Summary: Explanation Without A Cause

Introduction

The topic of my dissertation is explanation in functional biology. Functional biology is that part of biology which is concerned with the life of individual organisms: the way they are built, the way they work and the way they behave. Functional biologists often explain why an organism is built the way it is, why it works the way it works, or why it behaves the way it does, by appeal to the functions of an item[1] or behaviour pattern.

An example is Schwenk's (1994) explanation of why snakes have forked tongues.[2] Schwenk explains this forking by appealing to the function of the tongue. He argues that the snake's tongue has an important function in following scent trails (of preys and mates). Snakes follow scent trails by comparing the intensities of chemical stimuli at two sides of the body. This allows them to detect the edges of a chemical trail and follow it with minimal deviation. The chemical stimuli are collected by means of the tongue and passed to a pair of chemoreceptors in the snout. In order to compare stimulus intensities at two points, the snakes must be able to sample chemicals at two points simultaneously. This is made possible by the forking. Hence, Schwenk explains the forked character of the tongue by showing that this form enables the tongue to fulfil a certain function (namely to collect chemical samples at two points simultaneously).

Another example is Krogh's (1941) explanation of the presence of a circulatory system of in many kinds of animals (vertebrates, annelids, crustaceans and so on).[3] One of the functions of the circulatory system is to circulate oxygen. Krogh uses the laws a physical-chemistry to show that an organism in which the distance between the outside and the inner organs exceeds 1 mm would not be viable if all oxygen transport was to be achieved by diffusion. Diffusion is not fast enough to meet the needs of the inner cells. Larger organisms need a system of convection in addition to diffusion. The circulatory system solves this problem by providing a system of convection. Other organisms employ other kinds of convection systems. Insects, for instance, transport oxygen by means of small tubes that circulate air and sponges and coelenterates trans-

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[1] I use the term 'item' to refer to any part or substance of an organism (molecules, sub cellular organelles, cells, tissues, organs, organ systems and so on). Examples of items are chlorophyll molecules, chromosomes, the cell nucleus, membranes, white blood cells, hearts, limbs, fingers, the circulatory system and so on.

[2] Section 2.2.2, example 2.3.

[3] Section 4.2.3.

port oxygen by means of water currents. Hence, Krogh explains the presence of a circulatory system by showing that this systems fulfils a necessary function.

Biologist tend to call explanations such as those of Schwenk and Krogh ‘functional explanations’. Philosophers use the term ‘functional explanation’ also to refer to other kinds of explanations. To avoid confusion, I introduce a new term, namely ‘design explanation’, to refer to the kind of explanations exemplified above. Design explanations explain the presence, form or activity of an item or behavioural pattern (in a certain kind of organisms) by appealing to the function of that item or behavioural pattern (in that group of organisms).

To many people, functional explanations seem a little odd, at least at first sight. Their intuition tells them that explanations should show how the phenomenon to be explained is brought about by the explanatory facts. For example, an explanation of a solar eclipse tells us how an eclipse results from the moon sliding between the sun and the earth as a result of which the light from the sun cannot reach the earth. However, Schwenk’s explanation does not tell us how the tongue became forked. Neither does Krogh’s explanation show how larger organisms came to have a circulatory system.

In my dissertation, I develop a philosophical theory of design explanation. This theory addresses the question what design explanations add to our knowledge (in addition to the phenomena described in the explanation). For example, Schwenk describes the form of the tongue, he describes how snakes use their tongue and he relates how the latter phenomenon explains the first. What does this latter account add to the description of the phenomena described? Similarly, Krogh uses certain data about an organism’s need for oxygen and a well-known law of physical chemistry to show that an organism can never become large if oxygen transport is by means of diffusion alone. What does this calculation add to the data and the law?

Kinds of function

My account of design explanation starts with the observation that biologists use the term ‘function’ in a number of different ways. In the first part of chapter 2,[4] I distinguish four different uses of the term ‘function’, namely

(1) function as activity (function_1): what an item does or is capable of doing (its activities and capacities),

(2) function as causal role (function_2): the role of an item or behaviour pattern in maintaining a complex activity or capacity,

(3) function as survival value (function_3): the way in which a certain item or behaviour pattern contributes to the survival, reproduction or fitness of the organisms that have it,

[4] Section 2.2

(4) function as selected effect ($function_4$): the advantages of a certain trait for which it was selected in the past.

