Chapter 1: Introduction

Philosophers of science with an interest in biology have always been intrigued by the fact that biologists often explain phenomena by appealing to functions rather than to causes. Biologists are perceived as people who explain why certain organisms have certain parts or organs or why they perform certain activities by citing the functions of those items or activities. It is, for example, generally thought, among philosophers of science, that biologists explain the presence of hearts in many organisms by appeal to the heart's function to propagate the blood. Such explanations are called 'functional explanations'. The question how it can be explanatory to cite functions has become the classical philosophical issue in regard to biological explanation.

A related issue is the meaning of the notion of 'biological function'. Analyses of this notion have served quite different philosophical agendas. In the last decade philosophical analyses of function have become increasingly important in the philosophy of language and the philosophy of mind. The main impulse for this outburst was Ruth Millikan's *Language, Thought and Other Biological Categories* (1984). In this highly original and important work Millikan employs a certain theory of function (the so-called 'etiological theory') to solve many problems in the philosophy of mind and language. My agenda is different. I seek to understand the actual practice of explanation in functional biology.

Functional biology is that part of biology which is concerned with the structure, activity and behaviour of individual organisms. Functional biologists investigate how the different organisms that populate our planet are built, how they behave and how they work. Of course, functional biologists are not only interested in *describing* the parts, processes and behaviours of the organisms they study, they also seek to *explain* the way in which those organisms are built, the way in which those organisms behave, and the way in which those organisms work. It is those explanations in which I am interested.

The philosophical study of explanation is often viewed as an exercise in conceptual or linguistic analysis. On this view, the philosopher's main task is to provide a definition of the notion 'explanation' that applies to all or most of the examples that intuitively count as examples of good explanations. A theory of explanation should be criticized by providing counterexamples showing that certain explanations that are intuitively good explanations are not explanatory according to the criticized theory or that the theory does not exclude certain pieces of reasoning which are intuitively not explanatory. In regard to functional explanations the main question is whether and how appeals to function are explanatory. This question is to be answered by discussing how such appeals relate to one's favourite definition of explanation.

I am interested in a more substantial issue than the one above, namely the question what is achieved by a functional explanation (what do the pieces of reasoning which biologists call ‘functional explanation’ add to our knowledge?). I take the question ‘how can it be explanatory to appeal to a function?’ as meaning ‘what do biologists learn from accounts that appeal to functions on top of the descriptions employed in those accounts?’, ‘why is it useful to attempt an account in functional terms?’. That is, I am not interested in the question whether or not so-called ‘functional explanations’ are really explanations but in the question what such pieces of reasoning add to our knowledge.

In this introductory chapter I shall discuss how the problem of functional explanation entered contemporary philosophy of science in the context of the deductive nomological model of scientific explanation and what the current approaches to this problem are (section 1), summarize the main issues often discussed in relation to functions and functional explanations (section 2), and outline my own views on this subject (section 3).

1.1 The problem of functional explanation

The problem of function has entered contemporary philosophy of science in the context of the deductive-nomological model of scientific explanation (Hempel & Oppenheim 1948). According to this well-known model explanations deduce a statement describing the phenomenon to be explained from a combination of statements expressing general laws and statements describing initial conditions. This model was thought to capture the principal characteristics of explanation in the physical sciences. The deductive-nomological style of explanation was also found in biology. An example is the explanation of a certain regularity in the progeny of hybrid peas obtained by crossing inbred peas with round seeds with inbred peas with wrinkled seeds (the ratio of plants with round peas to plants with wrinkled peas in this so-called F_2 generation is approximately 3 : 1). This regularity is explained by deducing it from certain general principles of the Mendelian theory of heredity together with assumptions about the genetic constitution of the parent peas (Nagel 1961: 18). However, the proponents of the deductive-nomological model also noted that biologists frequently employ other “types” or “methods” of explanation that appear to be very different from the types or methods of explanation used in the physical sciences, at least at first sight. One such type or method was called “functional explanation” (Nagel 1961), “teleological explanation” (Nagel 1961, Pap 1962, Canfield 1964), or “functional analysis” (Hempel 1959). (I will use the term ‘functional explanation’.) The explanation of the heart or the beating of the heart by appeal to its function to circulate the blood has become the standard example of such a functional explanation.

