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# Are natural selection explanatory models a priori?

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**Abstract** The epistemic status of Natural Selection (NS) has seemed intriguing to biologists and philosophers since the very beginning of the theory to our present times. One prominent contemporary example is Elliott Sober, who claims that NS, and some other theories in biology, and maybe in economics, are peculiar in including explanatory models/conditionals that are a priori in a sense in which explanatory models/conditionals in Classical Mechanics (CM) and most other standard theories are not. Sober's argument focuses on some "would promote" sentences that according to him, play a central role in NS explanations and are both causal and a priori. Lange and Rosenberg criticize Sober arguing that, though there may be some unspecific a priori causal claims, there are not a priori causal claims that specify particular causal factors. Although we basically agree with Lange and Rosenberg's criticism, we think it remains silent about a second important element in Sober's dialectics, namely his claim that, contrary to what happens in mechanics, in NS explanatory conditionals are a priori, and that this is so in quite specific explanatory models. In this paper we criticize this second element of Sober's argument by analyzing what we take to be the four possible interpretations of Sober's claim, and argue that, terminological preferences aside, the possible senses in which explanatory models in NS can qualify, or include elements that can qualify, as a priori, also apply to CM and other standard, highly unified theories. We conclude that this second claim is unsound, or at least that more needs to be said in order to sustain that NS explanatory models are a priori in a sense in which CM models are not.

**Keywords** Natural selection · Sober · A priori explanatory models

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## Introduction

The epistemic status of Natural Selection (NS) has seemed intriguing to biologists and philosophers, both friends and detractors of NS, since its very beginnings to our present times. One prominent contemporary example from the friend side is Elliot Sober, who claims that a priori causal statements play a central role in NS and other biological—and maybe economic—theories. Sober's main anti-Humean point focuses on the "would promote" talk that, according to him, is both causal and a priori and plays an essential role in NS explanations. Lange and Rosenberg (2011) criticize Sober arguing that, though there may be some *unspecific* a priori causal claims (thus not *genuinely* causal), there are not a priori causal claims that specify particular causal factors, neither in NS nor elsewhere. Lange and Rosenberg focus on the general Principle of Natural Selection (PNS) and argue, roughly, that such a principle crucially involves the general property of fitness as a second order property, without *specific* causal powers, in contrast to its first order realizers which carry the specific causal powers. This principle may count as an a priori causal statement, but of a very peculiar nature for it is an unspecific second order statement, thus innocuous against the Humean thesis that they vindicate according to which there are no a priori causal statements specifying particular causal factors.

Our reply can be regarded as complementing Lange and Rosenberg's. On the one side, we share what we take to be the core of their objection, namely that a PNS is causally/explanatorily too unspecific to do any explanatory work in isolation; but we favor a different metatheoretical approach to PNS, and its applications, in terms of guiding principle-driven explanatory theory-nets, and the corresponding distinction between general guiding principles and specialized laws. According to this approach, the relation between general principles and special laws is more similar to the determinable-determined relation than to the second order-first order realizer one. On the other side, and more importantly, we think that their reply remains silent about a second element in Sober's dialectics, namely his claim that *specific* explanatory models/conditionals in NS are a priori in a sense in which explanatory models in Classical Mechanics (CM), and other standard theories, are not. This is the part of Sober's dialectics that we address here about which Lange and Rosenberg remain silent. Though the would-promote sentences that they discuss certainly play a central role in Sober (2011), we believe that this second aspect is also crucial in Sober's argument and essential in order to clarify the epistemic status of NS *vis-à-vis* CM. In contrast with Lange and Rosenberg, then, we scrutinize Sober's thesis by analyzing *particular* explanatory models that according to him are paradigmatically a priori in a sense in which mechanical explanatory models are not (by 'a priori' we simply mean now "justifiable independently of empirical information", but we will discuss the notion at length below).

In the first section, "Sober's claim and some paradigmatic examples", by formulating Sober's claim and reconstructing some *particular* NS explanatory models, including his preferred examples, such as Fisher's sex ratio model. We then proceed to discuss and assess Sober's claim according to what we take to be the possible interpretations of 'a priori explanatory model'. In the section "Explanatory conditionals considered in isolation" we discuss three interpretations focusing on particular explanatory models independently of their relation to a general adaptive principle. In "Explanatory conditionals and guiding principles" and "Do NSGP and CMGP differ with regard apriority?" we discuss a final interpretation analyzing the relation between particular explanatory models and a general adaptive principle as a case of the specialization relation within guiding principle-driven theory-nets, showing that the epistemically tricky aspects are common to all guiding principle-driven unified theories. We conclude that none of these interpretations makes Sober's claim tenable: according to some interpretations, NS contains a priori explanatory models, but so does CM; according to others, CM does not contain a priori explanatory models, but neither does NS. Thus, in absence of a new interpretation, there is no sense in which particular explanatory models are a priori in NS (and some other theories) but in CM (and most other theories) are not. In the final section we face two possible objections. We believe that, although Sober's position on a priori models in NS is not dominant in the field, the analysis we offer here not only crucially completes some criticisms already made, but also shades some light on central aspects of NS that have seemed intriguing to both philosophers and biologists from its very beginnings to present times.

## Sober's claim and some paradigmatic examples

Sober acknowledges that there is a sense in which all empirical theories make equal use of a priori models, namely: theoretical models are *defined* by theoretical axioms/laws, thus such models a priori satisfy these axioms/laws. These models a priorily defined by theoretical axioms are the ones used by semantic, or model-theoretic, accounts (such as Suppes', Van Fraassen's, Giere's, Suppe's or Sneedian structuralism) for characterizing empirical theories as sets of models (in all these accounts, though, the theory's empirical claims, i.e. the claims that certain part of the world is embeddable into a theoretical model, are never qualified as a priori). Yet, in several writings Sober also claims that there is other sense according to which NS, and few other theories, make use of a priori explanatory models while CM, and other standard theories, do not[1] (Sober 1993, 2008, 2011; Sober et al. 2010; in this discussion, Sober uses 'a priori' and 'non-empirical' simply as synonyms). This second claim is what interests us here.

Sober (2011) begins with a quite general principle of natural selection (PNS, so labeled in Lange and Rosenberg 2011: 592) as a case of a causal/explanatory adaptive claim which, according to him, is nevertheless a priori (Sober 2011: 575):

PNS If *A* is fitter than *B* in a population in which no other evolutionary causes are at work, and the traits are perfectly heritable, then *A* will, in expectation, increase in frequency

[1] Following Sober, we take explanatory models as summarized by conditionals with the explanans as the antecedent and the explanandum as the consequent. We ignore here the rich recent literature and discussion on models, explanation, and explanatory models in science, for nothing in this paper hinges on this simplification (see Díez 2014 for a model-theoretic account we favour).