The first three kinds of function correspond to different meanings of the term ‘function’ as this term is used by functional biologists. The fourth kind of function is embraced by many philosophers (this use of the term function was introduced by the evolutionary biologist George Williams (1966) but this use of the term ‘function’ made no headway among biologists).

When biologists contrast ‘form’ and ‘function’ they typically use the term function in the sense of *function as activity* ($function_1$). Roughly spoken, ‘form’ refers to what an item is made of, the way it is built and the way it looks like and ‘function’ (in this sense) to what an item does or is capable of doing. Examples of activity descriptions are: ‘the glands in the mouth secrete saliva’, ‘the heart beats’, ‘the heart rate of normal human beings at rest is about 70 beats per minute’. Activity descriptions tell us what a certain item does, but they do not detail how this activity is important in a larger context. I shall use the term ‘character’ to refer to both the form and the activity characteristics of an item. Activity characteristics have no special position in design explanation.

The notions of function as causal role ($function_2$) and function as survival value ($function_3$) are, on the other hand, of special importance to understand design explanation. The failure to distinguish these two kinds of function is a main obstacle towards a theory of design explanation.

Attributions of *causal roles* concern the position of an item or behaviour in the way in which the execution of a certain task is organized.[5] An example of such an attribution can be found in Schwenk’s explanation of the forked tongue: ‘the function of the tongue of snakes in trail-following is to sample two points at one time’. This claim positions the tongue in the system that has the task to follow scent trails. It details the subtask of the tongue in that system.

Statements about *survival value* concern the presence or the character of a certain item or behaviour. Such statements compare the organism that interests us with another, hypothetical, organism in which the item or behaviour in question is absent or in which that item or behaviour has a different character. Such statements claim that in certain conditions the real organism is better off than the hypothetical one and detail why this is the case. An organism is better off than another organism if the fitness[6] of the first organism is higher than that of the second. An example of a statement about survival value is: ‘the forked character of the snake’s tongue is

[5]Computer scientists would say that the causal role is the logical position of an item in a system (in contrast to its physical position) that performs a certain task. I use the, admittedly tiresome, phrase ‘position in the way in which the execution of a certain task is organized’ to express the same idea. The term ‘organization’ is closer to the biologist’s language than the term ‘logical’.

[6]Fitness is a technical term in biology. It roughly means ‘the expected number of offspring’.

useful to the organisms that have it, because it enables them to follow scent trails more efficiently than they would do if their tongue was blunt'. This statement compares a real snake with a forked tongue with a hypothetical snake with a blunt tongue. It says that if the tongue has a causal role in trail-following, the real snake is better off than the hypothetical one, because that causal role can be performed with a forked one but not with a blunt one.[7]

Comparison between a real organism and a hypothetical one is usually called 'counterfactual comparison'. Functional biologists routinely apply counterfactual comparisons in design explanations. Philosophers are wary of this kind of comparison. I argue that this suspicion is undeserved. It results from a confusion of function as causal role and function as survival value. Once the distinction between these two kinds of function is properly drawn, there remain no objections to the use of counterfactual comparison to determine survival value.[8]

Explanation in functional biology.

In the second part of chapter 2,[9] I situate function attribution and design explanations in the practice of functional biology . I show by means of examples that functional biologists aim to answer seven types of questions. The topics of research and the products of enquiry are summarized in the table below.

Research in functional biology.

Topic of research	Products of enquiry
Form and activity characteristics	Descriptions of the structure and activity of organisms and their parts
Causal roles	Attributions of causal roles
Causes and underlying mechanisms	Physiological explanations
Survival value of performing certain tasks	Design explanations (of the presence of the item or behaviour that performs the causal role)
Survival value of having a certain character	Design explanations (of the character of the item or behaviour in question)
Ontogeny	Developmental explanations
Evolution	Evolutionary explanations

[7]Section 2.2.2, 2.2.3 and 6.2.

[8]Section 6.3.

[9]Section 2.3.

The foundation of explanation in functional biology is provided by accurate *descriptions* of organisms, parts and behaviours.

Attributions of causal roles provide the key to explanation in functional biology. I return to this issue after I have described the four kinds of explanations in which functional biologists are involved.

Physiological explanations detail the causes and underlying mechanisms of the phenomenon to be explained. In line with Cummins (1975, 1983) , I distinguish two kinds of physiological explanations:

(a) explanations that explain how a certain type of change in the state of an organism is brought about (transition explanations), and

(b) explanations that explain the properties of an item or behaviour in terms of underlying structures and mechanisms (property explanations).