According to the proponents of the deductive-nomological model, functional explanations purport to explain items or activities in terms of the functions that item or activity has for the organisms which have that item or perform that activity. They are often characterized by the occurrence of teleological expressions such as ‘the function of’, ‘the role of’, ‘serves as’, ‘in order to', 'for the sake of', 'for the purpose of'. Functional explanations as they are used in biology have neither anthropomorphic nor vitalistic implications. That is, when biologists state that a certain item or activity has a function they do not imply that those items or activities result from design by an intellectual being (anthropomorphism) or from the activity of extra-physical, vital forces (vitalism). Yet, functional explanations differ considerably from explanations in the physical sciences. As Nagel put it in his *Structure of Science*:

> It would surely be an oddity on the part of a modern physicist were he to declare, for example, that atoms have outer shells of electrons in order to make chemical unions between themselves and other atoms possible (Nagel 1961: 401)

The absence of functional explanation in the physical sciences and its presence in biological sciences posed a two-edged challenge to the proponents of the deductive-nomological model in post-war philosophy of science. On the one hand they had to face the apparent consequence of their theory, namely that teleological language in biology was a sign of its immaturity. In the physical sciences teleology has been banned since the seventeenth century. Because of the prestige of physical sciences and because of the tendency of philosophers to regard physics as the paradigm of science many philosophers as well as scientists tended to view explanations that use teleological expressions as obscurant and suspicious. However, philosophers of science like Carl Hempel and Ernest Nagel, were very much aware of the success of the functional mode of explanation in biology and in the social sciences. This made it difficult for them to dismiss functional explanation simply as immature.

On the other hand they had to face those who argued that the differences between the mode of explanation in the physical sciences and the mode of explanation in the life sciences reflected a difference in the nature of the phenomena studied. The modes of explanation appropriate in physics, it was urged, are not appropriate in biology. This idea conflicted with the idea of the unity of science embraced by the philosophers of science of that time.

As a result philosophers of science with an interest in biology saw a two-fold task for themselves. Their first task is to show that the use of teleological language in biology is innocuous because teleological statements can be translated without any loss of content into statements that do not contain teleological expressions. Their second task is to account for the explanatory use of teleological expressions in terms of the deductive-nomological model.

The main obstacle to this program (at least as it was initially perceived) is the so-called 'problem of functional equivalents', that is the existence of different ways to perform a certain function (think of alternate devices such as artificial hearts that might circulate the blood). The classical analyses in this context are those of Hempel (1959) and Nagel (1961, 1977). Both Hempel and Nagel employed an inferential conception of explanation. On this view of explanation, explanations work by showing that the phenomenon to be explained was to be expected in virtue of the explaining facts. Hempel and Nagel differed on the issue whether or not function attributions allow one to infer the presence of the item to which the function is attributed. According to Nagel, given a certain form of organization, a certain item is necessary to perform a certain function (that is there are no real functional equivalents). Therefore, given the function (and the form of organization) one may infer the presence of the functional item and, consequently, functional explanations are really explanatory. According to Hempel on the other hand the existence of functional equivalents shows that functional traits are not really necessary (there are real functional equivalents). An organism must perform certain functions, but since there are different ways to perform those functions, the functional item itself is not necessary. Attributions of functions are explanatory only in the limited sense that they allow one to infer the presence of one of the several items of an ill-defined class of items capable of performing a certain function. The main scientific value of the pieces of reasoning which are often called ‘functional explanation’ is heuristic: they lead to the discovery of new phenomena.

Most recent accounts of function and functional explanation have abandoned the idea that functional explanations explain by deducing a sentence stating that organisms of a certain taxon (must) possess a certain item or perform a certain activity, from a combination of sentences stating initial conditions and sentences stating general laws. It was probably John Canfield (1964) who first distinguished functional explanations from explanations that fit the covering law model. According to Canfield, functional explanations do not subsume the presence of an item under a general law; instead they specify what that item does that is useful to the organisms that have it.

