**Teleosemantics and Tetrachromacy**[[1]](#footnote-0)

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**Abstract**

Teleosemantics explains mental representation in terms of etiological history: a mental state’s representational contents are the result of natural selection, or some other selection process. Critics have argued that the “swampman” thought experiment poses a counterexample to teleosemantics. In several recent papers, Papineau has argued that a merely possible swampman cannot serve as a counterexample to teleosemantics, but has acknowledged that actual swampmen would pose a problem for teleosemantics. In this paper, I argue that there are real-world cases of swampman-like representation, in the form of functional tetrachromacy. People with functional tetrachromacy are born with four types of cones in each eye, rather than the usual three, and as a result can represent a wider variety of colors than the average person. I argue that the functional tetrachromat’s additional color representations are not the result of a selection process. Functional tetrachromacy is therefore a real-world case of mental representation without an etiological history, and therefore poses a genuine counterexample to teleosemantics.

**1. Introduction**

 Some mental states are representational: they represent the world as being one way, rather than another. My belief that Paris is in France represents the city of Paris as being located within the borders of France. If Paris really is in France, then my belief is true; if Paris is not in France, then my belief is false. My belief therefore has truth conditions; it has representational contents. But where do these contents come from? In virtue of what does my mental state represent something out there in the world? One answer to this question is teleosemantics. Teleosemantics explains mental representation in terms of selection: a mental state represents because it has been selected for that purpose, e.g. by natural selection. However, this opens teleosemantics to the “swampman” objection: the possibility of randomly-generated beings with no selectional history, who nevertheless intuitively seem to represent. David Papineau (2001, 2006, 2016) has argued that merely possible swampmen do not pose a problem for teleosemantics, but that actual swampmen would pose a problem for the view. I argue that there are in fact relevantly swampman-like individuals, in the form of functional tetrachromats: people who have additional color representations due to their having a fourth cone in their retinas. I argue that these representations are not the result of natural selection or ontogenetic selection. Tetrachromats have representational mental states that are not the result of a selection process, and therefore they are a counterexample to teleosemantics.
 In section 2, I lay out the teleosemantic account of mental representation. In section 3, I outline the swampman objection, and the teleosemantic response to it. In section 4, I explain tetrachromacy, and discuss the novel mental representations that functional tetrachromats possess. In section 5, I consider a teleosemantic account of tetrachromacy based on natural selection, and reject it. In section 6, I consider possible teleosemantic appeals to ontogenetic learning, and argue that current empirical evidence does not support such appeals. In section 7, I consider several non-etiological versions of teleosemantics. In section 8, I consider the objection that tetrachromats are not sufficiently analogous to swampman, and reply to it. In section 9, I conclude that tetrachromats are apparent counterexamples to some versions of teleosemantics.

**2. Teleosemantics**

 There are many different versions of teleosemantics, each corresponding to a different theory of mental content. All versions of teleosemantics explain the contents of mental representations in terms of biological functions; otherwise, the theory would not qualify as a teleosemantic theory.

Teleosemantic theories can be divided into two categories, based on how they explain biological functions: etiological teleosemantics, and non-etiological teleosemantics. Etiological teleosemantics explains biological function in terms of selectional history, such that the biological function of a system is whatever it was selected to do (usually via natural selection). Non-etiological teleosemantic theories still explain mental contents in terms of biological function, but explain biological function in terms of something other than selectional history.

Most mainstream teleosemantic theories are etiological. For the majority of this paper, I will assume an etiological version of teleosemantics; I will discuss non-etiological theories in section 7. I primarily have in mind the consumer teleosemantic theories of Papineau (1984) and Millikan (1984), though the arguments below will also apply to the producer teleosemantics of Neander (2017).[[2]](#footnote-1)

According to etiological versions of teleosemantics, the biological function of a system is the effect that the system was selected to bring about.[[3]](#footnote-2) To use a non-representational example: the biological function of the human circulatory system is to circulate oxygen throughout the body. This is because the circulatory system was evolutionarily selected to circulate oxygen. The circulation of oxygen is precisely the effect of the circulatory system that gave our ancestors an advantage in survival and reproduction, leading their descendants to inherit the system. For the teleosemanticist, this selectional history gives the circulatory system its function: what it is to have the function of circulating oxygen *just is* having been selected for the effect of circulating oxygen.

Systems can also be decomposed into component systems, each of which has its own biological function. For example, within the circulatory system, the function of the heart is to pump blood, because the heart evolved to pump blood; it is precisely the blood-pumping effect that gave our ancestors an evolutionary advantage over their competitors. As a component of the circulatory system, the heart also participates in the circulation of oxygen. However, circulating oxygen is not the heart’s biological function, because that function is not specific to the heart. The biological function of a system, according to Papineau, is “the *most immediate* effect it is supposed to produce” when viewed as an unanalyzed whole (2016; emphasis mine). We can see that the circulation of oxygen is not the most immediate effect of the heart: if oxygen fails to circulate, that does not mean that the heart is malfunctioning; it could be that the lungs are malfunctioning (Papineau 2016).[[4]](#footnote-3)

The selection process need not be natural selection. Biological functions can also be bestowed ontogenetically, via some learning process. For example, Millikan (1984) and Papineau (1984, 1993) both take the trial-and-error learning of new behaviors to be a selection process that generates biological functions in much the same way that natural selection does. Similarly, mental states can be selected via ontogenetic learning, and can therefore acquire a biological function ontogenetically. As long as there is some selection process, there can be a biological function.[[5]](#footnote-4)

Using this account of biological functions, etiological teleosemantics reduces representational states to selectional states. What it is for mental state S to represent X is, roughly, for S to have been selected for the biological purpose of co-varying with X (Papineau 2001). Take, for example, the “seeing red” mental state one has when looking at a red apple. According to teleosemantics, this mental state represents the color red because it has been designed by natural selection to come about exactly in cases in which the object one is looking at is red. Our ancestors were better able to survive if they were able to distinguish objects of different colors, and recognize objects of the same color in different circumstances. A creature that was able to distinguish, for example, ripe red apples from rotten brown apples would have been better able to survive than one that could not, and so the “seeing red” mental state was evolutionarily selected for. The teleosemanticist argues that it is this etiological history that gives a “seeing red” mental state its representational contents.

The visual system produces an appropriate color perception state, which is then consumed by some system of later processing to output behavior (such as saying “that is red”, or eating the ripe red apple instead of the unripe green apple or the rotten brown apple). When this occurs successfully, and it results in mental states and behaviors that are appropriate to one’s circumstances, the biological function of the mental states to represent colors (and other properties) is fulfilled.