Recalling Molière's joke about *virtus dormitiva*, Sober defends that such a principle is a priori yet, contrary to Molière's *virtus*, scientifically relevant. Moreover, Sober claims that *specific* explanatory models in natural selection use regularities and causal claims that are not empirical but a priori: "Molière's joke is a joke, but the a priori causal models that are part of the theory of natural selection are no laughing matter" (Sober 2011: 573); "some causal claims are a priori. Molière's joke provides a trivial example of an a priori causal claim. Mathematical models of natural selection furnish non-trivial examples" (Sober 2011: 588).

One might wonder whether this a priori component is involved in all explanatory theories. Sober emphasizes that this is not the case, the use of a priori explanatory models is *not* a general feature of all explanatory theories:

> the pattern to which I have been pointing is far from universal… there are theories (like Newton's) that are both general and empirical … such theories differ from the models of natural selection that I have described.
>
> (Sober 2011: 581–582)

Thus, NS is *peculiar* in this regard, *compared to CM and other* "common" theories. Yet NS, though maybe the most prominent case, is *not* alone in this respect:

> I am not claiming that the pattern I have described is unique to natural selection. It also applies to other evolutionary processes;…. And perhaps there is a priori causal modeling in other sciences; maybe economics furnishes examples… What I do claim is that the pattern to which I have been pointing is far from universal.
>
> (Sober 2011: 581)

Sober's thesis, then, is the following:

(S) NS, and (few?) other theories contain a priori (causal) explanatory models in a sense in which CM, and (many) other theories do not

As a simple, first specific example Sober mentions the zebra-lion model:

> If lions were to hunt and kill slow zebras more successfully than they hunt and kill fast ones, and if this were the only source of fitness differences in the zebra population, then fast zebras would be fitter than slow ones.
> […] The model is a priori, whichever way it is represented. Of course, the existence of zebras and lions isn't a priori, nor is the fact that the population of zebras persists through many generations, nor is the fact that the traits in question are heritable. But the model does not entail any of these…. Humeans maintain that dynamical causal models are always empirical. The model just described is an exception.
>
> (Sober 2011: 577–578)

And he presents Fisher's sex ratio model as a more complex, interesting case representative of his claim: "I think that Fisher's theory is a mathematical truth; the consequent follows mathematically from the antecedent once everything is stated carefully" (Sober 2008: 45).

Since Sober himself presents the sex ratio model as a sufficiently interesting paradigm of his claim, we refer to it, together to other, simpler cases, in our discussion of (S) as a thesis about *specific* explanatory models (we'll come back to the general NSP below). What follows summarizes this model as he presents and reconstructs it in Sober (1993:16–17; for the history of sex ratio explanations see Edwards 1998; Sober and Elliott 2007):
*SexRatio*:

*IF* (1) in context *C*, mating is random
(2) in *C*, cost per son = cost per daughter
(3) sex ratio strategies are transmitted, with random variation, through generations
(4) mother's benefit provided per son/daughter is son's/daughter's average reproductive contribution[2]
(5) maximizing energy benefit is beneficial for differential reproduction
*THEN* (6) birth sex-ratio approximates 50–50

(Here '*x* is beneficial for differential reproduction' means that individuals that perform the function *x* better tend to increase their ratio in the population.) This is the model that explains 50–50 sex ratio. Different substitutions for (1) or (2) imply different explananda: if we have instead (1') brother/sister mating, then we obtain (6') female sex ratio bias. When the second premise is (2'') that cost is proportional to mortality, then we obtain (6'') mortality sex-ratio bias. Other changes for (1) and (2) account for other explananda in different sex ratio models (cf. Hamilton and William 1967). It is worth emphasizing that in NS sex-ratio models, (3)–(5) never change (more on this crucial fact below).

If we reconstruct the lion-zebra model in a similar manner we obtain:
*ZebraLion*:

*IF* (1) in context *C* lions are the only predators of zebras
(2) zebra speed is transmitted with random variation to the next generation
(3) zebras escape lions by running
(4) escaping predators is beneficial for differential reproduction
*THEN* (5) the proportion of fast zebras increases in *C* wrt slow zebras

While the sex ratio model explains the relevant trait as a case of *fecundity* adaptation, the zebra-lion model explains its relevant trait as a case of *survival* adaptation, in this case via the improvement of the escaping predator beneficial behavior by increasing speed (since zebras, and other animals, escape predators by running). Yet, not all adaptations via the improvement of the escaping predator behavior involve increasing speed. Another typical way of improving escaping predators is by camouflaging, as in the also paradigmatic case of black moths:

[2] Sober (personal communication) would write (4) as "a mother's fitness is her expected number of grandoffspring"; although we find this formulation also acceptable, given the huge discussion about the meaning of 'fitness', we prefer to avoid to use the term when possible.

*BlackMoths*:

*IF* (1) the majority of moths living on tree trunks in the Sheffield area in the late 1950s had white wings
(2) due to industrial pollution during the 1960s, the tree trunks in the Sheffield area changed from clear to dark
(3) wing color is transmitted with random variation to the next generation
(4) moths escape predators by camouflaging
(5) escaping predators is beneficial for differential reproduction
*THEN* (6) moths living in the Sheffield area changed from white to dark wings during the 1960s

Not all survival adaptations are of the escaping predators kind, there are other kinds such as food/energy supply, for instance the paradigmatic giraffe's neck case:
*GiraffeNeck*:

*IF* (1) in context *C* giraffes get food supply only from tall trees
(2) long neck facilitates reaching tall trees
(3) the length of the neck is transmitted with random variation to the next generation
(4) giraffes get energy by food supply
(5) energy supply is beneficial for differential reproduction
*THEN* (6) the proportion of long neck giraffes increases in *C*

And of course there also are adaptations that obtain not via facilitating survival but, for instance, facilitating mating, such as the also paradigmatic peacock's tail case:
*PeacockTail*:

*IF* (1) in context *C* peacocks' colorful tail facilitates (specific) visibility
(2) the color of the tail is transmitted with random variation to the next generation
(3) (specific) visibility facilitates attracting sexual partners
(4) attracting sexual partners is beneficial for differential reproduction
*THEN* (5) the proportion of peacocks with colorful tail increases in *C*

Here we have five *particular*, paradigmatic NS explanatory models that Sober claims (explicitly of the first two, and we assume implicitly of the rest) that are a priori in a sense in which common explanatory models in CM and other standard theories are not. What can he take to be a priori in them? This, and the assessment of (S), depends on how we understand the phrase 'a priori explanatory model' in this context. Let us proceed to make explicit the different possible interpretations and analyze (S) accordingly. We start with three interpretations that consider explanatory conditionals in isolation, and conclude with a fourth one that takes them as related with general guiding principles.

