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# A Domino Theory of Disease

Harriet Fagerberg
Department of History and Philosophy of Science, University of Cambridge, hf407@cam.ac.uk

**Abstract:**

This paper advances a theory of disease as domino dysfunction. It is often argued that diseases are biological dysfunctions. However, a theory of disease as biological dysfunction is complicated by some plausible cases of dysfunction, which seem clearly non-pathological. I argue that pathological conditions are not just dysfunctions but domino dysfunctions, and that domino dysfunctions can be distinguished on principled biological grounds from non-pathological dysfunctions. I then show how this theory can make sense of the problem cases; they are not diseases because they are not domino dysfunctions.

## 1. Introduction

Many philosophers argue that diseases are biological dysfunctions (Boorse, 1977; Wakefield, 1992). Dysfunction-talk also features prominently in the relevant sciences and clinical fields. However, a simple dysfunction-based theory struggles to make sense of some seemingly non-pathological instances of dysfunction. For example, does a single dead cell in an otherwise healthy body suffice for disease?

Some theorists use trivial dysfunctions of this sort to argue that disease is an anthropocentric or inherently evaluative notion (see Cooper, 2020; Wakefield, 2014). This paper instead advances a previously unexplored thesis; diseases are indeed dysfunctions, but of a special kind. On my view, diseases are 'domino dysfunctions'; dysfunctions in traits which, when they fail, cause other traits to fail too – like chains of toppling dominoes.

I begin by clarifying my approach, before defining biological dysfunction. I then consider a set of problem cases which complicate a theory of disease as, simply, dysfunction. I

procced to provide an account of environmental mismatches, before applying this distinction to the body's *internal* environment, coining the term 'somatic mismatch'. On this basis, I define 'domino dysfunctions' as dysfunctions that cause many more dysfunctions and/or mismatches, and distinguish them from 'trivial dysfunctions'; that is, dysfunctions which *fail* to have adverse 'knock on' effects on other traits. I then show how the Domino Theory can make sense of the cases which initially motivated us to refine the dysfunction-theory: they aren't diseases, because they aren't domino dysfunctions.

## 2. Approach

In this section, I clarify my methodology, and highlight a few assumptions which underpin my view. The disease-debate in philosophy is traditionally understood as a debate over the correct conceptual analysis of disease; in other words, over the criteria which people have in mind when they use terms like 'disease'. The theory I advance here however is not a conceptual analysis, but instead a descriptive theory of the structure underpinning a natural or real kind (more akin to what Millikan called a 'theoretical definition') (1989; 2017). Consistent with this, I assume that disease is a natural kind.[1]

It will also be helpful to say a few words about how I will be using the term 'disease'. In the philosophical debate, philosophers have often ended up employing distinct terminology (disease, disorder, malady, pathology etc.) to talk about what is ostensibly the same phenomenon. I have previously argued that philosophers' divisions over terminology, despite their insistence that they're all 'talking about the same thing', itself motivates thinking of disease as a natural kind (Fagerberg, 2023). In what follows, I assume that all diseased, disordered and legitimately medical conditions form a kind, and I will use the terms 'disease', 'disease-state' or 'pathological state' to refer to this kind.

Before moving on, I also need to make explicit two theoretical assumptions which I am unable to defend within the scope of this article. Firstly, as noted, there seems good *prima facie* reason to think that pathology has something to do with biological dysfunction, and this is also my starting point (see e.g. Wakefield, 1992; cf. Cooper, 2000). My second assumption

[1] I should also be clear that the thesis I advance is intended to be metaphysical, rather than epistemological. In other words, I am committed to the metaphysical thesis that a biological condition is a disease if it is a domino dysfunction; not the epistemological thesis that a biological condition is a disease if we can *identify* a domino dysfunction.

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is that the selected effects theory and its related conceptual apparatus provides the best foundation for thinking clearly about function (see Neander, 1991; cf. Boorse, 1976). I lean particularly on the distinction between proximal functions and more distal effects, and the Neanderian notion of a 'response function' (see Neander, 1995; 2017).

While I realise that these assumptions are to various extents controversial, I hope the sceptical reader will nonetheless be willing to grant them for the sake of argument, even if merely to see where they lead. The fact that these assumptions do support a coherent and plausible theory of disease as a natural kind arguably lends some further credence to them.

## 3. A Dysfunction Account

In order to understand what *dys*functions are, we must first get clear on what *functions* are. According to the selected effects theory, functions are those effects which caused their underlying trait to be selected.

> A *function* (F) of a trait (T) in an organism (O) is an effect that items in T's lineage yielded which increased the inclusive fitness of O's ancestors, in recent evolutionary history, such that T was naturally selected.
>
> (see Neander, 1991; Neander & Rosenberg, 2012; Godfrey-Smith, 1994)

So, for example, it is a function of my heart to pump, because that is what items of the lineage 'human heart' did in the past which conferred upon the organisms which possessed these hearts such fitness advantage that the genotype which codes for the phenotype 'human heart' was naturally selected.[2]

[2] Readers familiar with the function debate may be reminded at certain points of theories which attempt to make sense of functions in organisational terms (i.e. in terms of the contributions which traits make to their own self-persistence in a system) (see e.g. Mossio et al., 2009; Bich, 2024). While organisational theories certainly evoke similar ideas, and may in indeed be compatible with the account I offer, I am reluctant appeal to them explicitly, due to the problems of excessive liberality which continue to haunt organisational accounts (see Garson, 2019). In particular, some disease states might be self-persisting in relevant sense too, and it will be important for my purposes that they are at no risk of counting as functions.

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Having settled on a theory of function, we can now proceed to define *dys*function. At first glance, it seems obvious: if a function is a selected effect of some trait T, then surely a *dys*function is simply the *failure* of a selected effect of T? However, there's some further nuance to consider. Technically, hearts did many things which caused them to be selected. For example, hearts pumped, and hearts helped to circulate blood. Which of these is the heart's function? The selected effects theory would seem to support more than one possible conclusion. As Neander writes: "The answer seems to be both, for both were done, both were adaptive, and both caused the underlying genotype to be selected." (p. 114, 1995)

Now, consider that blood circulation may fail through no fault of the heart – as in the case of an arterial clot. In this case, the heart *is* failing to do one of the things it did in the past which caused its selection (for blood is not being circulated), and yet the heart *itself* is not dysfunctional. How then do we know which selected effect needs to fail for there to be a biological dysfunction of the heart *in particular*?

