# Functional explanation for technical artifacts

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**Abstract**

In this paper, I set out to develop an account of functional explanation that can be used to explain functions of technical artifacts. I start with a discussion of Ernest Nagel's account of functional explanation and argue that, although it can answer some explanatory questions concerning functions, it does not provide insight in another interesting type of explanatory questions about functions; how-questions. I then discuss Robert Cummins's account of functional explanation, which can deal with such questions, and show that it may be extended to include the fact that artifact functions are explained by both dispositional and categorical properties. The final step is to confront my extended version of Cummins's account with an empirical example of artifact explanation: Thomas Edison's patent of the first practicable electric lamp. This will give rise to a further refinement of the account.

## 1. Introduction

Engineers design and build technical artifacts: toasters, light bulbs, cars, microwave ovens, and so forth. Among the reasons for doing so would seem to be that these artifacts can perform functions. People use artifacts to accomplish all sorts of things: toasted bread, lighted rooms, getting from A to B, or a warm meal. Artifacts help us getting about in our everyday life. They make things easier for us or enable us to do things we could not have done without them – at least that is what they are supposed to do. We usually take it for granted that there will be good reasons for trusting artifacts to actually be able to perform the functions they are supposed to perform – everybody uses them, so surely someone will have given it some thought. Engineers or designers seem to be the qualified authorities *par excellence* in such matters. Having designed an artifact, an engineer can be expected to have at her disposal an adequate account of how and why the artifact can perform its function. It seems highly plausible that the designer of an artifact can provide an explanation of the artifact's function in terms of its physical make-up: a 'technological explanation'. At first sight, the *explanandum* of such an explanation would be that some artifact *a* can perform function $\varphi$[1] and the *explanans* would contain information about the various components and subcomponents of the artifact, the (geometrical, physical, and chemical) properties of these components, and the way these components interact. In this paper I will develop an account of such explanations.

The first thing that springs to mind here is functional explanation. And for good reasons; functional explanation is a respected species of explanation, especially in biology. To get a grip on what the explanation of an artifact function may look like, I will take my starting point in existing theories of functional explanation. Most of these theories were originally developed with an eye on explanation in biology, so it should be no surprise if a transfer to the domain of technology generates complications for most people agree that biology and technology differ in significant respects (cf. Preston, 1998 and Vermaas & Houkes, 2003 for opposing views on this issue). Such complications will not be my concern however. I will merely develop an existing theory of functional explanation that best suits my problem.

Here is the plan. The next paragraph sets the stage by introducing Nagel's (1961) account of functional explanation. The main result will be that we need to distinguish two types of functional explanation, one showing *that* a thing has a function and the other demonstrating *how* it performs this function. Since Nagel's account only deals with the first, I will use Cummins's (1975) account of functional explanation to construe the second type of explanation in the third paragraph. The fourth paragraph puts the extended Cummins account to work by confronting it with Edison's explanation of the first practicable electric lamp. This example will lead to a further refinement of the account in terms of two different types of explanatory factors. The fifth and final paragraphs sums up the results.

## 2. Nagel: indispensable functions

According to Nagel (1961) the task of a functional explanation is to explain the *presence* of an item in a system. The proper way to accomplish that task is by showing the item to be *indispensable* for the comprising system. In other words: by showing the presence of the item to be a necessary condition for the proper functioning of the thing. Let's look at the example Nagel gives. Plants contain chlorophyll because "the function of chlorophyll in plants is to enable plants to perform photosynthesis (i.e., to form starch from carbon dioxide and water in the presence of

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[1] Note that this formulation implies a deliberate choice: I will not consider *explananda* like: "The (proper) function of *a* is to $\varphi$ – and not to $\chi$, $\psi$, …)." I do think that an acceptable explanation can be given of why some specific artifact function is the proper function of that artifact – whereas some of the other things the artifact can do are not its proper, but accidental functions (cf. Millikan (1984) for this distinction) – but that raises questions different from those with which I will be concerned here.