Property explanation may involve two kinds of analysis:

(i) componential analysis: the part that has the property to be explained is analyzed into components,

(ii) property analysis: the property to be explained is analyzed into subproperties

A capacity explanation is a special kind of property explanation in which the capacity of an item or an organism to perform a certain task (i.e. causal role) is explained by appeal to the capacities of the parts of that item or organism to perform a series of subtasks which add up to the capacity to be explained. Capacity explanations in functional biology typically involve both componential and property analysis. Note that capacity explanations attribute causal roles to the parts.

Design explanations are concerned with the survival value of the presence or character of a certain item or behaviour. They explain why a certain item or behaviour is present in certain kinds of organisms or why that item or behaviour has the character it has in those kinds of organisms, by showing that in the conditions that apply to those organisms the trait in question is more useful some another conceivable trait.

Developmental explanations explain how a certain item or behaviour is brought about in the course of an individual's history. These explanations are of the same kind as physiological transition explanations.

Evolutionary explanations explain how a certain item or behaviour was brought about in the course of the history of the lineage. Evolutionary processes include mutation, gene flow, recombination, selection and genetic drift. Selection explanations are a special kind of explanations that attempt to explain the presence or character of a certain item or behaviour by appeal to past selection.

Attributions of causal roles tell us how an item or behaviour is situated in the organism's organisation. They provide a handle by means of which functional biologists get a grip on their subject matter. Such attributions are used in at least three different kinds of explanation:

1) capacity explanations—as I noted above, these explanations appeal to the causal roles of the parts of an item or behaviour in explaining a capacity of that item or behaviour;
2) design explanations—survival value is typically assessed in relation to causal role;
3) selection explanations—evolutionary-historical explanations typically appeal to the efficiency with which a certain causal role is performed.

Philosophical theories of explanation

Philosophers of science have developed several theories of explanation. Two of these general theories are often applied in philosophical theories of functional explanation: the inferential theory (Hempel & Oppenheim 1948) and the causal theory (Salmon 1984) . Those theories are often seen as competing definitions of the notion of explanation. The inferential theory defines an explanation as a (deductive or inductive) argument in which a description of the phenomenon to be explained is inferred from a combination of descriptions of the laws of nature and the conditions that apply to the phenomenon in question. According to this theory the explanation of an eclipse (mentioned above) is explanatory because it infers that the conclusion that the light of the sun cannot reach the earth from a description of the positions of sun, moon and earth, and the laws about the propagation of light. The causal theory defines an explanation as an account that details the processes or mechanisms that bring about the phenomenon to be explained. I have already explained why the explanation of an eclipse is explanatory according to a causal account.

I am not interested in such exercises in conceptual analysis. However, the theories of explanation I mentioned above might also be seen as (possibly complementary) hypotheses about what scientists learn from the kind of reasoning they call 'explanation'. According to the inferential theory such reasoning shows that the phenomenon to be explained is to be expected in view of the explanatory facts. According to the causal theory such reasoning makes plain how the phenomenon to be explained hangs together with other phenomena in the world. This theory assumes that the different events in our world are brought about by means of causal interactions between causal processes. Explanations fit the phenomenon to be explained into this pattern of processes and interactions; they show us how different events are causally connected. From this point of view the philosophical theories of explanations are highly relevant to my topic.

Philosophical analyses of function and functional explanation

In chapter 4 to 7 I discuss a number of philosophical analyses which are presented, by their proponents, as theories of function or functional explanation. These analyses suffer from a number of problems:

1) they do not refer to real examples of explanations in functional biology to which their analysis applies,
2) they fail to take properly into account that biologists use the term ‘function’ in a number of different ways (most notably, they fail to distinguish between function as causal role and function as survival value),
3) they fail to take properly into account that there are different kinds of explanations that appeal to functions (many authors ignore design explanations or confuse them with capacity explanation or selection explanations),
4) they ignore the complex structure of design explanations (philosophers tend to think of functional explanations as one sentence function attributions in answer to a why-question).

As a result of these problems the reader is often left without any clue about the kind of explanation to which a certain analysis is supposed to apply.

In chapter 4 I discuss the now classical attempts of Hempel (1959) and Nagel (1961, 1977). These attempts employ the inferential theory of explanation. Design explanations pose a problem to the inferential theory because there are often different ways to fulfil a need or task. For example, blood circulation, air tubes en water transport provide different means to meet the need for a system of convection in larger organisms. Hence, from the fact that a certain organisms is able to fulfil a certain task or meet one may not infer the presence of a particular item, behaviour or structure. This problem is known as ‘the problem of functional equivalents’.