An answer to this question was originally provided by Neander, and has recently been expanded and championed by Garson (Neander, 1995; Garson, 2019; Fagerberg and Garson, forthcoming). The short answer is that a trait *only* dysfunctions when it cannot yield that effect which is most proximal or specific to this particular trait.

The most proximal effect of trait T is that effect which occupies the lowest level of a functional analysis wherein T is still visible as an unanalysed part (see Neander, 1995; see also Cummins, 1975; Griffiths, 1993). Put differently, the most proximal function is the effect *in virtue of which* all the other, more distal effects of T are carried out (Garson, 2019). The heart pumps, the heart contributes to blood circulation, helps supply oxygen to the tissues of the body, including the brain, and thus enables cognitive function. However, one of these effects is more *specific* to the heart than the others. The heart cannot circulate blood without the contribution of the rest of the cardiovascular system, nor can it ensure normal cognitive function without the lungs and, of course, the brain itself. Moreover, the heart's contributions to these more distal effects are all *consequences* of its ability to pump. We could perhaps appeal to selected effects at even lower levels – such as the individual contributions of the ventricles – but at that point in the analysis, the heart itself would no longer appear as an unanalysed component. On this basis, we can say that the proximal function of the heart is to pump.

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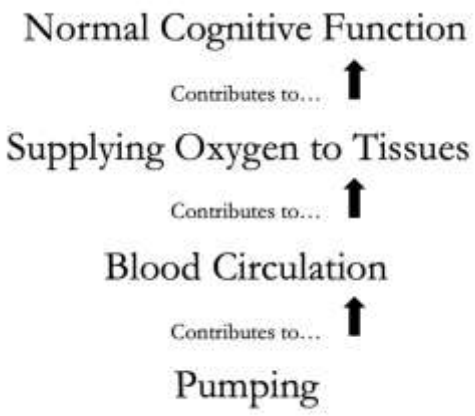


*Figure 1*

We can now see that these other, more distal selected effects of the heart are, in fact, proximal functions of larger systems which include the heart among their constituent parts. As we move up the hierarchy of our functional analysis, the selected effects in question (blood circulation, providing oxygen to tissues) involve larger and larger biological systems, of which the heart makes up a smaller and smaller part. As Neander put it, the most proximal function is that thing which the trait can do 'more or less on its own' (see Neander, 1995).

As Neander and Garson argue, T is only dysfunctional in a scenario in which T cannot perform its *most proximal function*. If T *can* perform its most proximal function, but is unable to yield one of the more distal selected effects associated with the trait, then T cannot count as being dysfunctional, but may instead be 'mismatched'. (I will return to and refine my approach to environmental mismatches in Section 5.) We are now able formulate a simple theory of pathology as biological dysfunction:

> A *function* (F) of a trait (T) in an organism (O) is an effect that items in T's lineage yielded which increased the inclusive fitness of O's ancestors, in recent evolutionary history, such that T was naturally selected.
>
> A *dysfunction* is the failure or inability of some trait T to perform its most proximal function.
>
> A *disease* is a dysfunction.

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My view is that this simple theory puts us on the right track. All diseases are dysfunctions, and most dysfunctions are also diseases. However, my view is that, due to the intricate dependence relations which obtain between evolved traits within the body, paradigm diseases are not *just* dysfunctions; they are dysfunctions which *cause* problems for other traits. In other words, diseases are domino dysfunctions.

Before outlining the Domino Theory in full (5), I will first introduce a set of 'problem cases' which illustrate the deficiencies of a simple dysfunction theory, and which motivate distinguishing domino dysfunctions from dysfunctions simpliciter.

## 4. The Problem Cases

I have said that the Domino Theory is not a conceptual analysis. However, this does not make the traditional disease debate entirely irrelevant to this discussion. Our thoughts, inferences and, indeed, philosophical debates may be shaped by the nature and existence of real kinds and properties in our world, even if we lack explicit awareness of this structure (Fagerberg, 2023). As such, classic problem cases in the disease debate may indicate something important about the nature of the kind which we seek to understand. In what follows, I shall consider a cluster of cases which I believe provide a clue as to the distinction between diseases and non-pathological conditions.

As noted, there seems to be a strong relation between dysfunction and disease. Most instances of biological dysfunction are also paradigm diseases – e.g. liver failure, stroke, hypothyroidism. However, some plausible cases of dysfunction appear to be non-pathological or compatible with health, and as such challenge the simple dysfunction theory outlined in the previous section. Consider the following:

*(1) A Single Dysfunctional Kidney* A kidney's function is to filter blood and remove waste from the body, because that is the effect which led to its natural selection. As such, should some particular kidney fail to perform this function, that would constitute a dysfunction of that kidney (Wakefield, 1992). And yet one can live a healthy life with only one kidney.

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(2) *One Dead Cell* A dead or dysfunctional cell is not functioning as it should.[3] However, we are all currently operating with dead cells within our bodies (Boorse, 1977; cf. Nordenfelt, 1995). And yet it does not seem that we are all, thus, diseased.

(3) *Prima Facie Fitness-Reducing Sexual Orientations* Another possible category of dysfunction in the absence of disease is sexual orientations that would appear, on the face of things, to be fitness-reducing, such as exclusive same-sex attraction or asexuality (see Boorse, 2014). Assuming that these are (or could be) dysfunctions, should they count as pathological?[4]

(4) *Contraception* We often choose to disable reproductive function for pragmatic reasons. We do not wish to conceive, and therefore choose to use contraceptives or undergo sterilisation. In such cases, the reproductive system cannot perform its function (see e.g. Kingma, 2014). However, these would not appear to be cases of us inflicting disease upon ourselves.

Wakefield and Cooper use cases such as these to motivate the necessity of attributions of harm for judgments about disease (Cooper, 2020; Wakefield, 2014). Boorse prefers to bite the bullet and count such cases as pathological – albeit divorced from any negative evaluation (Boorse, 2014). As I shall argue, these cases strike us as non-intuitive cases of disease because they are of a different biological kind to paradigm disease-states; they are not domino dysfunctions, but instead (at most) 'trivial dysfunctions'.