sunlight).” (ibid.: 403). It is not abundantly clear that this explanation really explains anything at all – it even seems to presuppose some sort of teleological force, which ‘causes’ plants to contain the right means to the ultimate end of survival. But this is mere appearance, Nagel argues, for we should unpack the content of a function statement, rendering a nonteleological explanation: “When supplied with water, carbon dioxide, and sunlight, plants produce starch; if plants have no chlorophyll, even though they have water, carbon dioxide, and sunlight, they do not manufacture starch; hence, plants contain chlorophyll.” (ibid.: 403). No mysterious forces remain in this unpacked function statement. The analysis shows that chlorophyll is indispensable for plants producing starch, so that is its function. Nagel’s functional explanations have the following general form[2].

> [1] Every system *S* with organization *C* and in environment *E* engages in process *P*; [2] if *S* with organization *C* and in environment *E* does not have *A*, then *S* does not engage in *P*; [3] hence, *S* with organization *C* must have *A* (ibid.: 403).

Bearing this in mind, we can ask for instance why CD-players contain lasers. The answer is that the function of lasers in CD-players is to ‘read’ the tiny bumps on the surface of a compact disc representing digitally encoded music fragments. Unpacking this statement renders: every CD-player with a lens system, spinning disc, tracking device, etc. plays music; if CD-players do not have lasers, even though they have all the other requisite parts, they do not read the bumps and thus not play music; hence, CD-players must contain lasers.

There are a number of objections to this account, but I will focus on two especially pressing ones from the artifact function perspective. First, the existence of functional equivalents seems to turn Nagel’s reconstruction into a *non sequitur*. If there exists a component *B* with the same functionality as *A*, it simply doesn’t follow that ‘*S* with organization *C* must have *A*’. It might just as well have *B*. Although Nagel has succeeded in showing the much weaker conclusion that the presence of *A* is a *sufficient* condition for *S* with *C* in *E* to engage in *P*, he has not shown that it is *necessary*. This is particularly troubling for artifact functions, since the existence of functionally equivalent parts is a plain fact of everyday engineering life. Sometimes engineers even create functionally equivalent things deliberately for reasons of reusability and design modularity or to avoid violation of patent rights. Nagel tries to tackle this point by stipulating that functional explanations only deal with specific definite systems – logical or physical possibilities do not matter for the explanation of an actual system. Misunderstandings arise through imprecise use of

[2] The attentive reader will notice that Nagel’s account of functional explanation fits Hempel’s deductive nomological (D-N) model of explanation. This is no coincidence; Nagel aims to unify various types of explanation under the D-N heading.

language. When we say: "The function of chlorophyll in plants is to enable plants to perform photosynthesis," we actually mean to ascribe a function to chlorophyll in *green* plants, not plants in general (ibid.: 404). I think this suggestion possesses at least some plausibility for biological purposes, provided we can find a satisfactory notion of natural kinds or species. A functional explanation could handle one particular species and only the normal exemplars of that species (aberrations or artificially manipulated cases, e.g. people with artificial hearts, are excluded). But when it comes to artifacts, this strategy leads to a dilemma because the construction of a notion of artifact species is far from trivial. Either a species is defined functionally as a class of artifacts having a certain (well-specified) function, or it is defined 'structurally' as a class having certain components. The first horn of this dilemma leads directly to the problem of functional equivalents. Take any precisely defined functional artifact species, which contains artifacts having component *A* necessarily. There is no reason to think that engineers will not be able to come up with a functionally equivalent component *B*. Hence, the conclusion that *S* must have *A* does not follow. On the second horn, the explanation is trivialized, because species are defined in terms of their components. The conclusion that *S* must have *A* follows trivially since it is part of the concept of *S* that it has *A*. However, we can go between the horns by (1) weakening the premises of the explanation from general statements about every system *S* with organization *C* to singular statements about one particular system $S_0$ with organization $C_0$[3], and (2) changing the conclusion to '$S_0$ with organization $C_0$ must have *A* or a functional equivalent of *A*'. This 'particularized' functional explanation works, but it is not very informative.

