

Chapter 5: The causal role theory

5.0 Introduction to chapter 5 to 8

In the previous chapter I argued that the attempts of Hempel and Nagel to account for the explanatory force of function attributions in terms of the inferential theory of explanation fail.

In chapter 5 to 7 I discuss more recent approaches to function: the causal role theory, the survival value approach, and the etiological account. In chapter 8 I present my own account. In chapter 5 to 7 I aim to evaluate the extent to which the different approaches account for the explanatory force of appeals to the different kinds of function as they are used in biology, especially in the disciplines known as functional morphology and ethology (see chapter 2). It will turn out that each of these approaches is concerned with only one type of function: the causal role theory is concerned with function as causal role (function₂), the survival value approach with function as survival value (function₃), and the etiological account with function as selected effect (function₄). As I mentioned in chapter 1, understanding the practice of biological explanation is not always the aim with which the theories I discuss were originally proposed. The proponents of the different theories often fail to realize that there are different notions of function and present, for instance, examples of attributions of causal roles (function₂) to support an analysis that applies only to function as survival value (function₃). It is important to distinguish the extent to which a philosophical theory of function captures the *meaning* of the different notions of function (as these are used in biology) from the extent to which that theory accounts for the *explanatory use* of appeals to the different kinds of function.

Chapter 5 is concerned with Cummins's (1975, 1983) causal role theory. I argue that this theory gives a correct analysis of the meaning of attributions of causal roles (function₂) and also that this theory accounts for one important explanatory use of attributions of causal roles, namely their use in what I call 'capacity explanations'. There are, however, other important explanatory uses of attributions of causal roles that are left unexplained, namely their use in design explanations and their use in evolutionary selection explanations.

Chapter 6 is concerned with the survival value approach. In the first part of this chapter I show that the survival value approach is on the right track as an analysis of the *meaning* of claims about survival value. I elaborate my own account of the meaning of such claims (presented in section 2.2.3) and show that the objections that have been brought up against other proposals within the survival value approach do not apply to my account. In the second part of chapter 6 I argue that the current proposals with the survival value approach fail to give a satisfactory account of the *explanatory use* of appeals to survival value.

Chapter 7 deals with the etiological account. I argue that appeals to function in explanations in functional biology concern function as causal role (function₂) and function as survival value (function₃). As the etiological theory does not apply to these kinds of function, this theory is irrelevant to my subject.

The main upshot of my discussion in chapter 5 to 7 is this:

- Cummins provides a satisfactory account of the notion of function as causal role (function₂);
- I do provide a satisfactory account of the notion of function as survival value (function₃);
- Cummins provides a satisfactory account of appeals to causal roles in capacity explanations;
- an account of appeals to causal roles and to survival value in design explanation is lacking;
- an account of appeals to causal roles in evolutionary explanations is lacking.

In chapter 8 I attempt to work out a theory that should fill the lacuna.

5.1 Introduction to chapter 5

Hempel and Nagel tried to account for the explanatory force of function attributions in terms of the inferential theory of explanation. On this theory explanations show that the phenomenon to be explained was to be expected in virtue of the explaining facts. Most of the more recent attempts employ the causal theory of explanation. On this theory explanations reveal the mechanisms and processes that bring about the phenomenon to be explained.

One of the first attempts to account for the explanatory force of function attributions in terms of the causal theory of explanation is that of Cummins (1975) (see also Cummins 1983, chapter 1 and 2). Cummins rejects the idea that functional explanations explain the presence of a certain item by attributing a function to that item. According to him, explanations that explain the presence of a certain item must appeal to factors that cause that item to be present. As the performance of a function is an effect of an item's presence rather than a cause, one cannot explain the presence of that item by appeal to its function. On Cummins's account, functional explanations explain the capacities of a system of which the item in study is a part. For example, the appeal to the heart's function to pump blood serves to explain the capacity of the system of heart and blood-vessels to circulate oxygen, nutrients and waste.

In the section 5.2 I describe Cummins's criticism of previous account of functional explanations and his own theory of functional explanation in more detail. In section 5.3 I show by means of an example that functional biologists indeed employ a kind of explanation (capacity explanation) that conforms to Cummins's theory. In addition, I show by means of several examples that function attributions in Cummins's sense are used in other kinds of explanation as well. These uses are ignored or denied by Cummins. In section 5.4 I show that Cummins's criticisms do not apply to the use of function attributions in design explanations. In section 5.5 I argue that Cummins's arguments against the use of attributions of causal roles in evolutionary

explanations do not hold water. In section 5.6 I discuss some objections brought up against Cummins's view by other philosophers. Finally, in section 5.7 I draw some conclusions.

5.2 Cummins's account of function and functional explanation

In this section I relate Cummins's criticism of the classical view on attempts to account for functional explanations on the inferential theory of explanation (5.2.1), Cummins's own account of functional explanation (5.2.2), and Cummins's account of function attribution (5.2.3).

5.2.1 Cummins's criticism of previous accounts of functional explanation

Cummins starts his "Functional Analysis" (1975) with the observation that all accounts of functional explanation from Hempel (1959) and Nagel (1961) onward have proceeded under two undefended assumptions, namely (1) that the point of a function attribution is to explain the presence of the item to which the function is attributed, and (2) that functions are a special kind of effects on a containing system¹ (for example those effects that satisfy a need of an organism, or those effects that contribute to a certain goal state of an organism). Note, that the first assumption concerns the *explanatory use* of function attributions, and the second their *meaning*. Taken together these assumptions yield the view that function attributions explain why a certain item is present in a certain system by pointing out that that item is present because it has a certain kind of effect on that system. Given this view the main task of a philosophical theory of function is to characterize the kind of effect that are functions.

Cummins rejects both assumptions. In regard to the first assumption he maintains that explanations of the presence of an item should appeal to causally relevant factors. Function attributions are concerned with the effects of an item. Since the effects of an item are causally irrelevant to the presence of that item one may not appeal to functions to explain the presence of that item.

The problem is [...] that to "explain" the presence of the heart in vertebrates by appeal to what the heart *does* is to "explain" its presence by appeal to factors that are causally irrelevant to its presence. Even if it were possible, as Nagel claimed, to *deduce* the presence of chlorophyll from the occurrence of photosynthesis, this would fail to *explain* the presence of chlorophyll in green plants in just the way deducing the presence and height of a building from the existence and length of its shadow would fail to explain why the building is there and has the height it does. This is not because all explanation is causal explanation: it is not. But to explain in the presence of a naturally occurring structure or physical process—to explain

¹A containing system is a system of which the item to which the function is attributed is a part.

why it is there, why such a thing exists in the place (system, context) it does—this does require specifying factors that causally determine the appearance of that structure or process (Cummins 1975: 745/6, italics in original).

In regard to the second assumption, Cummins argues that it is impossible to describe the kind of effects that are functions adequately. As a first attempt one may equate the functions of a part of a system with those effects that contribute to a function of that system. This system itself can be seen as a part of a more encompassing system and so on. The problem is that the chain of encompassing systems will have to end somewhere (for example with the organism) and the definition does not allow us to attribute functions to that final system. As a second attempt one may equate the function of a part of an organism with that part's contribution to that organism's health or survival. This definition has, at least, two problems. First, there are cases in which the exercise of a function is unfavourable to health and survival (for example, after mating many male spiders are eaten by their mate). Second, some healthy effects do not count as functions (for example, adrenaline secretion may effect loss of weight but this effect does not count as a function of adrenaline secretion). A third attempt may equate functions with effects that contribute to the organism's capacity to contribute to the survival of its species. According to Cummins, this attempt is too limited as we can easily imagine cases in which the exercise of a certain function would not contribute to the survival of the species. For example, if flying ceased to contribute to the pigeon's capacity to maintain its species we would still say that propulsion during flight is a function of the pigeon's wing.²

5.2.2 Cummins's account of functional explanation

Cummins presents his own account of functional explanation in section 3 of his "Functional Analysis" (1975: 758-761).and in the first two chapters of his *The Nature of Psychological Explanation* (1983: 1-27). Central to this account is the idea that functional explanation is a distinctive style of explanation that does not conform to the covering law model. This kind of explanation is used to explain complex capacities.

