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SHOULD WE BELIEVE IN CELLS, OR JUST REMAIN AGNOSTIC ABOUT THEM? A CRITICAL ANALYSIS THROUGH BAS VAN FRAASSEN'S LENSES

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Abstract. For constructive empiricism, being observable or unobservable is defining for deciding about the empirical adequacy and epistemic value of theory components. The classification of microscopic images has been particularly debated. van Fraassen initially classified microscope images as unobservable and then as mere images, like rainbows. Afterwards, he claimed it is not irrational to maintain neutrality about their classification and left them in some kind of limbo between being images of something real or being mere images. Here, I provide an argument to classify microscopic images of cells as copy-qualified images. The argument is described in general terms to sustain that any unobservable entity that is derived from observable self-dividing entities and looks similar to the observable entity when detected under the microscope, corresponds to a copy-qualified image of something real. Because of the existence in nature of large observable cells that fulfil these properties, I conclude that microscopic images of cells are images of something real. This determines their empirical adequacy and epistemic value, making them hard-core and stable components of biological theories. The argument described provides a strategy to develop a more grained classification of what is observable and unobservable with the consequent implications for theory development.

Keywords: van Fraassen • observable • microscopy • cells • copy-qualified

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1. Introduction

The debate between scientific realism and antirealism stances has been continually permeated through the history of philosophy of science. The discussion is mainly focused on the epistemic and ontological position of the observable and unobservable aspects of the scientific description of the world, an issue that is crucial for determining the epistemic and ontological value of the diverse components of the different scientific theories. Among the antirealist standpoints, Bas van Fraassen's constructive empiricism was one of the most prevalent views during the second half of the past century.

For constructive empiricism being observable or unobservable defines the epistemic attitude regarding the components of theories. A tenet of van Fraassen's own view is that something is observable if it is perceived without the aid of an instrument, and in that case, we are allowed to believe in the existence of those entities (Monton & Mohler 2017, p.3). On the contrary, we can remain agnostic about the unobservable. Because of this we can only claim that what we see through a microscope are images, implicating for example the nonbelief about the existence of entities such as cells (Monton & Mohler 2017, p.9). However, in his book *Scientific Representation* (2008), he claimed that is not irrational to maintain neutrality about the classification of microscope images, leaving them in a *limbo*, between being images of something real, or mere images. van Fraassen's definition of observable, and in particular his stance about microscope images, has received intense criticism and is not shared by several philosophers including many that support constructive empiricism.

Here, I will take advantage of this undetermined position to defend the thesis that microscope images of cells correspond to copy-qualified images, in other words that they provide images of real entities. The main argument that I will put forward is that observable entities that are able to self-divide into entities that are no longer observable, but that provide microscopic images that are like those obtained from the observable entity from which they derive, can be classified as copy-qualified images. The existence of the large observable entity, and the possibility in some cases to witness that we have a microscopic image of it, such as in the case of reflections and shadows that come from a real object, allows the classification of some microscopic images as copy-qualified images.

Because of the existence of large observable cells, which through self-division give rise to cells that at some point are no longer observable by the unaided eye, but provide microscope images that are very similar to those of the observable cells, it is possible to apply the thesis proposed to microscopic images of cells. From this, I claim that cells are part of the world and not just epistemic models, corresponding to veridical entities, and endorsing the belief in cells' existence, while remaining faithful to constructive empiricism. As a consequence, we can consider cells to be a stable component of our theories having a different epistemic status compared to other entities like particles and macromolecules such as proteins and DNA. Detailed analysis, like the one offered here, should contribute to attaining a more accurate classification of observable and unobservable components of theories, advancing the understanding of science through the lenses of constructive empiricism.

2. Van Fraassen's position about observable and unobservable: the case of the microscope

2.1. The original position described in *The Scientific Image*

Constructive empiricism is the scientific, antirealistic view that van Fraassen originally proposed in his book *The Scientific Image* (1980). He claims, that "the aim of science is to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate" (van Fraassen 1980, p.12). A theory is empirically adequate when it saves the phenomena. Constructive empiricism is epistemically humble compared to realism, for which the aim of science is to get the truth about the world (Chakravartty 2017).