Secondly, there is something odd about the intuition underlying Nagel's account. It supposes that a functional explanation amounts to demonstrating the indispensability of an item. But that is certainly not an uncontestable claim. Why not suppose that a functional explanation should explain *how* an item helps to realize a function of the comprising system? This leads to two different conceptions of what a functional explanation is: on the one hand it can be defined as an explanation that contains a function ascription (this is what Nagel does), and on the other as an explanation of the physical mechanisms that underlie a function ascription. On the former definition the appropriate explanatory question is: "Why does system *S* contain element *A*?" but on the latter it is: "Why (or how) can *A* perform function $\varphi$?" In practice we encounter both explanations, depending on the context. The second question can be regarded as an additional follow-up question to the first. Once it is clear that some part or thing is indispensable, we can ask why exactly it is indispensable. Suppose I am going to buy a car, firmly determined to make an impression on the car salesperson. Being utterly uninformed about cars, I might ask why a car

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[3] This escape is not available for Nagel, since it sacrifices the lawlikeness of the second premise and thus the possibility of becoming a true D-N explanation.

contains a carburetor. If she then tells me that a carburetor has the function of creating an explosive mixture of fuel and air for a combustion engine, which is indispensable for the proper functioning of the car, I will probably be satisfied. But if, for some reason, I have recently developed a special interest in cars, I will want to know more: "But how is it that a carburetor has this function; how does it do its job?" Now an answer requires quite an excursion into the technicalities of car engines, which would baffle me completely. But this is the kind of thing we expect engineers to have at hand.

To conclude this section, I suggest there are two different forms of functional explanation. I see no point in quarrels over which of the two is the rightful heir to the title of functional explanation. Roughly speaking, the first shows *that* an item has a function by demonstrating it to be indispensable for the realization of some purpose, whereas the second shows *how* the item functions by giving information about the structure and organization of the item and/or the comprising system. Which of the two is appropriate depends on pragmatic criteria, but the second can be embedded in the context of the first, for it provides supplementary information. The first will suffice in the context of everyday artifact use, whereas the second will be appropriate in a design context. I will devote the rest of this paper to the second form. Cummins's account of functional explanation serves as a starting point for the discussion.

## 3. Cummins and beyond: functions decomposed

Cummins (1975) analyses functional explanation in order to justify for function-ascribing statements. Like Nagel, he contends that things can only possess functions relative to an encompassing system *s*, so the general form of a function ascription is: 'the function of *x* in *s* is to *φ*'.

The analysis proceeds in three steps. He begins by claiming that function-ascribing statements imply disposition ascriptions. "If the function of *x* in *s* is to *φ*, then *x* has a disposition to *φ* in *s*." (ibid.: 758). Having disposition *d* means for an object *a* to exhibit regular lawlike behavior peculiar to objects having *d*. Were a certain range of events to occur, *a* would manifest *d* and it would do so inevitably. Being subject to a special behavioral regularity is a feature of objects that calls for explanation.

Therefore, Cummins's second step is to outline two general explanatory strategies for explaining dispositions: the subsumption strategy and the analytical strategy. The first strategy explains disposition manifestations by showing them to be instances of more general laws, i.e. "laws governing the behavior of things generally, not just things having *d*" (ibid.: 759). The buck is passed to (natural) science. Maybe a further explanation can be given for the relevant general laws, but that is no longer the business of functional explanation. The second strategy, which is more important for the present purpose, explains a disposition *d* by decomposing it into sub-dispositions $d_1, d_2, \ldots, d_n$ that jointly result in or amount to $d$ if programmed in a certain fashion. Sub-dispositions may be had either by $a$ or components of $a$ (ibid.: 759). Although Cummins does not explicitly discuss the possibility, this strategy obviously allows for nested explanations: the sub-dispositions may again be explained by sub-sub-dispositions and so forth. In a sense, exploiting this option goes beyond Cummins: his goal is *justifying* function ascriptions and that can be accomplished with one analyzing step. Since I am interested in *explaining* functions, I want to be able to nest several analyzing steps. The two strategies fit together nicely when the subsumption model is seen as an analysis-stopper: once a sub-disposition can be subsumed under general laws, the explanation stops.