## Explanatory conditionals considered in isolation

The first possible interpretation of the claim (S) is suggested by a passage quoted above: "I think that Fisher's theory is a mathematical truth; *the consequent follows mathematically from the antecedent* once everything is stated carefully" (Sober 2008: 45, our emphasis; cf. also 1993). According to this interpretation, (S) would claim that *NS models are conditionals in which the antecedent logically/mathematically implies the consequent*. And it is actually true that NS contains such a priori conditionals. Yet, the immediate reaction is to contend that this is not specific to NS compared to, say, CM: given certain initial conditions, together with (a specific application of) the Second Law and certain other empirical assumptions, we a priori infer, for instance, Galileo's free fall regularities, or Kepler's planetary movement, or the pendulum trajectory, etc. For instance, if we reconstruct the CM explanatory model for Galileo's free fall law we obtain the following conditional *EarthFF*:

*IF* (1) no friction
(2) zero initial velocity
(3) $mg = md^2s/dt^2$
*THEN* (4) $s = 1/2\ gt^2$

in which (4) logically/mathematically follows from (1)–(3). Sober (2011) acknowledges this objection:

> The objection I want to consider asserts that the pattern I have described in evolutionary theory applies trivially to all scientific theories. For example, consider Newtonian mechanics (mechanics + gravitation) which is generally taken to be an empirical theory. Since this theory (*T*) allows one to deduce a prediction (*P*) from a specification of initial and boundary conditions (*IB*), we can construct a conditional of the form 'If *IB* and *T*, then *P*' that is a priori true.
>
> (Sober 2011: 581–582)

This initial possible interpretation cannot then be atributed to Sober. After claiming that this was not his intended sense, he now presents what he wanted to mean thus

> [T]he situation in evolutionary theory is different. The models I have described are a priori; they have the form 'If *IB*, then *P*'; *there is no empirical law in the antecedent*. (Sober 2011: 582; our emphasis)

Yet this claim is not transparent, it has different readings depending on how we interpret the crucial sentence "they have the form 'If *IB*, then *P*'; there is no empirical law in the antecedent". We think there are three possible interpretations. In this section we analyze two of them that take explanatory models in isolation; in the next section we analyze the third one that links particular explanatory models with a general NS principle.

The first interpretation is suggested by the fact that in the description that Sober (1993:-16) does of Fisher's model, he does not mention *anything but initial and* *boundary conditions* as components of the antecedent (he does not mention *SexRatio* (4) or (5), without which the implication does not do, more on this later). So the first reading is to interpret that in these models the antecedent that *logically/mathematically implies* the explanandum contains only initial and boundary conditions *I* & *B*, and *nothing else*. According to this interpretation, (S) therefore reads as follows:

(S1) NS, and (few) other theories, contain a priori (causal) explanatory models in a sense in which CM, and (many) other theories do not, namely: *NS models are conditionals of the form 'If I & B, then P', in which the antecedent logically/mathematically implies the consequent and contains only I and B, nothing else*

We think that (S1) cannot be true. Moreover, Sober cannot endorse it for it is in tension with what he says in related issues. If what Sober meant by (S) were (S1), then Fodor (2008a, b,—and Fodor and Piattelli-Palmarini 2010a, b) would actually have a quite strong point: different explanatory models in NS would have *nothing (adaptive) in common* since *I* and *B* change from one explanation to another. Yet, in his discussion with Fodor, Sober (2008; Sober and Fodor 2010) correctly insists that different adaptive explanatory models share adaptive components which are explanatorily essential (though, according to him, a priori).[3] And Sober is right, and Fodor is wrong, precisely because (S1) can't be true: we have seen, for instance, that Fisher's explanation makes essential use of *SexRatio* (4)–(5), shared by all sex-ratio models, without which the derivation does not hold, *but* neither (4) nor (5) are initial or boundary conditions.

*SexRatio* (3) does not change in sex ratio models either, but it may count as a general initial condition common to all sex ratio models (actually, a transmissibility-with-variation of the relevant trait condition is included in all NS models). This does not work for *SexRatio* (4) and (5). To say that the mother's benefit provided per son/daughter is the son's/daughter's average reproductive contribution is neither an initial nor a boundary condition. Nor is the fact that maximizing energy benefit is good for differential reproduction. And the same applies to the two last premises in the other explanatory conditionals above. To say that zebras escape predators by running, or that black moths escape predators by camouflaging, is neither an initial nor a boundary condition (that fast zebras are better at evading lions than slow zebras, is empirical and a non-accidental regularity, i.e. nomological; more on this below). Neither is the fact that escaping predators is beneficial for differential reproduction. We have a particular proposal to make for the status of these clauses that will be defended below, but bracketing it now for a moment, we take it as uncontroversial that they are neither initial nor boundary conditions. Since they are indispensable for the logical/mathematical implication, (S1) cannot then be true. The antecedent of the conditional that logically/mathematically implies the

[3] Sober may reply that all models use the concepts of fitness and heritability (personal communication). We agree that some of these non *IB* conditions may be rephrased in terms of fitness (in one of its meanings), and that they also use the notion of heritability, but sharing concepts does not suffice for answering Fodor's charge, it is also essential that the contents/facts expressed by these concepts have something adaptive relevant in common. Our proposal below specifies what this content is.

explanandum, cannot contain *only* initial and boundary conditions, neither in CM, nor in NS, nor anywhere else.[4] We must look for an alternative interpretation.

In this first reading we assumed that the conditional is logically/mathematically true: the antecedent-explanans logically/mathematically implies the consequent-explanandum. The second interpretation comes out if one takes the conditional to which Sober is referring as containing only *I* and *B* in its antecedent, not as logically/mathematically true but just as a priori (yet not logically/mathematically) true. That is, in NS the explanatory models are conditionals *IF I* & *B*, *THEN P* with only *I* and *B* in the antecedent, in which the antecedent *I* & *B* a priori (yet not logically/mathematically) implies the consequent *P*. (S) would then read as follows:

(S2) NS, and (few) other theories contain a priori (causal) explanatory models in a sense in which CM, and (many) other theories do not, namely: *NS models are conditionals of the form 'if I & B, then P', in which the antecedent* a priori *(yet not logically/mathematically) implies the consequent and contains only I and B, nothing else*

How to assess (S2)? Take an a priori yet not logically true conditional such that "*IF* John is a bachelor, *THEN* John is not married". There exists some additional content, namely "bachelors are unmarried", which is a priori and such that added to the antecedent makes the resulting conditional "*IF* John is a bachelor & bachelors are unmarried, *THEN* John is not married" logically/mathematically true. Generalizing: if *IF X*, *THEN Y* (with *X* and *Y* not being a priori) is not logically/mathematically true but is nevertheless a priori true, there is *Z* such that *IF X* & *Z*, *THEN Y* is logically/mathematically true, and (when *Z* alone does not imply *Y*) *Z* is a priori. Thus, in this interpretation Sober would be committed to saying that in NS explanatory models, with the antecedent completely reconstructed for it to *logically/mathematically* imply the explanandum, the premises that are neither initial nor boundary conditions (e.g. that zebras escape predators by running, that moths escape predators by camouflaging, etc.) are themselves a priori.

