Why do Mirrors Reverse Left/Right and not Up/Down?

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Imagine a child’s toy arrow, sticking by its rubber sucker to a mirror’s reflective surface. We can call the direction in which such an arrow would point the \textit{finwards} direction (forwards into the mirror); and we can call the opposite direction \textit{boutwards} (backwards out). When we look at things in a mirror, their images are apparently just as far finwards of the mirror as the things themselves are boutwards of it. For example, if we look at the tail of our arrow and cast our glance finwards, we see first the tail, then the head, then the mirror, then the reflection of the head, and finally the reflection of the tail. We can therefore say that a mirror reverses things in the finwards/boutwards dimension. Moreover, the straight line connecting each thing to its image passes perpendicularly through the plane of the mirror. Hence there is no plane, apart from that of the mirror itself, such that the apparent location of each thing’s image is just as far to the one side of that plane as the original is to the other. This means that the reversal in the finwards/boutwards dimension is the only reversal of its kind to take place. In particular, there is no such reversal in any dimension at right angles to finwards/boutwards.

These are the uncontested facts about the optics and geometry of reflection in plane mirrors. These facts still leave us with some questions. Why is the image of my left hand my image’s right hand? Why does he wave his left hand when I wave my right? Why is his wedding ring on his right hand, not his left? And since there is this switch of left and right, why is there not also a switch of head and feet? Why are my image’s feet not the image of my head? Why does he not move his head when I move my feet? And why does he not wear his shoes on his head?

When you see yourself in a mirror, you are usually upright facing it, and it is usually vertical. We can therefore come to think of ‘left/right’ and ‘up/down’ as labels for two dimensions perpendicular both to one another and to finwards/boutwards. If we are not vigilant, we can then drift into imagining that our questions are to be answered by finding some difference between the ways that
reflections are formed in those two different dimensions. But that would be wrong, for at least two reasons. First, the optics and geometry of reflection are identical for all dimensions parallel to the mirror; the force of gravity, for instance, does not make anything of relevance happen in the vertical dimension. Second, the phenomena to which our questions allude occur even when there is no temptation to think of ‘left/right’ and ‘up/down’ as labels for two dimensions perpendicular to finwards/boutwards. For these phenomena occur whatever the place and orientation of the mirror and the object reflected. I might be in free fall in outer space, rotating gently before the mirror. Up and down would now make little sense; the mirror would be first on my left, then at my feet, and so on; but my left hand would all along still have a right hand for its reflection, and my reflection would all along still not wear his shoes on his head. What then does explain these phenomena?

‘A child may know which of her hands is the left one, yet not be able to tell which of her mittens is the left one.’ This is because there are two distinct criteria for leftness. The first criterion we may call the criterion of shape: my left-shaped hand is the hand that has its thumb to the north when its palm faces westwards and its fingers point up. The second criterion we may call the criterion of location: my left-located hand is the hand on the arm that is to the south when I stand upright facing westwards. In all normal cases, these two criteria give the same answer; mischievous transplants would make them diverge. Corresponding to these two criteria there are two switches that a mirror can perform: the transformation of left-shaped into right-shaped; and the interchange of left-located and right-located. Let us consider each switch in turn.

Spread before a mirror a left-shaped hand. Suppose, for example, that its palm is facing finwards. Then the palm of its image will face boutwards. But the finwards/boutwards reversal is the only one to take place. Therefore the fingers of the image will point in just the same direction as the fingers of the real hand; and the image’s thumb will point in just the same direction as the real hand’s thumb. Hence your left-shaped hand will have a right-shaped image. This would no longer be so if, in addition to reversing finwards/boutwards, the mirror also reversed in that way some other dimension perpendicular to finwards/boutwards. For suppose there is a second such reversal; suppose there is some plane perpendicular to the mirror such that the image of each thing is apparently just as far to the one side of that plane as the original is to the other. This second reversal will restore the image to being

left-shaped, just like the original. And the second reversal will have this effect even if the dimension in which it occurs can be labelled ‘the left/right dimension’, even if you have one hand on either side of the plane, and the plane runs vertically through your body. In short, the transformation that does take place, the transformation whereby a left-shaped hand has a right-shaped image, can take place only because finwards/boutwards is the sole dimension to be reversed.