> The latter [explanations fitting the covering law model] attempt to *account* for something’s being present, or having occurred, by subsuming it under a general law, and by citing appropriate ‘antecedent conditions’. [Functional explanations][1] in biology [...] do no such thing. They merely state what the thing in question does that is useful to the organisms that have it (Canfield 1964: 295).

It is important to distinguish two issues in the rejection of the deductive nomological model. One concerns the structure of functional explanation, the other their nature.

In regard to the first issue many recent writers appear to agree with Canfield that functional explanations consists of a single function attribution in answer to a question of the form ‘why do organisms of taxon *t* have item/trait *i*?’. For example, Millikan states:

> if you want to know why current species members have T the answer is, very simply, because T has the function F (Millikan 1989a: 174).

[1] Canfield uses the term 'teleological explanations'.

On the issue of the nature of functional explanations both Pap (1962) and Nagel (1977) are of the opinion that functional explanations are not of a causal nature. Pap emphasizes that

> although [functional explanations][2] have the same logical form as explanations in terms of efficient causes, it would be highly misleading to call them "causal." (Pap 1962: 361)

Nagel discusses an example of a functional explanation which has roughly the following form:

> (1) This plant performs photosynthesis.
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> (2) Chlorophyll is necessary for plants to perform photosynthesis
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> (3) Hence, this plant contains chlorophyll.

This explanation conforms to the deductive-nomological model. The second premise is lawlike, the first one states initial conditions. However,

> the performance of photosynthesis is not an *antecedent* condition for the occurrence of the chlorophyll, and so the premise is not a causal law. Accordingly, if the example is representative of [functional explanations][3], such explanations are *not* causal—they do not account causally for the presence of the item to which a function is ascribed (Nagel 1977: 300)

He adds to this that

> inquiries into effects or consequences are as legitimate as inquiries into causes or antecedent conditions (Nagel 1977: 301)

On the inferential conception of explanation, endorsed by the proponents of the deductive-nomological model, explanations need not be causal to be explanatory, provided that they make it plausible that one should expect the presence of the phenomenon to be explained. The causal conception rejects this view of explanation in favour of the idea that an explanation should show us how the phenomenon to be explained is brought about. Robert Cummins (1975) applies this idea to functional explanations and draws the conclusion that it is impossible to explain the presence of an item by appeal to its function:

> To attempt to explain the heart's presence in vertebrates by appealing to its function in vertebrates is to attempt to explain the occurrence of hearts in vertebrates by appealing to factors that are causally irrelevant to its presence in vertebrates. 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 of its shadow would fail to explain why the building is there and has the height it does (Cummins 1975: 745/6)

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[2]Pap uses the term 'teleological explanations'.

[3]Nagel, at this point, uses the expression 'explanations of function ascriptions'

Cummins, for that reason, rejects the assumption that “the point of functional characterization is to explain the presence of the item (organ, mechanism, process or whatever) that is functionally characterized” (p. 741). According to Cummins what we can explain and what we do explain by appeal to functions is the activity or the capacity of a system of which the item to which the function is attributed is a part. In his view, functional explanations explain how a system is able to perform a complex task by pointing to the capacity of the parts of that system to perform a series of subtasks that add up to the original capacity. For example, a functional explanation of an organism’s capacity to circulate oxygen would explain this capacity as the result of the combination of the capacity of the blood to carry the oxygen, the heart to pump the blood around, and the blood vessels to direct the blood from the lungs or gills (where the blood is aerated) to the organs (where the oxygen is consumed) and back. The attribution of the function of propagating the blood to the heart serves to explain the capacity to circulate the blood but it does not serve to explain the presence of the heart.

