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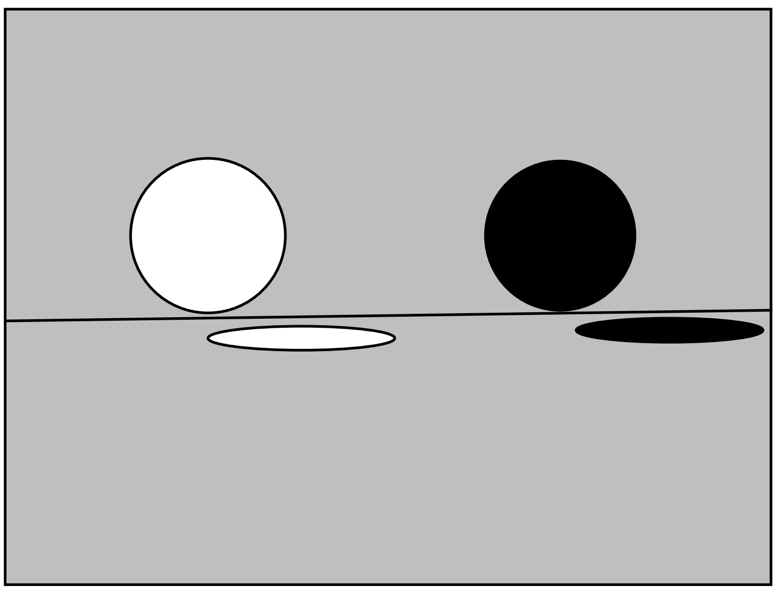
Para-reflections

Picture a white beach ball and a black beach ball afloat on a smooth lake:



The sun is shining from behind you and to your left. The white ball has a reflection because light is bouncing off the ball and onto the flat water. What about the black ball? If no light is bouncing off the black ball, then textbook definitions of `reflection' imply that it lacks a reflection. But most onlookers (unguarded physicists included) would say that the black oval adjacent to the black ball is its reflection.

1. The invisible red herring

Actually, a little light is reflected off the black ball. The blackness of a black surface is quite compatible with it reflecting light. Ancient Egyptians made mirrors from polished black granite.

Even a surface with a matte finish will reflect some light. The blackness of the object is only a relative indicator of how much light it reflects. A patch that looks black against one background will look gray against a darker background and even white against a much darker background (Land 1977, 109-16). Our visual systems are sensitive to the ratio of light differences between parts of a surface. The absolute amount of light is of minor significance. That is why we can continue to see colors fairly uniformly indoors and outdoors. When I go outside, the amount of light increases tremendously but the ratios stay about the same. Objects will look black when they contribute *relatively* little light.

This emphasis on contrast *supports* rather than undermines my thesis that we see a para-reflection of the black beach ball rather than its reflection. The absolute amount of light reflected by the black ball is visually insignificant. If one were to subtract photons from that region, people would still see an elliptical black patch. Indeed, the subtraction of photons would *increase* the sharpness of the image.

I want to stress my concession that the black ball has a perfectly standard reflection. Physicists place no minimum light requirement for reflection. In addition to reflecting the balls, the lake has reflections of the stars even though their light is swamped by sunlight. Nor is there any restriction to the visible portion of the electromagnetic spectrum. The black ball has a rich array of reflections: ultraviolet, infrared, radio, and so on.

But none of these invisible reflections are singled out when we point at the black patch adjacent to the ball. We are referring to a privational phenomenon.

The faint reflection of the black beach ball is an irrelevant distraction. We should not let its existence mask the existence of the black ball's para-reflection. The black ball's reflection and para-reflection exists in the same place at the same time. The reflection does not *camouflage* the para-reflection. We see only the para-reflection, not the reflection. The culprit is our pre-Newtonian visual system. The visual system does not treat darkness as a privation of light. As we shall see, this tendency to treat darkness as if it were substantial (or at least as substantial as light) is recapitulated in the history of optics.

2. Mind-independent privations

If a tree we falls in an uninhabited forest, does it make a sound? The question is ambiguous. `Sound' can mean a wave of a certain frequency. `Sound' can also mean an auditory sensation. Once `Does it make a sound?' is disambiguated, each of the resulting questions have easy answers.

But what if the tree fails to fall? Is it silent? This privational variation of the riddle does not suffer from the ambiguity of `sound'. If silence is the absence of waves of a certain frequency, then the undisturbed tree is silent. If silence is the absence of auditory sensations, then the tree is still silent.

