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An Inventor in the Garden of Eden

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Any photograph or actual view of a suburban scene will suffice to pose the simple question: 'Can you tell, at a glance, which objects that you see were made by human hands and which are alive and growing?' The answer is obviously 'Yes'. But the slightly more difficult question is: '*How* did you decide?' A first answer might be: 'By familiarity. I have seen many similar houses, and vehicles, and trees.' But is there, perhaps, one single rule that would guide you in a situation where the objects that were seen were less familiar? The best answer you will find to this question is surely 'shape' and, in particular, 'regularity'. Certainly colour is not a criterion. We can imitate all of nature's colours on canvas. We can outshine the most brilliant by the use of fluorescent paints. It is the shapes that are far more decisive. The shapes we make are still dominated by Euclidian geometry. We base so many of our creations on straight lines and circles, on cubes and brick shapes, on pyramids, cylinders, spheres and right circular cones – and we do most of it in the name of 'economics'. The shapes of nature we see as over-elaborate, wasteful and unnecessary. We see nature as having missed out on the wheel and as being incapable of using pure metals.

We have long seen humans as the superior beings on this planet, given 'dominion' over the lower animals, given the earth to 'subdue it'. It is impossible even to begin a treatise on the relationship between the Man-made and the God-made without involving religion, questioning evolution and even touching such subjects as extrasensory perception, students of which subject are still regarded by many 'pure' scientists as hardly respectable: topology for sure, will be our staple diet. Science will take second place to engineering and to the other technologies. This is no mere collection of facts. The text will pose a thousand questions for every one answered. But, hopefully, profitable messages will emerge out of the mist, however vast that which is obscure. One has only to contemplate the size of *Gray's Anatomy*[1] to realise that its contents relate to but one single species of mammal. Then to realise that there are over 400 000 species of beetle, nearly 200 000 species of butterfly and moth, is to be appalled at what one has undertaken to attempt.

Many facets of the subject and many profitable comparisons between the manufactured and the living will doubtless have been overlooked. A nature book on the same theme with the title *Nature, Mother of Invention*[2] was written by a botanist, and the opportunities that he missed only served to daunt the more in attempting the same task seen from 'the other side' (the engineering side). One is also mindful of a quotation from Max Delbrück, Nobel prizewinner for physiology: 'When a physicist or engineer starts work on a biological problem he is always afraid that he will not know enough biology. It invariably emerges that he did not know enough physics or engineering.'

Where to begin

Let us start with a little heart-searching that is calculated to bring a stream of humility before the end of the text. We humans would claim to be three-dimensional beings, whatever else we are. We are conscious that objects have length, breadth and depth. When we study topics of the nature of electromagnetism, or when we reach out for knowledge of the almost infinitely large (the Universe) or the almost infinitely small (the 'fundamental particle'), we are vaguely conscious of a fourth dimension that we cannot fully appreciate. Yet as our civilisation progresses we become more and more chained to two-dimensional objects which often require a 'translation' to 3-D inside the brain. The great majority of our learning is through the media of flat sheets of paper (book pages), flat chalkboards and cinema screens and the flat faces of

TV tubes. We have become so skilled at 'seeing' a 2-D picture as a 3-D object that the 'program' (to use computer language) has been transferred from the consciously thinking part of our brain to the automatic part which governs so many of our actions, such as walking, eating, picking up and handling objects, and so on. Once this transfer has been made it is easy to alarm the brain by relatively simple tricks, and the sight of the 'object' shown in Fig. 1.1 is most disturbing, especially to engineers. This drawing makes a good starting point for the many discussions of topology which we shall make in establishing profitable comparisons between the shapes of nature and those made by our own hands. Let us take Fig. 1.1 for what it is, and no more: lines on a piece of paper, some of which form closed areas whilst others merely