**3. The Swampman Objection**

 Teleosemantics often faces the “swampman” objection that there are possible beings (“swampmen”) that intuitively seem to represent, yet have no etiological history. The classic example is a being that spontaneously comes into existence, completely by random chance, and coincidentally happens to be an atom-for-atom duplicate of a human being (Davidson 1987). This being has no evolutionary history, and was not designed for any purpose; every aspect of the being is purely the result of random chance. As a result, the teleosemanticist must claim that swampman cannot represent. None of swampman’s mental states are the result of a selection process, and so they cannot have a function; they therefore cannot be representational according to teleosemantics.

As a result, some teleosemanticists, like Millikan (1996, 2010), deny that swampman has any mental representations. Millikan even goes so far as to deny that swampman thinks at all. She argues that since swampman’s organs have not been selected for any particular purpose, they cannot function properly or improperly. According to Millikan, swampman doesn’t truly have any beliefs, or thoughts, or visual perceptions. Although we might intuitively think that swampman has thoughts and beliefs and visual representations, Millikan thinks that this is a mistake.

 However, it intuitively seems that swampman *can* represent, and can misrepresent. Swampman seems to have beliefs, desires, and perceptions. These all seem to have truth conditions, and therefore seem to be representational. Swampman seems capable of having false beliefs, and of misperceiving the world around him. Swampman therefore seems to have mental representations. But if swampman represents, then there can be mental states with no etiological history that nonetheless represent. Representational mental states would therefore not be reducible to selectional states, and teleosemantics would be false.

 David Papineau (2001) has responded to this objection by arguing that merely possible beings cannot pose a threat to teleosemantics. On Papineau’s view, teleosemantics is an *a posteriori* scientific reduction of representation, like the scientific reduction of water to H2O. As such, the fact that there are merely possible swampmen is no more a threat to teleosemantics than merely possible water-like substances are a threat to the identity of water and H2O. The fact that there are possible worlds in which XYZ plays the *role* of water is not a threat to the *a posteriori* claim that H2O is what *actually* plays the role of water. Similarly, the teleosemanticist can acknowledge that swampmen’s mental states fulfill the *role* of representation, just as XYZ might fulfill the role of water in some possible world. However, Papineau argues, it is a true *a posteriori* fact that in the actual world the representational role is realized by selectional states, and so the correct account of representation *in the actual world* is in terms of selectional states.

Papineau’s response only succeeds if swampmen are *merely possible*. Papineau himself has said “if a swampman were to exist, then teleosemantics would simply be false” (2016; 115). If there are actual swampmen, then the representation role is sometimes realized by non-selectional states in the actual world. This would mean that representational states cannot be reduced to selectional states, as teleosemantics requires.[[6]](#footnote-5)

In fact, there is an actual condition that seems to give rise to real world examples of swampman-like representation: functional tetrachromacy.

**4. Tetrachromacy**

Tetrachromacy is a condition in which a person has four kinds of cones in each eye, as opposed to the usual three. The majority of human beings have three types of cone in each eye: a short wavelength cone (S), a medium wavelength cone (M), and a long wavelength cone (L). These are often referred to as the blue, green, and red cones, respectively. These cones are the basis of our color vision: each cone responds to different wavelengths of light, sending signals to the visual cortex and pre-cortical processing systems that allow us to represent colors (Nathans 1989).

However, in cases of tetrachromacy, an individual has four cones instead of the usual three, and in some cases this allows the tetrachromat to distinguish more colors than the average person. This is, somewhat ironically, the result of colorblindness. The genes for the L and M cones are located on the X chromosome. These genes are occasionally subject to random copying errors, resulting in anomalous cones. These anomalous cones are not the result of natural selection, but of random errors. The majority of cases of colorblindness are the result of inheriting such an anomalous L or M cone.

When a male inherits an anomalous L or M cone on his X chromosome, he will have red-green colorblindness: due to the anomalous cone, he will have difficulty distinguishing colors near the red and green wavelengths. Similarly, when a female inherits an anomalous L or M cone on both X chromosomes, she will have red-green colorblindness.

However, since human females have two X chromosomes, they can inherit the genes for an anomalous L or M cone as well as the genes for normal L and M cones; such women are called “heterozygous”. Due to random X-chromosome inactivation, the body will follow both sets of instructions, resulting in the subject having four types of cone in each eye, rather than the usual three: a normal S cone, a normal M cone, a normal L cone, and an anomalous L or M cone (Jordan et al. 2010). In most cases, this does not result in any difference in color vision. But in some cases, the heterozygote will be able to use signals from all four cones in visual processing, resulting in four-channel, “functionally tetrachromatic” vision (ibid). This results in improved color perception, and the ability to produce a wider variety of color representations that trichromats can.

One tetrachromat, subject cDa29 in (Jordan et al. 2010), has the normal three cones and an anomalous M cone. Her anomalous M cone is apparently the result of some exons from the L cone accidentally being copied onto the M cone of some past ancestor; her anomalous cone consists of four M cone exons and two L cone exons. This results in a cone with peak spectral sensitivity at a wavelength between that of the M and L cones.

Because of this cone, cDa29 can distinguish a greater variety of colors than trichromat humans can. For example, in Rayleigh tests she can accurately discriminate between an orange (590 nm) light and a mix of red (670 nm) and green (546 nm) light, when trichromats are unable to tell the difference (Jordan et al. 2010). She can discriminate between the two consistently, without error or hesitation. This suggests that she has novel color representations that she can use to make distinctions that trichromats cannot make.

As a result of her fourth cone, the tetrachromat’s visual system produces a strictly greater number of personal-level color representations than a trichromat’s visual system. Since the tetrachromat has more cones in her retina, her color representations are produced using more information about light wavelengths, and this results in her having more color-representing states. The tetrachromat does not see more colors than trichromats in the sense of seeing more wavelengths of the electromagnetic spectrum. The tetrachromat cannot see infrared or ultraviolet light, for example. But the tetrachromat has more color-representing states corresponding to the same portion of the electromagnetic spectrum, as compared to trichromats. This allows her to make chromatic distinctions that the rest of us cannot make.

The tetrachromat’s additional color perceptions are clear cases of representation, with their own truth conditions.[[7]](#footnote-6) In testing, cDa29 was able to consistently and accurately determine color differences that trichromats could not (Jordan et al, 2010). But one can easily imagine her sometimes failing to do so, perhaps under misleading lighting conditions, just as trichromats sometimes fail to distinguish color differences that they could normally distinguish. Intuitively, this would be a case of the tetrachromat misrepresenting colors that she could normally represent successfully.