The real issue is whether silence requires the expectation of sound. Jean Paul Sartre (1969, 7) contends that absences depend on human consciousness. When Sartre arrives fifteen minutes late for his appointment with Pierre, he sees the absence of Pierre at the cafe. But only because he was expecting Pierre. Charles DeGaulle is also not at the cafe. But Sartre does not see the absence of DeGaulle because he was not expecting DeGaulle.

Many people agree that *perceptions* of absence depend on the perceiver's expectations. But what about Sartre's metaphysical principle that the absences themselves also depend on human expectations? Here I disagree. Since most things are mind-independent, their privations are correspondingly mind-independent. I say that the undisturbed, unobserved tree is silent.

3. Para-reflections are mind-independent

Privations such as vacuums, holes, and silence are not subjective phenomena. The para-reflection of the black ball is not like an after-image. The para-reflection can be photographed. If there had never been any observers, there would still have been para-reflections. They are as independent of minds as reflections.

Not all para-reflections look like reflections. Consider a fluorescent button attached to a black velvet curtain. When viewed in a mirror without any further light source, many people regard only the glowing button as reflected, not the curtain. Para-reflections look most like reflections when they take center stage in a figure-ground relation. When para-reflections form a homogenous black backdrop, many people assume there is nothing there. The assumption is overridden if viewers start to picture the blackness as a table-cloth or an oil slick. Happily there is no need to linger over these peculiarities of gestalt organization.

Para-reflections do not depend on the quirks of human perceptual psychology. They are objective.

The black ball's para-reflection works by contrast rather than by the electromagnetic energy emitted by the ball. Most of the black ball's environment is being reflected in the positive way described by physics textbooks. But the area adjacent to the black ball is dark because of a combination of what the black ball's environment does (reflect visible light) and what the black ball fails to do (have a visually significant reflection).

Some privational phenomena, such as vacuums, behave according to distinctive principles. Others mimic their positive counterparts. Cold regions conform to the low-level generalizations that govern hot regions. Ernst Mach (1886, 1986) regarded heat and cold as equally real. According to Mach, cold is the absence of heat and heat is the absence of cold. He dismissed debate about who is really right as a verbal dispute. Only with subsequent realism about atoms did physicists (led by Ludwig Boltzmann) come to a consensus that the debate does not involve notational variants. In the hot and cold debate, hot wins. Cold is the absence of heat but not vice versa.

The first part of the law of reflection states that the angle at which a ray strikes a surface equals the angle at which that ray is reflected. (The second part of the law specifies that the incident ray, the perpendicular to the surface, and the reflected ray all lie in a plane.) The ancient Greeks inferred the law of reflection with the help of mirrors. Euclid's Optics and Caloptics show that the Greeks had a basic grasp of geometrical optics. However, their beliefs about light differed from ours. Anaximenes and Aristotle explained colors as modifications of light and dark. If these pioneers had been asked about para-reflections, they would have extended the law of reflection to them. Just as black balls and white balls are equally balls, the Greeks would have insisted that black reflections and white reflections are equally reflections. Johann Wolfgang von Goethe (1840) and other continental rivals of Newton would have applied the law of reflection with Greek impartiality. For Goethe agreed with the Greeks that darkness is no less fundamental than light.

Goethe and the Greeks could have used the optics diagrams of some contemporary physics textbooks. For these contemporary physicists often illustrate the law of reflection with black figures. Rays are drawn from these dark objects to the reflecting surface in strict accordance with geometrical optics.

And this works surprisingly well. Para-reflections behave just as this unblinking application of the law of reflection predicts. Major corollaries of the law of reflection go through.

For instance, a single para-reflection changes a right-handed system into a left-handed system. If you hold a right handed black glove to a mirror, the image will be of a left-handed black glove.

The nature of the reflection varies with the surface. An irregular surface creates a diffuse reflection. So if the lake becomes choppy, the para-reflection becomes more diffuse.

The sharpness of the dark image is also affected by one's point of view. The amount of light reflected from a surface increases with the angle of incidence. When you look at a puddle from straight above, it looks murky. When viewed from a distance, it is quite reflective. The artist John Ruskin spoke up for the puddle: "It is not the brown, muddy, dull thing we suppose it to be; it has a heart like ourselves, and in the bottom of that there are the boughs of the tall trees and the blades of the shaking grass, and all manner of hues of variable pleasant light out of the sky." From a distance, you can observe an eclipse reflected by the puddle. Increasing the angle of incidence strengthens the para-reflection because the extra reflected light strengthens the contrast.

Modern mirrors are highly regular and so provide sharp para-reflections. A dark mirror image is the same perpendicular distance behind the mirror as the object is in front of it. Thus the smallest plane mirror that can reflect your entire blackened body is half your height (with its upper edge lowered by half the distance between your eye and top of your head). Convex mirrors slenderize your para-reflection. Concave mirrors widen your para-reflection. Such conformity to optical principles tempt us to classify para-reflections as reflections.