Cummins starts his account of functional explanation by contrasting two main strategies of explanation: subsumption and analysis.³ Explanations by subsumption explain changes of state in a system as the effect of certain previous changes by appeal to causal laws. An example is the explanation of the increase in pressure in a certain container with gas as the effect of a change in

²Cummins does not discuss definitions that equate functions with those effects that contribute to an organisms inclusive fitness. The counterexample against the third definition would apply to this definition too.

³Cummins's (1983: 1-27) account of the difference between subsumption and analysis differs from Cummins (1975: 758-761). In this paragraph I follow his 1983 account.

volume by appeal to Boyle's law. Analytical explanations, on the other hand, are not concerned with changes but with properties. They explain how the properties of a certain system are brought about in terms of the properties of the components of that system and their mode of organization. An example is the explanation of the temperature of a certain gas by the law that the temperature of a gas is the average mean kinetic energy of the molecules in the gas. Cummins calls a law that specifies how a property is embodied in a certain type of system an 'instantiation law'. An analysis of a system into parts is called a 'componential analysis'.⁴ Analytical explanations often include another kind of analysis in addition to the componential analysis, namely an analysis of the *property* to be explained in terms of the properties of the parts. Cummins calls such an analysis a 'property analysis' if the property to be explained is non-dispositional, and 'functional analysis' if the property to be explained is a disposition or a capacity.⁵ Functional analysis proceeds by analyzing a capacity into a number of other capacities which add up, flow chart style, to the capacity to be explained.⁶

An analysis might appeal to properties or components which themselves require analysis. A componential analysis must eventually terminate in what Cummins calls 'nomic attributions'. Nomic attributions are fundamental lawlike statements to the effect that all components of a certain kind manifest a certain property (an example is the law of inertia in classical mechanics).⁷ A functional analysis must eventually terminate in dispositions which are explainable via componential analysis without further appeal to subcapacities. A functional analysis explains a capacity only if the explaining capacities at this elementary level are indeed instantiated by the system: functional analysis is the first stage of a functional explanation, instantiation is the second (Cummins 1983: 31).

According to Cummins, functional analyses are explanatory because they show us how a complex capacity is brought about by the co-ordinated activity of simple parts. The power, and, hence, the suitability of this style of explanation depends on the extent to which the explaining capacities are simpler than and different from the capacity to be explained, and on the relative complexity of the organization attributed to the system. This latter feature (complexity of organization) correlates with the first two: if the gap between the explaining capacities and the capacity to be explained is greater one needs a more complex organization to bridge that gap (Cummins 1975: 764, 1983: 30).

⁴Cummins also uses the terms 'system analysis' and 'compositional analysis'.

⁵Cummins (1983) uses the terms 'disposition' and 'capacity' as stylistic variants.

⁶Note, that Cummins's 'functional analysis' refers to a different activity as Hempel's. Hempel refers to the analysis of needs, Cummins to the analysis of a complex capacity into subcapacities.

⁷According to Cummins such nomic attributions require justification but not explanation.

5.2.3 Cummins's account of function attributions

According to Cummins, function attributions are best viewed as the products of functional analyses. The functions of an item are those capacities of an item which feature in a functional explanation of some complex capacity.

In the context of science, to ascribe a function to something is to ascribe a capacity to it that is singled out by its role in an analysis of some capacity of a containing system. When a capacity of a containing system is appropriately explained via analysis, the analyzing capacities emerge as functions (Cummins 1983: 28) (see also Cummins 1975: 765).

Hence, it is the applicability of a certain strategy of explanation (viz. explanation by functional analysis) that justifies the use of the term 'function', rather than the kind of effect singled out. For example, the capacity of the heart to pump blood counts as a function because the capacity of an organism to circulate oxygen, waste and nutrients is properly explained by appeal to (among other things) the capacity of the heart to pump blood. (In section 5.3.1 I will elaborate on this example.) As there is no functional explanation that appeals to the heart's capacity to produce sounds, the production of heart sounds does not count as a function.

5.2.4 Summary of Cummins's account

Thus, on Cummins's view, (i) functional explanations explain a complex capacity of a certain system by appeal to more simple capacities of the parts of that system, (ii) such accounts are explanatory on a causal account of explanation because they show us how a complex capacity is brought about by a system of simple subsystems, (iii) the function of a part of a system is a capacity of that part which features in a functional explanation of a capacity of that system, and, hence, (iv) the question whether or not a certain function attribution is justified comes down to the question whether or not a functional explanation is suitable. In the next section I discuss the applicability of this account to explanations in functional biology.

5.3 Evaluation of Cummins's account

What insights in explanation in functional biology does Cummins's account provide? In section 5.3.1 I show by means of an example that Cummins's account of functional *explanation* applies to an important kind of explanation in functional biology, namely capacity explanation. In section 5.3.2 I show by means of examples that Cummins's account of function *attribution* accounts for one way in which attributions of causal role are used in explanations (namely their use in capacity explanations), but leaves several other uses out of sight (namely their use in design explanations and their use in selection explanations). It also neglects the explanatory use of attributions of survival value.

5.3.1 Functional explanation

According to Cummins, functional analysis is widely employed in functional biology. Biologists typically explain the biologically significant capacities of the organisms they study by analyzing that organism into a number of systems (such as the circulatory system, the digestive system, and the musculoskeletal system). Each of these systems is defined by its characteristic capacities. These capacities in turn are analyzed into capacities of the components and so on. Ideally, this strategy is carried on until a level is reached at which the explaining capacities are sufficiently simple to explain them in terms of the physical and chemical characteristics of the components (Cummins 1975:760/1, 1983: 29).

Cummins does not discuss any detailed example of functional explanation in biology, but it is not difficult to find explanations that conform to his analysis in textbooks on functional biology. In section 2.3.2 I have labelled such explanations ‘capacity explanations’. For example, explanations of an organism’s capacity to circulate oxygen typically start by observing that the circulatory system consists of, say, three parts: a heart, the blood, and a system of blood-vessels. Next, they point out the causal role (function₂) of each of these parts in maintaining the circulation: the blood carries oxygen, the heart pumps the blood around (the heart is the source of energy for blood movement) and the vessels are arranged in such a manner that blood is transported from the heart to the lungs (where it is aerated) via another part of the heart to the organs (where oxygen is released) back to the first part of the heart. The capacities of these parts are in turn explained in terms of the capacities of their subparts. For example, the capacity of the heart to pump the blood around is explained in terms of its internal structure, its ability to contract, its rhythmicity and the nervous control. The capacity of the blood to carry oxygen is explained by the presence of haemoglobin, a respiratory pigment that has the capacity to carry oxygen. The system of blood-vessels is further divided into arteries, veins and capillaries. And so on, until a level is reached at which the capacities of the parts are explained in terms of their physical and chemical properties, without appealing to capacities again.⁸

For example, the capacity of the heart muscle (and more generally the capacity of any muscle) to contract is explained by the sliding filament theory, first proposed in 1954 by H.E. Huxley and J. Hanson and independently by A.F. Huxley and R. Niedergerke. According to this theory the change in muscle length is caused by two kinds of filaments (thick filaments and thin filaments) that slide past each other during contraction. The mechanism of contraction can be explained in molecular terms. The thick filaments are composed mainly of the protein myosin; the thin filaments are composed mainly of another protein: actin. The thick filament consists of a bundle of myosin molecules. A myosin molecule is an elongated, club-

⁸ Explanations of the capacity to circulate oxygen that match this rough sketch can be found in any textbook on functional biology, see, for example Johansen (1977) or Keeton and Gould (1993: 843-860).