According to this interpretation, then, Sober would be committed to saying that, in the above NS logically/mathematically true conditionals, *all* the components in the antecedents that are neither initial nor boundary conditions, are a priori knowable—in a sense in which the corresponding components in CM conditionals are not. We find this claim hard to defend. The fact that zebras (and other animals) escape predators by running, or that moths (and other animals) escape by camouflaging, do not seem knowable a priori in any reasonable sense of the term. And if one wants to claim that such facts are a priori, then, without additional argument there is no reason for not to apply the same terminological convention to non-*I* & *B* components in the antecedent of CM explanatory models. If this interpretation is the way that Sober wants to go, he needs to clarify a sense in which

[4] One might try to argue (Sober, personal communication) that the penultimate component of the antecedents (*SexRatio* (4), *ZebraLion* (3), *BlakMoths* (4), etc.) are empirical, general and with modal import, but also qualify as initial conditions. Yet, if (departing from what we think is standard) one reshapes the notion of initial condition for it to include empirical modal regularities of this kind, then the same move could be done in CM.

non-*I* & *B* conditions are a priori in NS but not in CM. In the absence of this further clarification, (S2) does not do either.

A last option is to weaken (S2) claiming that, although not all non-*I* & *B* components are a priori, *some* are, in particular the last component of the antecedent in our reconstructions, the one that establishes that some function is beneficial for differential reproduction; and that this is not the case in CM and similar theories. This would rescue a sense in which NS explanatory models contain *something* that is a priori which lacks in CM and other common theories. But, are conditions of the form "… is beneficial for differential reproduction" a priori? No, they are not. It might be true that in some cases these facts seem easier to know than other conditions such as "black moths escape predators by camouflaging". But this does not mean that they are knowable a priori in the sense that their justification is independent of empirical information. It is not. Their justification depends on empirical information. That stronger males do better as regard reproduction, is something one learns from experience, likewise with escaping predators, or food supply or attracting sexual partners. With all generality, then, the connection between specific functions/behaviors and long term differential reproduction is not a priori.[5] Thus in *particular* NS explanatory models, non-*I* & *B* conditions, *all* non-*I* & *B* conditions, are empirical.

This exhausts what we think are the possible interpretations of (S) that take explanatory models in isolation. We think, though, that there is still one more possible interpretation, related to what we believe is the correct reading of the non-*I* & *B* conditions in the antecedent, that links particular explanatory models with a general NS principle.

## Explanatory conditionals and guiding principles

We have seen that, in the conditionals that summarize NS-explanatory models, the antecedent that logically/mathematically implies the explanandum essentially includes, in addition to *I* & *B*, something else, *Z*, that is not a priori. Nevertheless, we believe that the empirical status of this non-*I* & *B* component *Z*, though a posteriori, differs in some relevant respects from that of *I* and *B*. On the basis of this difference, one might perhaps (with some terminological unorthodoxy) qualify these models as a priori. Yet, we are going to argue that one finds the same difference in CM.[6]

[5] This is so even in sex ratio models. The relation, in different fecundity models, between increasing the number of offspring and long term differential reproduction is far from a priori, and actually in some cases having fewer offspring (Fialkowski 1987), or sacrificing some (Einum et al. 2000), is more fecundity-adaptive.

[6] The comparison in this section between NS and CM focuses on NS general adaptive principle and Newton's Second Law, and is completely independent of other comparison made, and discussed, in the literature between NS and Newtonian theory focusing in so-called "zero-force laws" (Sober 1984; Matthen and Ariew 2002; Walsh et al. 2002; Stephens 2004; Brandon 2006, 2010; McShea and Brandon 2010; Brandon and McShea 2012, Barrett et al. 2012).

What is the status of this non-$I$ & $B$ component $Z$? Take e.g. *SexRatio* (4) and (5). *SexRatio* (5) is a general adaptive fact common to all optima models, in this case applied to reproductive-energy optimization. *SexRatio* (4) specifies, for this particular case, what the energy-benefit consists of. As we saw, both are essential for the derivation and neither is an initial or a boundary condition. According to our proposal, *SexRatio* (4) and (5) together express the particular application, to the 50–50 sex ratio explanandum, of a general adaptive NS principle, which we call the NS Guiding Principle (NSGP, pretty similar to PNS):

NSGP A fitter, transmissible trait $t$, i.e. a transmissible trait that in a context $C$ facilitates the performance of an adaptive function/behavior $f$, increases, *ceteris paribus*, its frequency in the population in $C$

In short: fitter[7] transmissible traits are beneficial for (positive) differential reproduction.

There are some aspects of this version of the general NS principle that might be discussed, but nothing in our account hinges on this. We could use, with slight modifications, PNS above, or other similar versions[8]; we prefer our NSGP simply for it highlights some features we want to emphasize. Our claim is that, whichever our preferred formulation of the general NS principle is, *SexRatio* (4) and (5) express the particular application, or *specification*, of this principle to the particular sex ratio explanandum. Every particular NS explanatory model/conditional specifies, together with $I$ & $B$ conditions, the trait $t$ in point and a function/behavior $f$ that is (i) beneficial for differential reproduction and (ii) performed better with than without the trait (we find this proposal congenial to the one defended in Brandon 1996: 51–52). In the *SexRatio* case: $t$ is the particular 50/50 sex ratio reproductive behavior and the function $f$ is the optimization of reproductive energy, specified in (5), together with what counts as the relevant value to optimize, i.e. the benefit specified in (4). Thus, (4) and (5) together specify, for the particular case of the 50/50 sex ratio explanandum, the relevant function/behavior left open in NSGP, and claim that it is beneficial for differential reproduction. It is in this sense that NSGP "implicitly appears" in particular NS models:the non-$I$ & $B$ components introduce the *essentially adaptive* conditions that specify the trait and the adaptive function in point.[9] This is why they *are* NS explanatory models.

7 'Fitter' not in the sense of having greater probabilistic propensity to expand, but in the above mentioned sense, i.e. solving ecological problems (Lange and Rosenberg 2011: 595–596, make a similar distinction).

8 For other, related versions of the principle, see e.g. Sober (1984, 1993), Brandon (1980, 1996), Kitcher (1993, § 2.4), Rosenberg and McShea (2008), Ginnobili (2010).

9 In *ZebraLion*, the trait $t$ is high speed, (3) specifies the function facilitated by the trait, in this case escaping predators, which makes this explanation a case, not of the "fecundity" sub-type like *SexRatio*, but of the "survival" one; and (4) specifies that such a function is, in the context, beneficial for differential reproduction. Thus *ZebraLion* (3)–(4) express the particular specification of NSGP for the particular explanandum in point. Likewise with *BlackMoths* (4)–(5), also a survival-by-escaping-predators case, though here performed not by running but by camouflaging. And similarly the giraffe's neck (with a feeding function), the peacock's tail (with a partner attraction function), or other more interesting cases like predator–prey models, or even more complex cases involving more than one function, like the explanation of color patterns in poeciliid fishes (cf. Endler 1983).