The separation between observable and unobservable entities is central for the empirical adequacy of theories. For van Fraassen, something is observable only if we can perceive it without the aid of an instrument (van Fraassen 1980, p.15). He is against the idea defended by realists of a continuum among observable and unobservable entities, and the impossibility to draw a line to separate them (Maxwell 1962). According to van Fraassen, accepting a theory means that what it "says about what is observable (by us) is true" (van Fraassen 1980, p.18), and that we can remain agnostic about the unobservable. Hence, it is critical to distinguish observable from unobservable because it determines different epistemic attitudes.

Some examples of observable and unobservable entities can be found in the book. Although a telescope is required to watch the moons of Jupiter, van Fraassen considers them as observable, because if we get closer, we will be able to see them directly (van Fraassen 1980, p.16). On the contrary, we can observe the trail of a particle in a cloud chamber, but the particle itself is unobservable, meaning that we can remain agnostic about those particles.

Therefore, van Fraassen's original view considers that we are not entitled to believe in things observed through a microscope. For example, seeing a paramecium, a unicellular organism, with the microscope does not allow us to claim that it is an object (van Fraassen 2008, p. 110). Thus, "one does not see cells through a microscope; instead, one sees an image, an image which the scientific gnostic understands one way but the scientific agnostic understands a different way" (Monton and Mohler 2017, p.9). Based on this van Fraassen invites us to remain agnostic about cells and use them as mere tools or models for scientific inquiry. Here, I aim to provide an argument to defend that we can believe that cells are real, while remaining faithful to constructive empiricism.

2.2. A refined proposition stated in *Scientific Representation*

Many authors including Hacking, Churchland, and Teller have raised criticism on van Fraassen's standpoint about microscope images (see section 2.3). This probably influenced him to recognize that he "did not have in mind while writing The Scientific Image some new ideas about the microscope" (van Fraassen 2001, p.162). In this section, I will summarize his refurbished description of microscope images mainly depicted in his book *Scientific Representation*.

In a first detailed catalogue of distinct kinds of images van Fraassen originally included images of things (paintings, photos), completely subjective images including private hallucinations, and images that he calls [public hallucinations], such as rainbows and reflections in water, that are not subjective because they can be captured by photography (van Fraassen 2001, p.159–160). In that work he classified microscope images as public hallucinations, like rainbows. For him, microscope images and rainbows were supposedly similar because both are optically produced, and publicly auditable (van Fraassen 2001, p.156-7). However, these hallucinations are not things or objects, they are just images, but they are not subjective because photographs of them can be obtained (van Fraassen 2001, p.162).

Afterwards, in his book *Scientific Representation* he again refined his view about microscope images and made a more grained classification of public hallucinations dividing them into two sub-kinds, denominated copy-qualified and not copy-qualified. On the one hand, the copy-qualified public hallucinations correspond to images about something real. However, these images and public hallucinations are not objects, because we cannot see the same from different places at a given time, e.g., water reflections, and shadows (van Fraassen 2008, p.105). On the other hand, the not-copy qualified subset includes images that are public hallucinations, but do not represent something real, e.g., rainbows, and mirages (van Frassen 2008, p.105).

Therefore, van Fraassen first classified microscope images as rainbow-like (van Fraassen 2001, p.157), but then, considering the classification of images just described, he added an adjustment. Besides the similarities, microscope images and rainbows are different because rainbows are not images of something real. In contrast, microscope images could be "either a copy of a real thing not visible by the naked eye or a mere public hallucination" (van Fraassen 2008, p.109). For that reason, van Fraassen maintains that it is not irrational to "keep neutrality in this respect and just think of the [microscopic] images themselves as public hallucinations" (van Fraassen, 2008, p.109). In my opinion, with the suggestion of neutrality, van Fraassen showed some irresolution, and left microscope images undefined, between the subkinds of copy-qualified (e.g., water reflection), and not copy-qualified e.g. (rainbow). Being in one or the other class points to very distinct epistemic statuses. Classification as copy-qualified alludes to images of real things and being in the other sub-kind means to be mere public hallucination images. In a more positive view, perhaps van Fraassen leaves the door open to finding new insights to take a more definitive opinion about microscopic images, something that is, of course, of great relevance for a better understanding of the empirical adequacy of the microscopic world. Here, I will take this indecision of van Fraassen's as an opportunity to provide an argument about microscope images of cells and provide support to classify them as copy-qualified images, allowing us to believe in the existence of cells.

