the consumption of a heavy meal constitutes a change in circumstances rather than a change in environment.) Rather than relativizing the efficiency of actual functioning to circumstances as well as to environments, physiologists and pathologists focus on functional *capacities* or *dispositions* of parts or processes. Some parts of organisms are always active, while others, such as the immune system or the digestive tract, while always on call, do not always have work to do. Moreover, even those parts that always have something to do, such as the heart, typically need to adjust their activity to the circumstances (Kingma 2010). What constitutes functioning well or badly depends on details of the circumstances in which an organism finds itself. To assign a level of functional efficiency to the capacities of some part or process is to assess its functional capacities with respect to specified system goals in relevant environments, where the assessment of its capacities turns on judgments concerning how it would function in relevant circumstances in those environments in response to the functioning of other parts and processes (Hausman 2011).

Speaking of the functional efficiency of a part thus presupposes an assessment of the functioning of that part with respect to what physiologists discover about the "engineering specifications" of the part and of the systems in which it has functions. This assessment may be very difficult, because there are multiple standards by which functional efficiency can be compared and because there are different *kinds* of malfunctioning. For example, how does one compare the effects on the functional efficiency of the eyes of color blindness, astigmatism, or myopia? One may attempt to compare the fitness consequences in a given environment of these different malfunctions, or one can consider separately how different functional capacities bear on the different goals of the visual system. Aesthetic preferences and judgments concerning well-being are bound to play some role in prioritizing some comparisons over others and in indicating functional efficiency. As the range of human activities and hence the environment have changed, the demands placed on our bodies and some of the standards of functional efficiency have changed, too.

Greater understanding of functioning provides better physical indicators of functional efficiency and diminishes the evidential role of aesthetic or well-being concerns. For example, contemporary medicine enables people to distinguish between displeasing appearance that is a consequence of a disease (where our reactions guide us correctly to identify something wrong) and displeasing appearance that is merely displeasing. Although expectations that what is healthy will be attractive and will contribute to well-being have guided people's judgments concerning what is healthy and what is not, the connection between what is aesthetically pleasing and what makes people better off on the one hand, and what is healthy on the other hand is causal rather than conceptual. As we learn more about the body, the evidential force of aesthetic and well-being considerations on judgments of functional efficiency diminishes.

The discussion in this section suggests the following characterization of the comparative functional efficiency of two sets of capacities C and C' of a part within some organic system S with goal G. On the assumption that the other parts of the organism or systems whose activities do not depend on C or C' are functioning adequately in a relevant environment

> The functional efficiency of C is greater than that of C' in some system S in an organism in reference class R with respect to some goal G if and only if C makes it more likely that S achieves G than does C'.[4]

This account relativizes assessments of functional efficiency to relevant environments as well as to goals of the organism as a whole or to goals of systems within the organism. So it permits one to compare how well the blood vessels within tumors are functioning, even if their functioning is irrelevant to the fitness of the organism as a whole or detrimental to it.

IV. PATHOLOGY

Once physiologists have figured out how to compare levels of efficiency of the capacities of some part or subsystem with respect to system goals, it does not greatly matter theoretically whether they classify any particular level of functional efficiency of a part within some system or within the organism as a whole as pathological or healthy.[5] Regardless of where the line between pathology and health is drawn, systems or organisms with higher levels of functional efficiency are, with regard to the particular part or process, healthier; and systems or organisms with lower levels of functional efficiency are less healthy. For example, if George's right hip does not permit him to walk more than a couple of blocks until the pain becomes overwhelming, while Peter's right hip, although preventing him from jogging, permits him to walk miles without pain, then Peter's right hip is healthier than George's. And if their health is otherwise the same, Peter is the healthier of the two.

In addition, although what contributes to systems achieving their goals typically also contributes to survival and reproduction and ultimately to fitness, pathologists can adopt alternative perspectives when functional efficiency within a system clashes with functional efficiency within the organism. In everyday conversation, functional efficiency within the organism is of more interest and importance than functional efficiency with respect to the goal of some narrower system. But pathologists and physiologists may take a variety of perspectives.