The tetrachromat’s additional color-representing states, which are distinct from the trichromat’s color-representing states, are novel representations. She has representational states that are not inherited, as they are the result of a genetic mutation that likely has not given any of her ancestors these same representational states. Her novel representations are therefore not obviously the result of a selection process, as teleosemantics requires.

David Papineau argues that swampman is not a counterexample to teleosemantics because swampman is merely possible; teleosemantics only requires that the “representational role” is always realized by selectional states *in the actual world*. But if the tetrachomat’s color-representing states are not the result of a selection process, then not all actual representational states are selectional states. If that’s the case, then Papineau’s response to the swampman objection fails.

There are several options for the teleosemanticist to try to explain the tetrachromat’s novel representations. The teleosemanticist can try to argue that the additional color-representing states are in fact the result of natural selection, or she can argue that they are the result of some ontogenetic learning process. She can also abandon an etiological account of biological function, and replace it with a non-etiological account. In the following three sections, I consider each of these options.

**5. Natural Selection**

In explaining biological functions, teleosemantics most often appeals to natural selection, the evolutionary selection process that takes place over many, many generations. Recall that according to teleosemantics, what it is for mental state S to represent X is, roughly, for S to have been designed by natural selection for the biological purpose of co-varying with X (Papineau 2001). Thus if the teleosemanticist wants to use natural selection to accommodate the tetrachromat’s novel states, those states must themselves be the product of natural selection.

The problem for the teleosemanticist is that the tetrachromat’s color-representational states did not appear over the course of many, many generations. The tetrachromat’s novel color-representing states arose with no phylogenetic selection history. Statistically, she probably does not have any functionally tetrachromatic ancestors. They are novel states that even her most recent ancestors did not have. They cannot be the result of natural selection because she is likely the first person in her phylogenetic line to have them. The states are the result of a random genetic mutation, not natural selection.

 The teleosemanticist might argue that the tetrachromat’s representational states are nevertheless the result of visual components operating in accordance with their biological functions. The teleosemanticist can argue that the function of the visual cortex and other post-retinal components is simply to perform certain manipulations on cone signals. As such, even if the visual cortex receives signals from more than the usual number of cones, the states produced by the visual cortex will be produced in accordance with the biological function of the visual cortex, and consumed in accordance with the biological function of later processing systems in the brain. This would seem to explain the tetrachromat’s novel representations in a way that is consistent with teleosemantics.

 The problem with this account is that the visual cortex is only one component of the visual system that produces these signals. Recall the point made by Papineau that the biological function of a system is “the most immediate effect it is supposed to produce” (2016). It may well be the case that the biological function of the visual cortex is to perform certain manipulations on cone signals. But the important point is that it is *not* the biological function of the visual cortex to produce representational states. We can see this in the fact that a failure to produce color representations does not mean that the visual cortex is malfunctioning; the retinas or the optic nerve may be malfunctioning.

 Rather, it is the visual system as a whole, from the retina up through the visual cortex, that has as its most immediate effect the production of color representation states.[[8]](#footnote-7) And this larger system is not acting in accordance with its naturally-selected biological function when it produces the tetrachromat’s color representation states.

The human visual system was not selected to produce tetrachromatic color states, because these are novel states resulting from a random genetic mutation. Part of the tetrachromat’s visual system—her anomalous fourth cone—is not the product of natural selection. Yet it causes her visual system to produce different states that it otherwise would. The visual system was selected to produce representational color states, but it was not selected to produce *tetrachromatic* representational color states. That is an evolutionarily novel function. In producing tetrachromatic color states, the tetrachromat’s visual system is *not* acting in accordance with its evolutionarily selected biological function. Her novel representational states are therefore not the product of natural selection.

 Alternatively, the teleosemanticist might argue that even if the states are novel, they are part of a color-representation scheme that is not. One way in which teleosemantics can accommodate novel representations is when a particular relation between representations and representata has been previously defined over a continuous space. Thus even if a particular representation has never occurred before, its contents are already specified by the pre-defined relation, which is itself the product of natural selection.

 One example of this is the so-called “waggle dance” of the honeybee.[[9]](#footnote-8) Upon finding pollen, the honeybee returns to the hive and performs a dance, in which the honeybee waggles and moves in a figure-eight pattern. The number of waggles represents the distance of the pollen, with more waggles indicating further distance. The orientation of the figure-eight relative to the vertical axis indicates the direction of the pollen relative to the direction of the sun, such that a dance performed at a 30 degree angle from the vertical axis indicates that there is pollen located 30 degrees from the direction of the sun.

 The rules of the honeybee dance fix an isomorphic relation between the waggles and orientation of the dance, and the distance and direction of the pollen. The honeybee dance is clearly an example of representation, with a relation defined over a continuous space of dances and pollen locations (Shea 2013). Thus even if there has never been a dance containing 6 waggles performed at a 25 degree orientation, such a novel dance would have definite representational contents. These contents would be derived from the relation between dances and locations as already defined over a continuous space of dances and locations — a space which includes a dance with 6 waggles at a 25 degree orientation and the corresponding location. The representation relation between dances and locations has a phylogenetic selection history, and this is sufficient to fix contents for the novel representation.

 The teleosemanticist might hope that such an account can succeed in the tetrachromat case. On such an account, the contents of the tetrachromat’s novel representational states would be fixed by an existing relation between a space of color-representing states and worldly color properties. Unfortunately, this does not seem to be a plausible explanation of the tetrachromat’s novel representations.

 Subject cDa29’s responses in Jordan et al. (2010) suggest that she has “strong” tetrachromacy: her color vision seems to be genuinely four-dimensional. Whereas the trichromat’s space of color representations is three-dimensional, the tetrachromat’s space of color representations is four-dimensional. There are four dimensions — one for each cone — along which the tetrachromat’s color representations can vary. This suggests that the tetrachromat’s novel representations are not simply new states in an existing scheme, but are part of a new, higher-dimensional representation scheme. The tetrachromat’s color-representing states must therefore stand in a novel relation to the worldly properties that they represent.

 In the honeybee case, a novel waggle dance can be accommodated by teleosemantics because there are rules for determining what a given dance in the “space” of possible waggle dances would represent, and these rules are the result of a selection process. Any dance in the space of waggle dances has its contents fixed by those rules, even if the dance has not been previously performed.