The third and final step is to argue that functions can only be ascribed relative to an analytical explanatory account of a disposition of the comprising system. When the analytical strategy applies functions are ascribed to analyzing sub-dispositions (or capacities[4]) if they 'contribute' to the disposition of the larger system. Here is Cummins's final proposal:

> $x$ functions as a $\varphi$ in $s$ (or: the function of $x$ in $s$ is to $\varphi$) relative to an analytical account $A$ of $s$'s capacity to $\psi$ just in case [1] $x$ is capable of $\varphi$-ing in $s$ and [2] $A$ appropriately and adequately accounts for $s$'s capacity to $\psi$ by, in part, appealing to the capacity of $x$ to $\varphi$ in $s$. (ibid.: 762)

So components have functions in virtue of their contributing to the disposition of the comprising system. Only if the component in fact has the disposition to $\varphi$ in $s$ does it have the function to $\varphi$ in $s$. This is required by the earlier claim that function ascriptions imply disposition ascriptions, which in turn reduce to conditional statements about the behavior of an object. Such statements are only true if the component in question actually possesses the required disposition. We can now couch our earlier example of the laser in Cummins's terms: because reading the bumps on a CD partly explains the disposition of a CD-player to play music when a CD is inserted, the function of the laser in a CD-player is to read the bumps on a CD.

Now let's take a closer look at Cummins's central tenets. First, function ascriptions imply disposition ascriptions. Wherever there is function, there is disposition. Really? I think this leads to unwanted disposition ascriptions. Think for example of a paperweight; calling 'exerts pressure if placed on a stack of paper' a disposition is certainly not widespread usage. Or take the blade of a knife: cutting food is a respectable function, but what could the associated disposition be – and

[4] Cummins prefers to speak of *capacities* instead of dispositions in the context of the analytical strategy. If I am not mistaken, more than a terminological shift is at stake: I take it that a disposition is usually considered to be a specific type of property of objects, while a capacity is, I think, commonly conceived as anything an object can do because of its having certain (dispositional and non-dispositional) properties. I will get back to this point in due course.

would one really call that a disposition? I concur with Cummins that function ascriptions can be translated into conditional statements describing the behavioral regularities of an object, but we need to extend his analysis and allow that such conditionals may be explained not only by the possession of dispositional properties but also by the possession of non-dispositional (categorical) properties.

Because I want to be able to nest several analytical explanations in order to explain an artifact function – not only ascribe one – this becomes even more important. We probably do not want 'dispositions all the way down' since categorical bases can explain most, if not all, dispositions ascriptions. So it is undesirable to grant explanatory power to disposition ascriptions only. To sum up the proposed extension: function statements imply conditional statements about the behavior of an object like 'if $\chi$-ed, $x$ in $s$ will $\varphi$', and such conditional statements are true in virtue of the object's having certain dispositional and categorical properties.