shaped structure with a linear tail and a globular head. Due to this structure, myosin molecules aggregate into filaments in which the molecules are arranged in two opposite directions, with clusters of the globular heads at the distal ends and their linear tails overlapping. The globular heads form a series of cross bridges to the actin filament. The cross bridges act as levers that pull the actin filaments towards each other during contraction. Contraction at this level is a kind of ratchet mechanism. After being activated by binding one ATP molecule (the source of energy for contraction), a myosin head binds to a special receptor site at the actin molecule. The energy for the binding is provided by the splitting of ATP in ADP and phosphate. The release of these two derivatives induces a change in the conformation of the myosin head due to which the actin filaments are pulled together. As the result of the bending the myosin disconnects from the actin and becomes free to start a new cycle. Due to the arrangement of the myosin molecules (in opposite directions) the actin filaments are pulled towards each other and the muscle shortens. Hence, the capacity of the muscles to contract is explained by (1) the arrangement of the thick and thin filaments, (2) the structure and arrangement of the molecules of which the filaments are composed, (3) changes in binding and in conformation of the molecules involved, (4) the release of ATP. At this level of explanation no further appeal to subcapacities is needed.⁹

This example indicates that Cummins has drawn attention to an important kind of explanation in functional biology, namely capacity explanation. This kind of explanation was completely ignored in the philosophy of science at the time Cummins's article appeared. Cummins account details the way in which capacity explanations are construed and brings to light the explanatory force of this kind of explanation (on a causal account): capacity explanations show us how complex capacities are brought about by the operation of systems of subsystems that are ultimately chemical or physical in nature.

5.3.2 Attributions of causal roles

In the previous section I discussed Cummins's account of functional *explanation*. I argued that this account reveals the explanatory force of an important kind of functional explanation, namely capacity explanation. In this section I evaluate Cummins's account of function *attributions*. In regard to this subject Cummins argues (i) that the assumption that the point of a function attribution is to explain the presence of the item to which the function is attributed is wrong (see section 5.2.1 above), and (ii) that functions are singled out by their role in capacity explanations (see section 5.2.3 above). As Cummins distinguishes between function and survival value (see Cummins 1975: 749-751) I will assume that these claims are meant to apply to

⁹ This account of muscle contractility is derived from Huxley (1965) and Keeton & Gould (1993: 1076-1081); for a more elaborated discussion of the quest for an explanation of the heart's capacity to contract see Robinson (1986).

function as causal role (function₂) only. In this section I argue, by means of examples, that Cummins is right that attributions of causal roles are singled out by their role in capacity explanations, but that capacity explanation is often not the main point of an attribution of a causal role. Quite often causal roles are attributed as part of an attempt to explain the design or the evolution of the item to which the causal role is attributed. I will use the examples of attributions of causal roles I brought up in section 2.2.2: Harvey's claim that the principle causal role of the heart is to propagate blood (rather than to produce heat and life), Miller's study of the causal role of the thymus, and Schwenk's explanation of the snake's forked tongue. If the point of an attribution of a causal role is to explain a capacity of a containing system one would expect that research into causal roles is guided by a (type 3) question of the form 'how are such and such organism able to perform such and such activity?'. However, in these three examples the questions that guide research are questions of the type 'why do such and such organisms have such and such type of item?'. Cummins does not pay attention to the use of attributions of causal role in answering these kind of questions.

The causal role of the heart

As I explained in section 2.2.2, Harvey's (1628) claim that pumping blood is the function of the heart is part of an attempt to establish the thesis that the blood circulates continuously through the body. His main argument for this thesis concerns the quantity of blood passing through the heart. In addition he argues that the thesis of a continuous circulation would explain a wide variety of phenomena by showing "for what cause they are made" (p. 133). Phenomena that would be "very hard for any one to explain by any other way" (p. 133). One such phenomenon is the beating of the heart. Another is the difference in thickness between the muscular wall of the left and that of the right ventricle of the heart. The wall of the left ventricle is much thicker than the wall of the right one. On the hypothesis that the main function of the heart is to pump the blood around, this difference is easily explained. Because, the left ventricle has to pump the blood through the whole body it needs more power, and hence more muscles, than the right ventricle which has to pump the blood only through the lungs (p. 124).

In other words, Harvey argues that attributing the function to pump blood to the heart helps to answer the following questions 'why does the heart beat?' and 'why does the heart have the structure it has?'. No doubt, he singles out pumping because pumping explains the activity in which he is interested (circulation), but at this stage of his argument his point is that the assumption that the heart has the causal role to pump the blood around helps to explain the structure and activity of the heart. In this example, the function attribution serves as a first step in a design explanation of the structure and activity of the item to which the function is attributed.

In defence of Cummins's position one might try to dismiss my reference to Harvey as irrelevant.¹⁰ "You aim to explain the current explanatory practice in biology", so the argument would go, "but the kind of explanation Harvey employed to explain the structure and action of the heart by appeal to its function is teleological in a way that is not acceptable today". To a certain extent I am sympathetic to this response. On the theory of explanation Harvey employed function attributions are explanatory because they identify the purpose for which the item to which the function is attributed was brought about. Today this is not acceptable as an account of why function attributions are explanatory. However, Harvey's function attribution is still accepted today, just as his explanation of the difference in thickness between the ventricles by appeal to this function. This can be checked in most textbooks on functional morphology. For example, Johansen (1977) observes that in birds and mammals

the structural design of the left and the right ventricles reflects their function as a volume pump and a pressure pump respectively (Johansen 1977: 388).

Among the differences in structure which are explained by the different causal roles of the ventricles is the difference in the thickness of the walls (I have discussed this explanation in section 2.3.4.). This shows that Harvey's explanations are today accepted as explanatory, despite the fact that his concept of explanation is not. Our task is to show how Harvey's explanation makes sense on our canons even if we do not accept the kind of teleology he accepted. Cummins's account is of no help here.

The causal role of the thymus

It is clear that in the second example of section 2.2.2 (the causal role of the thymus) the point of the function attribution is to make sense of the thymus, not to explain some capacity. It is true that the function which is finally attributed to the thymus (the function to initiate the differentiation of T-lymphocytes) is singled out by its role in an explanation of the development of the immune system, but Miller's (1961) studies did not aim to explain the development of the immune system. Miller did not even know that the immune system develops. He aimed to find out how the thymus contributes to our physiology. The existence of the thymus was a complete riddle because it appeared to have no effect at all on the organism's physiology. Part of this riddle was solved by showing that and how the thymus contributed to the development of the immune system.

¹⁰In a similar vein, Neander (1991a) rejects the argument against the etiological approach that Harvey talked of functions without having heard of natural selection on the ground that "Harvey obviously did not have natural selection in mind when he proclaimed the function of the heart but that does not show that modern biologists do not have it in mind" (p. 176).

Hence, the question that guided research was the question ‘why do many vertebrates have a thymus?’. Miller’s experiments provide a partial answer to this question: the thymus has a causal role in the development of the immune system. This answer situates the thymus in the organization of the machinery by which vertebrates meet their needs. This answer is partial because it does not tell us why this task is performed by a specialized organ. It lasted until the 1980s before Langman (1989) came up with a design explanation that answers this question (I have outlined this explanation in section 2.2.3).

The snake’s forked tongue

In the third example of section 2.2.2 (the snake’s forked tongue) the function attribution (the tongue has a trail following role) is singled out by its role in an explanation of the capacity to find prey and mates. Yet, as the title of Schwenk’s (1994) paper (“Why Snakes have Forked Tongues”) indicates, the insight that the tongue has a trail-following role does not only serve to explain the snake’s capacity to find prey and mates, but also to explain why the tongue is forked. As I discussed the forking is explained at two levels. At the organismal level the forking is explained by means of a design explanation that appeals to the requirements imposed on the tongue by the mechanism of trail-following. At the historical level the increase of forking is explained by an evolutionary selection explanation that appeals to the fact that the causal role to follow trails was performed more efficiently by those individuals that had tongues that were forked more than average.