 But the tetrachromat’s novel representations are not new representations in an existing space of color representations. The tetrachromat has a new space of color-representations, rather than having new representations in the original color space. Individual representations in her higher-dimensional color space cannot have their contents fixed by the rules of the original trichromat color space, because those rules only determine representational contents for representations in a three-dimensional color space. The novel, higher-dimensional color space requires novel rules for determining what representations in this new space will represent.

 If the tetrachromat simply had novel representations in an existing space of color representations, then her novel representations could be accommodated in much the same way that the teleosemanticist can accommodate novel waggle dances. But since the tetrachromat has a novel, higher-dimensional color space, her novel representations cannot be accommodated in this way.

It is important to note that the tetrachromat’s representation relation is not simply a more fine-grained version of the trichromat’s representation relation. In the Rayleigh test, subject cDa29 was able to tell the difference between a monochromatic orange light (590nm) and a mix of red (670nm) and green (546nm) light, regardless of the red-to-green ratio in the mixture stimulus. If her representation relation were simply a more fine-grained version of the trichromatic representation relation, then we might expect her to be able to distinguish, say, 590nm light from 591nm light more effectively than trichromats. But in fact, she can distinguish disparate stimuli that the trichromat cannot distinguish. The reason that the trichromat cannot distinguish these stimuli is that the stimuli are mapped to the same representational state in the trichromat’s three-dimensional color space. In effect, they are mapped to the same “location” in the trichromat’s three-dimensional color space, despite their separation on the electromagnetic spectrum. But these two stimuli are mapped to separate locations in the tetrachromat’s novel four-dimensional color space. This is why the tetrachromat is able to distinguish them without hesitation or error at any ratio and luminance. Her representation scheme is not just more fine-grained; it is higher-dimensional.

 If the tetrachromat’s color representations were simply more fine-grained than the trichromat’s, then the teleosemanticist could argue that the tetrachromat’s novel states were simply refining an existing representation relation, rather than introducing a novel representation relation. But if the tetrachromat’s color representations are defined over a higher-dimensional color space, then this seems to require a novel representation scheme. The rules for mapping stimuli into a higher-dimensional space of representations must themselves be novel, and so the tetrachromat’s color representations cannot have their contents fixed by the original trichromatic rules.

Although existing representation schemes like that of the honeybee dance can allow teleosemanticists to accommodate novel representational states, they cannot do so in the tetrachromat case. Her higher-dimensional color space is not simply a more fine-grained refinement of the trichromat’s color representations, but a novel higher-dimensional representation scheme. Her representations therefore stand in a novel relation to the worldly properties that they represent, and so their contents cannot be fixed by the trichromat’s phylogenetically selected representation scheme.

**6. Ontogenetic Selection**

Although discussions about teleosemantics usually focus on natural selection, this is not the only selection process that the teleosemanticist can accommodate. Ontogenetic selection processes are also able to bestow biological functions, at least according to most versions of teleosemantics. Millikan (1984) and Papineau (1984, 1993) both take the trial-and-error learning of new behaviors to generate biological functions in much the same way that natural selection does. In these cases, successful behaviors are retained and reproduced, while unsuccessful behaviors are not. Or, in the case of mental states, states that lead to successful behaviors are retained and reproduced over states that do not lead to successful behaviors.

Given this, the teleosemanticist could argue that the tetrachromat’s color states *are* selectional, but were selected ontogenetically. She could argue that, while the fourth cone was not selected for by evolution, the resulting representational states *are* selected for over the course of the tetrachromat’s life via ontogenetic learning. The tetrachromat’s brain would learn, presumably during the early months of life, which responses to the fourth cone’s signals lead to successful behaviors and which do not, with the successful responses being selected over the unsuccessful responses.

On this ontogenetic picture, the cone signals themselves need not be the result of any selection process. Once those signals are sent from the retina, later visual processing systems learn by trial and error which color-perception states result in beneficial behavior. Over time, behavioral feedback teaches the visual cortex what states to produce given certain combinations of cone signals. States that lead to successful behaviors are reproduced later, in response to the same cone signals, while states that lead to unsuccessful behaviors are not. The resulting states will be representational, as they are selected over other states to ensure beneficial behaviors that are only beneficial when certain conditions regarding worldly properties obtain. Thus the tetrachromat’s color-perception states can be representational, even if they are not the result of natural selection.

However, it’s not clear that this ontogenetic account is scientifically accurate. In fact, there is some evidence that this ontogenetic account is false.

Much about the neural development of the visual system is still unknown (Kiorpes 2016). However, we know that infants as young as 3 months have already developed trichromatic vision (Siu and Murphy 2018). It is hard to see how this could depend on trial-and-error behavioral learning, given that at 3 months the infants’ motor skills are still largely undeveloped; it is some months before the infants are even able to crawl.

It is true that there are “critical periods” in the development of the visual system, during which visual experience (or lack thereof) can impact the development of the visual system, and some of these periods occur before the 3 month mark (Bourne 2010). However, there is no evidence that these critical periods involve any trial-and-error learning involving behavioral feedback. In fact, as explained in Kiorpes (2016):

“What has emerged from [recent research into the rules governing visual development] is a picture of the infant visual brain, the organization of which is largely specified prenatally, based on a genetic plan, but which requires normal cell-cell interactions and activity patterns to be expressed.”

This suggests that the organization of the infant visual system is not determined by trial-and-error learning, but by genetic wiring. Indeed, Kiorpes makes it clear that “the role of postnatal visual experience is to maintain and refine that existing organization,” rather than organizing the neural structures from scratch (2016).

If the color-representing states of the human visual system were the product of a trial-and-error learning process, then we would expect that, prior to visual experience, much of the infant visual cortex would lack adult-like organization. It would be waiting for behavioral experience to provide success and failure feedback in order for it to learn. But in fact, studies have confirmed that cortical organization is adult-like even in the brains of newborns infants (Kiorpes 2016).

This does not necessarily rule out the possibility of trial-and-error learning. It is still possible for the overall organization to be largely determined by genetics, but for important details to be determined by ontogenetic learning. This may be enough for the teleosemanticist’s purposes. But there is a bigger problem for the trial-and-error learning picture: namely, the fact that representational mental states seem to predate their role in determining behavior.

On the ontogenetic learning picture, representational visual states are selected by behavioral trial-and-error; states that lead to behavioral successes are reproduced later, while states that lead to behavioral failures are not reproduced later. Thus the visual cortex selects which states to produce in response to specific cone signals on the basis of behavioral feedback.