Secondly, we have to face another complication. Is it really true that function ascriptions always imply true conditional statements about behavior? It would certainly be a happy world if they would, for that would rule out the possibility of malfunctioning. Alas, we are all too familiar with losing our textual brainchildren to fatal errors in the operating system of our computer or cars breaking down when we were just leaving for a nice weekend trip. The problem is that we still want to ascribe functions to malfunctioning artifacts – why else call them mal*functioning*? – even though such function ascriptions do not entail true conditional behavior statements. I have two replies. The first is that this kind of objection does not affect the present project, since I am interested in developing an explanatory account of how an artifact can perform its function and the question: "Why can $a$ perform $\varphi$?" already presupposes that $a$ can perform $\varphi$. And besides, even if $a$ malfunctions the question of how it was supposed to perform its function is still legitimate. Hence, malfunction is barred from the analysis. I admit that this reply smacks of ducking the question, so here is the second reply. It is no simple business to guarantee the truth of conditional statements about the behavior of objects. The messy vicissitudes of our world can always thwart an expected course of events. For instance, some quirk of fate has lately caused my CD-player to haphazardly ignore some of the CD's I put in it. So far I have no clue as to what triggers this frustrating behavior but clearly something is malfunctioning. Since this possibility of interfering background conditions can never be excluded, conditional behavior statements need qualification. It is, practically speaking, impossible to append a list excluding all possible interfering factors, for nobody could list all conditions that might prevent manifestation of the described behavior within a lifetime. We have to settle for an admittedly imprecise and context-relative notion of normal circumstances. A function ascription, and thus a conditional behavior statement, implies that although the artifact may in fact not behave as specified, it will do so under suitable normal circumstances. What these suitable normal circumstances are, depends on the concrete context of the function ascription. But, assuming the function ascription is made for good reasons, the normal circumstances will be such that they usually obtain when that function is ascribed. The ascription licenses someone to expect a certain regularity in behavior even though the expectation may prove unmerited. To wrap up this point: function statements imply qualified conditional behavior statements of the following form: 'under normal circumstances $N$, $x$ in $s$ will $\varphi$ if $\chi$-ed'.

The second step in Cummins's analysis was to outline two explanatory strategies, the subsumption and analytical strategy. Since the analytical strategy drew heavily on the disposition analysis from the first step, it is now in need of reconsideration. The foregoing discussion leads to the following semi-formal scheme of my extension of the analytical explanatory strategy:

(1) performing $\varphi$ implies: under normal circumstances $N$, $x$ in $s$ will $\varphi$ if $\chi$-ed;
(2) $x$ has components $c_1, c_2, \ldots, c_n$ in configuration $C$;
(3.1) $c_1$ has (dispositional and/or categorical) properties $P_1$;
⋮
(3.n) $c_n$ has (dispositional and/or categorical) properties $P_n$;
(4) having $P_1, P_2, \ldots, P_n$ implies exhibiting behaviors $B$;
(5) programmed manifestation of $B$ results in $\varphi$-ing if $\chi$-ed under $N$;
(6) hence, $x$ in $s$ can perform $\varphi$.

The explanation proceeds by decomposing the artifact into an organized assembly of components with several properties. In virtue of having these properties components behave in a regular manner and the joint behavior of the components results in the overall behavior of the artifact. Like (3), premises (4) and (5) may be unfolded into separate statements about particular components and their respective properties and behavior. That allows for a detailed account of the roles of the components. Obviously, nesting several analytical explanations is possible. Replace '$x$ in $s$' by '$c_i$ in $x$' and the whole procedure repeats itself on a lower level. At some basic level further decomposition will become impossible and then the subsumption strategy can stop the explanation. That strategy is pretty much unaffected by my discussion: substituting 'regularity in behavior' for 'disposition' does the job. In fact, this already showed in the original formulation where Cummins said that this strategy looks for "laws governing the *behavior* of things generally" (ibid.: 759, my italics).

Now that we have an initial model of the second type of functional explanation (i.e., an answer to questions like: "How can *a* perform $\varphi$?"), my next step is to confront this model with an empirical example of technological explanation. Thomas Edison's famous patent of the electric lamp will be the primary point of reference.

## 4. Edison's electric lamp: further explanatory refinements

Surely Thomas Edison is a person one would expect to be a competent explainer of artifact functions. Personally, I would consider an analysis of technological explanation useless if even a world-famous inventor could not live up to its standards. That is why I will scrutinize the patent of one of his legendary inventions, the first practicable incandescent electric lamp (Edison, 1880), to see if the analysis so far can be put to work. I show some examples of the extended analytical strategy at work, but unfortunately it does not quite stand up to the entire patent. Therefore, the strategy will have to be refined by adding different types of explaining factors.