[3] With the exception of programmed cell death (apoptosis), which is adaptive.

[4] Note that this need not be the case. Traits that appear to be fitness reducing *prima facie* may nevertheless be products of selection. For example, it may be that some minority sexual orientations were selected not due to increasing the fitness of the individual bearers of the trait, but by increasing the fitness of *relatives* of bearers of the trait (known as kin selection). Kin selection hypotheses also purport to account for self-sacrificing altruism and the menopause – also traits that, on the face of it, appear to be fitness-reducing (see Eberhard, 1975; Hawkes et al, 2017). Note also that it is not same sex attraction that is evolutionarily surprising, rather the *absence* of opposite sex attraction. Sex between members of the same sex occurs in a range of animal species, including some our closest relatives, such as bonobos (see e.g. Bailey & Zuk, 2009).

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## 5. The Domino Theory

Domino dysfunctions are biological dysfunctions in traits which are situated within the rest of the body in such a way that, when they fail, they disrupt the normal functioning of other traits which depend on them. More precisely, the view I defend is that diseases are dysfunctions which either cause other traits to become somatically mismatched, or which cause other traits to become dysfunctional, or both.

As now becomes clear, the viability of the Domino Theory will depend on a good account of dysfunctions, mismatches and the relationships between these. In Section 3, I defined dysfunction. In Section 5.1, I will give an account of environmental mismatches, distinguishing two types of mismatch via the types of dependence relations which give rise to them: 'fuel failures' and 'signal failures'. In Section 5.2, I will then generalise this account to the dependence relations which obtain between evolved traits within the body, coining the term 'somatic mismatch'. This finally allows me to outline the Domino Theory in full, and to distinguish domino dysfunctions from trivial dysfunctions.

### 5.1. Environmental Mismatches

Although environmental mismatches are not necessarily diseases in and of themselves, as we shall see, an account of environmental mismatch will allow me to define its analogue within the body –somatic mismatch – which in turn will help me define domino dysfunction and, thus, disease.

While accounts of environmental or evolutionary mismatches already exist in the philosophical literature (Cofnas, 2015; Morris, 2020; Matthewson & Griffiths, 2017; Bourrat & Griffiths, 2021), none is explicitly premised upon the distinction between proximal functions and distal effects. As such, they are unable to distinguish types of mismatches in terms of the trait's ability to perform its proximal function, as I do in the below. Obscuring the distinction between functions (which are proximal) and more distal selected effects renders functions technically indeterminate and so inevitably yields some imprecision (Fagerberg and Garson, forthcoming; cf. Griffiths and Matthewson, 2017). Because mismatches play a key role in defining domino dysfunctions, and thus disease, it will be important in what follows that they are precisely defined. Existing views were not quite up to this task.

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In general, environmental mismatches occur where the functioning of a biological trait T is impacted or interrupted by some factor in T's *actual* environment differing from T's selective environment – that is, the environment in which traits of T's type evolved. A little reflection on this phenomenon reveals to us that environmental mismatches are possible because biological traits are adapted to and depend on features of the organism's external environment. Because traits depend on their environment, abnormalities in a trait's actual environment (relative to its selective environment) can prevent a trait from functioning 'as it should'. And yet the trait is not necessarily *dysfunctional*. In some cases, the trait is functioning precisely as it was designed to function by natural selection – and yet, it is operating maladaptively due to a mismatched environment. In what follows, I distinguish two types of environmental mismatch on this basis: (1) 'fuel failures' and (2) 'signal failures'.

Recall that we defined dysfunction as the failure of T to perform its proximal function. The first type of environmental mismatch occurs when T depends on some feature or aspect of the environment for the performance of its proximal function – i.e. to avoid *failing* to perform its function or becoming dysfunctional. Let's call environmental mismatches of this type 'fuel failures':

(1) *Fuel Failure:* Trait T depends on some feature C of its selective environment for the performance of its proximal function. Because T's actual environment differs from its selective environment in respect of C, T cannot perform its proximal function.

By 'fuel' I just mean some environmental condition without which T cannot perform its proximal function. Let us consider an example. It is a proximal function of my lungs, along with other muscle groups, to enable breathing. However, my lungs cannot perform this function in an environment without breathable air. As such, they are suffering fuel failure or, put differently, a type 1 environmental mismatch.

The second type of mismatch is due to some abnormality in a 'signal' in T's actual environment which it is T's proximal function to respond to. Signal failures are distinguished from fuel failures in that they are compatible with trait T performing its function precisely as designed, and yet functioning strangely, even maladaptively. This phenomenon reflects not the dependence of traits on their environments for the performance of their proximal functions, but rather their dependence on environmental cues for their proximal functions, whatever they are, to actually contribute to more distal selected effects.

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(2) *Signal Failure:* Trait T has as its proximal function F to yield some outcome or effect in response to or in proportion to some input S in its selective environment. Because T's actual environment differs from T's selective environment in respect of S, T is caused to perform its proximal function F in such a way that F fails to contribute to more distal selected effects of T.

Signal failures are only possible where some environmental dependence is built into trait T's most proximal function – in Neanderian terms, where T's most proximal function is a 'response function' (see Neander, 2017). Response functions are functions where trait T has as its proximal function to yield some outcome in response to or in proportion to some input from the environment.

Let us consider a plausible example. Imagine a young gosling that happens to imprint upon a fox due hatching into an abnormal environment (see also Wakefield, 2017; Garson 2021). The gosling's imprinting mechanism is performing its proximal function just fine – that is, the mechanism is causing the gosling to become attached to "the first large, suitably moving object" (p. 342, Garson, 2021) it meets upon hatching. However, the imprinting mechanism is *not* causing the gosling to form an attachment specifically to a its *mother* – a more distal selected effect which the imprinting mechanism normally contributes to in its selective environment. Indeed, being emotionally attached to an unsympathetic fox likely yields none of the mechanism's usual beneficial effects.