However, current evidence suggests that the infant visual cortex produces representational states *before* the states produced by the visual cortex start influencing behavior. As Kiorpes explains, “what [the data] show is that there is high-quality visual information represented in the infant brain that is not being used to guide behavior” (2016). In fact, the findings suggest that human infants improve on purely cortical measures of visual sensitivity, like the visual evoked potential (VEP) test, faster than they improve on behavioral measures of visual sensitivity (Kiorpes 2016). This suggests that the visual cortex is producing well-developed visual representations before those states begin to influence behavior. But if that’s the case, then behavioral feedback cannot be the basis for selecting visual representational states. The states cannot have been selected based on the success or failure of the behaviors they determine if they are not yet being used to determine behavior. The ontogenetic learning picture therefore seems to fail as an explanation of the tetrachromat’s color-representing states; the states in question are produced before they play their intended role in determining behavior.

However, this is not the only ontogenetic explanation available to the teleosemanticist. Not all ontogenetic selection relies on feedback from successful *behavior*. Garson (2011, 2017) presents a general account of neural selection as a selection process in which synapses or neurons are selected over other synapses/neurons, in a way analogous to natural selection. As Garson defines neural selection, it is a process “that causes certain [neural] structures to be retained and others eliminated over a period of days, weeks, months, or years, because of their differing levels of effectiveness” (Garson 2011).

Importantly, this effectiveness need not be *behavioral* effectiveness. Unlike the trial-and-error learning considered above, neural selection does not require selective feedback involving behavioral success or failure. In neural selection, synapses or neurons are in competition over some resource; neurons and synapses are *differentially retained*, based on the success or failure of signals they send (Garson 2011). There needs to be some sort of positive and negative feedback to facilitate the selection of successful signals over unsuccessful signals, but the feedback does not necessarily need to be *behavioral* feedback.[[10]](#footnote-9) Neural selection could in theory take place before any behavioral feedback loop is in place.

This may give the teleosemanticist a way to account for the tetrachromat’s novel representational states. As Wachtler et al. point out, a fourth cone would not provide any improvement in chromatic discrimination unless there were cone-specific wiring in the tetrachromat’s brain (2007). This means that there must have been some neural development of cone-specific wiring in the brain of the functional tetrachromat, and this would presumably need to occur ontogenetically. Behavioral successes or failures are probably not involved, for reasons discussed above, but that does not rule out a neural selection process as the basis of the tetrachromat’s novel representations. As long as the neural structures underlying the tetrachromat’s color-representing states are the result of a neural selection process, the teleosemanticist can account for them on Garson’s generalized account of functions.

However, this neural development is not necessarily a case of neural selection. Garson (2011) is careful to distinguish neural *selection* from neural *construction*. Neural construction is the non-competitive construction of neural connections and structures, without the differential retention of synapses or neurons. Neural construction can be experience-dependent, but there is no competition over resources. Synapses and neurons are not *differentially retained* in neural construction. One neuron or synapse is not selected *over* another. Neurons and synapses are built and strengthened in an experience-dependent way, but they are not strengthened *because* their signals lead to any sort of success. Neural construction is therefore not a function-bestowing selection process; if it were taken to generate new functions, then the teleosemanticist would end up with an overly liberal view of biological function (Garson 2011).

Both neural selection and neural construction are known to occur in the developing brain. The formation of ocular dominance columns, for example, is known to be the product of a competition between synapses, and therefore is produced in a neural selection process (Garson 2011). Unfortunately for the teleosemanticist, current evidence suggests that many of the neural structures involved in color vision are the product of neural construction processes, rather than neural selection processes.

For example, modelling work done by Wachtler et al. (2007) suggests that cone-specific wiring in the visual cortex can be constructed via unsupervised Hebbian learning. Hebbian learning is a form of associative learning, in which the synaptic weight of neural connections increases when the neurons fire in quick succession; it is often characterized by the slogan “neurons that fire together wire together”.

As Garson (2011) explains, Hebbian learning is not a form of neural selection; it is a form of neural construction. There is no competition between neurons or synapses, and the strengthening of one neural connection has no effect on the strengthening or weakening of any other connection. In Hebbian learning, the synapses are strengthened simply as a result of repeated activation, not because of any successful effects they bring about. The synapses are not differentially retained over other synapses, and are therefore not *selected* in the sense needed for a teleological account of function (Garson 2012). If the cone-specific wiring of the visual cortex is the result of Hebbian learning, then such wiring is the result of neural construction, rather than neural selection.

Similarly, modelling work done by Eguchi et al. (2014) suggests that the development of color-selective neurons, including the spatial organization of those neurons, can be explained by spike-timing dependent plasticity (STDP). Like Hebbian learning, STDP learning is not a neural selection process. In STDP learning, there is an automatic strengthening or weakening of neural connections based on the order of pre- and post-synaptic spikes. Synaptic weight increases if the pre-synaptic spike occurs before the post-synaptic spike, and synaptic weight decreases if the pre-synaptic spike occurs after the post-synaptic spike (Eguchi et al. 2014).

STDP learning involves no competition for resources between neurons or synapses, and takes no feedback from the success or failure of any signals sent. In neural selection, one synapse must be retained or strengthened over another because of some useful effect; that is the sense in which the synapse is “selected”. The retention of one and the elimination of the other cannot be causally independent; it must be the result of a competition between them (Garson 2017).

In STDP, no synapse is strengthened *over* another. Some synapses are strengthened and some are weakened, but these events are causally independent. The synapses that are weakened are not weakened because other synapses were strengthened, nor are the strengthened synapses strengthened because other synapses were weakened. The synapses are not competing for any resource, and synapses are not differentially retained over other synapses. They are therefore not participating in a neural selection process. If the development and spatial organization of color-selective neurons is the result of STDP learning, then those neurons are the result of neural construction, rather than neural selection.

This does not necessarily mean that there are no neural selection processes involved in the development of human color vision. Much of the development of the human visual system is still a mystery (Kiorpes 2016). It is possible that some of the structures involved in human color vision are the result of neural selection processes. And even if the neural structures behind trichromatic color vision are the result of neural construction, it is still possible that neural selection is involved in the neural development of the tetrachromat’s color vision. Wachtler et al. (2007) conclude that, although unsupervised Hebbian learning can explain the cone-specific wiring of *tri*chromats, there is not enough information in natural scenes for unsupervised Hebbian learning to develop cone-specific wiring for an anomalous fourth cone with peak sensitivity between the L and M cones. This is exactly the sort of cone that the tetrachromat has. So the evidence for neural construction rather than neural selection might not apply to the tetrachromat, specifically.