But let's warm up with some examples of successful analytical explaining. The function of a lamp obviously is to provide light, or to light a room or space. The corresponding behavior is something like: 'when turned on (connected to a power source), radiates light' – assuming that normal circumstances obtain, i.e., no parts of the lamp are missing, the voltage of the power supply is proportioned to the lamp's resistance, etc. Against this background the patent clarifies the roles of various components of the lamp. For example, when discussing the coiled carbon wire serving as the source of light radiation, the patent reads: "[A] cotton thread properly carbonized […] offers from one hundred to five hundred ohms resistance to the passage of the current" (ibid.: 1), "[I]f the thread be coiled as a spiral and carbonized […] as much as two thousand ohms resistance may be obtained" (ibid.: 1), and "[T]he exterior [of the coiled filament], which is only a small portion of its entire surface, will form the principal radiating-surface; hence I am able to raise the specific heat of the whole of the carbon, and thus prevent the rapid reception and disappearance of the light." (ibid.: 2). The carbonized wire has high resistance as a property and since resistance increases with length, a long spiral-shaped wire offers even greater resistance. In virtue of this resistance the passing of electrical current heats the wire, resulting in "light by incandescence" as Edison calls it. We can describe this as a dispositional property: 'glows if heated'. Furthermore, Edison claims, because the filament has the property of being spiral-shaped it allows for higher temperatures than plain wires and therefore the filament glows more steadily and gives unwavering light. Having the properties of being carbonized, having high resistance, and being spiral-shaped accounts for the behavior of the filament (glowing steadily when electrical current runs through it), and the fact that the filament exhibits this behavior partly accounts for the behavior of the lamp as a whole.

Another example clarifies the use of platinum wires to connect the filament inside the glass bulb with the leading wires outside it: "By using the carbon wire of such high resistance I am enabled to use fine platinum wires for leading-wires, as they will have a small resistance compared to the burner, and hence will not heat and crack the sealed vacuum-bulb. Platina [sic] can only be used, as its expansion is nearly the same as that of glass." (ibid.: 2). The function of the platinum wires is to conduct the electric current into the bulb to the filament. Since platinum wires have the property of conductivity, they exhibit the required behavior. And because of their relatively small resistance, the wires will not heat excessively (which was a major disadvantage of earlier electric lamps for they had filaments with small resistance) causing the glass bulb to crack. The minor expansion that does occur because of heating will not be detrimental since the expansion of platinum and glass are approximately equal. Again, we witness the analytical explanatory scheme at work: platinum wires have certain properties (conductivity, small resistance, expansion by heating) and therefore they exhibit the behavior associated with their function. This behavior partly accounts for the overall behavior of the lamp.

So far, so good; the analytical strategy works fine for these explanations. But now I want to draw attention to some features that upset this picture. First a remark about pragmatics which will not really affect the scheme, and then a more fundamental point which will lead to a distinction between different types of explanatory factors.

A striking feature of the examples I gave is that they seem to be explaining more than just the mere possibility of providing light. Whereas I suggested that a technological explanation should explain how artifact $a$ can perform function $\varphi$, Edison also demonstrates that his lamp provides unwavering light, that it can do so for a considerable amount of time, and that the lamp will not crack after a few minutes. We can understand this by realizing ourselves that we generally take a lot of things for granted when we describe artifact functions. In practically any conceivable situation the expression ‘the function of a light bulb is to provide light’ presupposes that the light should not flicker, that the light should last for more than a few seconds, that the bulb should not crack when the light is switched on, and much more. But why did Edison choose to mention exactly these taken-for-granted features and not others, e.g. that the color of the light does not turn to blue after five minutes? This is where context-sensitive pragmatic aspects enter. There had been other patented attempts to build a viable electric lamp before Edison, but they were considerably less successful for just the kind of reasons that Edison excludes here for his lamp. The material for the filament did not have high resistance, the wires going into the bulb led it to crack, the filament was plain instead of coiled, etc. Much of the tacit presuppositions that are inherent in our conception of the function of a light bulb, were in Edison’s time far from obvious and that is why he emphatically presents them as valuable improvements over earlier lamps. The contrast classes (cf. Van Fraassen, 1980; Lipton, 1990) of his explanations were different than today. He had to explain the functioning of his lamp in the context of flickering and cracking lamps, but nowadays the fact that a light bulb gives stable, as opposed to wavering, light isn’t much of a surprise and neither is the fact that the glass bulb remains intact instead of cracking. That is just how it is; we no longer accept flickering light bulbs that crack after some time. The ones that do are simply done away with as being defective.