Conclusion

As I said in the introduction to this subsection, if the main point of an attribution of a causal role is to explain a complex capacity, one would expect that research into functions is guided by a question of the type ‘how are such and such organism able to perform such and such activity?’. However, in all three examples the question that guides research is not a question about a capacity but a question about an item. Harvey was interested in the structure and activity of the heart, Miller in the causal role of the thymus and Schwenk in the forked character of the tongue. As a first step in answering this question the researchers attribute a causal role to the item in which they are interested. This attribution situates the item in a system that performs a certain task. It tells us how that item contributes to that task. Subsequently, this hypothesis about the place of the item in the way in which the organism is organized is used to explain the presence or character of that item. This can be done at two levels. In a design explanation it is shown that the item performs its causal role better if it has the character it has (rather than if it had some other character). In an evolutionary explanation the character of the item is explained by showing how the causal role of that item influenced the evolution of that item. This means that in addition to the use of attributions of causal role in capacity explanations, there are at least two

other uses of attributions of causal roles, namely (i) the use of attributions of causal role in design explanations, and (ii) the use of attributions of causal role in evolutionary explanations. Cummins appears to ignore this. As I said in section 5.2.1, Cummins argues that attributions of causal role cannot be used in explanations of the presence of the item to which the causal role is attributed. In the next sections I will discuss whether his arguments apply to the use of attributions of causal roles in respectively design explanations (section 5.4) and evolutionary explanations (section 5.5).

5.4 Design explanations and causality.

As I said before, Cummins (1975: 746) maintains that explanations of the presence of a naturally occurring item or physical process must appeal to causally relevant factors. Because, the performance of a causal role is the effect of an item's presence (and not its cause) one may not appeal to the causal role of a certain item to explain the presence of that item.

In a certain sense (of 'explain the presence of an item'), design explanations explain the presence of the item or behaviour to which the function is attributed. As I showed previously, design explanations are taken to explain why certain organisms have a certain kind of item or perform a certain kind of behaviour. Schwenk, for example, explains why snakes have a forked tongue (example 2.3 of section 2.2.2) and Krogh explains why larger organism have a circulatory system (see section 4.2.3).¹¹

However, design explanations do not explain the presence of an item in the sense in which Cummins uses the phrase 'explain the presence of an item'. Cummins seems to refer to explanations that explain how a certain kind of item became present in a certain place in the course of time. Design explanations do not explain the presence of an item or behaviour in that sense, they explain how a certain item or behaviour is useful (synchronically) not how it came about in the course of time (diachronically). This justifies the conclusion that Cummins's thesis, that explanations of the presence of an item must appeal to causally relevant factors, cannot be used to argue against appeals to causal roles and survival values in design explanations. Such explanations do not pretend to explain the presence of an item in the way in which Cummins uses that phrase.

Cummins (1975: 746) explicitly states that there might be explanations that do not explain the presence of an item and that such explanations need not be of a causal nature. As I discussed in section 5.2.2, Cummins (1975: 758-763, 1983: chapter 1) distinguishes two kinds of explanations: explanations that explain changes (explanations by subsumption) and explanations that explain properties (analytical explanations). He tends to restrict the term 'causal ex-

¹¹ See also section 2.3.2.

planation' to explanations of the first kind. However, both kinds of explanations are causal in the sense in which I use that word: explanations by subsumption show us how a certain change is brought about by preceding changes, analytical explanation show us how a certain property of an item or behaviour is brought about by the action of its components. Design explanations belong to neither of Cummins's categories: they do not explain changes and they do not analyze a thing into components. They are not of a causal nature because they are not concerned with the mechanisms that bring about a certain change, property, state or ability. Instead they show us why a certain item, behaviour or character is useful to its bearers. One of the main challenges of a theory of design explanation is to explain how this kind of reasoning can be explanatory.

5.5 Attributions of causal roles in selection explanations

In section 5.4 and 5.5 I deal with Cummins's arguments against the use of attributions of causal roles to explain the presence of the item to which the causal role is attributed. I discuss the question whether these arguments apply to the appeal to causal roles in design explanations respectively evolutionary explanations. As I said before, Cummins maintains that appeals to causal roles to explain the presence of a certain kind of item are to be rejected on the ground that causal roles are causally irrelevant to the presence of that item. In regard to design explanations I argued (in section 4.5) that design explanations are not meant to explain the presence of the item to which the function is attributed (in Cummins's sense of 'explain the presence'). In regard to appeals to causal roles in evolutionary explanations I shall argue (in this section) (i) that such explanations do explain the presence of certain kind of item, and (ii) that such explanations appeal to causally relevant factors. In section 5.5.1 I expose my own views on this subject. In section 5.5.2 I show that Cummins does not provide valid arguments against this view. In section 5.5.3 I draw the conclusion that there are no objections to appeal to causal roles to explain the evolution of the item to which the causal role is attributed.

5.5.1 A causal account of appeal to causal roles in evolutionary explanations

For a start, consider the historical part of Schwenk's explanation of why snakes have a forked tongue. At the historical level Schwenk explains the presence of forked tongues in currently living snakes as the result of a series of past changes at the level of the population. These changes resulted in a gradual increase of the forking of the tongue in the course of evolution. Schwenk explains this increase by appeal to selection to perform the trail-following role of that item more efficiently. This explanation assumes that in an ancestral population of snakes with moderately forked tongues certain mutations occurred as the result of which the tongues of the mutant organisms were more highly forked than average. Due to this increased forking the tongue of those mutants performed its trail-following role more efficiently than average. This

increased the relative fitness of those mutant organisms. As a result, the mutation spread through the population and the average forking of the tongue in that lineage increased.

Schwenk, clearly, explains the presence of forked tongues in currently living snakes and he does so by appeal to the causal role of that item. The explanation says that one of the processes that gave rise to the phenomenon to be explained (the presence of highly forked tongues in currently living snakes), was selection for a better performance of the trail-following role. Thus, the fact that the tongue had a trail-following role is a positive causal factor for the increase of the forking in the course of the evolution: if the tongue had another role an increased forking would probably not have been advantageous and mutations with more than averagely forked tongues would probably not have spread through the population. Hence, this way of appealing to causal roles to explain the presence of a certain kind of item is acceptable on a causal view of explanation.

In order to avoid misunderstandings, let me emphasize two distinctions. The first distinction is a distinction between two levels at which processes may take place: the level of the organism (individual) and the level of the lineage (population). In Schwenk's explanation, it is the fact that the tongue had a trail-following role in *individuals in an ancestral population* that explains the appearance of highly forked tongues *in the lineage*.

The second distinction concerns two ways in which items may be grouped into kinds: on the basis of structural similarity and on the basis of homology. The concept of 'homology' is subject to discussion but for my purposes one should think of homologous items as items that have the same evolutionary origin.¹² For example, bird hearts are homologous to mammal hearts because if one traces their evolutionary history one would find that both these hearts originate as modifications from the heart of some reptile-like common ancestor. However, insect hearts are not homologous to vertebrate hearts because (to our best knowledge) the most recent common ancestor of insects and vertebrates did not have a heart (which shows that vertebrate hearts and insect hearts did not originate from one original). Although the tongues of all reptiles are homologous to each other, its forked character in the lineages that have a forked tongue is not homologous in all those lineages: Schwenk showed that this character evolved at least twice. In the context of evolutionary explanations two items in different organisms are seen as occurrences of the same item in the lineage if those items are homologous.

Hence, Schwenk explains the appearance of a certain kind of items (i.e. *items that have a certain structure*) in a lineage by appeal to the causal role of those items (i.e. *homologous items*) in past individuals of that lineage. Note, that in this kind of explanations the bridge between the

¹²A more precise definition can be given with help of Millikan's (1984: 23-25) notion of 'reproductively established family': two items are called 'homologous' if they belong to the same (higher-order) reproductively established family.

level of the individual and the level of the population, is provided by natural selection: an item changes (at the level of the lineage) due to heritable fitness differences between individuals as the result of heritable differences in the way in which that item performs its role in different individuals. The way in which an item performs its role is, therefore, a causally relevant factor in the evolution of the item to which the function is attributed. In the next section I discuss Cummins's views on this issue.