We thus claim that particular NS explanatory models are of the form "If $I$ & $B$ & $Z$, then $P$", where $Z$ is a particular application of the general NSGP for the particular explanandum in point. This provides a sense in which $Z$ could *derivatively* qualify as a priori: *if* one accepts (as we do, see below) a sense of 'a priori' according to which the general adaptive principle NSGP (or PNS, or your preferred version of the general adaptive principle) is a priori, *then* one could derivatively say that particular explanatory models are a priori in the sense that their antecedents include a component $Z$ that, though not a priori itself, is a particular application-specification of the a priori general principle to the explanandum in question. This provides a last interpretation of 'a priori model' and of (S):

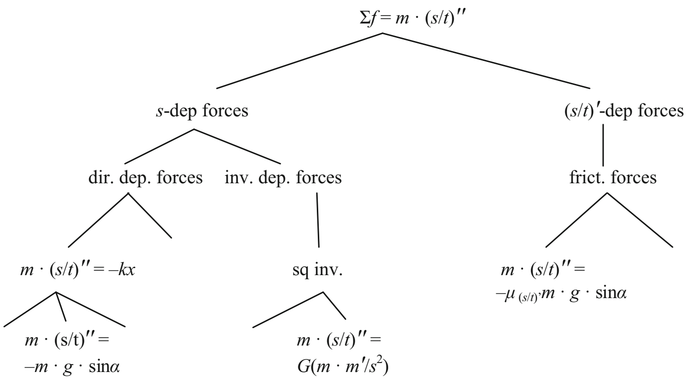
(S3) NS, and (few) other theories contain a priori (causal) explanatory models in a sense in which CM, and (many) other theories do not, namely: *NS models are conditionals of the form 'If I & B and Z, then P', in which the antecedent logically/mathematically implies the consequent, and Z is a particular application of a general, a priori guiding principle for the explanandum in point*

Yet, if this is the sense in which one claims that NS selection explanatory models are (derivatively) a priori, it does not support Sober's thesis either, for the epistemic status of NSGP, and of its particular applications-specializations in particular explanatory models, is not exclusive to NS wrt to CM and other theories but characteristic of every highly unified theory (in physics, biology or any other field). To our knowledge, the first that called attention to this general-principle-plus-specification-relation feature as essential to all highly unified theories, was Thomas Kuhn in a passage that takes, precisely, CM as a paradigmatic example:

> […] generalizations [like $f = ma$…] are not so much generalizations as generalization-sketches, schematic forms whose detailed symbolic expression varies from one application to the next. For the problem of free fall, $f = ma$ becomes $mg = md^2s/dt^2$. For the simple pendulum, it becomes $mg\mathrm{Sin}\theta = -md^2s/dt^2$. For coupled harmonic oscillators it becomes two equations, the first of which may be written $m_1d^2s_1/dt^2 + k_1s_1 = k_2(d + s_2 - s_1)$. More interesting mechanical problems, for example the motion of a gyroscope, would display still greater disparity $f = ma$ and the actual symbolic generalization to which logic and mathematics are applied. (Kuhn 1970: 465)

This Kuhnian idea has been elaborated in detail by Sneedian structuralism with the notions of *specialization* and *theory-net*, and has been applied to several unified theories.[10] For instance, the CM theory-net looks (at a certain historical moment) as follows (only some, simplified, terminal nodes are shown here, but this suffices for our present exemplification concerns):

[10] For a standard and totally precise exposition, and application to CM, Thermodynamics and other theories cf. Balzer et al. (1987). For a more informal presentation, see Moulines (2002). The program originates in Sneed (1971), and Kuhn (1976) acknowledges that it is the approach that captures his proposal best. The expression 'guiding principle' is coined in Moulines (1984).




The net has Newton's Second Law as the top unifying nomological component, i.e. as its Classical Mechanics Guiding Principle:

CMGP For a mechanical trajectory of a particle with mass $m$, the change in quantity of movement, i.e. $m \cdot a$, is due to the combination of the forces acting on the particle

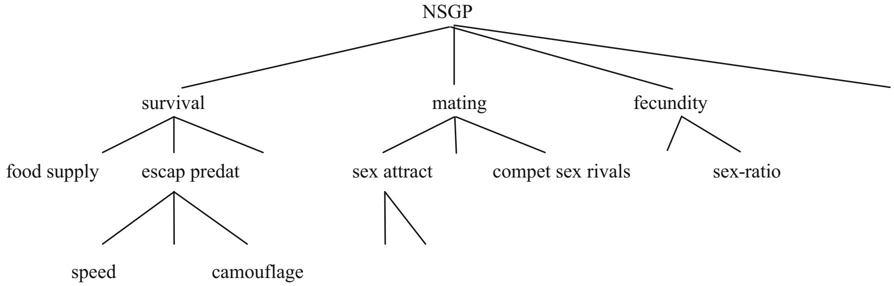
The CM guiding principle at the top specializes down opening different branches for different phenomena/explananda. This specification/branching is reconstructed in different steps: first, space-dependent forces versus velocity-dependent ones; then the space-dependent branch specializes into direct and indirect space-dependent; direct space-dependent branch specializes in turn into linear negative space-dependent and…; inverse space-dependent branch specializes into square inverse and…; at the bottom of every branch we have a completely specified law that is the version of the guiding-principle for the specific phenomenon in question: pendula, planets, inclined planes, etc. (Kuhn's "detailed symbolic expressions"). It is worth emphasizing that the top–bottom relation is *not* one of implication or derivation, but of *specialization* in the structuralist sense (Balzer et al. 1987, ch. IV): bottom laws are specific versions of top ones, i.e. they specify some parameters and functional dependences that are left partially open in the laws above in the branch.[11]

NS has a similar structure, with NSGP as its top unifying principle, specializing down toward different kinds of more specific adaptive generalizations[12]: for survival functions, for mating functions, for fecundity functions. These in turn

[11] It is in this regard that, as we noted at the beginning, the specialization relation is more similar to the determinable-determined relation than to Lange and Rosenberg's second order-first order realizers one. In both interpretations general principles are empirically unspecific and characterize only very abstractly the conceptual role theoretical entities, but it is essential to guiding principles that they mention at least the *kind of thing* one has to look for in the specializations, a feature that is not captured by a purely second order characterization.

[12] Note that what makes something a guiding principle worth to occupy the top of the net, is not simply that it is "general", but that it possesses the kind of generality that unifies the different applications of the theory by having open parameters that different specializations specify step by step. This is why some general adaptive principles (such as the so-called Fisher's Fundamental Theorem, the Hardy–Weinberg Law, or some general mathematical models developed by Haldane and Wright) do not qualify as guiding

specialize down to more specific functions: food supply, escaping predators,… as different survival functions; attracting sexual partners, competing with sexual rivals,… as different mating functions, etc. The escaping predators node specializes in turn through different functions, such as increasing speed, improving camouflage,[13] and so on. The theory-net has roughly the following structure (Díez and Lorenzano 2013, for a more complete reconstruction, see Ginnobili 2010):




At the bottom of this net we find particular NS explanatory models, such as *SexRatio*, *LionZebra*, *BlackMoths*, *GiraffeNeck* and *PeacockTail*. In all these models we find the "If $I$ & $B$ & $Z$, then $P$" form, with $Z$ specifying particular adaptive regularities that specialize the general NSGP.