The distinction between the inferential and the causal conception of explanation has been driven home by Wesley Salmon in his “Why Ask, ‘Why?’?” (1978). Salmon’s *Scientific Explanation and the Causal Structure of the World* (1984) is the classical statement of a causal theory of explanation. As Salmon (1984: 15-20, 1989: 119-121) puts it the inferential conception is oriented towards the notion of nomic expectability. On this view an explanation is an argument that reveals that the phenomenon to be explained was to be expected in virtue of the laws of nature and the conditions in which that phenomenon occurred. The causal conception, on the other hand, focuses on how phenomena fit into the causal structure of the world. On this view, explanations reveal the mechanisms that produce the phenomenon (transition, state or property) to be explained.

In the causal view of explanation the problem how it can be explanatory to cite the function of an item takes a form different from the one it had on the inferential theory. Whereas on the inferential conception the main problem of functional explanation is the problem of functional equivalents, on the causal conception the main problem of functional explanation is the problem that function attributions apparently refer to effects rather than to causes. This problem has been formulated most clearly by Karen Neander

> The general prima facie problem with [functional explanations][4] is often said to be that they are ‘forward-looking’. [Functional explanations] explain the means by the ends [...], and so the explanans refers to

[4]Where I have put "functional explanations" the author uses the expression "teleological explanations", this category includes two kinds: intentional explanations and functional explanations. She adds that the solution of the problem is transparent in cases where an intentional agent is involved (that is in the cases of intentional explanations and of functional explanations that appeal to the functions of artefacts). The more intransigent problem arises where there is no intentional agent involved, as with biological function.

> something that is an effect of the explanandum, something that is forward in time relative to the thing explained. [...] Indeed, because [functional explanations] seem to refer to effects rather than prior causes, it looks at first sight as though backward causation is invoked. [...] The prima facie problem gets worse, if that is possible, because many [...] functional effects are never realized (Neander 1991b: 455/6).

Sandra Mitchell makes a similar point:

> The classic[5] philosophical puzzle regarding functions is how could appeal to a consequence of the presence of a trait explain why the trait is in fact present, since the functional consequence is temporally later and so cannot be causal in a straightforward sense (Mitchell 1993: 249)

As I mentioned above, Cummins tries to solve this problem by maintaining that functional explanations are not intended to explain the presence of the item to which the function is attributed. According to him functional explanations explain a capacity of a system of which the item to which a function is attributed is a part. Cummins emphasizes the difference between explanations that explain changes in the state of a certain system (transition explanations) and explanations that explain the properties of a certain system (property explanations). According to him the covering law model applies to transition explanations but not to property explanations. Functional explanations are a special kind of property explanations, in which the property to be explained is a complex capacity and the explanation proceeds by analyzing that complex capacity into a number of less complex capacities. Cummins tends to restrict the term ‘causal explanations’ to explanations that explain transitions. However, functional explanations in Cummins’s sense are causal explanations in the sense in which Salmon uses the term ‘causal explanation’: they reveal the processes and mechanisms that bring about a certain phenomenon (in the case of functional explanations the phenomenon to be explained is a capacity). I shall use the term ‘causal explanation’ in Salmon’s sense. This means that, on my account, functional explanations in Cummins’s sense are of a causal nature.

Whereas Cummins solves the problem of functional explanation on the causal account by denying that function attributions are used to explain the presence of the item to which the function is attributed, most other authors have attempted to reconcile the idea that functional explanations explain the presence of the item to which the function is attributed with the causal account. One of the first attempts to formulate such a theory of function is the theory of Larry Wright (1973, 1976). According to Wright:

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[5] Apparently, Mitchell is herself not aware that this wording of the problem of functional explanation is peculiar to the causal conception of explanation and she assumes, mistakenly, that Hempel resolved this problem by arguing that functional explanations do not meet the conditions of legitimate explanations

> The treatments we have so far considered have overlooked, ignored, or at any rate failed to make, one important observation: that [function attributions][6] are—intrinsically, if you will—explanatory. Merely saying of something, *X*, that it has a certain function, is to offer an important kind of explanation of *X* (Wright 1973: 154),

He adds to this that the explanatory force of function attributions is not merely that they state "what the functional thing is good for" (as Canfield has argued). Function attributions are "explanatory in a rather strong sense" (p. 155): they explain "how the thing with the function got there" (p. 156). Hence, they are explanatory on a causal view of explanation.