5.5.2 Cummins's view of causal roles and natural selection.

Cummins (1975: 749-751) explicitly rejects the view that "natural selection provides the missing causal link between what something does in a certain type of organism and its presence in that type of organism" (p. 750), but it is difficult to lay ones finger on exactly what view Cummins rejects and what exactly his arguments are. In the next section I will show that his discussion does not yield a tenable argument against my thesis that one might explain the presence of a certain kind of item in the lineage by appeal to the way in which past occurrences of that item performed their causal role.

Cummins's examples and his main thesis

Cummins starts his discussion of the view he rejects by considering two examples of attributions of causal roles:

- (a) The function of the contractile vacuole in protozoans is elimination of excess water from the organism
- (b) The function of the neurofibrils in the ciliates is coordination of the activity of the cilia (Cummins 1975: 749)

According to him such attributions have two distinct uses in biology. They serve (i) to explain specific capacities of individual organisms, and (ii) to explain how organisms that have items "of the sort in question" are able to survive.¹³ For example, attribution (a) is used to explain (i) how certain organisms are able to get rid of water, accumulated by osmosis, and (ii) why protozoans that have contractile vacuoles do not explode in fresh water. Similarly attribution (b) is used to explain (i) how the activity of neurofibrils in ciliates is co-ordinated, and (ii) why ciliates incorporating neurofibrils are capable of fairly efficient locomotion. According to Cummins the impression that function attributions help to explain the presence of the "sort of

¹³ Actually, Cummins's distinction lumps two contrasts together. One is the contrast between explaining a capacity of a certain individual and explaining a capacity of those individuals that are build in a certain way. The other is the contrast between explaining a specific capacity of an individual (c.q. those individuals that are build in a certain way) and explaining the ability of a certain individual (c.q. those individuals that are build in a certain way) to survive.

item” (p. 750) to which the function is attributed is due to a confused interpretation of the second use of function attributions:

It might seem that natural selection provides the missing causal link between what something does in a certain type of organism and its presence in that type of organism. By performing their respective functions, the contractile vacuole and the neurofibrils help species incorporating them to survive, and thereby contribute to their own continued presence in organism of those species, and this seems to explain the presence of those structures in the organisms incorporating them (Cummins 1975: 750).

Cummins argues that the view stated in the quote above “involves a subtle yet fundamental misunderstanding of evolutionary theory” (p. 750).

Before considering Cummins’s arguments let me emphasize that I do not want to defend the view rejected by Cummins. Talk of “sort of item” and “type of organism” is too vague¹⁴, and appeal to “survival of the species” is irrelevant. If this was the “subtle yet fundamental misunderstanding” Cummins talks about I would wholeheartedly agree with him. However, I do want to defend the view that the attribution of a causal role to an item sometimes helps to explain the evolution of that item and Cummins suggests that the misunderstanding is in this general idea, rather than in the wording he chooses. So, it seems that his arguments are also pertinent to my account. In that account the mechanism of natural selection provides the causal link between what an item did in certain organisms and its presence and character in the *lineage* of those organisms. Moreover, the link is provided not by the influence of the way in which a certain causal role is performed on the survival of the species (as Cummins suggests) but by the influence of the way in which a certain causal role is performed in a certain organism on the *relative fitness* of that *organism*.

Cummins’s argument centres around four claims: (1) the thesis that “the same” explanation might explain the presence of items that have quite different causal roles and survival values, (2) the thesis that the processes that lead to the incorporation of a certain item are insensitive to what that item does, (3) the thesis that the genetic plan of an organism is independent of the life chances of the organisms having that plan, and (4) the thesis that natural selection may destroy but not alter “genetic plans”. I shall discuss each of these claims and argue that they yield no argument against my account.

¹⁴It is not clear whether Cummins’s ‘sort of item’ consists of homologous items or of items with a similar structure. It is also not clear whether Cummins’s ‘type of organisms’ means ‘species’ or ‘the set of organisms that incorporate a certain item’ or ‘the set of organisms that incorporate a structural similar item’

Cummins's first claim

According to Cummins a clue to the mistake involved in the view that natural selection provides a link between “what something does in a certain type of organism and its presence in that type of organism” can be found in his example (a). In fresh water species the contractile vacuole has survival value because it enables the organism to get rid of the water that accumulates in the organism as the result of osmosis in organisms surrounded by a semi-permeable membrane. However, there are also marine species that have contractile vacuoles. These species do not have an excess-water problem but the reverse problem. Hence, the causal role and/or the survival value of contractile vacuoles are not the same in marine protozoans and in fresh-water species. However, according to Cummins, the explanation of the presence of contractile vacuoles in marine en fresh-water species is “almost certainly the same” (p 750). According to Cummins:

This fact reminds us that the processes actually responsible for the occurrence of contractile vacuoles in protozoans are totally insensitive to what that [item]¹⁵ does (Cummins 1975: 750).

This first argument is far from clear. Cummins does not tell us what it is for two explanations to be “the same”. He also does not state whether the explanations in question are concerned with the genesis of the contractile vacuole in the ontogeny (that is with the development of the item in the individual) or with the genesis of the contractile vacuole in the phylogeny (that is with the evolution of the item in the lineage). Moreover, he does not give bibliographical references to support his view.

It is easy to see that Cummins's first claim is irrelevant if it is concerned with explanations of the development of a contractile vacuole in the individual (whether it is true or not). Cummins might mean that the ontogeny of the contractile vacuole in marine protozoans is similar to the ontogeny of contractile vacuoles in protozoans that live in fresh-water. He might also mean that similar or homologous genes are involved in both ontogenies. Anyway, it is difficult to see how the claim that similar ontogenies may give rise to items with different causal roles and/or survival value would count against my view that the way in which a certain item performs its causal role may causally influence the character of that item in the lineage.

Let us, therefore, see what remains of Cummins's first claim if it is applied to the evolution of the item in the lineage. If we are to explain the evolution of contractile vacuoles the first thing to find out is whether or not contractile vacuoles in fresh water species are homologous to those in marine species. The second thing to find out is what the environmental conditions were that influenced the evolution of that/those item(s). Suppose that the contractile vacuoles evolved once (this might be what Cummins means if he says that the two explanations are the same) in,

¹⁵Cummins uses the term “structure” instead of “item”.

say, a population of protozoans living in fresh water. The current species that incorporate contractile vacuoles descend from this ancestral population. If this scenario is true the causal role and survival value of the contractile vacuole in the current marine species is probably different from the causal role and survival value of that item in the ancestral population. Perhaps, in marine protozoans contractile vacuoles have no causal role at all; just as the human veriform appendix they are simply the remainders of a bygone past. Perhaps, the survival value of contractile vacuole is negative in the sense that it would be easier to survive for protozoans living in marine environments if they had no contractile vacuoles. This reminds us to the well-known fact that the causal role that helps to explain the evolution of a certain item need not be the causal role that item currently performs. However, it does nothing to undermine my view that the way in which a certain item performs its causal role could influence the presence and character of that item in the lineage.

Cummins's second claim

According to Cummins the “fact” (p 750) that “the two explanations are almost certainly the same” (p. 150) should remind us that “the processes actually responsible for the occurrence of contractile vacuoles in protozoans are totally insensitive to what that [item] does” (which is Cummins’s second claim). This claim suffers from an ambiguity similar to the one in the first claim: it is not clear whether the phrase “the processes actually responsible for the contractile vacuoles in protozoans” refers to the genesis of vacuoles in the individual (that is to the ontogeny) or to the evolution of vacuoles in the lineage (that is to the phylogeny). It should be noted that the claim that the presence and structure of a certain item are insensitive to its causal role and survival value, applies to individuals at most. The processes responsible for the occurrence of a contractile vacuole in a certain protozoan individual are, perhaps, insensitive to what that vacuole does. But the processes at the population level that gave rise to the evolution of contractile vacuoles, were definitely not insensitive to what those items did. If those items were not advantageous to the individuals that had it, they probably would not have spread through the population.