This brief sketch suffices to underline the similarities between NS and CM, and other unified theories, which are relevant to our case. Particular explanatory models in CM at the bottom of the CM theory-net, such as *EarthFF* above, also show the same "If $I$ & $B$ & $Z$, then $P$" form, with the nomological (i.e. non-accidental) component $Z$ that specializes the general guiding principle (note that *EarthFF* (3) is precisely the form that, according to Kuhn, Newton's Second Law takes for free fall). And we find a similar structure in other unified theories, not only in physics but also in biology, such as Mendelian Genetics (Lorenzano 2000).

We can see now that (S3) does not do either: the sense in which NS models can qualify derivatively as a priori in that they include a non-$I$ & $B$ component $Z$ that has modal import and is a specialization of the a priori NSGP, also applies to CM and all unified guiding principle-driven theories. There is no difference in this regard.

The only alternative to defend (S3) is to claim that there is a difference with regard apriority between guiding principles *themselves*; that is, that NSGP is a priori but CMGP is not. In such a case, NS models could qualify derivatively as a priori while CM models could not. In the next section we show that this last try does not do either.[14]

Footnote 12 continued
principles *for the whole NS theory-net*, although they may perfectly well be the dominating principle in some sub-branch.

[13] Some functions, such as camouflaging, may serve different adaptive needs, such as escaping predators (e.g. black moths) and food supply (e.g. chameleons). We will not enter into these complications here.

[14] Kuhn himself claims that his generalization-sketches have a peculiar epistemic status, which he characterizes by using the expressions *quasi-analytic* (cf. Kuhn 1970: 304 n. 14; 1976: 198 n. 9) and even *synthetic* a priori (cf. 1989: 22 n. 19; 1990: 317 n. 17); we think that the idea is similar to ours (cf. also

## Do NSGP and CMGP differ with regard apriority?

If we understand 'a priori' in a way that it applies, together with logical implications, only to "bachelors are not married" kind of cases, then CMGP is not a priori, but NSGP neither. The issue is whether there is a broader, yet still acceptable sense of 'a priori' that applies to NSGP but not to CMGP. Let us quickly check the best candidates.[15]

### Justifiable independently of the experience

According to this sense (the objection would go), Newton's Second Law would not be a priori since it was established with the aid of empirical information. Yet, if what matters is how the principle was *actually* established, there is no difference with regard to the general adaptive principle; Darwin used a great deal of empirical information as well, as his work witnesses. And if (as it should be) what matters is whether the principle *can* be established without the aid of empirical evidence, then both need empirical aid as well.

### Concept constitution

One might say that NSGP is a priori in that it is "concept constitutive", it constitutes (perhaps together with other things) the meaning/content of NS theoretical terms/concepts. We agree that guiding principles are constitutive of theoretical concepts (Díez 2002, Lorenzano 2006), and also that this qualifies them as a priori in a relevant sense (the *relative*-a priori sense). There actually is wide agreement that T-laws constitute the meaning/content of T-theoretical terms/concepts (the disagreement lies in which laws and how). But even if one departs from this agreement, and denies that (some) T-laws constitute T-concepts, what matters to our case is that one must *prima facie* take the same general stance. If one is willing to defend that NS-laws, and at least NSGP, constitute the NS-theoretical concept of fitness but that no CM-law, not even CMGP, constitute the CM-theoretical concept of force, then the burden of the proof lies on her side.

### Revisability

Another option would be to claim that one may say that CMGP is not a priori since it has been revised, but that NSGP is since it is not revisable. Yet, all we know is that NSGP has not (*yet*) been revised, which does not mean that it is not revis*able*. And our current feelings do not matter at all: for almost two centuries scientists felt that Newton's core principles were non-revisable. On the other hand, we already

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Footnote 14 continued
Earman and Friedman 1973 for a classical discussion about the epistemic/empirical status of Newton's Second Law and other mechanical laws).

[15] We do not aim to make here even a brief overview of the vast literature and discussion on apriority, conceivability and related notions. The following comments are confined to our NS *vs* CM case and apply only in this respect.

know that concept constitutive principles are revisable: that combustion consists in expelling a substance is constitutive of the concept "phlogiston" though of course revised and abandoned more than two centuries ago.

## Empirical non-restriction and heuristic character

Other option is to defend that NSGP is a priori in that it is merely programmatic, it says empirically "almost nothing". We agree, but also claim that this applies to CMGP as well. As Kuhn's quote above suggests, and Sneedian structuralism has emphasized, guiding principles, *all* guiding principles, are epistemically peculiar in that they cannot be empirically tested "in isolation", they can be tested, and eventually falsified, *only through one of their specific versions for a specific phenomenon*. In this sense guiding principles are programmatic/heuristic: they tell us *the kind of things* (a specific dynamic force, a specific adaptive function) we should look for when we want to explain a specific phenomenon. As a heuristic promise, NSGP has a clear programmatic reading: "When a trait changes in a population, look for its adaptive force: a function or behavior that, in the given environment, enhances reproductive success and is performed better with than without the trait". But so does CMGP: "When mass particle changes its motion, look for forces that when combined account for its change in motion".[16]

Taken in isolation, without their specializations, guiding principles say empirically very little. They can be considered, when considered in isolation, "empirically non-restrict" (Moulines 1984). Given their schematic character, with free parameters left open, they cannot be tested even with auxiliaries, they need a concrete specification of the parameters, i.e. to take the form of a specialized law, in order to be tested (with the corresponding auxiliaries). Their knowability is tricky, for they need empirical research to be known (they are not explicit, *dispensable* definitions such as "bachelors are unmarried adult men" or "acceleration is the second derivative of space over time"), but are empirically non-restrict at the same time. One can qualify their peculiar empirical status with the term one likes best, including 'a priori', but what matters to our case is that, whatever terminology one prefers, one must qualify all them, NSGP, but also CMGP and others, alike.

## Emptiness

One may finally insist that "still, NSGP sounds more empty, void, trivial" than CMGP. We do not think so. CMGP tells us that the changes in quantity of movement *that CM takes as explananda*, must be explained in terms of specific forces we have to postulate/discover. We do not think this is less empty than saying

[16] It is worth emphasizing that, though heuristic, they are not intended to apply everywhere. There are trajectories that CMGP does not aim to apply to; for instance the movement of a pen in somebody's hand at will; or more interestingly the trajectory of light beams (which for a while was considered to be a mechanical trajectory to be explained with its special law, but finally it was expelled out as a non-mechanical explanandum). Likewise there are "trait trajectories" that are not intended to be explained adaptively, e.g. series of mice with tails cut at somebody's will; or more interestingly, genetic drift or horizontal transmission phenomena.

that the changes in traits in a population *that count as NS explananda*, must be explained in terms of adaptive behaviors and fitter traits. It is true that if we conceive of adaptive functions/behaviors as those relevant for reproduction, what we claim in NSGP taken in isolation is very little, but it is also true that if we conceive of mechanical forces as those relevant for trajectory change, what we claim with CMGP taken in isolation is also very little as well. Without their specializations both principles sound equally "empty", they just tell us the kind of thing we have to look for; this is very little, but (*contra* Fodor) enough to make them something else, and more interesting, than mere truisms like "if something happens it is because of something". But again the diagnosis is the same for both NSGP *and* CMGP.