The fidelity of para-reflections to standard optical principles is dramatized by images that are mixtures of normal reflections and para-reflections. Consider the mirror image of a black and white checkerboard. The black squares seem to behave with the same optical propriety as the whites squares. Indeed, we regard the reflection of the checkerboard as a unitary phenomenon. But only half of the checkerboard's squares have genuine reflections.

4. Parasitical entities

Isaac Newton demonstrated that darkness is the absence of light and not vice versa. Since there are no rays of darkness, the law of reflection does not directly apply to para-reflections. Para-reflections only obey the law of reflection parasitically. In this respect they resemble holes (Casati and Varzi, 1995). Much of the environment is reflecting light in accordance with the law of reflection. Since the environment's pattern of reflection is molded by this law, the contrast image inherits most of its optical properties. But it is the host that is governed by the law of reflection, not the parasite.

The mere fact that para-reflections owe their existence to reflections does not make them reflections. Consider Newton's rings. If you place a spherical glass surface on a flat glass surface, the multiple reflections will create circular interference patterns. The dark rings are not reflections even though they are products of reflections. When you make a soap bubble, a black spot appears just before the bubble bursts. This is also due to destructive interference between light coming from two surfaces of the bubble. When the wall of the bubble thins, light reflected at the air-to-soap surface of the soap bubble undergoes a phase reversal. Light reflecting from the soap-to-air surface has the same phase as the incident light. The two reflections come back with opposite phase and so cancel out.

There are some geometrical differences between para-reflections and reflections. Reflections require surfaces. Since light cannot bounce off of a hole, no hole has a reflection. But holes can have para-reflections. Hold a sealed styrofoam cup in front of a mirror. The entire front surface is reflected. Now punch a hole in the middle of this white cup. You will see the hole para-reflected in the mirror. But you cannot see a reflection of the hole.

Now fill in the hole's para-reflection with a black marker. This act destroys the para-reflection. The defaced mirror has a black dot but no longer has an image of the hole. If you fill in the para-reflection carefully, the result may be an overall image of the cup that is indistinguishable from the original. However, even a perfect resemblance to an image of a scene is not sufficient for being an image of that the scene. An artist could paint the whole mirror so that scene involving the cup is qualitatively identical to that originally produced by the unpainted mirror. The painted mirror is no longer reflects the scene because the mirror no longer causally sensitive to the scene. Para-reflections inherit the causal requirements of reflection. Although a para-reflection may originate from a non-surface, it must land on a surface.

Para-reflections disappear when isolated. If the environment of a para-reflection is draped in black velvet (which reflects only a negligible amount of light), then the para-reflection goes out of existence. There is only darkness. No host, no parasite.

Reflections are autonomous. If the area around the white ball is darkened, the white ball still has a reflection.

The black beach ball's para-reflection can also be destroyed by focusing more light on just the black ball. This will increase the amount of light reflected by the black ball and thereby decrease the contrast with the environment that constitutes a para-reflection. When the amount of light reflected by the black ball equals the amount of light being reflected by the ball's environment, the para-reflection ceases. The black ball will itself look grayer. If enough extra light is focused just on the black ball, it will look as white as the white beach ball. And the black ball will have a white reflection.

Silhouettes have the same relational nature as para-reflections (Sorensen 1999). A ship forms a silhouette as it sails in front of the setting sun. But once the sun goes down, the silhouette of the ship disappears. If a curtain with a single puncture is placed in front of a single light source, then we see the silhouette of the curtain. If the hole is mended, then the scene is completely dark. The silhouette has gone out of existence.

The relational aspect of silhouettes and para-reflections does not render them subjective. An object's weight depends on the body to which it is gravitationally attracted. But weight is still an objective property because the relatum is not a perceiver. An object's para-reflections are similarly independent of observers.