Hempel accepts the existence of functional equivalents and draws the conclusion that the kind of reasoning which is usually called ‘functional explanation’ is merely heuristic. It helps us to discover new phenomena but fails to explain them. I argue that Hempel’s account fails to account for many insights provided by design explanations.[10]

Nagel argues that there are no real functional equivalents. If both the function and the conditions in which the function is to be performed are specified in detail there remains only one way to perform that function. For example, given the way in which vertebrates are built, circulating oxygen by means of air or water currents is no option. I argue that this move does not work. In many cases one may only exclude functional equivalents by including into the explaining law the condition that the phenomenon to be explained is present. However, a statement of the type ‘all vertebrates that circulate blood, circulate blood’ is not a law of nature but a truism.

[10] Section 4.1

Furthermore, one of the insights provided by a design explanation is the insight that different systems meet the same need. If one does not allow functional equivalents one cannot account for this insight.[11]

Most (but not all) recent attempts to account for so-called functional explanations employ the causal theory of explanation. Proponents of the causal account have another problem with design explanation. Design explanations seem to explain the presence of a certain item, behaviour or trait by appealing to the fact that a certain task or need is fulfilled. However, the fulfilment of that task or need is an effect of the presence of the item / behaviour / trait, not a cause. Proponents of the causal theory respond in different ways. Some (e.g. Schaffner 1993: 362-410) maintain (just as Hempel did) that the scientific value of so-called 'functional explanations' is merely heuristic, not explanatory. Others try to show that this kind of reasoning, if properly viewed, really gives insight in the causes of the phenomenon to be explained. There are two kinds of approaches within the latter group: the disposition theory (Bigelow & Pargetter 1987) and the etiological theory.

The three main approaches to functions and functional explanations in contemporary philosophy are: the causal role theory (Cummins 1975, 1983), the survival value approach (for example Canfield 1964, Wimsatt 1972, Ruse 1973, Bigelow & Pargetter 1987, Horan 1989), and the etiological theory (for example Neander 1980, 1983, Millikan 1984, 1989b, Neander 1991a, Millikan 1993a).

In chapter 5 I discuss Cummins's causal role theory. According to this theory function attributions describe the role of an item in maintaining a capacity of a system to which that item belongs. For example, to say that the heart has the function to propagate the blood is to say that propagating the blood is what the heart does that accounts for the organism's capacity to circulate the blood. I argue that this theory applies to causal roles. There are, however, other uses of the term 'function', which are left unanalyzed. Cummins argues that function attributions (i.e. attributions of causal roles) are not meant to explain the presence of the item to which the function is attributed. Instead, they are used to explain a capacity of a system of which that item is a part. I argue that Cummins's account applies to capacity explanations. However, my main interest is in design explanations and Cummins's account fails to provide insight in this kind of explanation.[12]

In chapter 6 I discuss the survival value approach. This approach identifies functions with effects that currently make a causal contribution to the survival and reproduction of an individual organism. For example, the function of the heart is to propagate the blood if that is how hearts currently contribute to the survival and reproduction of the organisms that have hearts. I

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[11] Section 4.2

[12] It is unclear whether Cummins ignores, misrepresents or denies the existence of design explanations.

argue that this kind of definition confuses function as causal role and function as survival value. The proponents of the survival value approach differ in the way in which they account for the explanatory force of such function attributions. Horan (1989) employs the inferential theory of explanation. Bigelow & Pargetter (1987) favour a causal theory.

According to Horan, functional explanations show us how a certain trait is maintained in the population. I argue that this idea is most promising, but that Horan's elaboration of this idea is utterly confused.[13] There are other authors who have done a better job. Sober (1984) argues that appeals to overall fitness (i.e. function as survival value) are explanatory because they might show why a certain trait frequency distribution is maintained in the population. Reeve & Sherman (1993) suggest that appeals to adaptation explain why a trait remains prevalent in a population. Their notion of adaptation is very similar to my notion of function as survival value. I argue that this use of function as survival value accounts for part of the insights provided by appeals to survival value. However, it cannot be the whole story. Design explanations provide insights in the way in which certain kinds of individuals hang together, in addition to insights in population level processes. The explications of Sober and Reeve & Sherman do not account for these insights at individual level relations.

