Natural cadmium is made up of a number of isotopes with different abundances: Cd^{106}(1.25%), Cd^{110}(12.49%), Cd^{111} (12.8%), Cd^{112} (24.13%), Cd^{113} (12.22%), Cd^{114}(28.73%), Cd^{116}(7.49%). Of these Cd^{113} is the main neutron absorber; it has an absorption cross section of 2065 barns for thermal neutrons (a barn is equal to 10^{-24} sq.cm), and the cross section is a measure of the extent of reaction.

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When Cd^{113} absorbs a neutron, it forms Cd^{114} with a prompt release of γ radiation. There is not much energy release in this reaction. Cd^{114} can again absorb a neutron to form Cd^{115}, but the cross section for this reaction is very small. Cd^{115} is a β-emitter (with a half-life of 53hrs) and gets transformed to Indium-115 which is a stable isotope. In none of these cases is there any large release of energy, nor is there any release of fresh neutrons to propagate any chain reaction.

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The Möbius Strip

The Möbius strip is easy enough to construct. Just take a strip of paper and glue its ends after giving it a twist, as shown in *Figure 1a*. As you might have gathered from popular accounts, this surface, which we shall call M, has no inside or outside. If you started painting one "side" red and the other "side" blue, you would come to a point where blue and red bump into each other.

The space M is the simplest example of a *non–orientable* surface. In fact, it is a theorem that a surface (i.e. a two dimensional manifold) is non-orientable if and only if it contains a Möbius strip embedded inside it. That is, you could take a pair of scissors and cut out a Möbius strip from it. *Figure 1b* illustrates this for the other famous non-orientable surface, called the Klein Bottle.

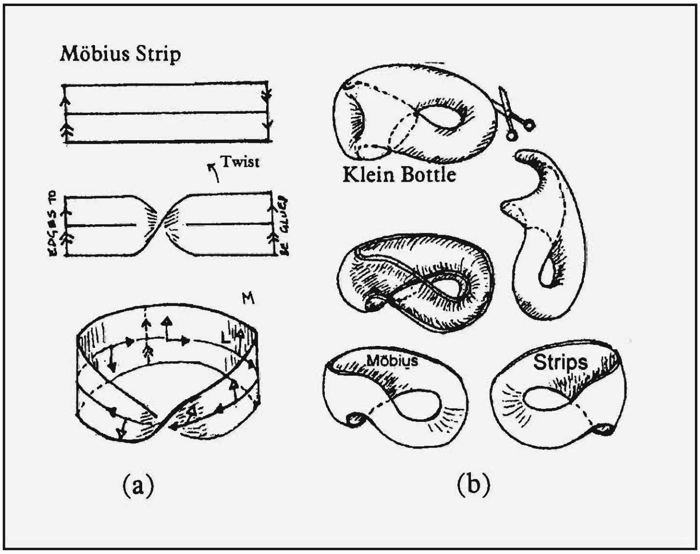

Figure 1a,b.

I will, of course, be unable to define orientability precisely here. Roughly speaking, a surface is orientable if it is possible to consistently choose (say) a right handed coordinate system at all points. Again, *Figure 1a* shows the impossibility of doing so for the Möbius strip M. Contrast this with the cylinder C, which is just a strip of paper with the ends glued without a twist, and is mathematically described as the product space of a circle and a closed interval, which *is* orientable. How would one show that there is no homeomorphism (continuous map with continuous inverse) between M and C? Here's an argument. Take the central (simple non self-intersecting) loop L of M, which is not null-homotopic in M. That is, it cannot be continuously shrunk to a point in M. If there were a homeomorphism f between M and C, it would take the loop L to a simple loop $f(L)$ in the cylinder C. Thus f would also be a homeomorphism between $M-L$ and $C-f(L)$. However, by running a pair of scissors through the middle of the Möbius strip, one sees that $M-L$ is connected, whereas every simple closed loop disconnects C. (Proof ?)

Roughly speaking, a surface is orientable if it is possible to consistently choose (say) a right handed coordinate system at all points.