Actually, even at the individual level it is in general not true that the processes responsible for the development of an item are totally insensitive to what that item does. There are many cases in which feedback mechanisms ensure that the character of an item is influenced by the manner in which that item performs its causal role. For example, it is well-known that the form of a bone is influenced by the forces operating on that bone and, hence by what that bone does. Another example is the influence of resistance on the ventricular walls: in mammals with a pathological high resistance in the pulmonary circuit, the right ventricular wall becomes thicker and resembles the left ventricle. What is true, of course, is that the causal role performed by a certain item in a certain organism and the survival value of that item for that organism do not

influence the genotype of that organism. This is probably what Cummins means (see my discussion of Cummins's third claim in the next section).

In sum, Cummins's claim that "the processes actually responsible for the occurrence of contractile vacuoles in protozoans are totally insensitive to what that [item] does" can be interpreted in two ways. It might be seen as a claim about the emergence of contractile vacuoles in the course of the evolution or it might be seen as a claim about the emergence of contractile vacuoles in the course of the ontogeny. In the first case the claim is false. In the second case it is irrelevant to my account (which concerns evolution rather than ontogeny)

Cummins's third claim

The third claim can be found in the next paragraph of Cummins's paper. At this point Cummins observes that whether an organism incorporates a certain "sort of item", depends on whether that sort of item is specified by the "genetic 'plan'" (p 751) of that organism, not on its causal role or survival value. According to him this is clearly shown in case of mutations. If the genetic plan of an organism is changed by mutation the organism will incorporate the modified item, regardless of its causal role or survival value.

The characteristics of organisms which determine their relative success or failure are determined by their genetic plan, and the characteristics of these plans are utterly independent of the relative success of organisms having them (Cummins 1975: 751).

Cummins's thesis that the genotype is independent of the relative success of the organisms having them is ambiguous, again.¹⁶ If he means that the genotype of a certain organism is independent of the relative success of that organism he is certainly right. However, from this it does not follow that the presence of a certain genotype in the lineage is independent of the success of the organisms that have that genotype.¹⁷ Natural selection cannot alter the genotype of

¹⁶In addition: the thesis that the characteristics of organisms that determine their relative fitness are determined by their genetic plan is, at best, too simple. One reason is that the relative fitness of an organism depends on the environment as well as on the constitution and behaviour of that organism. Another is that the constitution and behaviour of an organism in their turn depend on the environment as well as on the genetic constitution of that organism.

¹⁷A similar point is made by McClamrock (1993). McClamrock argues that

His [Cummins's] arguments all depend on an illegitimate move from the observation that the causal (including functional) effects of a particular *instance* of a structure can't include the presence of that very structure (a trivial observation about the rejection of backwards causation) to the general (and incorrect) claim that a structure's having a certain function can't be a part of a causal account of the structure's presence (McClamrock 1993: 257, where Clamrock uses the term "structure" I would use "item").

an individual organism, but it can alter the genetic make up of the lineage. If a mutation influences the relative fitness of an organism its share in the population will change accordingly. For example, if a certain mutation is advantageous its share in the population increases and it might eventually become prevalent. If the increase in fitness was the result of the way in which a certain item performs its causal role that causal role helps to explain why the current organisms of a certain lineage incorporate an item different from its original item in its ancestors.

Hence, one again Cummins brings up a thesis that might be interpreted in two ways. If it is interpreted in one way (the genotype of a certain individual is independent of the relative success of that individual) it is true but irrelevant to my account (which is about the change of the genetic makeup in the lineage). If it is interpreted in the second way (the genetic makeup of the lineage is independent of the relative success of the individuals instantiating the genepool) it is relevant but false.

Cummins's fourth claim

This leads us to Cummins's fourth claim. Cummins acknowledges that the influence of a mutation on the fitness of an organism might influence the genetic makeup of a population. However, he maintains that this should not be seen as an alteration of what he calls "the genetic plan".

If the alteration [introduced by a mutation in the "genetic plan"] is advantageous, the number of organisms inheriting that plan may increase, and, if it is disadvantageous, their number may decrease. But this has no effect whatever on the plan, and therefore no effect whatever on the occurrence of s' [the modified trait] in the organisms in question (Cummins 1975: 750).

This quote shows the now familiar ambiguity in the phrase "the organisms in question". As said before, Cummins is right that the success of a certain trait in a certain organism does not influence the genotype of that organism, but from this it does not follow that that success does not influence the occurrence of that genotype in the lineage.

In this part of his argument Cummins makes another error (in addition to the familiar juggling with the level of explanation). Cummins explains himself as follows:

We could [...] think of natural selection as reacting on the *set* of plans generated by mutation by weeding out the bad plans: natural selection cannot alter a plan, but it can trim the set (Cummins 1975: 751, emphasis his).

Clamrock points out that all that is needed to see how the function of past instantiations of a certain item can influence current presence is an account of a mechanism. This account is provided by the theory of natural selection.

In this quote Cummins takes the metaphor of natural selection too literary. Natural selection primarily consists in heritable differences in fitness between the organisms of a population. These differences influence allele frequencies¹⁸ in the genepool of that population. As a result of natural selection (that is as a result of individual heritable fitness differences) the relative frequency of a certain allele in the lineage may change:¹⁹ it may decrease or increase.²⁰ A decrease may eventually result in the disappearance of the allele in question. As a result of an increase a certain allele may eventually become prevalent in the lineage. It is, therefore, wrong to view natural selection solely as a destructive force, as Cummins seems to do: natural selection decreases the frequencies of some alleles and increases the frequencies of others.

It is also wrong to think of the genepool of a population as a *set* of genotypes (as Cummins seems to do), because in doing so one ignores the *frequencies* of the different alleles. Since, changes in relative frequencies of alleles in the population are the primary effect of natural selection, it is a serious error to ignore them.

Cummins's contention that natural selection merely weeds the plans generated by mutation is, therefore, fundamentally mistaken. Both mutation and natural selection directly influence the frequencies of alleles in the population. Changes in the frequencies of alleles in the genepool of the population may lead to changes in the structure or activity of an item or behaviour (in the lineage) and, hence, to the appearance of new kinds of items or behaviours (that is to items or behaviours whose structure and activity differs from their predecessors). Natural selection (that is heritable differences in fitness of different variants in a population) is one of the processes that may effect changes in the genepool. Hence, natural selection is one of the causal factors in the appearance of new structures and behaviours (in the course of evolution).²¹

Cummins's conclusion

Cummins concludes his discussion of appeals to functions in evolutionary explanations as follows:

Thus, we may be able to explain why a given plan is not a failure by appeal to the functions of the structures it specifies. [...] But this is not to explain why, e.g., contractile vacuoles occur in certain protozoan, it is to explain why the sort of protozoan incorporating contractile vacuoles occurs. Since we cannot

¹⁸Roughly speaking, alleles are different forms of the same gene.

¹⁹Natural selection may also result in stable polymorphism. I ignore this possibility in this paragraph, because I am concerned with explanations that appeal to directional selection, rather than with selection in general.

²⁰Of course, the decrease of a certain allele at a certain locus is complementary to the increase of another allele at the same locus.

²¹As the results of plant and animal breeding testify, even in the absence of new mutation selection may lead to considerable morphological, physiological and behavioural changes.

appeal to the relative success or failure of these organisms to explain why their genetic plan specifies contractile vacuoles, we cannot appeal to the relative success or failure of these organisms to explain why they incorporate contractile vacuoles (Cummins 1975: 751).

This passage shows Cummins caught in his own words. For, assume that “the sort of protozoan incorporating contractile vacuoles” refers to the subclass of protozoans that have contractile vacuoles, then to explain “why the sort of protozoan incorporating contractile vacuoles occurs” (why there are protozoic individuals that have contractile vacuoles) is the same as to explain “why contractile vacuoles occur in certain protozoan”. On the other hand assume that “the sort of protozoan incorporating contractile vacuoles” refers to the lineage(s) of protozoans having contractile vacuoles, then Cummins’s remark that to explain “why a given plan is not a failure by appeal to the functions of the structures it specifies” is to explain “why the sort of protozoan incorporating contractile vacuoles occurs” (why there evolved lineages of protozoans with contractile vacuoles) is false. On the contrary, it was one of Darwin’s important insights that to explain why organisms that are built in a certain way are viable, is not sufficient to explain why such organisms evolved.