Does this influence the explanatory scheme? I think not. Strictly speaking, the explanandum has not changed; it is still the possibility of an artifact performing a function. The implicit assumptions in the function ascription however have changed – and thus the relevant (implicit) contrast classes for the explanation. These implicit assumptions and contrast classes are highly context-dependent and can change over time, so it is hard to tell exactly what they are. Nonetheless I think we generally share a common sense understanding of what can reasonably be expected of the artifacts we encounter in our everyday lives.

This concludes my first point about pragmatics. For my second point I need another example from the patent. One of the clever ideas of Edison's electric lamp was that it placed the filament in a vacuum, and not in a non-reactive gaseous mixture. The point is this: "[A filament] placed in a sealed glass bulb exhausted to one-millionth of an atmosphere […] is absolutely stable at very high temperature." (ibid.: 1). The filament reaches temperatures high enough to cause spontaneous combustion in normal air. But since combustion requires oxygen, it will not happen in a vacuum[5] and the wire is therefore "absolutely stable". At first glance we can readily employ the earlier analysis again. The vacuum has the function of preventing the filament from combusting. The corresponding behavior conditional would be something like: 'prevents combustion if an incandescent filament is placed in it' and this can be explained by the vacuum's possessing the property of 'not containing oxygen'. But isn't there something rather discomforting about vacuums that fulfill causal roles and have causally effective properties? Vacuums do not *do* things for they are, properly speaking, not objects. They are 'nothing' and nothings do not cause events – at least I sure hope they do not.

Nonetheless the vacuum is indispensable for Edison's electric lamp and the general phenomenon exemplified by this vacuum is certainly not exceptional. A lot of artifacts contain components that do not really add to their functions, but only make those functions possible. Such components help 'set the stage' for proper functioning. Take a car engine again and look at the coolant or the oil sump and pump. They do not directly add to the function of the engine (i.e., do not really help drive the wheels), but without them the engine could not function. I conjecture we must distinguish between two sorts of 'explainers'. On the one hand, we have components that *contribute* directly to the function – in the case of the light bulb most notably the filament with current running through it and the leading wires. On the other hand there are components that do not directly contribute to the main function, but instead *enable* the function to be fulfilled – such as the vacuum in the bulb. We can call the former functional *contributors* and the latter

[5] The vacuum also serves to prevent the transport of heat inside the bulb by convection and conduction, which greatly increases the efficiency in energy use of the lamp. Edison does not mention this advantage.

functional *enablers*.[6] The distinction readily applies to the examples I gave earlier. A laser in a CD-player is a contributor, since reading the bumps on a disc directly contributes to playing music, but the tracking mechanism is an enabler since it enables the laser to read the right bumps. We can ask ourselves: is this element part of the main function of the artifact, or does it create the conditions for a proper fulfilling of the main function? Sometimes one and the same component can do both. I am tempted to say that the platinum wires contribute to the function of lamp by their conducting the current, but also make that function possible because of their heat expansion, which is nearly equal to that of glass so that the bulb does not crack.

How can we represent this distinction in the explanatory scheme? The earlier scheme tacitly left open the question of how the various behaviors result in the overall behavior; look again at premises (4) and (5).