Note that the boundary of M is just a circle, whereas that of C is two disjoint circles (and this can be used as another argument

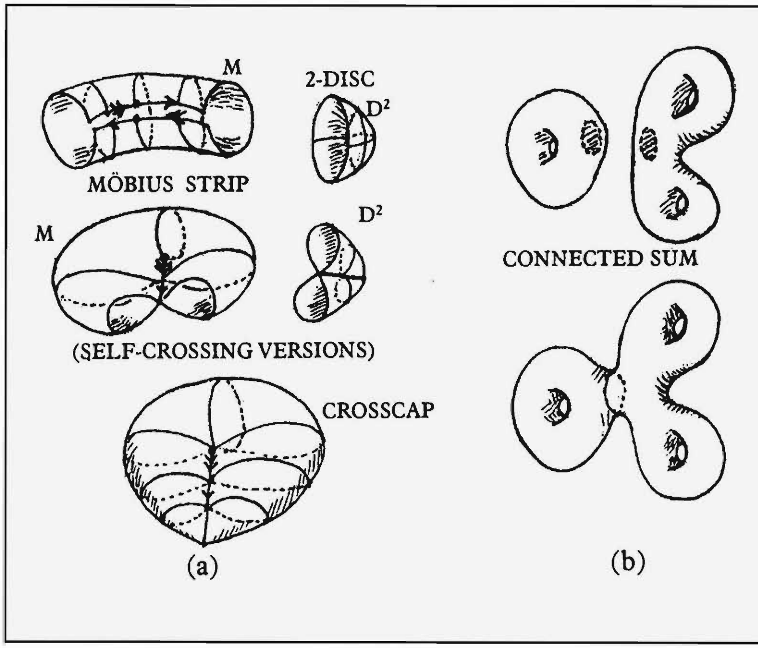

Figure 2a,b.

that they are not homeomorphic). If one takes a 2-disc D^2 and sews its boundary circle to the boundary circle of M, what does one get? You will get another famous non-orientable surface called the "crosscap", or real projective space of dimension two. This space, like the Klein bottle, cannot be embedded in Euclidean 3-space $\mathbf{R}^3$, and what you see in *Figure 2a* is an image in $\mathbf{R}^3$ which self intersects.

Every non-orientable compact connected surface is a connected sum of finitely many crosscaps.

The crosscap occupies a very central position in the topology of surfaces. In the sequel, the word surface means surface without boundary. You might have heard that every (compact, connected) orientable surface which is not a sphere can be built by cutting out discs from tori (handles) and sewing along the boundary circles. This operation of combining two surfaces by cutting out a disc from each and sewing along the boundary circles thus created is called the "connected sum" operation (*Figure 2b*), so the theorem above says that *a compact connected orientable surface which is not a sphere can be expressed as the connected sum of finitely many tori*. Similarly, it turns out that *every non-orientable compact connected surface is a connected sum of finitely many crosscaps*. Note that a crosscap minus a disc is a Möbius strip, so knocking out a disc from a surface and sewing on a Möbius strip along the boundary circle is the same as taking the connected sum with a crosscap. This is the "reason" why (at least compact connected) non-orientable surfaces contain an embedded Möbius strip. For example, sewing two Möbius strips along their common boundary circles gives the connected sum of two crosscaps, and is the Klein bottle (*Figure 1b*). The theorem says every compact connected non-orientable surface is built up via this operation. For a lucid exposition of the proof (for both orientable and non-orientable surfaces) see the book *Introduction to Algebraic Topology* by W S Massey. One puzzle remains. What if one took connected sums of handles and crosscaps ? By the foregoing, it should be non-orientable, and hence also be obtainable as a connected sum of only crosscaps. The answer is : the connected sum of a handle and a crosscap is the same as the connected sum of three crosscaps. It is a not so trivial exercise to convince oneself of this. Thus in a handle-crosscap mixture, as long as there is at least one crosscap, one can go on replacing handles by pairs of crosscaps in an inductive manner.

The connected sum of a handle and a crosscap is the same as the connected sum of three crosscaps.

We leave the reader with the following project. Instead of cutting a Möbius strip along the central loop, one could commence cutting at $1/n$ units away from the boundary (assuming the Möbius strip has width one unit), and proceeding in a direction which is always parallel to the boundary. For example, if you take $n = 3$, you will get a Möbius strip and a cylinder linked together. The cylinder doesn't look like a cylinder, but it is a strip with two twists in it, and thus homeomorphic to the cylinder, though this embedding of it in $\mathbf{R}^3$ is not "isotopic" to the standard embedding of the cylinder in $\mathbf{R}^3$ (the strip with no twists). What does one get for general n? More importantly, why?