The disposition theory of Bigelow & Pargetter sees a function as a *disposition* to have an effect (that enhances the fitness of the individuals that produce that effect) rather than as that effect itself. The disposition explains the subsequent occurrence of the effect in the same way as the fragility explains its actual breaking. Mitchell (1995) argues convincingly that even if a disposition can be seen as the cause of survival (it might explain why an organism with a certain kind of item survives) it may not be seen as the cause of the presence of that kind of item (it does not explain why that kind of item is there (why it is present). Hence, the disposition theory does not provide insight in design explanations.

In chapter 7 I discuss the etiological theory. This is presently the dominant theory among philosophers of science with an interest in biology. According to this theory the function of an item / trait is to produce the effects for which it was selected in the past and which explain the item's / trait's current presence in the population. For example, hearts have the function to propagate the blood, if and only if propagating the blood is what hearts did that caused them to be favoured by past natural selection. This theory emphasizes that functions should not be seen as present effects of the item to which the function is attributed, but rather as past effects of past occurrences of that item in an ancestral population. Past effects, can be causes of present phenomena, of cause, and the etiological theory identifies the functions of an item with those past consequences that *were*, as a matter of fact, causally effective in the evolution or maintenance of

[13] Section 6.6

the item to which the function is attributed. I argue that this notion of function (function$_4$) is a philosophical fantasy that does not provide insight in design explanations.

I draw the conclusion that neither the inferential theory nor the causal theory provide an adequate account of the insights supplied by design explanations.

The structure of design explanation.

In chapter 8, I provide my own account of functional explanation. In the first part[14] I present my account of the structure of design explanations. According to this account a design explanation has two parts. It starts by specifying the causal role of the item or behaviour that interests us. Next, it discusses the survival value of the presence or character of that item or behaviour (on the basis of the preceding attribution of a causal role). In regard to the topic of explanation, I distinguish two variants: design explanations that explain the presence of the kind of item or behaviour to which the function is attributed (an example is Krogh's explanation of the presence of a circulatory system in several groups of animals) and design explanations that explain the character of the kind of item or behaviour to which the function is attributed (an example is Schwenk's explanation of the forked character of the snake's tongue). Both kinds start with an attribution of a causal role but they differ in their second component. Design explanations of the presence of a certain item or behaviour in certain kinds of organisms point out why it is useful to perform this causal role in the conditions that apply to the organisms in question (for example, Krogh points out that the circulatory system meets the need for a system of convection created by the size of vertebrates). Design explanations of the character of a certain item or behaviour explain why given this causal role and given the conditions in which this role is to be performed the role is better performed in the way it is performed than in some other conceivable way (for example, Schwenk points out why the trail-following role of the snake's tongue is better performed it the tongue is forked than if it is blunt).

Another distinction concerns the strength of the claim about survival value: requirement claims state that the trait to be explained is needed to survive and reproduce (examples are 'a forked tongue is needed to sample two points simultaneously' and 'organisms of a certain size need a system of convection'), optimality claims state that the trait to be explained is the best among the alternatives considered (for example a deeply forked tongue is more useful than a lesser forked one). Many design explanations make several claims about survival value, some of them are optimality claims and others requirement claims.

Philosophers of science tend to ignore this complex structure of design explanations. They think of functional explanations as statements of the form 'the function of *x* in organisms of taxon *t* is *y*' in answer to a question of the form 'why do organisms of taxon *t* have or perform

[14] Section 8.1.

x?’. It will be clear that this mistake is facilitated by the failure to distinguish between function as causal role and function as survival value. It will also be clear that this lack of insight in the complexity of design explanation is not conducive to understanding the explanatory force of this kind of reasoning.

The explanatory force of design explanations

In the second part of chapter 8[15] I discuss the explanatory force of design explanations and the nature of the relations with which design explanations are concerned. I argue that the explanatory force of design explanations must be sought in their ability to fit the presence and the character of the items and behaviours that interest us in the structure of functional interdependencies that exists between the different parts of an organism, its behaviour and the state of the environment in which it lives. The main difference between such relations of functional interdependence and causal relations is this: causal relations determine what is brought about (what happens), functional interdependencies determine what may exist (which combinations of traits of organisms and environmental states are viable). The most important relations of functional interdependence are ‘... is needed’ (for example, ‘vertebrates need a circulatory system’ and ‘... demands for ...’ (for example, the size of vertebrates demands for a circulatory system). Design explanations show us (i) how the properties of certain kinds of organisms and the states of the environment in which they live, pose a problem to the life of those organisms, and (ii) how those problems are solved in the organisms in question.

[15] Section 8.3 and 8.4.