Current theories of functions and functional explanations come in roughly three kinds.[7] According to the *etiological theory* (for example Millikan 1984: 17-49, Millikan 1989b, Mitchell 1989, Brandon 1990: 184-189, Neander 1991a,b, Millikan 1993a)[8] function attributions specify the effects for which a certain trait was selected in the past. These effects are the functions of that trait (many proponents of an etiological account speak of "proper functions" where I would use "functions"). For example, hearts are said to have the (proper) function of

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[6]Wright uses the words "functional ascriptions"

[7] See Amundson and Lauder (1994). Achinstein (1977) and, in his trail, Reznek (1987) distinguish three kinds of explications of (F) "The function of X (in Y) is Z": (1) (the "good-consequences doctrine" or "evaluative theory"): X does Z and X's doing Z contributes to the good of Y (for example Hempel 1959, Canfield 1964, Sorabji 1964, Lehman 1965a, Ruse 1973, Hull 1974, Woodfield 1976); some accounts in this class identify specific goods (e.g. Hempel and Ruse who define the good as "adequate working order" respectively "survival and reproduction") others (e.g. Sorabji and Woodfield) leave this open; (2) (the "goal doctrine" or "teleological theory"): X does Z and X's doing Z contributes to some goal of Y (for example Nagel 1961, Boorse 1976); and (3) (the "explanation doctrine" or "etiological theory"): X does Z and X doing Z makes a causal contribution to X's occurrence in Y (for example Ayala 1970, Wright 1973, Bennett 1976, Levin 1976, Wright 1976). Apart from some differences on who belongs to which approach, their classification differs from mine on three points: (1) Achinstein and Reznek fail to take Cummins's approach into account; (2) Achinstein's and Reznek's descriptions of the etiological account are ambiguous about the level of explanation (does Y refer to an individual or to a population?); (3) I do not distinguish a separate "goal-doctrine". Depending on what kind of goals are involved I treat the different goal-doctrines as variants of either the causal role theory or the survival value approach.

[8]Forerunners of the etiological theory as it is defined here are Ayala (Ayala 1970) and Wright (1973, 1976) according to whom functions are determined partly, but not wholly by a selection history. Wimsatt's (1972) account, also, has certain elements of an etiological theory but its main tenure is that of a survival value account. A related approach is that of Reznek (1987: 117) according to whom the functions of the trait are the effects that make a causal contribution to the continued presence of the trait in the population via the mechanism of natural selection.

propagating the blood, if and only if propagating the blood is what hearts did that caused them to be favoured by past natural selection. The etiological theory of function attributions fits nicely with the causal conception of explanations. On the etiological view, function attributions are intrinsically explanatory in that they specify the factors that account for a trait's presence in a certain population. They specify the effects of a certain trait that were causally effective in the evolution of that trait. Among evolutionary biologists and among naturalistic philosophers of science the etiological view "is fast becoming the consensus" (Neander 1991a: 168).

A second approach identifies functions with effects that currently make a causal contribution to the survival and reproduction of an individual organism (for example Canfield 1964, Wimsatt 1972, Ruse 1973, Bigelow & Pargetter 1987, Horan 1989). On this view the function of the heart is said to propagate the blood because that is how hearts currently contribute to the survival and reproduction of the organisms that have hearts. I shall call this approach the *survival value approach* to functions. The proponents of the survival value approach differ in the way in which they account for the explanatory force of function attributions. Canfield denies that function attributions explain the presence of the item to which the function is attributed, function attributions merely show us how a certain item is useful. Ruse and Horan employ the inferential theory; they attempt to account for functional explanations as deductive arguments that allow one to infer the presence of the item to which the function is attributed. Wimsatt, too, employs the inferential theory, but according to him functional explanations have a statistical rather than a deductive character. Bigelow & Pargetter attempt to account for functional explanations in terms of the causal theory by emphasizing that a function is a disposition to have a certain effect, rather than that effect itself.