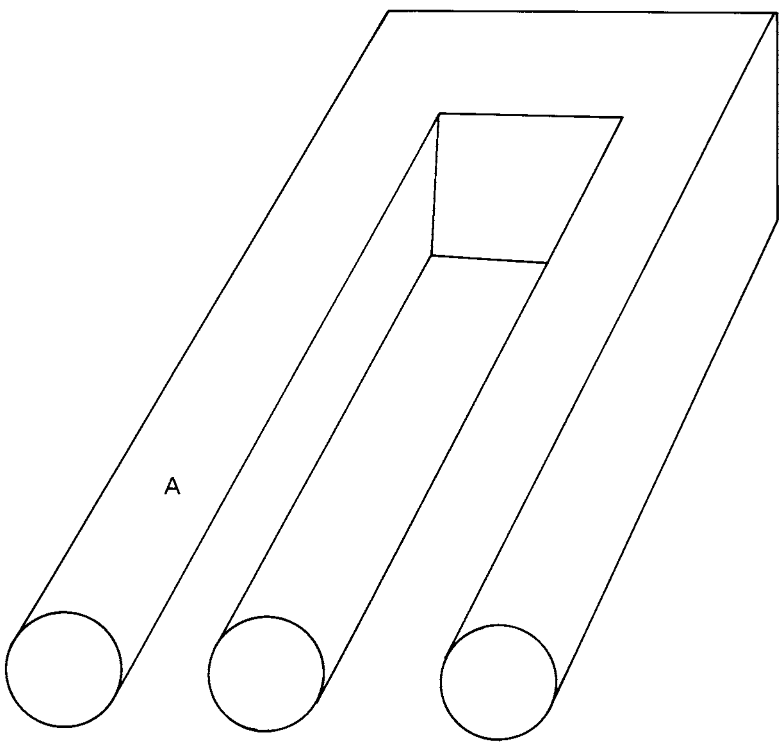

Fig. 1.1. An impossible object.

join such areas together. Figure 1.2 is topologically identical to Fig. 1.1, and no-one is going to see *this* as three-dimensional. What is interesting is the extent to which we become conditioned to the 2-D–3-D 'translations'. When we are young, Fig. 1.1 seems almost as 'flat' as Fig. 1.2. Given crayons to colour it, we will fill in all the fully bounded areas as shown in Fig. 1.3, making no attempt to start colouring the space A, which we see at once is not totally contained by lines. It is also interesting to show how Fig. 1.1 loses its '3-D-ness' when coloured, and which combination of colours gives the greatest sensation of flatness. Readers who are 'of riper years' might like to test their visual memory by trying to re-draw Fig. 1.1 some 24 hours after seeing it in these pages. It is not half so easy as it appears.

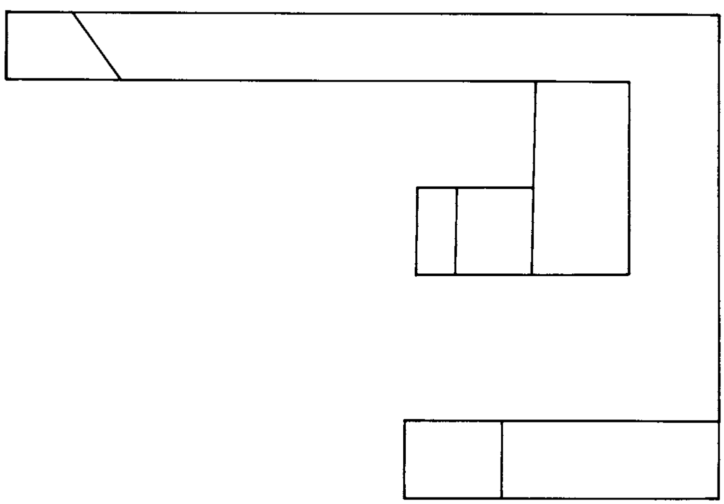

Fig. 1.2. A drawing topologically the same as Fig. 1.1.