In this case, the imprinting mechanism is in a state of 'signal failure' or type 2 environmental mismatch. Due to the gosling's actual environment differing from its selective environment (the environment in which the mother is present) in respect of some input on which the imprinting mechanism depends, imprinting fails to contribute to the more distal, fitness-boosting effects which it had in its selective environment.

Type 1 and 2 environmental mismatches – or fuel failure and signal failure – are similar in that they reflect how evolved traits depend on features of their selective environments in order to function 'as they should'. The difference between them is that they reflect different types of evolved dependence relations. A trait can depend on its environment for 'fuel' – some precondition for the performance of its proximal function – or for 'signalling' – some cue or input which T has as its proximal function to respond to. In the latter case, the responsiveness to environmental cue S is built into T's proximal function F, and thus, T behaving in a strange and seemingly fitness-compromising manner is compatible with T

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performing its proximal function just fine. In fuel failure, on the other hand, T is *prohibited* from performing its proximal function by an inappropriate environment.

Let us now consider some cases that would *not* count as environmental mismatches on this view. Firstly, if, while minding my own business in an environment approximating the one in which my species evolved, I suddenly suffer a blood clot in my leg that prohibits the passage of blood through my vein, that would be a straightforward endogenous dysfunction – not an environmental mismatch. Dysfunctions aren't necessarily mismatches, just as mismatches aren't necessarily dysfunctions. However, as we shall see, mismatches are often *causes* of dysfunction.

Secondly, trait T does not count as mismatched when a distal selected effect of T fails to be performed, but for reasons unrelated to T. Consider our gosling again. Suppose everything went as planned and the gosling imprinted on its mother. In this case, the imprinting mechanism is contributing as designed to the more distal effect of creating a fitness-boosting relationship with the mother goose. Suppose further that the gosling is not in its selective environment (say it lives on a farm run by humans), and so his mother is removed an early stage of development. In this case, again, the unfortunate gosling does not enjoy a fitness-boosting attachment to its mother. However, this outcome has nothing to do with the imprinting mechanism. The imprinting mechanism contributed as designed to the more distal selected effects to which the imprinting mechanism normally contributes – however, something *else* went wrong which interrupted the casual chain.

I have said that environmental mismatches are not necessarily dysfunctions. However, over time, being mismatched can *cause* dysfunctions, even independent dysfunctions which endure even when the organism is relocated to an appropriate environment. Being out of water will quickly cause the functioning of the fish's brain to break down due to lack of oxygen (fuel failure). Now the fish is *both* currently mismatched relative to its actual environment, *and* the fact of it being mismatched is *currently* causing a dysfunction. Moreover, very quickly its tissues will become damaged by oxygen deprivation. At this stage, if we were to reintroduce the fish into water, it would no longer be in a mismatched environment, but the dysfunction – via damage to its neural tissues – would remain.

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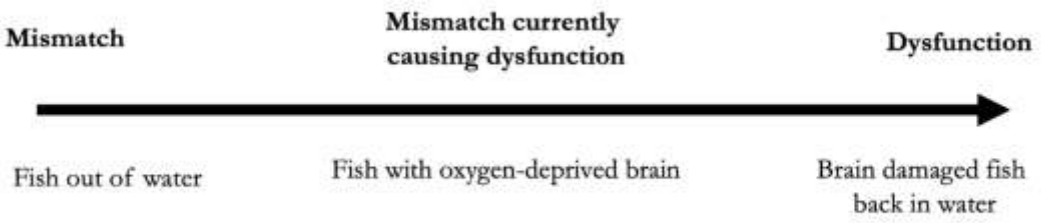


*Figure 2*

We can see, then, a mismatched environment can occur without dysfunction, can be a current cause of current dysfunction, and can be past causes of current dysfunction.

### 5.2. Somatic Mismatches

With this understanding of mismatches in hand, we can now turn to the dependence relations which obtain between evolved traits *within* the body. Traits do not rely solely on preconditions and cues in their *external* 'ecological' environment. Traits are also adapted to and dependent upon *other traits* within the organism. For example, the brain relies on the heart to pump properly, so that the cardiovascular system can supply oxygen to the brain which, in turn, enables cognition. Once we recognise these intricate dependence relations between evolved traits within organisms, we can see that there is an internal 'somatic' analogue to the classic environmental mismatch. When the somatic environment within the body is disrupted by some trait becoming dysfunctional, dependent traits are often affected too.

These dependent traits are, on my view, 'mismatched' to their somatic environment. Just as there are two ways in which a trait T can be adapted to its *external* environment, there are two ways in which a trait T1 can be adapted to another trait T2 in its *somatic* environment, and thus two types of somatic mismatch.

(1) *Fuel Failure:* Trait T1 depends on some other trait T2 for the performance of its proximal function. Because T2 is dysfunctional, T1 cannot perform its proximal function.

Suppose there is a dysfunction in the heart which is causing a severely reduced heart rate (bradycardia). This reduction in heart rate in turn causes insufficient oxygen supply to the

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brain which, in turn, causes the brain to fail to perform some of its proximal cognitive functions – perhaps the individual loses consciousness. Now the brain is unable to yield one or more of its proximal functions, because it lacks one of the environmental predispositions (oxygen) for the performance of those functions. As such, the brain is experiencing somatic fuel failure or a type 1 somatic mismatch.

We turn now to signal failure, or type 2 somatic mismatch:

(2) *Signal Failure:* Trait T1 has as its proximal function F to yield some outcome or effect in response to or in proportion to some input from T2. Because T2 is dysfunctional, T1 is caused to perform its proximal function F in such a way that F fails to contribute to more distal selected effects of T1.

As an example of somatic signal failure, consider the dependence relation which obtains between the heart and the vagus nerve. One of the functions of the vagus nerve is to regulate the heart rate, and one of the functions of the heart is to regulate its rate *in response* to input from the vagus nerve (a response function). As such, if there is a dysfunction of the vagus nerve – if, for example, if it is overactive – this can thus lead to an abnormally low heart rate which, in turn, may cause other problems.

If part of the function of the heart is to regulate its rate in response to input from the vagus nerve, then the heart is not dysfunctional when it lowers its rate accordingly. Nevertheless, if given the *wrong* input from the vagus nerve, the heart may perform its proximal function *in such a way that* it fails to contribute to more distal effects of the heart (such as supplying oxygen to cells). In this case, the heart is a victim of somatic signal failure or, in other words, somatic mismatch type 2.