5.5.3 Conclusion

I have argued that appeals to causal roles (function₂ attributions) in explanations of the evolution of the item or behaviour to which the causal role is attributed are acceptable on a causal account of explanation. The way in which a certain item or behaviour in a certain individual performs its causal role influences the fitness of that organism. Differences in the way in which homologous items or behaviours in different individuals in a population perform their causal role, may lead to differences in fitness between those organisms. These differences may lead to a subsequent change of the character of those items or behaviours in the lineage. Thus, natural selection provides the mechanism by which the causal role of an item or behaviour influences the presence and character of that item in the course of evolution.

Cummins seems to disagree with this view and I have considered his arguments. I have shown that these arguments suffer from a number of obscurities, such as vague talk of “sorts of items” and “types of organisms”, drivel about “survival of the species”, unsubstantiated and vague claims about two explanations being “almost certainly the same”, a recurrent failure to handle the distinction and the interaction between population level and individual level processes correctly, and a mistaken view of natural selection as trimming a set of genetic plans. A charitable reading of his argument may yield two tenable thesis, namely (1) the causal role that influenced the evolution of an item or behaviour might not be the causal role that item or behaviour currently has, and (2) the way in which a certain item or behaviour in a certain organism influences the survival of that organism does not influence the genotype of that organ-

ism. Both these theses are irrelevant. I, therefore, draw the conclusion that Cummins's argument gives us no reason to doubt the thesis that natural selection provides the mechanism by which the causal role of an item or behaviour influences the presence and character of that item or behaviour.

5.6 Discussion of some criticisms of Cummins's account

My main interest is in an account of functional explanation. In this section I deal with two issues in regard to Cummins's notion of function. First, I discuss Amundson & Lauder's (1994) defence of Cummins's account of function. Second, I discuss the idea that Cummins's analysis provides us with a necessary but not with a sufficient condition to attribute a causal role to an item.

5.6.1 Amundson & Lauder (1994)

In a paper titled "Function without purpose" (1994) the philosopher Ron Amundson and the morphologist George Lauder co-operate in a defence of Cummins's account of function. More specifically, they argue (i) that Cummins's account of function closely matches the concepts of function used in functional morphology, (ii) that the philosophical criticisms of Cummins's concept of function put forward by Millikan (1989b), Neander (1991a) and Sober (1993) do not hold water, (iii) that functions as causal roles can not be eliminated from functional biology in favour of functions as selected effects, and (iv) that functions in Cummins's sense are essential to certain important research programs in evolutionary biology.

Unfortunately Amundson & Lauder fail to distinguish between function₁ (activity) and function₂ (causal role). In this section I discuss their argument ad (i) and ad (iv). Ad (i) I argue that Amundson and Lauder are right that Cummins's account of function closely matches many uses of the term 'function' in functional morphology (see section 5.3) but they do not show that. Instead, they point out that the notion of function as activity (function₁) is important in functional morphology. Ad (iv) I argue that Amundson and Lauder point to important uses of both the notions of function as activity (function₁) and function as causal role (function₂) in evolutionary biology. Strange enough they do not mention the appeal to causal roles in selection explanations (see section 5.5 above). I return to their argument ad (ii) the next section (5.6.2) and to their argument ad. (iii) in section 7.3.1.

Amundson & Lauder's main argument that Cummins's account matches the concepts of function used in functional morphology rests on Walter Bock and Gerd von Wahlert's (1965) account of the vocabulary of functional morphology.²² Amundson & Lauder point out that

²² I have discussed Bock and Von Wahlert's paper in section 3.1.

according to Bock & Von Wahlert's the form and the function are both at the "methodological base level" (p. 449) of morphological research: form and function are observable qualities which are not inferred from an evolutionary narrative, but, on the contrary, serve as the starting point to address questions about survival value and evolutionary history. Without such a base research in survival value and evolutionary history could not get off the ground. According to Amundson & Lauder Cummins's concept of function is similar to that of Bock & Von Wahlert's because both define 'function' without invoking evolutionary history or survival. And, indeed, Bock & Von Wahlert and Cummins agree on this point. However, there is an important difference between these accounts. Amundson & Lauder rightly point out that according to Bock & Von Wahlert the functions of an item are observable qualities and function attributions state what an item does. However, in Cummins's account functions are not observable properties, but capacities singled out by their role in capacity explanations, that is by the way in which a certain item is used.²³ Amundson and Lauder are aware of this difference where they observe that Bock & Von Wahlert's account is more radical than Cummins's.

In one way, Bock and von Wahlert's concept of function is even more radical than Cummins's. Cummins assigns functions only to those capacities of components which are actually invoked in a [capacity explanation],²⁴ those which are believed to contribute to a higher level capacity to be analyzed. Bock and von Wahlert include *all possible* capacities (causal powers) of the [item],²⁵ given its current form. (Amundson & Lauder 1994: 450).

However, they set this issue aside with the following words:

Apart from the issue of unutilized functions, Cummins's concept of function matches the anatomists' (Amundson & Lauder 1994: 450).

Actually, this issue is crucial both from the point of view of Bock & Von Wahlert and from that of Cummins. As I discussed in section 3.1, one of the central issues in Bock & Von Wahlert's account is the distinction between "function" and "biological role", words they use to refer to the distinction between what an item does and what it is used for. The distinction is crucial from Cummins's point of view because according to Cummins function attributions owe their meaning to capacity explanations. There would be no reason to call an activity of an item a function if that activity had no role in a capacity explanation. Hence, Amundson & Lauder do not show what they purport to show, namely that functions in Cummins's sense play an important role in functional biology. My examples in section 5.3 show that they are nevertheless

²³In other words: a function in Cummins's sense is not a property but a position in a system that performs a certain task.

²⁴Amundson & Lauder say "functional explanation".

²⁵Amundson & Lauder, following Bock and Von Wahlert, say "feature"

right. What they do show is that the notion of function as potential activity (function₁) plays an important role in functional biology. This point is well worth making.

In section 7 of their paper, Amundson & Lauder argue that Cummins's concept of function is essential to certain important research programs in evolutionary morphology. These research programs are not concerned with selection. Amundson & Lauder list three kinds of research programs in which Cummins's concept of function is essential: (i) attempts to reconstruct phylogenetic trees, (ii) explanations that show how certain important evolutionary changes were made possible by so-called key transformations, (iii) explanations of why certain evolutionary pathways were not taken by appeal to the constraints put on evolution by the causal role of the items involved. The first kind of research program is concerned with the reconstruction of the evolutionary history, rather than with its explanation. Amundson & Lauder point out that functional characteristics can be used to reconstruct phylogenetic trees in exactly the same way as morphological characteristics. The two other kinds of research programs seek to explain evolutionary history. An example of a key transformation is the duplication or repetition of parts of the body (i.e. segmentation). Segmentation appears to be a vehicle for the generation of evolutionary diversity because it facilitates independent specialization of the components (Lauder & Liem 1989). Another example (not mentioned by Amundson & Lauder) is the development of a circulatory system. This transformation facilitates the development of larger organisms (Krogh 1941). In regard to the third kind of research program, Amundson & Lauder point out that in generally many items work together to perform a certain activity, for example, jaw movement. In such case minor changes in form might have a deleterious effect on the performance of that role.

Amundson & Lauder's examples of the second and third kind of research programs show that the study of functional interdependencies plays an important role in explanations in evolutionary biology that do not centre around selection. This underscores my thesis that the central notion of function in functional biology is the notion of function as causal role. Amundson & Lauder give the impression that the concept of function as selected effect does play an important role in selection explanations in ethology. I contend that even in selection explanations the relevant concept of function is function as causal role (see especially section 5.5 and 7.2).