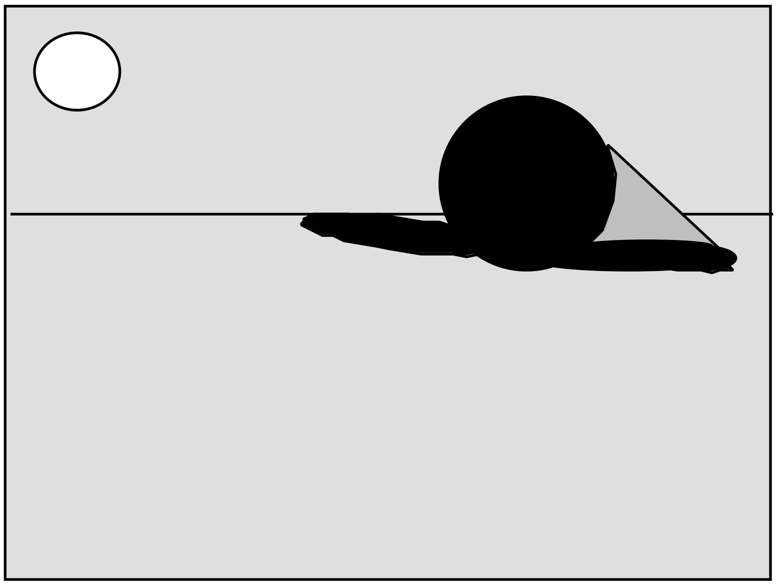
Since many reflections are invisible, many para-reflections are also invisible. Only high speed photography can capture the para-reflection of a black bullet being shot past a mirror. Since the speed of some reflections exceed the speed limits of photo-chemistry, there are para-reflections that cannot be seen with any recording device.

5. Para-refractions and shadows

What goes for para-reflections goes for para-refractions. If you are viewing a black fish in clear water, there is a virtual image that makes the fish appear higher in the water than it really is. The exact discrepancy is predicted by the law of refraction (Snell's law). However, the success of the prediction cannot be directly explained by the law. The law only applies to the black fish's environment.

If the water is clear, you may see the shadow of the black fish. The image of the shadow is also refracted.

A para-reflection forms on the side of the object nearest the light source. The shadow of the object forms on the side opposite the light source. The difference between shadows and para-reflections is dramatized by objects that simultaneously cast shadows and para-reflections. The black ball has a para-reflection on the side near the sun and a shadow on its far side.



Since there is light striking the illuminated side of the object (it merely is not being reflected), the para-reflection is two dimensional. In contrast, the shadow is three-dimensional. For the back side of the object is not receiving light. A hot duck who wants to be sheltered from the sun will paddle to the shady back-side of the ball, not toward the ball's para-reflection.

The difference in dimensionality between shadows and para-reflections can be underscored by having our two beach balls drift onto a dirty oil slick. The dirty oil forms a dull black plane. Neither ball casts a visible shadow on the blackened water. However, there is some dust in the air, so each ball has a shadow that is visible above the water. As architects stress, shadows are three dimensional volumes. People focus on the surface of the shadow that makes contact with objects. This misleads them into thinking that shadows are two-dimensional. They are tempted to conclude that neither ball on the oil slick has a shadow.

Scientists, like philosophers, are uncomfortable with privations. This discomfort issues from a wholesome view of reality as something that is essentially positive (Gale 1976). It is difficult to square this view with truths about privational entities such as shadows, para-reflections, and para-refractions. Thus scientists and philosophers have a tendency to substitute positive entities for privations.

6. How science has coped with privations

Physicists have overcome this prejudice in the past. In 1672 Otto von Guericke undermined the long held notion that nature abhors a vacuum with the help of his new air pump. After evacuating the air from attached two copper hemispheres, he had two teams of eight horses try to pull the hemispheres apart. After the horses failed, Guericke let air into the hemispheres by opening a stopcock. The hemispheres then separated easily. This showed that the hemispheres stayed together because of a failure to counter the pressure of the atmosphere. Similarly, beginning physics students learn that there is no need to postulate a positive force of suction. When students suck beverages through a straw, they are not pulling the liquid up. They are merely letting the atmosphere push the liquid up the straw.

But this style of negative thinking does not come naturally to us. We tend to revert to positive species of causation.

What goes for hydraulics goes for optics. Our preference for positive thinking leads us to mischaracterize phenomena that we encounter daily. Whenever we look into the mirror, we see a para-reflection. Our pupils are holes in our eyeballs that trap light. As a consequence, our pupils are very black. Indeed, they approximate blackbodies. Since the pupil fails to reflect light while the iris does reflect light, the mirror para-reflects the pupil.

The pupil itself conducts para-reflections as well as reflections into the eye. Whenever a dark thing is seen, the retina must contain the corresponding image as a para-reflection. No dark object could be seen without a para-reflection of it. Para-reflections are literally inside our heads because our eyeballs are inside our heads.

A good theory of optics should not talk around such pervasive phenomena. To describe para-reflections accurately, we need to take privations seriously. We must resist the temptation to reconstrue privational phenomena as positive phenomena.

In commerce, we are warned of those who say they will give us something but wind up giving us nothing. In optics, we should be wary of those who say they will give us nothing but wind up giving us something.

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