On the third approach, function attributions describe the role of a certain part or activity in maintaining a certain capacity of a system to which it belongs. On this account to say that hearts have 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. This approach is best known from Cummins's "functional analysis" (1975). The idea is also present in embryonic form in Nagel's (1961, 1977) work:

> [Functional explanations][9] make evident one role some item plays in a given system (Nagel 1977: 300).

Following Neander (1991a: 181) and Amundson & Lauder (1994), I shall call this approach the *causal role theory* of function. On the causal role theory, function attributions serve to explain a complex capacity of a system of which the item to which the function is attributed is a part. Such an account is explanatory on a causal theory of explanation.

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[9] At this point Nagel uses the expression "explanations of function ascriptions".

The inferential theory of explanation and the causal theory of explanation offer two different answers to the question what is learned from explanations. On the inferential theory of explanation explanations tell us that the phenomenon to be explained is to be expected in view of the laws of nature and the conditions applying to that phenomenon. On the causal theory of explanation explanations reveal the mechanisms that produce the transition, state or property to be explained. The different philosophical theories of functional explanation explain whether, why and how appeals to function are explanatory (or not) on some view of explanation. Philosophers who think that appeals to function are not explanatory on their favourite theory of explanation tend to think of the scientific value of such appeals as heuristic rather than explanatory; by this they mean that the scientific value of this kind of reasoning is to be located exclusively in the process of the discovery of new facts, rather than in the explanation of the discovered facts.[10]

As I said in the introduction to this chapter, I aim to understand the practice of explanation in functional biology. I seek to answer questions like 'why is it useful to attribute functions to the parts and behaviours of organisms?' and 'what do biologists learn from the pieces of reasoning in which they appeal to functions?'. This means that the problem of functional explanation in which I am interested is different from the problem of functional explanation on the inferential theory and also from the problem of explanation on the causal theory. My starting point is not a philosophical theory of explanation but the practice of reasoning in functional biology. I aim to understand what the different kinds of reasoning that constitute this practice contribute to the process of enquiry. I focus on reasoning concerning functions. I distinguish several kinds of reasoning concerning functions. My main contention is that functional biologists propose and defend (among other things) accounts which do not show how a certain transition, state or property is brought about, nor do they show that a certain phenomenon was to be expected in the light of the facts mentioned in the explanandum. Yet, they add something to our knowledge in addition to the new discoveries to which such reasoning may lead.[11] I shall call this kind of reasoning 'design explanation'. An example of a design explanation would be an explanation of the hollow character of the heart by showing that this character is needed to enable the heart to pump blood (if the heart were solid or spongy it would not be able to pump blood). Design explanations are overlooked in contemporary philosophy of science. The problem of functional explanation as I see it, is the problem what design explanations add to our knowledge (in addition to the facts they describe).

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[10] A recent proponent of the view that functional or teleological language is merely heuristic is Schaffner (1993: ch. 8).

[11] See Resnik (1995) for an account of the role of functional language in biological discovery.

1.2 The main issues discussed in connection with the notion of 'function'

In the previous section I discussed the problem of functional explanation and outlined the main approaches to this problem. In this section I shall list a number of issues often discussed in philosophical analyses of the notion of function (remember that not all analyses aim to account for the problem of functional explanation). Woodfield (1976) lists three issues that tend to show up in philosophical analyses of functions (Reznek (1987: 99/100) and Pranger (1990: 64) copy this list without much commentary):

> (1) Hempel's problem. Why is it that only some of the item's activities are functions, and the others accidental?
>
> (2) Nagel's problem. Why is it that we ascribe functions to the parts of some systems (like organisms) but not to the parts of others (like the solar system)?
>
> (3) The problem of functional explanation. How can it be explanatory of an item to cite one of its effects? (Woodfield 1976: 108)

Already in Woodfield's time it was clear that Hempel's problem (the function/accident distinction) consists of a number of different problems/distinctions that can not always be treated equally. The analyses of Wright (1973, 1976), Millikan (1984) , Horan (1989) and Neander (1991a) added new problems to the agenda.