Thus there is no sense then in which NSGP does qualify as a priori but CMGP does not. This closes our analysis of (S3): (S) read as (S3) is also untenable. Thus, (S1), (S2) and (S3) are untenable. In absence of an alternative interpretation, (S) is then untenable.[17]

## Objections

To conclude, let us briefly discuss two objections (Sober, personal communication) which are worth to consider and serve to clarify some aspects of NS explanatory models.

First, one may insist that, even *if* one granted all the above, there *still* is a difference between NS explanatory models and CM, and others, explanatory models. The difference would be that the $Z$ components in CM and other mechanical theories like Relativistic and Quantum mechanics, and maybe in other theories, differ from the $Z$ components in NS and other biological theories in the following respect: the $Z$ component in mechanical explanatory models includes universal exceptionless laws while in natural selection and other biological theories they do not; the non-accidental regularities they use are neither universal nor exceptionless but, rather, domain-restricted and with exceptions (and, though with modal import, relatively contingent on the evolution of the universe). Since there is a sense of 'law' according to which laws are universal and exceptionless, antecedents in explanatory models in NS would not contain laws, and a fortiori not empirical laws, while in mechanical theories they would, thus making (S) true. This would square with Sober's worries about some so-called laws in biology not being really laws (cf. e.g. Sober 2011: 12).

This reply relies on the idea that there are no laws in biology, and thus biological explanations do not use laws (Smart 1963; Beatty 1995; Rosenberg 2001). We think, though, that this would be a verbal victory. First, there is no widespread agreement that 'law' should apply only to universal and exceptionless non-

[17] We have looked for interpretations that make the relevant conditionals (in NS but not in CM) a priori. One could argue that what Sober qualifies as a priori is not the relation between the antecedent/explanans and the consequent/explanandum, but the relation between the conditional as a whole and something else (we thank an anonymous referee for this suggestion). We have not found in Sober's works textual evidence for this interpretation. In absence of Sober's specification of what this relation could be, it is not possible to check whether it would distinguish NS from CM as Sober intends.

accidental generalizations. Many philosophers of biology, and of physics as well, accept a broader sense that does not require non-accidental generalizations to be universal and exceptionless in order to qualify as laws (Carrier 1995; Mitchell 1997; Lange 1999; Dorato 2005, 2012; Craver and Kaiser 2013; Lorenzano 2014). Second, even in physics it is hardly the case that laws are always universal and exceptionless (Dorato 2005). Third, and most important, even if there were sufficient cases in which such a difference applied, this difference would not do for Sober's case, for, in the absence of an argument to the contrary, universality and exceptionlessness do not have anything to do with a priori *vs* empirical knowability. To defend (S) on the sole basis of this alleged difference would, terminological infelicity aside, make (S) much less interesting than it was aimed to be, for it would reduce to the claim that explanatory models in NS make use of (non-accidental) general facts that are neither universal nor exceptionless. This would not be real news. And, more importantly, it would not cut where Sober initially aimed, leaving evolutionary and some other biological theories (and maybe some economic theories as well) on one side and all other theories on the other. So we think that, verbally felicitous or not, this reply does not serve Sober's goals either and he still needs to offer a clear sense of 'a priori explanatory model' that makes (S) true.

Second, even if one accepts that the explanatory conditionals of *particular* explanatory models in NS are not distinctively a priori in comparison with particular explanatory conditionals in CM, there are some more abstract or schematic NS explanatory patterns that are. For instance the following referred by Sober himself as "a simple model" (2011):

> Consider a generation of organisms in a population that all begin life at the same time. Every zygote in this generation has trait $A$ or trait $B$, so the trait frequencies, $p$ and $q$, sum to 100 %. Suppose that individuals with trait $A$ have a probability ($w_A$) of surviving to reproductive age while individuals with trait $B$ have a probability ($w_B$) of surviving. These two probabilities, $w_A$ and $w_B$, are fitnesses that pertain to viability; they say nothing about how reproductively successful $A$ and $B$ individuals would be if they managed to reach reproductive age. We assume that $A$ and $B$ individuals that manage to develop from egg to adult take the same amount of time to do so.
> If $w_A \neq w_B$, natural selection will occur. … The frequencies of the two traits at the adult stage, $p'$ and $q'$, will have the following expected values:
>
> $$E(p') = pw_A/w \quad E(q') = qw_B/w$$
>
> Here $\mathrm{w} = pw_A + qw_B$; $w$ is the average fitness of the organisms in the population at the egg stage. Notice that it follows from the above two equations that
>
> $$E(p') > p \text{ if and only if } w_A > w_B:$$
>
> In expectation, trait $A$ will increase in frequency precisely when trait $A$ is fitter than trait $B$.

We bracketed before these kind of cases for not entering in the huge discussion about the meanings of ‘fitness’, since it was not necessary for analyzing the *particular* explanatory models above. But, contrary to the specific ones, this more abstract, schematic pattern does not mention any specific explanandum, nor any specific trait or any function whose performance by the trait is relevant for differential reproduction. It just assumes that traits have different fitnesses (thus one is fitter than other), *defining* fitness as probability of surviving to reproductive age, and demonstrates that greater fitness is correlated with increasing frequency. If we reconstruct this pattern we obtain:

*Freq*

*IF* (1) The probability of surviving from *t* to *t’* of individuals with trait *A* is greater than individuals with trait *B*

*THEN* (2) The expected frequency of individuals with trait *A*(/*B*) at *t’* increases (/decreases) wrt the frequencies at *t*

Of course this implication is a priori, as a priori as the above ones. The question is: Is it a priori in the sense of its antecedent containing no empirical modal generalization? There are two readings of *Freq*. First: *Freq* (1) is a brute statistical fact that counts as an “initial condition”. Then the antecedent, that contains only (1), contains no empirical nomological regularity. *But*, in this *purely frequentist* reading of fitness, *Freq* is hardly explanatory in general, and for sure it is not in particular a NS, *adaptive* explanation of anything. It is true that you can use *Freq* to construct an explanation for some particular population and traits distribution in that population, but also an explanation for anything else, adaptive or not (or even biological or not, if one accepts non biological individuals and traits). There is nothing adaptive here. This probabilistic/frequentist reading simply says that the ratio of objects with certain property in a sample decreases/increases when the objects with the property survive/disappear more than objects with other properties. There is nothing adaptive in the antecedent (1), not even in instances of (1) when variables *A* and *B* are substituted by particular biological traits. This implication does not provide any causal/factual explanation, it is a purely conceptual, empirically useless implication, exactly like “if random device with *n* possible outcomes is not biased, then the expected frequency of each outcome is 1/*n*”.