It is worth noting that Wachtler et al. only consider a hypothetical tetrachromat with an anomalous L cone, rather than an anomalous M cone (2007). This would result in a different L-to-M-to-anomalous-cone ratio than subject cDa29 actually has (Jordan et al. 2010). It is possible that the ratio between cones is important in some way. There is evidence that cDa29’s cone mosaic is dominated by L cones (Jordan et al. 2010). This may be important; Hood et al. speculate that the signal sent by the anomalous M cone would be “most salient in those heterozygotes who have few M cones and for whom the normal L/M signal is weak” (2006). Wachtler et al. (2007) do not consider a variety of cone ratios, so we cannot be sure whether or not this makes a difference to the potential use of Hebbian learning to develop a fourth cone-specific channel.

It is also possible that the functional tetrachromat’s environment simply had an abnormally large amount of information in the spectrum between the L and M cones’ peak sensitivities. This would potentially allow for the development of a fourth channel by Hebbian learning. But it is also possible that the tetrachromat’s cone-specific wiring for her fourth cone is not the result of Hebbian learning at all. Instead, it could be the result of an as-yet-unknown neural selection process; the available evidence is not conclusive.

But overall, current evidence points to neural construction, rather than neural selection, as the basis for much of the neural structure underlying human color vision. In order to account for the tetrachromat’s color-representing mental states, the teleosemanticist needs them to be the result of neural selection, rather than neural construction. But the available evidence suggests that this is likely not the case.[[11]](#footnote-10)

**7. Non-Etiological Explanations**

Mainstream teleosemantic theories of mental representation agree on two key points: (1) mental representation is to be explained in terms of biological function, and (2) biological function is to be explained in terms of selectional history. Each of these claims is accepted by the teleosemantic theories posited by Millikan (1984), Papineau (1984, 1993), and Neander (2017).

However, these two claims are perfectly separable. One can endorse (1) without endorsing (2). Such a theory would not be an etiological theory, but could nonetheless be considered a form of teleosemantics. Given that tetrachromacy poses a problem for teleosemantics precisely because it lacks a selectional history, one might hope that non-etiological versions of teleosemantics fare better than mainstream, etiological teleosemantics.

Whether or not tetrachromacy poses a problem for non-etiological versions of teleosemantics depends a great deal on the details of the non-etiological replacement for selectional histories. Some versions have no trouble at all with tetrachromacy, while some fare no better than etiological theories. In this section, I will discuss what I take to be a small but representative sample of the non-etiological options.

There have been several attempts to give a non-etiological account of a trait’s biological function that still appeals to the trait’s contribution to an organism’s ability to survive and reproduce. These attempts include the ancestral history account of Abrams (2005), and a number of forward-looking accounts, such as the modal account of Nanay (2014).

Abrams (2005) gives a non-etiological account of biological function that relies on ancestral history, but does not appeal to natural selection. Abrams’s primary concern is accommodating real and hypothetical cases in which a trait T seems clearly to have a function, but in which an organism’s ancestors did not have any competitors lacking that trait (Abrams 2005). In such cases, natural selection cannot be said to have taken place, since organisms with trait T were not selected over organisms without trait T.

Abrams solves this problem by replacing natural selection with what he calls an “ancestral history relation” (Abrams 2005). Rather than comparing an organism’s ancestors to competitors that did not have the trait, the ancestral history relation compares an organism’s ancestors to yet earlier ancestors that did not have the trait. In order for an organism’s trait T to have a function on the ancestral history account, the organism must have inherited the trait from an ancestor that had trait T, and having trait T must have improved that ancestor’s fitness compared to earlier ancestors that did not have trait T.[[12]](#footnote-11)

Abrams’s account agrees with the standard etiological account insofar as an organism’s trait T cannot have a function unless that organism has ancestors with trait T, in whom the trait made a contribution to fitness and from whom the organism inherited that trait (Abrams 2005).

However, there is no reason to suppose that subject cDa29 has any ancestors with functional tetrachromacy. Having ancestors with functional tetrachromacy would not necessarily make cDa29 more likely to have functional tetrachromacy, because functional tetrachromacy is not directly inheritable. As such, functional tetrachromacy does not satisfy the ancestral history requirement for biological functions on Abrams’s account. The tetrachromat’s states have no ancestral history, and thus cannot have a function on Abrams’s account.

Alternatively, one could advocate a non-etiological version of teleosemantics that is future-oriented rather than history-oriented, defining functions in terms of future biological benefits that an organism will pass on to its descendants, rather than past biological benefits that an organism’s ancestors passed onto it. The most sophisticated such theory is the modal account proposed by Nanay (2014).

Nanay (2014) gives a modal account of biological function, on which F is the biological function of trait X iff relatively close non-actual worlds in which X’s doing F contributes to inclusive fitness are closer than any worlds in which X does F but F does npt contribute to inclusive fitness.

One might think that this suffices to explain the tetrachromat’s extra representation. If representing colors is beneficial to survival and reproduction, then surely representing *more* colors should provide an advantage in survival and reproduction.

However, it isn’t clear that tetrachromacy will benefit inclusive fitness. For one thing, the relative frequency of colorblindness in the modern population suggests that the effect that seeing more or fewer colors has on inclusive fitness might be negligible, with the result that worlds in which tetrachromacy contributes to inclusive fitness are not any closer than worlds in which it doesn’t. In fact, they might be farther. The evolutionary ancestors of mammals were originally trichromats, but mammals evolved to become dichromats, having only two cones types (Bowmaker 1998). It is only relatively recently in evolutionary history that primates re-developed trichromatic vision; most mammals are still dichromats (ibid). This suggests that having an extra cone could potentially be a *detriment* to inclusive fitness; perhaps the additional processing required to handle a fourth cone is inefficient and more effectively used elsewhere, and thus ultimately detracts from inclusive fitness. If this is the case, then worlds in which tetrachromacy contributes to inclusive fitness might actually be farther away than worlds in which it does not.

A further problem for such an account is that the odds of the tetrachromat having a tetrachromatic descendant are much lower than the odds of her having a colorblind descendant.

Tetrachromacy is the result of the tetrachromat’s fourth cone, which is itself the result of her having a normal M cone on one X chromosome and an anomalous M cone on the other. This means that each of her male children has a 50% chance of inheriting the anomalous cone and being colorblind, and each of her female children has a 50% chance of inheriting the anomalous cone and being heterozygous.[[13]](#footnote-12) But not all heterozygous women are functional tetrachromats; most heterozygous women show no signs of using the fourth cone’s signals in their color perceptions (Jordan et al. 2010). This means that the majority of the tetrachromat’s descendants who inherit her anomalous cone will see *fewer* colors, not more. If the argument is that seeing more colors is beneficial, then presumably seeing fewer colors is detrimental. The tetrachromat’s anomalous gene therefore seems to pose a net *loss* for her future descendants.