(4) having $P_1$, $P_2$, …, $P_n$ implies exhibiting behaviors $B$;
(5) programmed manifestation of $B$ results in $\varphi$-ing if $\chi$-ed under $N$;

The comfortably vague expression 'programmed manifestation results in' does not dictate either enabling or contributing. It is easily seen that contributors do not pose a serious problem. Replacing 'results in' by 'contributes to' makes (5) represent the role of contributors. Capturing the role of enablers involves more subtleness. Enabling may consist in at least two things: either (1) helping to establish the required but not normally occurring antecedent events for the behavior of a contributor, or (2) preventing certain undesired normally occurring consequences of the behavior of a contributor[7]. Examples of the former are the oil sump and pump: they lubricate the moving parts in the engine to prevent excessive friction or even blocking. This does not happen spontaneously or normally, but it is required for the engine to operate properly. The vacuum in the glass bulb exemplifies the latter: normally an incandescent filament would combust, but due to the lack of oxygen in the vacuum it does not.

I think we can capture the role of enablers by revising premises (4) and (5) as follows[8]:

(4.1) having $P_1$, $P_2$, …, $P_n$ implies exhibiting desired behaviors $B$, some of which are only exhibited under certain special circumstances $D_d$;

[6] I have adopted and adapted this terminology from Dancy (1993).

[7] Maybe we need to distinguish even further here: prevention may be realized by taking countermeasures that neutralize the unwanted behavior, or by removing the antecedent conditions for the unwanted behavior. The vacuum is an example of the second case.

[8] For the sake of clarity I chose to add as few extra indexical letters as possible to the already intricate presentation. I think it is easily appreciated that greater precision may be attained without principal difficulties.

(4.2) having $P_1$, $P_2$, …, $P_n$ implies exhibiting undesired behaviors $U$ under normal circumstances but not under special circumstances $D_u$;

(4.3) having $P_1$, $P_2$, …, $P_n$ implies exhibiting requisite behaviors $R$, which establish special circumstances $D_d$;

(4.4) having $P_1$, $P_2$, …, $P_n$ implies exhibiting preventive behaviors $V$, which establish special circumstances $D_u$;

(5.1) programmed manifestation of $R$ contributes to realizing special circumstances $D_d$ required for some of the behaviors $B$;

(5.2) programmed manifestation of behaviors $V$ establishes special circumstances $D_u$ under which behaviors $U$ are prevented;

(5.3) programmed manifestation of $B$ contributes to $\varphi$-ing if $\chi$-ed under $N$;

A few final remarks for clarification. First, just like the earlier version this scheme leaves open the possibility of unfolding premises (4) and (5) into separate statements about the contributions of particular components and their properties. Secondly, premises (4.1) and (5.3) deal specifically with contributors, whereas the other premises describe the different roles of enablers. Thirdly, the above formulations again contain context-sensitive expressions like ‘normal’ and ‘special’ circumstances and ‘programmed manifestation’. This is inevitable for both pragmatic and principal reasons discussed earlier. Pragmatic, because which behaviors and properties desire explanation strongly depends on implicit assumptions and contrast classes. Principal, because it is infeasible – and useless – to try and list all the relevant normal and special circumstances in any reasonable amount of time.

## 5. Conclusion

To sum up, I have developed an account of functional explanation that can be used to explain artifact functions: a technological explanation. First, Nagel’s account of functional explanation gave rise to a distinction between two complementary types of functional explanation: one showing *that* an artifact or component has a function and the other demonstrating *how* it can fulfill this function. In the context of everyday artifact use the first usually suffices, but in an engineering or design context the second must be available. The first can be handled by a ‘particularized’ version of Nagel’s account. Secondly, I used Cummins’s functional explanations to construe an account of the second type of explanation. This led to an extended version of his analytical explanatory strategy. Finally, this extended account was confronted with an empirical example of a technological explanation, Edison’s patent of the electric lamp. This necessitated a refinement in the account developed so far: a distinction between *contributors* and *enablers*. I have no intention of claiming that these two types of explanatory factors exhaust all possible explanatory factors. I am content if I have shown that at least these two are required if we want to understand functional explanation of technical artifacts.

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