2.3. Critique of van Fraassen's position about microscope images

The restriction of observability to entities that can be seen only by unaided eye and the doubt about the veridicality of what we observe with instruments is the source of a "general dissatisfaction with van Fraassen's treatment of the issue of observability" (Gava 2018, p.3). In particular, authors have opposed to van Fraassen's view on microscope images. To contextualize the argument that will be discussed in this work I will briefly describe some of the most salient opinions against van Fraassen's standpoint on observability and microscopes, including critiques from Hacking, Teller, Alspector-Kelly, and Gava, among others.

Ian Hacking who has a realist stance about microscope observations provides three reasons against van Fraassen's view: i) "manipulative realism", ii) "the argument from preposterous coincidence" and iii) "the argument of the grid" (Hacking 1983). Here, I describe the first two, and the third one will be discussed in section 4.

To defend the existence of entities that are not detectable by naked eye, including cells, Hacking introduced the concept of "manipulative realism", based on his idea of "don't just peer: interfere" (Hacking 1983, p.189). He claims that the ability to interfere with the cells detected under the microscope and see an effect reinforces the belief in the existence of the cells. For example, with a microscope we can follow the microinjection of a fluid into a cell, we can see the entry of the minute needle, and the release of the fluid into the cell. This practice reveals the real structure of what is detected and brings conviction about the reality of what is being observed (Hacking 1983, p.190).

Regarding "the argument from preposterous coincidence" the main idea behind it is that one can observe the same cellular structure (e.g., black spots in red blood platelets) using microscopes that are based on completely different physical principles, such as the electron and the fluorescence microscope. For Hacking, seeing similar spots in both observations, regardless of the artefacts, would be an unbelievable coincidence (Hacking 1983, p.201–2). van Fraassen's counterargument is that both observations are not independent, because it is possible that we used the observation of one microscope to calibrate the second one, in order to observe the same thing (van Fraassen 1985, p.297-8). Furthermore, he claims that the same entities interacting with similar, although not identical, instruments will produce related images (van Fraassen 1985, p.298).

Following on Hacking's criticism, Paul Teller agrees with van Fraassen's idea that some instruments produce new phenomena but considers microscopes as one important exception. For him, microscopes do not produce a pre-phenomenal object, what we see "is not an image, but the paramecium itself" (Teller 2001, p.133). There is not an intermediate or independent image, nor a new phenomenon produced by the microscope, but a direct image, what counts as observable is what we experience in real time (Teller 2001, p.134). van Fraassen replied that, based on the number of geometrical invariances and because we are unable to establish a geometrical relation between real entities and images, we are not allowed to believe in the latter (van Fraassen 2001, p.160).

Furthermore, just as Teller had pointed out, Alspector-Kelly claims that there is "no intervening observable between the eye and the slide" (Alspector-Kelly 2004, p.334) giving the "phenomenologically irresistible" sensation that looking at a cell with a microscope gives access to something that is real (Alspector-Kelly 2004, p.336). In addition, there is no justification to favor that the information gathered by naked-eye should be more reliable than the one obtained with the microscope, particularly if we accept that the human eye is a measuring apparatus with its own biological, physical, and psychological limitations (Alspector-Kelly 2004, p.338–9). For this author, the decision about what is observable and unobservable should be based on two epistemic considerations: the reliability of the causal process that connects the perceiver and the perceived, and the fidelity of the correlation between them (Alspector-Kelly 2004, p.344). In other terms, the trust in perception gained by naked-eye or by any enhancement technology needs to be based on epistemological means.

The "biological objection" is a very straightforward argument against van Fraassen's observability criteria. This is based on the case of the small mite *Histiostoma laboratorium* (Chihara & Chihara, 1993). This organism, barely visible to the naked eye, has even smaller leg-like structures that are only visible under the microscope, meaning for van Fraassen that keeping an agnostic attitude about them would not be irrational they are non-existent for van Fraassen. When these structures are removed under the dissection microscope the mites are no longer able to move, something that can be seen with the naked eye. If the legs do not exist, claim the authors, how to explain the empirical observation that the mites no longer move when these inexistent structures are removed. van Fraassen defends that constructive empiricism makes better sense of science than realism (van Fraassen 1980, p.73) but examples like the one just depicted would favor the support of a realist standpoint, especially for people getting their fly cultures infected by the legged mite (Chihara & Chihara 1993, p.657).