 Abrams (2005), Nanay (2014), and the standard etiological account of function all require that a trait makes some contribution to fitness, whether past or future, possible or actual. Tetrachromacy poses a problem for these views because it is a case of representation that has no phylogenetic history and seemingly makes no contribution to inclusive fitness. In order to account for the tetrachromat’s novel color states, the teleosemanticist needs an account of function that does not appeal to the history or fitness of a given trait.

One alternative to fitness-based theories of function is what is often called the “systemic” theory of function.[[14]](#footnote-13) On a systemic theory of function, the function of a component is determined not by its history, but by the role it plays in a larger organized system. As in etiological teleosemantics, systemic theories of function decompose complex systems into their components. But unlike etiological theories, a systemic theory does not consider the purpose for which that component was selected. Instead, the systemic theory considers the role that the component actually plays in the larger system.

For example, both etiological and systemic theories of function conclude that the biological function of the heart is to pump blood. The etiological theory claims that this is because the heart has been naturally selected to pump blood. On a systemic theory of function, the function of the heart is to pump blood simply because that is the role the heart plays in the circulatory system. The circulatory system circulates oxygen through the body, using blood to transport that oxygen. The heart’s role in the circulation of oxygen is to pump the blood that carries the oxygen. The heart plays no role in getting oxygen into or out of the blood, it simply pumps blood through the body. That is its contribution to the larger system. On a systemic theory of function, *that* is why pumping blood is the biological function of the heart; phylogenetic history and inclusive fitness have nothing to do with it.

Because of this, systemic theories are able to attribute a function to the tetrachromat’s novel representations. The tetrachromat’s anomalous fourth cone is playing the same role in the visual system that her other cones are playing—namely, signalling the presence or absence of specific wavelengths of light—so her anomalous fourth cone has a biological function according to the systemic theory. Similarly, the tetrachromat’s color-representing mental states play the role of color representations in the larger systems of her brain; they can be used to determine chromatic properties and to guide behavior, just as the trichromat’s color-representing states do. The tetrachromat’s color-representing mental states contribute to the successful functioning of larger systems, and therefore they do have a function on a systemic theory of functions.

One could combine a systemic theory of function with the teleosemanticist’s claim that mental representation should be explained in terms of biological function. The resulting theory, which I will call “systemic teleosemantics”, can accommodate the tetrachromat’s novel color-representing states. The fact that the tetrachromat’s color states are not the result of a selectional history poses no problem for the systemic view, as long as they do in fact make real contributions to the systems of which they are a part.

However, systemic teleosemantics abandons some of the appeal of etiological teleosemantics. For example, systemic teleosemantics has trouble naturalizing the notion of malfunction, and therefore of misrepresentation (Davies 2001). This is a serious problem, as the ability to *mis*represent is usually taken to be a necessary condition for representation. If a system cannot misrepresent, then it cannot represent at all. However, if the systemic account of function can be revised to give a satisfactory account of malfunctioning, and therefore of misrepresentation, then systemic teleosemantics could be a viable alternative that avoids the problem of tetrachromacy.

**8. Are Tetrachromats Really Swampman-like?**

The teleosemanticist might argue that the tetrachromat is not analogous to swampman, and that therefore tetrachromacy is not a case of swampman-like representation. Swampman is an atom-for-atom duplicate of a human being, but he is assembled entirely at random. Nothing about the swampman is the result of any design or selection process whatsoever; swampman’s alleged representational systems are entirely random, and thus have no biological function. The teleosemanticist might argue that in order to be analogous to swampman, the tetrachromat’s whole representational system would have to be similarly novel, and similarly without biological function. But the tetrachromat’s visual system is not entirely novel: the tetrachromat’s color-representation system is almost entirely the result of natural selection. The tetrachromat has an anomalous M cone, which has been altered by a phylogenetically recent random mutation, but her anomalous M cone is still a retinal cone with an evolutionary history. Most of the cone’s structure is the result of natural selection. It therefore has a biological function, according to the teleosemanticist, and is not a purposeless swamp-organ. The rest of the tetrachromat’s visual system is also the result of natural selection, and therefore has a biological function. The teleosemanticist might therefore argue that the tetrachromat is not analogous to swampman, and so she cannot be the real-world counterexample to teleosemantics that I have claimed she was.[[15]](#footnote-14)

 It is true that the tetrachromat is not completely analogous to swampman. The tetrachromat’s visual representation system is almost entirely the result of natural selection, and has been only slightly altered by a recent random mutation. However, the tetrachromat need not be completely analogous to swampman in order to pose a problem for teleosemantics. The tetrachromat’s novel representational states have some selectional history, but the teleosemanticist does not and should not accept this as sufficient for representation. In order for a state to represent something, it needs to have been selected *for the purpose* of representing that thing. This is a necessary condition for representation, according to teleosemantics, and it is a condition that the tetrachromat’s novel states fail to meet.

As I understand the swampman objection, swampman poses a threat to the teleosemantic account of mental representation precisely because swampman has mental states that represent, but were not selected to co-vary with their representata. Swampman’s mental representations pose an alleged counterexample to teleosemantics because they truly represent things without having been selected for that particular purpose. They are therefore representational states that the teleosemanticist cannot claim are representational.

According to teleosemantics — or at least the Papineau version of teleosemantics — representational states are *a posteriori* reducible to selectional states. What it is for a state to be representational is for it to be selected to co-vary with some representata. Therefore if there is a real-world mental state that is representational but has not been selected to co-vary with its representata, then teleosemantics must be false. This is the threat that swampman allegedly poses to teleosemantics: if swampman represents, then swampman has representational states that have clearly not been selected for that purpose.

 The tetrachromat poses a problem for teleosemantics because she has novel representational states that truly represent certain worldly properties, but have not been selected to co-vary with those properties. The tetrachromat’s visual system is the result of natural selection, and even the anomalous M cone has a selectional history. But the recent mutation in the anomalous M cone has caused it to send signals that co-vary with certain properties, and the M cone was not selected to send signals that co-vary with those properties. This, along with some non-selective neural construction processes, causes the visual system to produce novel representational states that represent particular worldly properties. These novel states can represent and misrepresent their representata, just like any mental representation can. But these novel representational states were not selected for this purpose; the states were not selected to co-vary with the worldly properties that they represent. The states are therefore representational states that were not selected to represent their representata. The teleosemantic reduction of mental representation to selectional states is therefore false.