### 5.3. Secondary Dysfunctions

As we have seen, mismatches can also *cause* new dysfunctions. For example, insufficient oxygen supply to the brain as a result of heart failure can make it impossible for the brain to perform its proximal functions, and over time may cause such damage that the dysfunction remains even when the trait is returned to its selective environment (in this case, when the brain is re-supplied with oxygen). In such cases, the mismatch (type 1) is causing a secondary dysfunction.

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Similarly, type 2 mismatches can over time put such stress on mismatched traits that new dysfunctions arise. For example, in hyperthyroidism elevated levels of the hormone thyroxine can stimulate the heart to pump rapidly and irregularly which, over time, may lead to heart failure. Thus, traits being somatically mismatched (type 2) can *cause* them to become dysfunctional over time.

Due to the hierarchical organisation of the body, whereby more specific functions (e.g. the heart's pumping) contribute causally to increasingly general selected effects (e.g. blood circulation) of larger and more complex systems (e.g. the cardiovascular system), there is also another way in which a dysfunction in some trait T2 can cause a dysfunction in trait T1. If T2 is a *part* of T1, on which T1 relies for the performance of T1's proximal function, then a dysfunction in T2 could conceivably 'bring down' the whole larger system T1. For example, if the heart (a part of the cardiovascular system) cannot perform its proximal function of pumping, then the cardiovascular system cannot circulate blood around the body. Thus, dysfunction in the heart is *causing* dysfunction of the cardiovascular system.

For present purposes, we shall call dysfunctions such as those described above 'secondary dysfunctions'. Secondary dysfunctions are dysfunctions which are caused by some original 'primary' dysfunction – either via a somatic mismatch, or via the failure of a part causing the failure of a larger trait.

### 5.4. The Domino Theory in Full

Due to the intricate dependence relations which obtain between traits within the bodies of complex organisms, there are a number of ways in which a dysfunction of some trait T2 can cause problems for another trait T1. We have considered these dependence relations in depth above, but let's briefly recap.

Firstly, a dysfunction in T2 could cause T1 to become somatically mismatched in two overarching ways. It could be that T2 has as its function to provide some precondition or 'fuel' which T1 needs for the performance of T1's proximal function, as in the case of fuel failure or type 1 somatic mismatch. Alternatively, it could be that T1's proximal function is a 'response function' which depends on some cue or input from T2, as in the case of signal failure or type 2 somatic mismatch.

Secondly, a dysfunction of T2 could cause an independent secondary dysfunction of T1. T2 could cause T1 to become dysfunctional via a type 1 somatic mismatch or, over time, via

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a type 2 somatic mismatch. Alternatively, it could be that T1 is a larger system that depends on a part T2 for the performance of T1's proximal function.

My claim is that diseases or 'domino dysfunctions' are dysfunctions of traits on which many other traits depend in the ways outlined in the above, and which therefore cause widespread problems when they fail. Finally, we are able to sum up the Domino Theory in full:

A *dysfunction* is the failure or inability of some trait T to perform its most proximal function.

A *somatic mismatch* occurs where a trait T1 is in state of *fuel failure* or *signal failure* relative to some dysfunctional trait T2.

*Fuel Failure:* Trait T1 depends on some other trait T2 for the performance of its proximal function. Because T2 is dysfunctional, T1 cannot perform its proximal function.

*Signal Failure:* Trait T1 has as its proximal function F to yield some outcome or effect in response to or in proportion to some input from T2. Because T2 is dysfunctional, T1 is caused to perform its proximal function F in such a way that F fails to contribute to more distal selected effects of T1.

*Domino dysfunctions* are dysfunctions which either cause other traits of the organism's body to become somatically mismatched, or which cause other traits of the organism's body to become dysfunctional, or both.

Diseases are *domino dysfunctions.*

We are now in a position to draw a principled distinction between two kinds of biological dysfunction: (i) pathological or domino dysfunctions, and (ii) non-pathological or trivial dysfunctions. Because our bodies are characterised by a high degree of functional integration and inter-dependence, most dysfunctions are not *just* dysfunctions – they are also *causes* of failures of appropriate functioning in other traits. However, not *all* biological dysfunctions have such widespread knock-on effects. Some traits relate to other traits in such a way that,

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when they fail, there are no, or very few, consequences for other traits. These dysfunctions are, on my account, 'trivial', and do not constitute diseases.

> *Trivial dysfunctions* are dysfunctions which cause no, or few, other traits of the organism's body to become somatically mismatched or dysfunctional.

In the following section, I shall consider trivial dysfunctions – and when they might occur – in more depth.

## 6. Types of Trivial Dysfunction

Having distinguished trivial dysfunctions from domino dysfunctions, let us return to the problem cases which initially motivated a revision of the simple dysfunction theory. Can the Domino Theory explain why these cases are anomalous? I will argue that the problem cases are all plausibly instances of trivial, rather than domino, dysfunction, and that trivial dysfunctions fall into three broad sub-types. While explaining how the problem cases fit this scheme, I will also extend these principles to consider other cases which have received less attention in the literature, but which nonetheless are plausible examples of trivial, non-pathological dysfunction.

### 6.1. Spare Traits

Sometimes the dysfunction of some trait T fails to have any adverse knock-on effects on other functional traits simply because the trait is 'spare'. That is, although the body depends on traits of this *type* (for example, the body certainly needs cells) the body does not depend crucially on any given *token* of this type (it does not depend on any *given* cell). Thus, when a spare trait fails, this need not have any adverse effects.

It is no accident that the body contains spare traits. Natural selection favours robustness, and thus often selects for 'spare' parts and fallbacks that can step in and ensure that the overall functioning of the body continues intact even it a part is damaged. As Plutynski puts it: "Multicellular organisms like us have distinctive functional organization and a high degree

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of … redundancy. These features are adaptive; redundancy enables functional parts to take over when one such part fails" (p. 165 – 166, Plutynski, 2018). Because of redundancy, some dysfunctions have few, or only very local, 'knock-on' effects in the form of somatic mismatches and secondary dysfunctions. This is why a biological dysfunction in a single cell, or even a single kidney, is compatible with overall health.