If the line between the pathological and the healthy is both possibly ambiguous and not as important theoretically as it may have initially appeared, then there may be no theoretical need to draw it. On the other hand, the distinction between health and pathology seems to be of practical importance for purposes such as determining who qualifies for disability payments. Distinguishing levels of functional efficiency of the eyes with respect to various system goals does not answer questions such as "Who needs glasses or other treatment of their eyes?" "Who can see well enough to drive a car?" "Whom should we criticize for picking so few strawberries?"[6] If someone's vision is adequate, they do not need the services of opticians or optometrists, and they can readily spot ripe strawberries. A single rough summary distinction between good and faulty vision may accordingly be useful.[7]

The tendency of the activities of the parts of an organism to promote system goals depends on the external environment and on the activities of other parts of the system. Inferences concerning the functional efficiency of a part on the basis of its effects typically assume as a point of departure that the other causally independent parts of the organism are themselves functioning adequately. Judgments whether part functioning is healthy or pathological (as opposed to judgments of comparative functional efficiency), however, must not be relativized to the actual functioning of other parts nor to the actual external environment, even if the external environment is relevant (in the sense specified), unless the actual environment is a benchmark environment and the functioning of other parts is healthy. Otherwise, one would conclude that it is healthy (because statistically normal) to have rickets in environments lacking in vitamin D or scurvy in environments lacking in vitamin C. Judgments whether functional capacities are healthy or pathological instead compare functioning in the actual environment to functioning in "benchmark" environments, where benchmark environments are relevant, wide-spread, long-lasting, and stable. There will usually be multiple functional dispositions that are most efficient in one or another benchmark environment, because there may be ties or noncomparability with respect to efficiency, because different functional dispositions may be more efficient in different environments, and, owing to the fact that the functional efficiency of one part depends on how the other parts are functioning, there may be a variety of combinations with maximal efficiency. So there will be multiple healthy states of parts and processes.

Pathologists could then decide to treat any functional capacities whose functioning is worse than any of the capacities with maximal efficiency as pathological, no matter how slight the difference. But drawing the line at the maximal levels would imply, implausibly, that pathological part functioning is ubiquitous rather than exceptional. Although it may well be the case, as the BST implies (1977, 560), that it is typical for an organism to experience some minor pathology somewhere among its myriad parts and processes, the line between the healthy and pathological functioning of individual parts and processes should be drawn so that in benchmark environments healthy functioning is not rare.

How then should the line between health and disease be drawn? Just as we say that people are tall if they are taller or significantly taller than most of those in some reference class, so one might say that the functional disposition of a part is pathological if its efficiency is significantly worse than most of those in the reference class (with respect to some benchmark environment).[8] Boorse's view, as I read it, is that the functional disposition of a part is pathological if and only if its efficiency is appreciably worse than the part's median efficiency in the reference class in some benchmark environment.[9] On this view, statistical considerations play their role in determining what counts as "adequate" functioning. Functioning is adequate if it is not much worse than the median. Statistical considerations play no further role in determining whether a level of functional efficiency that is worse than the median level counts as pathological. That judgment depends on how much worse than the median level the functioning is.

Although I disagree with Boorse's view that the median level of functional efficiency in a benchmark environment *defines* an adequate or healthy level, I suspect that, as a matter of fact, the median level of functional efficiency is almost always an adequate level. With respect to traits such as sensory acuity, metabolic efficiency, or internal temperature regulation, where organisms could survive and reproduce with lower acuity, lesser efficiency, or larger temperature fluctuations, functioning at the median level or not far below it counts as healthy. To draw the line between adequate and inadequate functional efficiency is then a matter of evaluating levels of functioning. Though Boorse says virtually nothing about how to do this, his vague account of how to distinguish between health and pathology seems compatible with the discussion of functional efficiency in the previous section. On this interpretation, Boorse takes for granted some way of assigning efficiencies to functional capacities and devotes his efforts to the question of how to classify levels of functional efficiency as pathological or nonpathological. Statistical normality serves merely to define adequate functioning, and Schwartz's criticism is moot.