On a second reading, (1) is not a brute statistical fact, but inferred from (or substituted by) an adaptive fact, namely that (in a context *C*) trait *A* performs better than trait *B* a function *f* that is beneficial for surviving, or reproducing, or feeding, or … But on this reading what we have is simply a masked *particular* adaptive explanation with a specific trait, function and context, belonging to a specific branch of the above NS theory-net.[18]

Sober (2011: 6) argues that the claim (*) “IF *A* is fitter that *B*, THEN *A* increases its frequency” (or, in the would-promote talk, “*A* is fitter than *B* would promote that *A* increases its frequency”) provides causal information, for one may, for instance, artificially select fruit flies for longer wings allowing only fruit flies with long wings

[18] The same applies to the application of *Freq* across generations in order to “explain” the substitution of one trait by another.

to breed, obtaining a population with longer wings; and after that one can reverse the selection allowing only the fruit flies with shorter wings to breed, obtaining a decline of average wings' length. According to Sober, this simple manipulation experiment "provides an excellent reason to think that fitness differences cause changes in trait frequencies". But it is obvious that here 'fitness' does not just primitively refer to the probability/frequency of individuals with the trait to survive. Here 'fitness' refers to the capacity of the trait to perform a function which is, in the context, relevant for differential reproduction; in this case of artificial selection the function is simply being chosen by the (intentional) selector for breeding.

Sober's (*) is similar to the conditional (**) "IF coin 1 is more biased towards heads than coin 2, THEN, when tossed $n$ times, coin 1 will land heads more often than coin 2". If 'biased towards heads' simply means "lands heads more frequently", then (**) is analogous to "IF $A$ is bachelor, THEN $A$ is unmarried", with no causality or factual explanatory relation involved.[19] If 'biased towards heads' means "manipulated in such and such physical manner", then (**) provides factual/causal explanatory information: the fact that the coin is biased, in this sense of being manipulated in specific physical manner, causally/factually explains that it leads more heads. In one reading we have a conceptual/linguistic a priori "explanation"; in the other reading we have a factual/causal explanation. No reading gives you *both* causation and the apriority that Sober wants.

## Conclusion

We have shown that the different possible interpretations of (S) we have analyzed make (S) untenable: in the senses of 'a priori model' in which one can reasonably say that NS explanatory models are a priori, so are CM explanatory models; in the senses in which CM explanatory models are not a priori, neither NS models are. Therefore, in the absence of a new, different interpretation of "a priori explanatory model" that applies to explanantory models in NS but not in CM, (S) is untenable. We have also answered two possible objections, arguing, first, that though there may very well be differences between the non-$I$ & $B$ nomological regularities present in NS and CM explanatory models, such differences have nothing to do with knowability; and secondly, that there is no coherent reading of 'fitness' that provides *both* merely conceptual a priori content *and* causality.

If correct, this analysis helps, not only to show why Sober's thesis is untenable, but also the possible source of the mistake. Sober's intuition, against which we have argued in this paper, is that in physical theories, such as classical or quantum

[19] This answer is related to the one given by Lange and Rosenberg (2011: 594) when they claim that "The mother failed in distributing evenly (and without cutting them) the strawberries among her children because she had 23 strawberries and three children" is not a causal explanation at all. Although there is a kind of explanation involved, there is nothing relevantly causal involved. It is a purely mathematical explanation like "There remain three berries because there were five and I ate two". Note also that (terminological infelicity aside) this would not serve to Sober's goals either, for it is as easy to apply this to evolutionary concepts as to mechanical concepts. There is nothing specific "strawberry-al", evolutionary or mechanical in them, the explanation is purely mathematical.

mechanics, there are claims that are *both* general and empirical, whereas in NS (and some other theories) there are no such claims: if general, they are a priori (not empirical), if empirical, they are not general. Where may this idea come from? One possible source is the above acknowledged fact that some modal regularities used in NS explanations are more local or domain restricted than many used in physics. But as we pointed out, this has nothing to do with knowability and thereby does not serve to Sober's goals.

Other possible source may come from comparing relata of different kinds: if we compare the *general* adaptive principle with some *specific* mechanical model, we may find differences with respect to their empirical status. But if, as we should, what we compare is analogous relata, then there is no difference with respect knowability: (a) *General* NS and CM guiding principles are equally epistemically peculiar, and both deserve to be qualified, in a relevant sense, as a priori (though not the same sense of "bachelors are unmarried"). (b) If we compare the explanans of *specific* mechanical and adaptive explanatory models, we find that both contain, for the explanandum in point, particular nomological specializations of the corresponding guiding principle; although these special laws are not a priori in any relevant sense, both kinds of models may, if one wants, *derivatively* qualify as a priori in including (non-a priori) specializations of an a priori guiding principle. (c) Finally, comparing the whole CM and NS theory-nets, both include a general (a priori) guiding principle together with a hierarchized collection of special (non-apriori) nomological regularities.

Another source might be the fact that there can be NS explanations using "only" NSGP *if* you get fitness values as given. But the same happens in CM if you receive the value of the total force as given. In both cases, the received values allow you to calculate (explain?) some other value (acceleration, increase in frequency), but this "explanation" is very week (unless we know from which specific force/adaptation they come from). And weak or strong, they are alike in both cases.

A final source could be the idea that CMGP, Newton's Second Law, applies to every "trajectory", but NSGP does not apply to every change in traits proportion (e.g. genetic drift). But as we mentioned in Sect. 4 (fn 16), this is not true, CMgp does not apply to any trajectory. Related to this, Sober (personal communication) may say that classical or quantum mechanics are refutable while the general NS principle is not. Again, if we compare similar relata this is not true. Specific explanatory models in the theory net are equally refutable in NS and CM. And if we compare their guiding principles, they are also equally "refutable" in the Kuhnian sense: when too may particular explanations fail and scientists are not able to successfully fix anomalies using the guiding principle, they lose their confidence in the guiding principle and start looking for alternatives. But this happens in mechanics, biology and everywhere.

To conclude: Other possible differences notwithstanding, no difference with regard the knowability status of explanatory models in Natural Selection (and some other theories) on the one side, and Classical Mechanics (and most other theories) on the other. Sober's own (particular and general) examples of a priori causal models do not satisfy his claim (S). There might be other examples that satisfy it, but they still need to be shown.

**Acknowledgments** This paper develops and, introducing essential new elements, elaborates in detail an objection very briefly sketched in Díez and Lorenzano 2013. We want to thank D. Blanco, S. Ginnobili, C. Hoefer, E. Sober, A. Sole and two anonymous referees for their helpful comments on previous versions of this paper, and the research projects FFI2012-37354/CONSOLIDER INGENIO CSD2009-0056 (Spain), FFI2013-41415-P (Spain), PICT-2012 No. 2662 (ANPCyT, Argentina) and PIP No. 112-201101-01135 (CONICET, Argentina) for financial support.

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