### 6.2. Isolated Traits

I have said above that, because of the functional inter-dependency of traits, the failure of one very often leads to the failure of others. However, not all traits are equally tightly integrated into the functional architecture of the body. More specifically, some traits do not have, or have very few, dependent traits. These traits are, as I shall term it, 'functionally isolated'. When isolated traits fail, precisely because other traits are not reliant on them, the ramifications also tend to be local and isolated.

Let us consider an example: the peacock's tail. The peacock's tail was sexually selected, and its function as such is to be aesthetically pleasing to peahens. However, it is not the case that many other biological traits *depend* on the tail performing its function of looking good for *their* function. For example, it is not the case that the peacock's vital organs depend on the tail for their normal operation, nor that the tail is needed for motor control – indeed, the most impressive tails are often so large as to be *hindrance* to the peacock's free movement. Thus, if the tail was to be absent, or otherwise to fail to perform its proximal function (that is, to be attractive) this would be unlikely to have adverse knock-on effects.

A similar story might be told about sexually selected traits in our own species. For example, While females of most other mammalian species remain flat chested when not breast feeding, some have hypothesised that the 'perennially enlarged breasts' of human females were the result of sexual selection (for discussion, see Pawłowski & Żelaźniewicz, 2021). Supposing this hypothesis is correct, if a human female *fails* to have perennially enlarged breasts, this would be a dysfunction, because her breasts would not be doing one of the things they were naturally selected for (aesthetic signalling), but this is unlikely to affect other traits. Sexually selected traits have a function, and can as such dysfunction, but when they do, it has little effect on the rest of the body – they are functionally isolated.

How does this apply to the problem cases cited in Section 4? Well, consider asexuality. Suppose a neural mechanism was selected for opposite sex attraction, and that this mechanism is dysfunctional; that is, it is failing to cause the individual to be attracted to

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members of the opposite sex. Now, even so, it is hard to see which other dependant traits would be affected. Other functions of the brain (perception, mood, etcetera) operate normally, and other systems such as the endocrine system or the digestive system are not affected at all. In this sense, asexuality – whether a biological dysfunction or not – fails to qualify as a domino dysfunction, and thus is not pathological.

At this point, some may wonder whether the reproductive system of, say, an asexual woman could nonetheless count as being somatically mismatched, as a result of a dysfunction in the (hypothesised) mechanism for opposite sex attraction, if it causes her to fail to become pregnant or give birth to children.[5] However, I don't think this would follow. Suppose that the proximal function of the female reproductive system is something like 'develop a foetus when an egg is fertilised' (a response function). If so, then the failure to develop a foetus in the *absence* of fertilisation is *not* a failure of proximal function and, hence, *not* a fuel failure. Now consider; does the reproductive system have as its function to *respond* to input from the mechanism for opposite sex attraction (such that the reproductive system might be in a state of signal failure)? Arguably, no. The proximal function of the reproductive system depends on *fertilisation* occurring, not on opposite sex attraction. As such, there is no signal failure either. If the condition in question causes no secondary dysfunction, no fuel failure, and no signal failure, then it does not count as a domino dysfunction.

Functional isolation can arguably also account for why we sometimes choose to disrupt reproductive function without any sense that we are causing pathology. If I were to disable some part of my cardiovascular system, many other traits would soon be affected. Similarly, if endocrine function or liver function were disrupted, the effects would be far reaching. However, if the reproductive system is disabled (say, a man chooses to undergo voluntary sterilisation by having his vasa deferentia severed) very little happens elsewhere in the body. This is why voluntary sterilisation and contraception differ *in principle* from having a vital organ such as the liver removed. Traits in the rest of the body simply do not rely on reproductive traits for their normal operation.

We have seen how the functional isolation of certain traits and systems can make sense of some of the problem cases cited in Section 4. It is also possible that this idea has novel implications for some conditions we have not yet considered. If contraception and voluntary sterilisation are not diseases on the grounds that the rest of the body does not depend on reproductive function, then it would seem that *involuntary* infertility is not a disease either.

[5] I'd like to thank Marta Conti Lorenzo for raising this objection.

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However, I will suggest in Section 7.2. that infertility (voluntary or otherwise) may in fact best be counted among a number of interesting borderline cases.

### 6.3. Traits that Can be Compensated For

I will now consider a third and final type of trivial dysfunction: dysfunctions in traits that can be compensated for in some way should they fail. That is, even when the trait in question is failing to function, other traits are able adequately to compensate for this loss of function such that dependent traits remain unimpacted.

For example, in some cases of injury to a brain region which was selected for the performance of some function, other areas are able to reconfigure themselves through neuroplasticity in such a way as to compensate for the loss of function in the injured area. This does not change the fact that there is neurological dysfunction in the damaged region of the brain – it is no more able to perform its function than before – but the compensation renders the dysfunction trivial by guarding against any impacts on other traits.

For example, in a 2018 study Liu et al. describe the remarkable case of U.D., a six-year-old boy who had his entire right occipital lobe and parts of his temporal lobe removed as a treatment for epilepsy (2018). These regions are implicated in the recognition of objects and faces, among other capacities, and damage to the occipito-temporal lobe is associated with acquired prosopagnosia (see Biegler et al., 2018; Corrow et al, 2016). The researchers tracked U.D.'s recovery and found that, by the age of ten years and ten months, he had regained almost all cognitive and perceptual functions, including normal capacities for facial recognition. Imaging data indicated that regions in the left hemisphere had been recruited to compensate for the missing regions (Biegler et al., 2018).

If we suppose that face recognition is a selected effect of (some part of) the missing occipital and temporal areas, then it appears there is a clear brain dysfunction in this case. These regions of U.D.'s right hemisphere are in *no* position to perform face recognition – in fact, these regions are entirely missing. However, because other regions have reconfigured themselves through plasticity to perform this function instead, this failure will not have any further adverse effects on other dependent functions (such as, for example, social functions of the brain which might depend on facial recognition).