Another criticism of van Fraassen's stance concerns the differentiation that he makes between telescopes and microscopes. As described above, he classified the moons of Jupiter as observable even though we need an instrument - the telescope – to see them (van Fraassen 1980, p.16). It seems that van Fraassen picked an unnecessary fight, because it looks inconsistent to defend that observable are only those things that we can see with unaided eyes, and at the same time accept images obtained with a telescope as real (Gava 2014, pp.15–7). Even Kusch, one of the main adherents to van Fraassen's standpoint on the microscope debate, is not very convinced with the possibility of seeing or observing with a telescope (Kusch 2015, p.178). Perhaps the problem is that relating veridicality to observability is a "very weak criterion" (Gava 2014, p.16) and a more modest attitude is needed "acknowledging that the assertion of the veracity of an instrumentally produced image can only be vindicated with a comparison with the real state of affairs" (Gava 2014, p.19). Following on this, Contessa criticizes the weakness of using observability as a criterion for ontological commitment and states that believing in theoretical kinds, but not in the existence of individual entities, is necessary to accept a scientific theory (Contessa 2006, p.454–5).

All these views support the possibility that a constructive empiricist stance is compatible with a realist interpretation of microscopic images and describe some of the weaknesses of van Fraassen idea about microscope images. In line with this, here I offer one more argument to defend that some entities with specific properties could be real even though in most cases the microscope is needed to see them. The argument depicted here tries to use van Fraassen's own lenses to defend the veridicality of some particular objects observed by the microscope.

3. Microscope images of cells are copy-qualified images of real things

3.1. The argument of the observable self-dividing entities

The argument that I will discuss is applicable to any observable entity that self-divides into smaller entities that, at some point, are no longer observable by unaided eye, but can be detected under the microscope. The premises and the argument that I introduce here are independent of the knowledge of any theory, hence are not theory laden. The premises that sustain the argument can be outlined as follows:

(i) Large entities named "L" are observable by unaided eyes and can go through a process of self-division giving rise to entities of smaller size, denominated medium-size entities (M).[1]

(ii) The process of self-division is iterative. We can see by unaided eyes, although blurred, that M divides and gives rise to N, that is smaller in size than M; then N divides and gives rise to O, that is smaller in size than N; etc.

(iii) Self-division goes on and at some time t, it is not possible to observe any entity by unaided eyes, but it is possible to detect a microscope image S'.
(iv) L' and M' correspond to the microscope images of L and M, respectively. A rigorous and public comparison of L' and M' with S', showed a strong similarity.
(v) Because L and M are observable, we can consider that L' and M' are copy-qualified images of L and M.
(vi) Applying the transitivity property of similarity (TPS), if M' is a copy-qualified image of M, and S' is similar to M', then S' is similar to M, meaning that S' is a copy-qualified image. In conclusion, S' is an image of something real.

The main support for the argument proposed here is the existence of large observable entities that are able to self-divide, and the application of the TPS. In simple terms, the TPS states that if x is similar to y and y is similar to z, then x is similar to z. Using this property, we can explain the argument depicted above in more detail. M' is the microscope image of the large observable entity M. Following van Fraassen, M' is like the water reflection of M, so M' is a copy-qualified image of M, because M' is an image of something real implicating that M is similar to M'. In addition, M' is similar to S', because if two uninformed observers, or non-theory-laden viewers, draw what they see under the microscope they will make a very similar drawing of both images (see more on this below). Consequently, based on the TPS, if M' is a copy-qualified image of M' and M' is similar to S', then M is similar to S', entailing that S' is a copy qualified image of something real, even though we are not able to observe with an unaided eye what generates S'. Note that for this argument to be true we do not need to claim the direct observation of a putative entity S, arguing that this argument is not begging the question.

Because of this it is important to clarify doubts about the entity that gives rise to image S'. The first entities generated by self-division are observable, but at some point, the putative products of the self-division are no longer observable by unaided eyes. The fact that we are not able to observe any new entity can have two simple explanations: a) there is no generation of a new entity, or b) the new entity is not observable by unaided eyes. However, we can claim, as stated in premises (iii) and (iv) that the microscope image S' obtained after time t is similar to images L' and M'. Based on that, and because all these images (L', M', S') are derived from the same original entity L, we can consider that S' is a copy-qualified image because it is derived from an observable entity, that we know is a real object. This situation is very much like the trees that produce the water reflections or shadows, something that I will defend below. In that sense S' is not like a rainbow that is just an image produce by light interactions, as they do not have the equivalent of the tree for water reflections, or the large observable entity that self-divides like in the case that I am proposing here.