In sum: Amundson & Lauder give interesting examples of the use of the concept of function as activity (function₁) in both functional biology and evolutionary biology, as well as of the importance of the concept of function as causal role (function₂) and of the concept of functional interdependencies in explanations in evolutionary biology.

5.6.2 Is Cummins's analysis in need of supplementation?

In section 5.3.2 I argued that Cummins's idea that function attributions are singled out by their role in capacity explanations applies to function₂ attributions (attributions of causal roles).

In the philosophical literature surface a number of counterexamples that suggest that not all capacities singled out by a capacity explanation should count as functions and, hence, that Cummins's analysis should be supplemented with another condition. Candidates for such an additional condition are the condition that the exercise of the causal role has positive survival value and the condition that the exercise of the causal role has contributed to the evolution of the item to which the function is attributed. The counterexamples fall into two kinds. The first kind of examples consists of examples in which Cummins's analysis would single out a certain capacity of a part of an organism as a function, whereas one normally would not call the exercise of that capacity a function of that part. The second kind consists of examples in which Cummins's analysis would allow us to attribute functions to parts of systems of which one normally does not attribute functions to their parts.

A counterexample of the first kind is brought up by Neander (1991a: 181). Neander contends that the pressure exercised by a tumour on a certain artery in the brain helps to explain an organism's complexly achieved capacity to die of cancer. Yet, this causal role does not count as its function. According to Neander tumours don't have functions at all. Sober (1993: 86) advances a similar counterexample. He objects that on Cummins's account one of the functions of the heart is to weigh what it does because this contributes to the organism's capacity to tip the scales on a certain number of pounds.

Counterexamples of the second kind are furnished by Millikan and Neander. Millikan (1989b: 294) states that on Cummins's account in the context of the water-cycle system "it is arguably the function of clouds to make rain with which to fill the streams and rivers", for this helps to explain "how moisture is maintained in the soil so that vegetation can grow". According to Neander (1991a: 181) Cummins's analysis bestows functions to plate movements, for they help to explain earthquakes.

None of Cummins's critics document their examples, nor does any of them details the capacity explanation that would justify the counterintuitive function attribution in question.

As Amundson and Lauder (1994: 452) have pointed out some of these purported counterexamples must be rejected outright: for on Cummins's criteria (see section 5.2.2) there is no reason to apply the strategy of functional analysis to the systems in question. The explaining capacities would not be simpler than and/or would not differ in kind from the capacities to be explained and the organization of the explaining capacities would not be very complex. Amundson and Lauder take Neander's contention that Cummins's account allows us to attribute functions to plate movements as their main target. They answer that such attributions are not allowed because plate movements are not simpler than earthquakes and because although the geological structures that bring about earthquakes are complex, the structure of the capacities that would explain the earthquake would be simple.

Sober's alleged counterexample ("a function of the heart is to weigh what it does") is another clear case that should be rejected on the ground that there is no reason to suppose that the relevant capacity (i.e. the capacity of the heart to weigh what it does) is singled out by a suitable capacity explanation. An explanation of the capacity of a certain organism to tip the scales on a certain number of pounds would start with the observation that scales measure weight. So to explain the capacity of a certain organism to tip the scales on a certain number of pounds one should explain the weight of that organism. One may explain the weight of an organism in terms of the weights of its parts and the fact that weights are additive. This would be an analytical explanation but not a capacity explanation. The analysis on which the explanation is based is componential rather than functional.²⁶ After all, the property of the parts that helps to explain the weight of the organism is the same for all parts: that part's weight. On Cummins's account a mere componential analysis does not justify the attribution of functions to the parts. Therefore, the explanation of the capacity of an organism to tip the scales on a certain number of pounds by appeal to the weight of its heart does not justify to attribute to the heart the function to weigh what it does.

Millikan's purported counterexample ("it is the function of clouds to make rain with which to fill the streams and rivers") is worthless as it stands. According to Millikan, the explanation that justifies the function attribution explains "how moisture is maintained in the soil so that vegetation can grow". It is not at all clear what capacity the purported capacity explanation would explain (is 'so that' part of the description of a capacity?) and in which system that capacity is instantiated, still less how that explanation would proceed (what exactly are the explaining parts and what the explaining capacities?). Millikan's words suggest that the capacity to be explained Millikan has in mind is something like the capacity of the soil to supply the vegetation it has with enough water. But in that case it is not clear how such an explanation can attribute functions to clouds, which are not part of the soil. This consideration suggests that the capacity to be explained is to be attributed to the atmosphere. It is not difficult to imagine a capacity explanation of the capacity of the atmosphere to sustain life on land that appeals to the capacity of clouds to produce rain. Such an explanation would analyse the ability to sustain life on land into a number of subcapacities such as the ability to maintain a certain temperature, the ability to maintain a water cycle, the ability to shed ultra violet radiation and so on. The ability of the atmosphere to maintain a water cycle in its turn is analysed into the ability of clouds to produce rain, of streams to transport water to the sea, of soil to accumulate ground water, of water surfaces to evaporate water, of organisms to transpire and so on. If someone comes up with such

²⁶The capacity of the scales to measure weight can be suitably explained by means of a capacity explanation. However, such an explanation would bestow functions to the parts of the scales, but not to the weights it measures.

an explanation no one would have hesitations to speak of functions. Indeed, in papers discussing the earth's economy it is quite common to talk of the functions of e.g. soil, sea and clouds in e.g. the water cycle (see for example Keeton & Gould (1993: 1154-1169) and Rimmer (1998). It seems that Millikan's counterexample turns into an example if the relevant capacity explanation is properly worked out.

Neander's example of cancer tumours is the most interesting one. However, cancer is a difficult subject and this book seems not the proper place to discuss it. As long as Neander herself has not substantiated her claim I see no reason to accept it.

I draw the conclusion that none of the criticisms mentioned discussed here gives us reason to doubt Cummins's view that attributions of causal roles are singled out by their role in capacity explanations.

5.7 Conclusion

Cummins distinguishes two kinds of explanation: explanation by subsumption and analytical explanations (see section 5.2.2 above). Explanations by subsumption are used to explain changes as the result of preceding changes. Analytical explanations are used to explain the properties of a certain system in terms of the properties of the components of that system and their mode of organization. According to Cummins, functional explanations are a subspecies of the category of analytical explanations. Functional explanations explain a dispositional property (capacity) of a complex system. In addition to the componential analysis, they provide a functional analysis of that capacity: they analyze the capacity to be explained into a series of subcapacities (instantiated in the components) that add up to the capacity to be explained.

Cummins's account enables us to understand the structure and the explanatory force of capacity explanations. Such explanations show us how the ability of a certain item or behaviour to perform a certain complex task results from the capacity of the parts of that item or behaviour to perform a series of more simple tasks which add up to the complex ability. This procedure is repeated until a level is reached at which the simple capacities might be explained by the physical and chemical of the parts and the way in which they are organized. Such explanations are explanatory because they show us how a complex capacity is brought about by the co-ordinated activity of simple building blocks.

Attributions of causal role owe their scientific meaning to this strategy of explanation. They tell us what tasks a certain item or behaviour has. In that way they situate an item or behavioural pattern in the organism's organization.

Cummins restricts his account of 'function' to the use of attributions of causal role in capacity explanations. I show that attributions of causal role have other uses too. If the place of an item or behaviour in the animal's organization is known this knowledge can be used to explain

the presence and character of the item to which the function is attributed in two ways, namely in design explanations and in selection explanations.

Design explanations fall outside the scope of Cummins's categories. They explain the properties of an item or the behaviour of an organism. They do so by relating those properties to other properties of the organism in question and to the state of the environment in which it lives, not by analyzing that item into components. This means that Cummins's account does not help us to understand design explanations.

Selection explanations do explain changes and the appeal to causal roles in this kind of explanations is explanatory on a causal account: selection for a more efficient performance is one of the processes that may explain how a certain kind of items is brought about in the course of evolution.