Similarly, it may be that biological dysfunctions which are compensated for by highly effective prosthetics fail to count as diseases. Consider a case of valvular dysfunction that is sufficiently compensated for by an artificial heart valve. The dysfunctional heart valve is *of*

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*course still* failing to perform its function, but because this failure of function is sufficiently compensated for by an artificial valve, this will not have the sorts of domino effects which a dysfunctional heart valve would normally have.

## 7. Implications

Having outlined the Domino Theory, and the types of trivial, non-pathological dysfunction implied by it, I will now consider two implications of this theory. Firstly, on the Domino Theory the distinction between disease and non-disease is not strict, but rather exists on a continuum. Secondly, the Domino Theory appears to give us the resources to distinguish between diseases and certain types of risk factors.

### 7.1. A Continuum of Pathology

I have said that domino dysfunctions cause widespread dysfunctions and/or mismatches in other traits, while trivial dysfunctions cause none, or very few. If this is so, then the distinction between disease and non-disease is not strict, but rather exists on a continuum. This is not a problem *per se*, so long as we can account for why some conditions are *more* paradigm disease-states than others. In what follows, I explore this implication and propose some distinctions, before suggesting that the degree and extent to which a dysfunction has knock on effects tracks something like 'clinical significance'.

Firstly, it may be relevant to draw a distinction between those dysfunctions that cause *dysfunctions* in traits of which they are not part, including independent dysfunctions that remain in the absence of a mismatch, and those dysfunctions that do *not* cause additional dysfunctions of this kind. For example, heart failure will quickly cause other vital organs to fail, and eventually lead to the death of the organism. Similarly, paradigm cases of serious disease – malignant cancers, degenerative diseases like Huntington's, or other types of organ failure – would, if left untreated, likely have *many* adverse effects on traits in the rest of the body, including secondary dysfunctions in a wide variety of traits and systems.

Contrast these conditions with dysfunctions which cause the larger system of which the trait is a part to fail (in virtue of that system's reliance on this constituent trait) but do *not* cause dysfunctions in any *other* traits *outside* of this system. Perhaps infertility is in this category: if I were to sever my fallopian tubes this would prevent my reproductive system *as a whole* from performing its function, but *only* in virtue of the dysfunction in my fallopian

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tubes. Moreover, no traits *outside* of the reproductive system would seemingly be affected. This also suggests another dimension along which domino dysfunctions may vary: domino-effects may be more or less widespread within the systems of the body, and transcend levels of biological organisation to a greater or lesser degree.

Similarly, we might think dysfunctions which cause mismatches, but do not cause enduring, independent secondary dysfunctions, are less paradigm disease-states. Perhaps some of what we think of as paradigm disabilities are in this category. For example, my systems for motor control are certainly adapted to me being sighted. As such, if I lost my sight, it is plausible that these systems might be caused to perform their functions in ways that compromise more distal selected effects (type 2). However, my blindness is not going to damage the internal constitution of dependent traits, thus causing further independent dysfunctions, and thus would not be *degenerative* in this sense.

As such, it seems the Domino Theory gives us the resources to distinguish between serious degenerative conditions, on the one hand, and 'stable' conditions on the other, exemplified perhaps by paradigm disabilities such as deafness or lacking a limb. This distinction goes some way to explain why a social model of disability might be thought appropriate for deafness, but inappropriate for, say, Huntington's. Deafness does not cause widespread and enduring dysfunction in other systems, and thus exists at the opposite end of the spectrum to Huntington's.


*Figure 3*

My suggestion, illustrated in Figure 3, is that the more extensive adverse effects (in the form of dysfunctions, mismatches and, in particular, dysfunctions in systems of which the affected trait is not part) are caused by a particular biological dysfunction, the more disease-like it is.

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Conditions that are perhaps associated *only* with mismatches, or *only* with higher-level dysfunction due to a faulty part, are *less* disordered.

In is interesting to observe, at this stage, that the degree of domino effects appears to track something like 'clinical significance'. The more dysfunctions and mismatches are associated with a condition, the more clinically significant, serious or incompatible with health the condition seems to be. Conditions that are associated with few adverse knock-on effects tend to be controversial cases of disease, or the types of conditions which are sometimes argued to be compatible with health. For example, one might be considered healthy whilst lacking a limb, but few would argue that the absence of a vital organ is similarly compatible with health. My view is that this is because the failure of a vital organ, unlike the absence of a limb, is almost guaranteed to cause a large number of dysfunctions and mismatches in a wide variety of dependent traits, and as such is a paradigm domino dysfunction.

Drawing a strict line anywhere along this continuum is neither possible nor desirable. The important point is that biological dysfunctions are not created equal. Liver failure is different in principle to contraception, or the death of a single cell, and the Domino Theory gives us the resources to draw this distinction on objective biological grounds – even if this distinction is not strict.

### 7.2. Diseases versus Risk Factors

Secondly, I suggest that the Domino Theory can help us make sense of the distinction between diseases and risk factors. Sometimes, trivial dysfunctions, which do not count as pathological, may nonetheless count as *risk factors* for disease in that they increase the likelihood of future domino dysfunctions.[6]

I noted in Section 6.1. that natural selection favours spare parts and fallbacks. Precisely because they are spare and as such not crucially relied upon, dysfunctions in spare parts don't count as pathological. However, damage to a spare part may nevertheless cause the system to become less resilient against future damage. The more spare parts and fallback mechanisms are lost to damage and dysfunction, the less robust the system becomes. In other words, dysfunctions of spare traits may not be pathological in and of themselves, but they will put the organism at greater risk of pathology.

[6] I'd like to thank Nick Shea and an anonymous reviewer for pointing me in this direction.

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For example, with two intact kidneys, either kidney is spare. Thus, dysfunction of either one of these is compatible with health. However, if one of the kidneys is removed or compromised, the remaining kidney becomes essential, and no longer spare. Whereas the system could previously afford to lose a kidney, it now relies crucially on the one kidney it has left. As such, even if the individual is not suffering a domino dysfunction, they are now at increased *risk* of domino dysfunction due to a loss of robustness. The loss of a single kidney is in this sense a risk factor for pathology.