Regarding premise (iv) it is important to explain what is meant with the claim that a rigorous, and public comparison of the images is required to show that L', M', and S' are very similar. This implies that any observer should be able to describe what she sees, and all of them will provide a similar description of the images without having any previous knowledge or prejudice about the entities under evaluation. It means that randomly selected observers, following the rules of a double-blinded evaluation[2] will arrive at the conclusion that the microscope images L', M', and S' are very similar. Even more, if the images are projected on a screen, they can be compared and discussed publicly, allowing the community to reach the conclusion about the sameness of the images. In case there is agreement that L', M' and S' look the same, premise (iv) will be fulfilled.

In the same venue, someone can claim that what we are detecting under the microscope could contain some distortion. This is something that is not possible to discard because of the intrinsic properties of microscopes, but it will not affect the argument. The point I want to make here is that what we see for L', M', and S' is very similar. This conclusion would not be affected as far as the possible visual alterations are common to all of them, something we can assume if the same instrument is used for all the observations. Furthermore, when we see a tree reflected in water or its shadow, we also see some distortion, but we will not conclude from this that the tree does not exist or that it is not real. Importantly, images L', M' and S' can be obtained with the same microscope, and the use of different calibrations of the instrument should not preclude the possibility to determine if what is observed is similar between the different images.

Following van Fraassen's view about the reflection of the tree in the water supports the conclusion that microscope images of entities with the properties described here correspond to copy-qualify images. For van Fraassen, water reflections are images of something real because they support geometrical relations between three empirical phenomena: the eye of the observer, the reflection in the water, and the tree, something that is not possible to acquire for most microscope images (Kusch 2015, p.172). However, for large observable entities that can self-divide we do have a third empirical phenomena, the large entity itself, that is equivalent to the tree on the case of water reflections. The large observable and self-dividing entity together with the eye of the observer and the microscope image, provide the three empirical phenomena necessary to conclude that we have a copy-qualified image, or the image of something real.

To further understand the argument depicted, we can also rely on the concept of *ground truth*, proposed by William Seager following the discipline of remote sensing. To be able to acquire a reliable interpretation of x-ray and infrared imagery a *ground truth* is needed, meaning that "somebody, sometime went to see just what corresponded with what in an infrared image of a real field of potatoes" (Seager 1995, p.469). No such *ground truth* exists to support the interpretation of images obtained by different instruments (Seager 1995, p.475) including microscopes (Alspector-Kelly 2004, p.336). Here, I propose that large observable and self-dividing entities play the role of *ground truth* for the unobservable derivatives of those entities, as the tree plays such role for the water reflection.

I propose that the argument depicted here will apply to any entity, unobservable to the naked eye, that is derived from the self-division of a large observable entity that looks similar when detected with the microscope. Microscope images that fulfil these properties could be classified as copy-qualified images of something real. In the following section I will defend that microscope images of cells can be classified as copy-qualified images, implicating that cells are real.

3.2. Applying the argument of observable self-diving entities to microscopic images of cells

The argument described above can be applied for the classification of microscopic images of cells as copy-qualified images, allowing us to offer an answer to the recommendation of van Fraassen's about being neutral in relation to microscopic images of cells.

In nature we can find cells such as frog oocytes and zygotes that fulfil the properties of L- type entities (del Pino et al. 1986; Brown et al. 2004; Schafer et al. 2019). Typically, they correspond to spherical entities of around 1–6 mm in diameter that can be seen by unassisted eyes.[3] Importantly, these cells can go through iterative self-division giving rise to smaller cells, and at some time *t the process of cell division is no longer observable to the naked eye.* Microscopic images of observable cells, the equivalent to L and M entities, are similar to the microscopic images of unobservable cells, something conceptually equivalent to the S' images from the above section. The similarity of this kind of microscopic images has been accepted by the community of observers, after sharing many public images of cells of different kinds (Hausen & Riebesell 1991).