Such transformations of shape happen also when heads and feet are reflected. The difference is simply that when they happen to a head or to a pair of feet, those transformations are less visible. Unlike a hand, a head is—fine details apart—symmetrical. Hence the transformation that turns a left-shaped hand into a right-shaped hand will turn a head into something that is—fine details apart—shaped exactly the same as the original. This is why the transformation can go unnoticed. The same is true of a pair of feet. When you stand normally before the mirror, your two feet form a composite and—fine details apart—symmetrical object. This is why you may not notice that the image of this composite object has undergone the very transformation that turns left-shaped into right-shaped hands. A mirror transforms the shapes of everything. In particular, it transforms the shapes of all my body’s extremities, whatever their direction from my torso, whether leftwards, upwards, rightwards or downwards. The only contrast is that some of these transformations, those of the grossly asymmetrical extremities, are more readily noticed than others. Thus my head and my feet undergo exactly the transformations of shape that we should expect by analogy with the transformations of shape undergone by my hands. In consequence, my head does not have a feet-shaped image, nor do my feet have a head-shaped one. But we should not expect this; nor will we expect it, unless we misunderstand the transformation that the mirror works on the shape of my hands.

Much of what is true of shape is true also of location. Hold up before the mirror a left-located hand, a hand that would be on your south were you standing upright facing west. Now suppose that you are, for example, standing upright facing finwards. Then your image is facing boutwards. But there are no reversals apart from that in the finwards/boutwards dimension. Hence the hand which reflects the hand you are holding up would be on the north side of its owner were its owner standing upright facing west. It follows that your left-located hand has a right-located hand for its image. The same thing happens of course regardless of the direction in which you are facing. And it happens only because the mir-
ror reverses things in the finwards/boutwards dimension alone; for if it were to reverse them also in some dimension at right angles to finwards/boutwards, then the second reversal would undo the first, and a left-located hand would have as its reflection another left-located hand. In particular, the second reversal would still undo the first, even if the dimension in which it took place could be labelled ‘left/right’.

What happens when heads and feet are reflected? We can say, obviously enough, that head-located things are those at the same end of a body as its head, and that feet-located ones are those at the same end as its feet. It is then tempting to take this distinction as entirely analogous to the distinction between right-located and left-located. Once we do take the two distinctions to be entirely analogous, we will expect that since a left-located part of my body has a right-located image, the image of something foot-located should by analogy be head-located. Hence we will start to wonder why this expectation is disappointed.

The expectation deserved to be disappointed; for the two distinctions were never analogous in the first place. We can tell that a bodily extremity is head-located simply from the fact that it is head-shaped. In consequence, when we tell that a bodily extremity is head-located, we need not rely on information about which bit of the body is the front: we can tell which is the head end of a bandaged mummy or a matchstick man, even though we have no idea whether the thing is facing us or not. We had however to distinguish shape from location as two different criteria of leftness. Shape alone therefore is not always a certain guide to whether an extremity is left-located. Now your left-located hand, remember, is the hand on the arm that is to the south when you are standing upright facing westwards. Hence, in order to tell which of your two hands is the left-located one, we need to know both which bit is your head (‘standing upright’) and which bit is your front (‘facing westwards’). Thus the distinction between left-located and right-located is not at all analogous to the distinction between located at the head and located at the feet. So we have no reason to think that the images of head-located things should themselves be feet-located.