In contrast to Boorse, I deny that prevalence in a benchmark environment defines whether a level of functional efficiency is healthy or pathological. It is not always the case that median functional efficiency of a part in a benchmark environment counts as healthy, nor is it always the standard against which actual functioning is compared. If there are maximum performance levels that are also readily attainable (such as teeth that are entirely free of decay), these define health, even if they are comparatively rare. On the other hand, if there are levels of functioning that threaten system goals, such as severe diarrhea, fever, paralysis, or vertigo, while other levels of functioning that are not extremely rare promote system goals, then the levels of functioning that threaten system goals are pathological, regardless of frequency.

On the view sketched here, if ideal part functioning is readily attainable in some benchmark environments, it will define healthy functioning; and if levels of functioning seriously threaten system goals (as compared to readily attainable functioning in benchmark environments), then these will be pathological, regardless of their frequency. These separate sufficient conditions for the health and pathology of parts and processes constrain where the line between health and pathology should be drawn, but they typically do not determine its location. Within those constraints, comparisons to median functional efficiency determine the cut-offs. Among various levels of functional efficiency that are neither healthy nor pathological by the above standards, those that are not much worse than the median are healthy and those that are significantly worse than the median are pathological.

V. CONCLUSIONS

This essay defends a naturalistic view of health that closely resembles Boorse's. By noting that the parts of organisms are also parts of subsystems within organisms, whose goals do not always conduce to the organism's fitness, I have explained why it is reasonable to take survival and reproduction as the central goals of organisms, and I have explained how there can be pathologies that do not undercut survival and reproduction. Through examining the notion of "functional efficiency" upon which Boorse's account relies, I have clarified the role of statistical considerations in Boorse's account. What is most important in the understanding of health is the determination of greater or lesser functional efficiency, which is not a statistical matter. Statistical considerations play a constrained role in distinguishing healthy from pathological part functioning.

One arrives at (a) a naturalistic theory (b) that relies on a goal-contribution view of functions, (c) that links health to the efficiency of part functioning, and (d) that relies in part on the statistical distribution of capacities to distinguish healthy from pathological part functioning. In these regards, this essay continues Boorse's work and aims to strengthen his account. At the same time, it emphasizes that the distinction between health and pathology relies on more fundamental comparisons of levels of functional efficiency, which do not depend on statistical considerations. Though not found in Boorse's work, this emphasis is compatible with Boorse's views.

NOTES

1. Boorse accidentally reverses the labeling of the axes.
2. See also Boorse 1977, 559.
3. See also Boorse 1987, 371.
4. Since the account of "adequate" functioning, which is discussed in the next section, depends on comparisons of functional efficiency, the definition is circular. Pathologists break into the circle by making the revisable assumption that statistically normal functioning is adequate.
5. I am here adapting Schroeder's views (2012). Worrall and Worrall (2001) reach a similar conclusion, though by a very different route.
6. In his autobiography, *Models of My Life* (Simon 1996), Herbert Simon reports that he discovered his red-green color-blindness when as a child he had trouble finding strawberries and distinguishing which were ripe.
7. Worrall and Worrall (2001) cast doubt on whether a general distinction between health and disease is in fact the best way to address practical questions such as these, and Boorse points out that medical professionals need different distinctions for different purposes, such as diagnosis or therapy (Boorse 1987, 365; Boorse 1997, 12–13).
8. Schroeder (2012) explores this analogy though not with respect to a comparative notion of overall health rather than with a comparative notion of part function. For this reason, in contrast to this essay, he does not interpret Boorse as implicitly implementing a comparative view of health of the sort that Schroeder favors.
9. For example, Boorse writes, "I defined medical normality as 'the readiness of each internal part to perform all its normal functions on typical occasions with at least typical efficiency'—that is *at an efficiency level not far below the reference-class mean*" (2002, 90; italics added). Elsewhere he writes, "Likewise, statistical variation in any part's performance is also normal if it is not too far below the population mean" (Boorse 2011, 28).

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