The first entities or cells derived from the large observable oocytes or zygotes are observable by unaided eye. However, it is important to discuss the fact that although the process of self-division is also observable directly with unaided eyes, the visualization in some cases could be faded or blurred and improved using a magnifying glass. This in no case invalidates the observations attained by naked eyes, as it is like the need for eyeglasses for reading documents with very small fonts. In those situations, we will not claim that the letters in the newspaper, or the letters in this essay do not exist, simply because we see them blurred. The eyeglasses for reading, like the magnifying glass for the observation of self-division, provide a more detailed confirmation of the faded visions obtained by naked eyes. The magnifying glasses provide a more accurate view, but we can always have in our view the real object (e.g., large zygote) and the image coming from the magnifying glass. Furthermore, when we use a magnifying lens there is no formation of an extra image besides the one formed on the observer's retina, making it difficult to defend that when using this kind of optical instrument, we are not really seeing the actual object; it would be like denying that we can see with naked eyes (Gava 2019, p.20). It is similar to what happens when we observe a reflection or a shadow: we are able to see the general shape of the real object, but not the details. Having in front of us at the same time the object and the reflection allows us to see the details. The same happens when we observe the self-division, with just unaided eyes we can see clearly that the large entity is dividing, but with the aid of the magnifying glass we can confirm that and get a more detailed view.

As a consequence, the existence of L-type cells such as large amphibian oocytes and zygotes, that can undergo self-division, guarantees that microscope images of cells are copy-qualified images of real objects. Following the reasoning depicted above, we can compare microscope images of cells with water reflections. For van Fraassen, water reflections are not objects, but they refer to something real. The main reason for this is the fact that we can observe the real thing, not just the image, e.g., we can see the actual tree that produces the water reflection. The relation to the large observable cells provides a third invariance that is missing in rainbow-like images and makes the microscope image of cells very much like water reflections, allowing its classification as *"copy" qualified* public hallucinations.

In conclusion, a microscope image of cells corresponds to a particular case of microscope images, so they can be classified as copy-qualified public hallucinations of real things, supporting the belief in cells, while remaining faithful to constructive empiricism.

4. Hacking's grid argument and the case of the Paramecium

Here, I describe two different arguments in favor of microscope images being images of something real in order to reinforce the proposal that microscope images of cells are images of real cells. As indicated above, the argument of the grid is one put forward by Hacking to defend a realist stance about microscope observations (Hacking 1983, p.202-5). Hacking's argument is based on very tiny grids, too small to be seen by naked eye, that are made from large grids that have been shrunk photographically. When looked under different microscopes, the very small grids show the same shape of the larger ones. Hacking claims that this "is veridical because we made the grid to be just that way" (Hacking 1983, p.203). For him, this is like van Fraassen's argument about Jupiter, but in this case instead of taking a long interspatial flight, we have a reliable machine that "shrinks the visible world" (Hacking 1983, p.203). van Fraassen is not convinced by this argument, he believes that it is circular and involves an inference to the best explanation (Kusch 2015, p.170).

The similarities of the grid argument with the one introduced here about large observable entities with self-dividing properties are many. The large observable entities would correspond to the large grid, that goes through a shrinking process, the self-division process, to generate minute grids, in this case the unobservable entities, that when looked under the microscope look very similar to the large observable entity or the large grid. Based on this we can give further support to the veridicality of the unobservable entities that give rise to image S', that is the microscopic cells, as Hackings claims the belief in the structure of the smaller grids. Importantly, for the grid argument it would be a gigantic coincidence that the large grid had been shrunk into a small non-grid that looks like a grid using any kind of microscope, in Hacking's words "to be an antirealist about that grid you would have to invoke a malign Cartesian demon of the microscope" (Hacking 1983, p.203), something that with the similarities described will apply also for the case of large observable entities with self-dividing capacities such as the cells.

The second argument in support of the thesis depicted in this work is the paramecium, a unicellular organism of about 0.25 mm, that has been used extensively as an example for the discussion about microscope images. Gava, in opposition to van Fraassen, defends that the microscope allowed the observation and not just the detection of the paramecium because it is possible to interact with them following its movement and obtaining different visual angles (Gava 2014, p.293). The later means that paramecia can be placed at the center of a perceptual polygon and satisfy the invariance criterion implicating that they do exist (Gava 2014, p.294), supporting the veridicality of objects observable only using the microscope. Furthermore, the microscope image of the paramecium fulfills Bueno's counterfactual dependence, that is the establishment of a particular dependence between samples and image giving epistemic support to the reliability of microscope observations (Bueno 2011, p.255-6). Importantly, as indicated, the paramecium is a cell, somewhat bigger than the average, but smaller than those oocytes and zygotes mentioned above. In that sense, all the arguments that sustain the paramecium's existence would apply to cells unobservable to the naked eye.