The following list presents a fairly comprehensive overview of the issues that have been raised with respect to biological function in the form of a list of desiderata.

1) A theory of function should not allow one to ascribe functions to parts of "purely physical" systems such as solar systems (Nagel 1961: 406). The challenge is, of course, to define 'purely physical systems'.
2) A theory of function should distinguish between activities that are functions (such as the beating of the heart) and activities that are useless side-effects of functional organs (such as heart sounds and pulses) (Hempel 1959).
3) A theory of function should not depict the use other organisms make of the items of a certain organism as functions of those items. It is, for example, not a function of a dog's long hair to harbour fleas (Ruse 1973: 183).
4) A theory of function should distinguish between effects that are functions and effects that are accidentally useful. Although belt buckles occasionally save their wearers' life by deflecting bullets, it is not a function of belt buckles to deflect bullets (Wright 1973: 147).
5) A theory of function should not depict the use of existing items for new purposes as functions of those items. It is, for example, not the function of the human nose to support eyeglasses (Wright 1973: 148).

6) A theory of function should distinguish currently functional items from vestiges (like vermiform appendices in humans and vestigial eyes in cave dwellers) (Wright 1976: 87, Griffiths 1993).
7) A theory of function should enable us to attribute functions to items that are incapable of performing their function (e.g. malformed hearts) or do not actually perform it (e.g. most sperm cells) (Millikan 1984, Millikan 1989a, Neander 1991a).
8) A theory of function should not confuse functional explanations and evolutionary explanations (Horan 1989, Godfrey-Smith 1994).

1.3 An outline of my argument

I start with a description of the practice of functional biology (chapter 2). After a short introduction I focus on the notion of ‘function’ (section 2.2). Most of the proponents of a certain account of function assume that within biology the word ‘function’ has a unique meaning. The different proposals are usually seen as rival analyses of that unique notion of function. I shall show by means of examples of real biological research that the word ‘function’ is used in biology in a number of different ways. In relation to the problem of explanation it is important to distinguish at least four kinds of function:

(1) function as activity ($function_1$)—what an organism, part, organ or substance does or is capable of doing;
(2) function as causal role ($function_2$)—the role of a part, organ, substance or behaviour of an organism in maintaining a complex activity or capacity;
(3) function as survival value ($function_3$)—the survival value of a certain part, organ, substance, or behaviour; or of a part, organ, substance or behaviour having a certain character;
(4) function as selected effect ($function_4$)—the effects for which a certain trait was selected in the past and that explain its current presence in the population.

For example, in the case of the heart, the beating of the heart is an activity ($function_1$), the performance of which explains the heart’s causal role ($function_2$) in circulation, namely propagating the blood. The survival value ($function_3$) of having a heart is presumably that it is more efficient to have one organ (the heart) as a source of energy for circulation than to have all big blood-vessels beating.[12] It is highly problematic and speculative to specify why the heart was

[12] A good explanation by specification of function as survival value ($function_3$) must of course specify how the heart is more efficient than a system of beating blood-vessels. The survival value ($function_3$) of the system of heart and blood-vessels as a whole is that it satisfies the need for circulation of, among others, oxygen.

selected in the past (function$_4$), but we may guess that the aforementioned efficiency has played a role.

In section 2.3 I show that functional biologists try to answer seven different types of questions. These questions concern:

(1) the structure and activity of the organisms they study;
(2) the causal roles of the parts and behaviours of those organisms;
(3) the mechanisms by means of which these causal roles are performed,
(4a) the survival value of performing these causal roles;
(4b) the survival value of having a certain character;
(5) the development of those organisms in the course of the ontogeny;
(6) the evolutionary history of those organisms, their parts, and their behaviour.

The products of enquiry are respectively:

(1) descriptions of the structure and activity of organisms and their parts;
(2) attributions of causal roles (function$_2$ attributions);
(3) physiological explanations;
(4) design explanations;
(5) developmental explanations;
(6) evolutionary explanations.