Similarly, it seems plausible that, in certain circumstances, trivial dysfunctions can over time cause biological changes that do not count as domino effects *per se* – i.e. they aren't fuel failures or signal failures – but which nevertheless affect the organism in ways which increase the risk of future pathology. For example, suppose a woman uses a copper coil and therefore (by choice) never becomes pregnant. This would not amount to a (paradigm) disease. However, never being pregnant could have consequences which, although they aren't domino effects, increase the risk of breast cancer (Husby et al., 2018). In this sense too, trivial dysfunctions may be risk factors – even if they aren't diseases.

Perhaps this notion of risk factors does not capture all of the ways in which risk factor is used in medicine – more work is required to situate this distinction within existing theories and concepts employed in the medical literature. However, the Domino Theory does neatly capture a distinction
between full-blown pathological conditions (domino dysfunctions) and, at least, some types of risk factor for disease.

## 8. Counter Examples and Disease-Talk

I have said that some commonly recognised pathological conditions do not count as diseases on the Domino Theory. As such, is the Domino Theory just too revisionist?[7] In what follows, I respond to two versions of this objection: (1) the first pertains to the theory's alleged inability to explain how 'disease' is ordinarily used; (2) the second pertains to the role that disease-talk plays in medical discourse.

(1) The first version of the objection states that the Domino Theory violates normal medical usage of terms like disease. For example, the Domino Theory implies that even life-long unwanted infertility, which (let us suppose) is due to an injury and causes emotional

[7] Thanks to two anonymous reviewers for raising this objection.

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distress to the individual, does not count as a paradigm case of disease – because any domino effects are local. And yet, many would say that such infertility is *clearly* diseased. As such, the Domino Theory provides a poor explanation for medical usage, and thus fails to live up a decisive desideratum: that an adequate account of disease should be able to make sense of our normal application of the term within medicine.

My first response is that this desideratum is decisive only for a conceptual analysis – which the Domino Theory is not. The Domino Theory is a theory the underlying kind, and there is no reason to assume that the boundaries of the kind must conform precisely to our intuitions as to when we would, and would not, apply the term. As such, the Domino Theory is not beholden to usage at every twist and turn.

Some may retort that, even so, if the Domino Theory is *so revisionary* as to have completely veered off topic, or 'changed subject', then it is a poor theory of the kind which it purports to describe (see e.g. Haslanger, 2020). However, the Domino Theory is not *wildly* revisionist in this sense. In fact, it concurs with normal usage in almost all cases, and where it does depart from such usage, a little reflection on the case reveals that the condition was always in some sense anomalous. For example, it is true that *unwanted* infertility is considered a disease. However, if we were to classify infertility *per se* as disease, then that would yield an unintuitive result for contraception and sterilisation. This suggest, to me, that reproductive dysfunction was always an unusual case. There are not many other functional traits which people voluntarily disable, and where doing so is seen as being compatible with heath.

(2) The second version of the objection states that the Domino Theory compromises some important pragmatic functions of disease-talk. For example, on the Domino Theory, whether a condition counts as a disease can depend on facts *external* to the dysfunctional trait, such as whether compensatory mechanisms are in place to guard against domino effects. However, sometimes a clinician or researcher might simply want to say: "This brain is missing large sections of the occipital lobe, and so is *clearly pathological*". Perhaps disease-talk of this kind – which lacks regard for what is going on in the rest of the organism – is also quite useful in certain contexts. Does the Domino Theory then not just violate ordinary usage, but in fact impede some important pragmatic functions of disease-talk?

In response, I will make two related points. Firstly, there is a usage of pathological (exemplified by the use-case considered in the above) which is ambiguous between abnormal, dysfunctional, and diseased. However, there are good reasons to think that these notions are not co-extensive. A trait can be structurally abnormal while performing its

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function impeccably, such as with a foot with two fused toes. Moreover, as argued, dysfunction can seemingly occur in the absence of disease, such as in the case of a single dead cell in an otherwise healthy body. As such, although we certainly want a philosophical theory that is able to say *something* informative about cases such as that of U.D., I believe that this folk usage of 'pathological' is unhelpful in that it is imprecise and open to misinterpretation.

The question from here becomes: does the Domino Theory give us the conceptual resources to discuss such cases in useful and precise language? Of course, the Domino Theory gives us the conceptual resources to do much more than just point out domino dysfunctions. For example, the judgment that the trait in question is dysfunctional – that the occipital lobe itself cannot perform its function – does not depend on what's going on in the rest of the body, and so can be inferred from facts about the trait itself. Thus, the Domino Theory is no barrier to describing such cases adequately; we can agree that the trait is dysfunctional without any need to assess the extent of the adverse effects.

However, the conceptual framework suggested by Domino Theory also prompts novel questions which challenge us to be even more precise. If the trait is dysfunctional, what *sort* of dysfunction is it? If it is a domino dysfunction, what kind of effects does it have? If it is a trivial dysfunction, could it nevertheless be a risk factor? In this way, rather than *obstructing* disease-talk, the Domino Theory in fact has the potential to *improve* medical discourse by prompting us to be more precise and to the point. Instead of simply saying that the trait is 'pathological' (which is potentially ambiguous), the Domino Theory invites more *nuanced* disease-talk, where things going awry within a complexly interdependent organism can be expressed in more biologically precise terms.

## 9. Conclusion

I have argued that diseases are domino dysfunctions – that is, dysfunctions that cause adverse knock-on effects in other, dependent traits. Domino dysfunctions can be distinguished on principled grounds from non-pathological or 'trivial' dysfunctions. Previous attempts at defining pathology in terms of dysfunction overlooked the degree of functional integration within organisms, and thus failed to recognise that most biological dysfunctions are not singular, local phenomena, but rather *causes* of biological disruptions in dependent traits and systems elsewhere in the body.

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In order to spell out the Domino Theory in full, I first defined dysfunction and distinguished dysfunctions from environmental mismatches. I then applied my account of environmental mismatches to the relationships which obtain between traits within the organism's body, distinguishing two forms of 'somatic mismatch': fuel failures and signal failures. Domino dysfunctions, I argued, are dysfunctions which cause other traits to become either somatically mismatched or dysfunctional or both. I then considered three clusters of 'trivial dysfunctions'; biological dysfunctions which fail to constitute domino dysfunction and thus diseases. I finally considered two implications of my view, before responding to the objection that the Domino Theory is too revisionist.

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