Accepting the existence of the paramecium is just a displacement of the observable/unobservable line, something that does not go against the antirealist view of van Fraassen's constructive empiricism (Gava 2014, p.299), who argues that his point is "not much affected by just where the precise line is drawn ... [but] would be lost only if no such line drawing was to be considered relevant to our understating of science" (van Fraassen 2008, p.110). This means also that the consideration of the cells as real will not go against constructive empiricism.

5. Objections considered

Some objections or doubts about the claim that microscope images of cells are copy-qualified images of something real can be raised. Here I will discuss the following two important concerns: i) Is the thesis defended extensive to all cells or does it only apply to cells derived from L-type cells? and ii) What about the ultrastructure of the cells (e.g., organelles)? What we detect under the microscope and is the same for all cells is the ultrastructure of cells: is it also real or is that part of the cells that corresponds to theoretical models?

The first critique could be dubbed as the non-universality argument. This critique originates from the fact that the argument defended here - that cells images are copy-qualified images of something real - is based on specific examples of zygotes and oocytes that are large and observable with naked eyes. However, in most cases the zygotes from which cells are derived are unobservable to the unaided eye. This raises the valid criticism that microscopic images of cells are copy-qualified images of something real just in those cases when the zygotes are observable, but not something that can be concluded for all cells that are observed by the microscope.

The argument discussed here considers that we have cells that are entities observable with naked eyes, and entities that are only detected under the microscope but look very similar to the microscopic images of observable cells. As described above, if an untrained observer is provided with samples of cells derived from observable or unobservable entities, she would not be able to distinguish them looking through the microscope (Hausen & Riebesell 1991). Again, based on the TPS, I claim that those unobserved entities are also cells, because they are very similar to the microscope images of observable cells (e.g., large zygotes). Thus, those images are also images of something real giving a defense against the argument of non-universality.

The second objection, that can be named as the ultrastructure argument, is the following. The thesis defended here concludes that cells are real because we can directly observe some cells, but it does not say anything regarding the cellular contents (e.g., organelles) because those are not observable with naked eyes in any circumstance. Thus, we can claim that cells exist, but we must remain agnostic about their contents. Here, I will propose that using other techniques such as cellular fractionation and Hacking's argument of "preposterous coincidence" we can support the existence of the cellular contents and avoid the contradiction about believing in the cell and not its contents.

Cell fractionation is a completely different methodological approach to studying the cellular components that is complementary to the use of microscope images. It was introduced in the first half of the past century and has been of key importance to relating microscopic images with biochemical observations and organelle function (Bechtel & Bollhagen 2019). Cell fractionation allows the separation and characterization of cellular components (e.g. organelles). The procedure starts with the disruption of the plasma membrane producing a cell homogenate, a suspension containing undamaged cellular components such as organelles. Differential or density-gradient centrifugation is then applied to the cell homogenate allowing the separation and purification of organelles based on their size and density. The presence of different organelles in each fraction after centrifugation is established measuring the presence of organelle specific proteins, usually an enzyme, or other molecular markers using biochemical methods (Lodish et al. 2008, p.391-2).

Relevant for this discussion, the results obtained by cellular fractionation correlate with the morphological observations provided by the microscope. Many examples of this have been reported, here I describe the case of peroxisomes. Peroxisomes are organelles of 0.2 – 1.0 μm in diameter mainly involved in oxidative reactions (e.g. fatty acids oxidation) that produce large amounts of hydrogen peroxide, a dangerous molecule that is rapidly eliminated by the presence of catalase, an enzyme that degrades hydrogen peroxide to water and oxygen (Lodish et al. 2008, p. 374-5). Treatment of cells with drugs that affect fatty acid metabolism results in a large increase in the number of peroxisomes observed by electron microscopy. Concomitantly, an increase in the levels of catalase activity is detected in the fraction containing peroxisomes after cell fractionation (Lazarow & de Duve 1976). Thus, the structures observed by microscopy seems to correspond to the organelle detected by cellular fractionation. Following Hacking's argument of "preposterous coincidence", it is very unfeasible that the coherent results obtained for peroxisomes, and similar outcomes described for other subcellular components, using completely independent methodologies could be explained as a mere and accidental coincidence, confirming the existence of cellular organelles detected by microscopy. In Hacking's words, the intersection with biochemistry gives further support to confirm "the structures that we discern with the microscope" (Hacking 1983, p.209).