So although the tetrachromat is not completely analogous to Swampman, she poses the same problem: she has representational states that were not selected to co-vary with the properties that they represent. Since there are actual tetrachromats walking among us, this means that there are actual representational states that teleosemantics does not account for. Tetrachromacy therefore does provide a real-world counterexample to teleosemantics.

**9. Conclusion**

 Functional tetrachromats seem to provide actual cases of swampman-like representation: they have representational mental states that are not the result of a selection process. Given the available evidence, the tetrachromat’s novel representational states appear not to be the result of natural selection or of ontogenetic selection. If so, the standard teleosemantic reduction of representational states to selectional states is inadequate, because there are actual representational states that are not selectional. The fact that the tetrachromat’s representational states are phylogenetically novel, and do not seem to contribute to inclusive fitness, poses a problem for several—though not all—non-etiological teleosemantic theories as well.

Papineau has said that “if a swampman were to exist, then teleosemantics would simply be false” because “selectional histories wouldn’t be an *a posteriori* important part of what representing agents have in common” (2016; 115). Functional tetrachromats seem to be real-world representing agents with representational states that have no selectional history. Selectional histories are therefore not an *a posteriori* important part of what representing agents have in common. As such, it seems that teleosemantics is simply false.

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2. Roughly, the difference between consumer and producer teleosemantic theories is this: consumer teleosemantics takes the contents of a signal to be fixed by the function of the system that *consumes* the signal, while producer teleosemantics takes the contents to be fixed by the system that *produces* the signal. Both versions accept the core claim that any representational state must be the result of a selection process, and that is the claim that the existence of tetrachromacy seems to challenge. [↑](#footnote-ref-1)
3. Different theories impose different conditions on function-generating selection processes. For example, Millikan (1984) requires that the selected trait be reproduced; Papineau (1984) does not. The description of teleosemantics that follows should apply to each of the main versions of teleosemantics, as should the arguments involving tetrachromacy in later sections. [↑](#footnote-ref-2)
4. It is worth noting that this account does not only apply to naturally occurring functions, but other functions as well. For example, an artificial heart has roughly the same function as a biological heart. The artificial heart’s function is not the result of natural selection, but the result of an intentional design process. This design process is what gives the artificial heart its function, just as the “design” process of natural selection gives the biological heart its function. [↑](#footnote-ref-3)
5. This allows teleosemantics to account for mental representations of objects and phenomena that are too novel to have played any role in natural selection. This will be discussed in more detail in section 6. [↑](#footnote-ref-4)
6. Papineau’s response to the swampman objection is not the only response that the teleosemanticist can take. As mentioned above, Millikan (1996, 2010) denies that swampman has any mental representations. Neander (1996) argues that even actual swampmen would not show that teleosemantics is a bad theory of broad content. Each of these responses is open to the teleosemanticist, but they are not targets of this paper. Millikan would need to deny that the tetrachromat’s novel color representations are true representations, and Neander would have to deny that the tetrachromat’s color representations have any broad contents. Each of these claims strikes me as unappealing, but I will not argue against them in this paper. [↑](#footnote-ref-5)
7. Millikan may disagree here. Millikan (1996, 2010) denies that swampman has any mental representations, and would likely deny that the tetrachromat’s color perceptions are representational. Millikan might argue that since they are not selected for any particular purpose, the tetrachromatic color perceptions have no normal or abnormal function, and can therefore neither represent nor misrepresent. However, the tetrachromat’s color perceptions *do* seem to be able to function normally or abnormally, and they do seem to be able to represent and misrepresent. The tetrachromat’s color perceptions therefore do seem to be representational, despite the lack of selection history. Nevertheless, it should be noted Millikan may be willing to bite this bullet. [↑](#footnote-ref-6)
8. Or at least a large portion of the visual system that includes the retinas, LGNs, and much of the visual cortex. Not all areas of the visual cortex are involved in color perception, and those areas will not be part of the system that has as its function the production of color representations. The important point is that color representations are produced by a system that includes areas of the visual cortex, but also includes the retina and other precortical components. [↑](#footnote-ref-7)
9. For more information about the honeybee waggle dance, see Shea (2013). The bulk of the information of the following paragraphs is taken from Shea (2013). [↑](#footnote-ref-8)
10. For example, a population of synapses sending signals to a target neuron could “compete” for a nutritive substance that is made available by the target neuron (Garson 2011). This would be competition for a proximal reward, not needing the dopamine-dependent reward signals of organism-level behavioral success (Garson 2011). [↑](#footnote-ref-9)
11. There is one respect in which this may in fact be good news for the teleosemanticist. As Bence Nanay (2014) worries, teleosemantics can seem to be a degenerative scientific research program, in the sense of Lakatos (1970, 1974): it purports to be a genuine scientific research program, but it “makes no (or hardly any) new predictions or new explanations” (Nanay 2014). However, if teleosemantics is expanded to include neural selection, then it does in fact make genuine empirical predictions. Namely, teleosemantics predicts that our color-representing mental states—apparently corresponding to neural codes in hV4 (Bannert and Bartels 2018)—are the result of neural selection, rather than the result of neural construction. Although there is some evidence pointing to neural construction as the basis for much of the neural development of color vision, many aspects of neural development are still unknown. It is an open question whether or not neural selection processes are involved in the development of color representing mental states. Teleosemantics, if expanded to include neural selection, makes the testable scientific prediction that color-representing mental states (or their neural correlates) are the result of neural selection, not merely neural construction. [↑](#footnote-ref-10)
12. This is a somewhat simplified version of Abrams’s account. Abrams does not explicitly discuss contributions to an organism’s overall fitness, but instead focuses on one collection of properties being “fitter” than another, and of causing events of a certain type more often being fitter than causing them less often (2005). This is a minor point; the important thing for my purposes here is Abrams’s requirement that there be ancestors that have the trait. [↑](#footnote-ref-11)
13. This ignores the relatively small chance that the tetrachromat could have a colorblind daughter, who would have to inherit her tetrachromatic mother’s anomalous cone *and* inherit a second anomalous cone from her father. But this only increases the odds of the tetrachromat having a colorblind child, and so does nothing to help the teleosemanticist. [↑](#footnote-ref-12)
14. See e.g. (Cummins 1975), (Davies 2001), and (Craver 2001). [↑](#footnote-ref-13)
15. Many thanks to an anonymous reviewer for pressing me on this point. [↑](#footnote-ref-14)