What would be an interchange of head and feet strictly analogous to the interchange that gives left-located hands right-located images? To specify the strictly analogous interchange, we need to introduce some extra labels. To begin with, let us call ‘cordial’ the side of the body where the heart is. We can now define a pair of labels ‘the A-end’ and ‘the Z-end’. They are to be defined in terms of ‘front’ and ‘cordial’, just as ‘left-located’ and ‘right-located’ are
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defined in terms of 'front' and 'head'. Your left-located hand is the one that is to the south when you face west with your head uppermost. Likewise, your A-end is the one that is at the south when you face west with your cordial side uppermost; and the other end is your Z-end. The mirror will not interchange cordial and uncordial, any more than it interchanges head and feet: if, for example, there is a wedding ring on your cordial hand, there will be a wedding ring on the cordial hand of your image—just as there will be glasses on your image's head if there are glasses on yours. The mirror will however interchange A and Z: if your shoes are at your A-end, then their image will be at your image's Z-end—just as your image's watch will be on your image's right wrist if your watch is on your left; and if you nod your Z-end, then the A-end of your image nods—just as the left hand of your image clenches when you clench your right. In short, the contrast between left/right and up/down occurs for the same reason as the contrast between A/Z and cordial/uncordial. The contrast, we may say, is not so much a physical contrast with a physical explanation, as a contrast between two different principles for labelling directions by reference to parts of the body.

That leaves a problem. Why does our most familiar vocabulary combine those two different principles? Why have we not settled on just one of these principles, for use in both cases? Why do we not in both cases use labels that are interchanged by mirrors, and find it most easy to speak in terms of A/Z and left/right? Why do we not in both cases use constant labels, and find it most easy to speak in terms of head/foot and cordial/uncordial? Furthermore, if we are to depart from uniformity, why not depart from it by combining the interchanged A/Z with the constant cordial/uncordial? Why do we instead combine the interchanged left/right with the constant head/foot?

A cordial/uncordial terminology is harder than a left/right one to devise and teach. In devising our special sense of 'cordial', we invoked something so little on display as the position of the heart. We were forced to do this, since we are not like those crustacea that have a big pincer on one side and a little pincer on the other: the natural shape of the human body displays no gross and readily visible asymmetries between its two sides. Human symmetry makes difficulties, not only for devising, but also for teaching, our special sense of 'cordial'. Imagine children reared in a community where the adults use 'cordial' and 'uncordial' instead of 'left' and right' The children learn such drills as 'For a reef knot, put cordial over uncordial and under; then uncordial over cordial and under' and 'Look uncordial, then cordial, then take a quick look uncordial
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again; and if all is clear, walk smartly across the road'. The children are not told explicitly the formal definition of 'cordial' as 'on the side where the heart is', any more than our own children are told explicitly that your left hand is the one that is to the south when you face west with your head uppermost. Unless and until the children encounter adult talk about reflections, they will therefore encounter nothing to show that the word 'cordial' actually means *cordial* rather than *left*. Which of these two will they take it to mean? When such children first encounter mirrors, which hand of an image will they call 'cordial'? My guess is that, until they are corrected by adults, their previous rearing will make them call 'cordial' the image's left hand. Human symmetry will encourage this misapprehension; and the fact that an image's left hand is shaped the same as the original's cordial hand will do nothing to discourage it. When instructed by their elders in a cordial/uncordial terminology, the young of a visibly asymmetrical breed would readily get the point; symmetrical creatures, like ourselves, would not.

Similar things are true of an A/Z terminology. It is more difficult to devise than a terminology of head and feet, since its explanation relies on the unobtrusive asymmetry in the location of the human heart. An A/Z terminology is also more difficult to teach. How can children be expected to guess that the distinction between the A-end and the Z-end turns on something as unobtrusive as the location of the heart, when the patent contrasts between head and feet cry out to be labelled? Unless explicitly warned to the contrary, children exposed to an A/Z terminology would therefore be liable to imagine that the 'Z-end' simply meant the head, and to misdescribe the feet of a mirror-image as its 'A-end'. Hence human nature predisposes us to think in terms of head and feet, just as it predisposes us to think in terms of left and right.

In short, the mirror's contrasting effects on up/down and left/right are an artefact of what we may grandly call our conceptual scheme. But the fact that we work with such a scheme is itself due to nature: not indeed to the nature of light, mirrors and reflection, but to the natural shape of the human body.

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