6. Implications of considering microscope image of cells as images of real things

Does it really matter how we classify microscope images of cells? Is it relevant for the scientific endeavor if cells are mere public hallucinations, copy-qualified or not copy-qualified ones? For van Fraassen none of these qualifications should prevent scientists from obtaining empirical information, and providing medical advice, based on those images. Even more, for him the distinction between observable and unobservable is irrelevant for the discussion about empirical adequacy, as long as we define a clear separation (van Fraassen 2001, p.163). Only if that line is not established could it have implications for our understanding of science (van Fraassen 2008, p.110).

Proper classification of microscope images of cells is relevant to determining the epistemic value of cells. The epistemic question to answer is to decide whether cells are putative entities, that might or might not exist, or are part or not of the real world. It is clear that science can advance and progress in both scenarios, but to know if cells are just part of our mental ideas or part of the world will make a difference for the way we treat them. In that venue, accepting the argument defended here has immediate consequence on their epistemic value. In case that the microscope images of cells are just public hallucinations that do not represent something real, we have to consider cells as models or theoretical components of the cell theory, and we are not able to claim its vericadility. In such a case we are not able to claim that cells do exist. On the contrary, images of cells being of the copy-qualified type implies that microscope images of cells are images of something real, supporting the veridicality of cells. In this case, we can believe in cells, and not just accept them. Therefore, cells will have a different epistemic value compared to other entities like physical particles such as electrons, or macromolecules like proteins and DNA.

Steven Weinberg has proposed that theories have hard-core components which "represent permanent accomplishments" of a mature theory, that are durable and difficult to change, and soft- core parts that are easily changeable (Weinberg 1998, p.50). Based on Weinberg's terms van Fraassen challenges philosophers: "if you are going to distinguish between a hard and soft part of science, in some such way, tell us how you draw the line" (van Fraassen 2001, p.163). Here, I pick up the ball from van Fraassen, and defend that microscopic images of cells are copy-qualified images, making cells a hard-core component of our knowledge of the world, durable and difficult to change. In more general terms this should apply to any microscopic image, derived from observable entities that are able to self-divide, and produce unobservable entities that produce microscopic images with similar structures. Furthermore, I propose that a detailed analysis about the components of a theory, especially those that are unobservable, is very important to produce a more grained classification of observable and unobservable entities and determine which are hard- and soft-core components of our theories. In other words, an overgeneralization of what is observable and unobservable should be avoided and each specific case should be analyzed with approaches similar to the one described here.

7. Conclusions

Here, I defended the argument that in certain cases we are allowed to conclude that microscope images of cells correspond to images of something real and classify them, following van Fraassen, as copy-qualified public hallucinations. As a consequence, we can believe that cells are something real, and not mere scientific tools, giving them a stronger and more durable epistemic value. The main basis for this conclusion is the existence of large observable cells that self-divide giving rise to unobservable entities that look similar under the microscope. We conclude that microscope images of cells are very much like water reflections, because the large observable cells provide an actual and real reference to the microscope images, like the actual tree provides a reference of truthiness about the water reflection of it.

This classification of images of cells remains faithful to constructive empiricism and takes advantage of the opportunity provided by van Fraassen who remained neutral about the classification of microscope images. In this way, the essay should contribute to improving the resolution of van Fraassen's image classification, allowing a more accurate grouping of the observable and the unobservable. The argument described here adds to the list of arguments that have been raised against van Fraassen's stance about observables and microscope images. In the future, the identification of other microscopic images that can be considered as images of real things is an open challenge that will require further research but could aid in the understanding of science through the lenses of constructive empiricism.

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Notes

[1]Medium-size entities refer to those entities of a size relatively smaller in relation to the original large entity "*L*".

[2]A double-blinded evaluation of experimental results is one in which neither the participants nor the researchers know which intervention is being received by each participant.

[3]See images of large oocytes:
https://www.researchgate.net/figure/Figura-1-Gastrotheca-orophylax-A-Hembra-adulta-de-la-que-se-obtuvo-los-oocitos_fig1_332003071; https://i.stack.imgur.com/AUuYL.jpg

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