I also show that attributions of causal roles are the handle by means of which functional biologists get a grip on their subject matter. They are used in at least three different types of explanations:

1) physiological explanations of the capacities of a system of which the item to which the causal role is attributed is a part (capacity explanations). For example, the insight that the heart propagates the blood helps to explain how the organism is able to circulate oxygen.
2) design explanations of certain aspects (shape, structure, activity etc.) of the part or behaviour to which the causal role is attributed. For example, the causal role of the heart in blood circulation helps to explain why the heart is hollow.
3) explanations of the evolution of the part or behaviour to which the causal role is attributed. For example, the causal role of the heart in oxygen circulation helps to explain why the heart evolved from a two chambered to a four chambered state.

The attribution of a causal role is the first step in these explanations but it does not constitute the complete explanation.

In chapter 3 I relate the description of the practice of functional biology which I presented in chapter 2 to some descriptions of that practice by biologists.

In chapter 4–7 I investigate the extent to which the philosophical theories of function and functional explanation are of use to understand the practice of functional biology.

In chapter 4 I am concerned with the attempts of Hempel and Nagel to account for functional explanations in terms of the inferential theory of explanation. Hempel and Nagel do not give real examples of the explanations about which they talk. This makes it difficult to determine which kind of explanation they have in mind when they talk of "functional explanations". I suggest that they are concerned with design explanations. I argue that they fail to account for the explanatory force of this kind of explanation (that is they fail to explain what design explanations add to our knowledge).

In chapter 5 I am concerned with Cummins's causal role theory of function. I argue that this theory offers an excellent account of the notion of function as causal role ($function_2$). Moreover, Cummins offers an excellent account of an important kind of physiological explanation, namely capacity explanation, and of the role of attributions of causal roles in that kind of explanation. His theory fails to account for the role of attributions of causal roles in design explanations and evolutionary explanations.

In chapter 6 I discuss several proposals within the survival value approach. I argue that these proposals tend to confuse the notion of function as survival value ($function_3$) with the notion of function as causal role ($function_2$). Nevertheless, they offer important contributions to an analysis of the notion of survival value ($function_3$). However, the current proposals fail to account for the explanatory force of appeals to survival value (they fail to explain what one learns from an appeal to survival value). In this chapter I also elaborate on my own account of survival value which I started in chapter 2.

In chapter 7 I argue that the etiological theory does not apply to most function attributions in both functional and evolutionary biology. As a result it leaves the explanatory force of all these function attributions unexplained (that is, it tells us nothing about why such function attributions are important in science). This means that this approach is irrelevant to my project, which aims to understand the practice of explanation in functional biology.

In chapter 8 I present my own account of design explanation. The basic idea of my account is that design explanations relate the way in which an organism is built, the activities of its parts, its behaviour and the condition of the environment in which it lives in terms of what is needed or useful to survive and reproduce rather than in terms of causes. There are two types of design explanation.

The first type of design explanation seeks to explain why it is useful to certain organisms to perform a certain role, for example why it is useful to Vertebrates to transport oxygen (this kind of design explanation answers a type 4a question). Such explanations proceed in the following manner:

(1) identify a need satisfied by the performance of the causal role in question;
(2) explain how that need relates to the other traits of the organism and the environment in which it lives.

The second type of design explanations seeks to explain why it is useful that a certain item or behaviour has a certain character (this type of design explantion answers a type 4b question). Such explanations proceed in the following manner:

(1) determine a causal role of the item or behavioural pattern the character of which is to be explained;

(2) 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 way. A certain performance counts as better than another if it results in a higher fitness than that other.

I argue that such explanations are not of a causal nature. That is they do not explain how or why a certain phenomenon (transition, state or property) is brought about (neither how it is brought about in a certain organism nor how it is brought about in the course of evolution). Instead, they relate the different traits of an organism and the condition of the environment in which it lives in terms of what is needed or useful to survive and reproduce.