Evolution and design

Quite apart from considerations of wheels and pure metals, many readers might be prepared to go along with the idea that the greatest dividing wall between manufactured articles and living

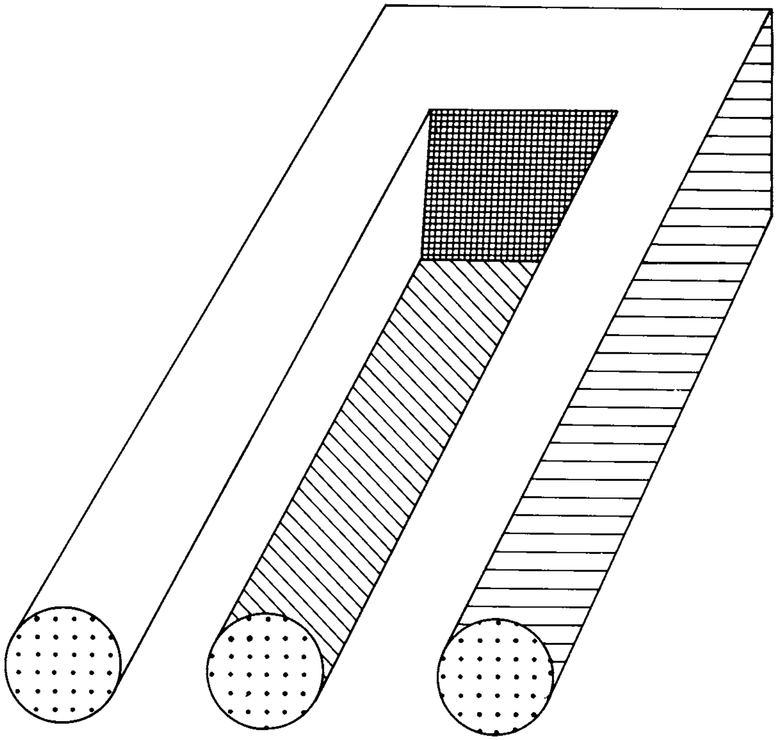

Fig. 1.3. Filling in the spaces.

organisms is that the former are the result of 'design', whilst the latter are products of 'evolution'. Let me say at once that the devout will always maintain that our 'creator' designed all things. If that be true, He, She or It made some monumental mistakes in the process – like giving wings to ostriches. What is much more certain is that remarkably few of the products of modern technology have in fact been *designed.* By this I mean that the person who thinks about the layout of the parts of a motor car for next year-but-one's Motor Show is much more conscious of what will appeal to the customer and what will make more profit than of what will actually work better. The 'designer' is going to make use of as much of the experience of all earlier designers as possible. After all, is there a better process for rapid development than learning by the mistakes of others?

Let me illustrate what I mean by using a much simpler manufactured article – the common teapot (Fig. 1.4). If all teapots had the date of manufacture stamped on them under the base, it would be impossible to guess the date on this one to within 50 years or more. This 'design' might be compared, on a vastly reduced time scale, to the common woodlouse that has remained unchanged by the ravages of this planet and by the processes of evolution for millions of years. We might conclude that both woodlouse and teapot are examples of 'near-perfect' designs.

Let us, however, look at the teapot as might a fifth form school pupil doing a scientific experiment. Such pupils are taught to write formally under headings such as 'Purpose', and in this case what would follow would be: 'A vessel for the brewing and dispensing of a liquid which is called "tea".' So we will examine it as an instrument for this purpose. The brewing facility is fine. The pot does not crack when subjected to a sudden influx of water at 100 °C. A little stirring done, we begin the process of pouring. We are surprised by the weight of a full pot and since the handle is on one side, the centre of mass is several inches displaced from the centre of grip. It tips and we pour a little tea before we intended – usually on to the tablecloth. At this point we must ask

Fig. 1.4. A traditional teapot.

why the handle was so placed. Could it be because there is a small hole in the lid to prevent steam from building up pressure inside and rattling the lid? Steam escaping from the hole would scald our hand if the handle were situated over the mass centre. True, but we have had experience with kettles like the one shown in Fig. 1.5, a typical modern 'design' with a vent in the lid so placed in relation to the handle that the designer was obviously intent on scalding everyone who used it! Kettles, if anything, get hotter than teapots. Yet the usual designs invariably have the handle on top.

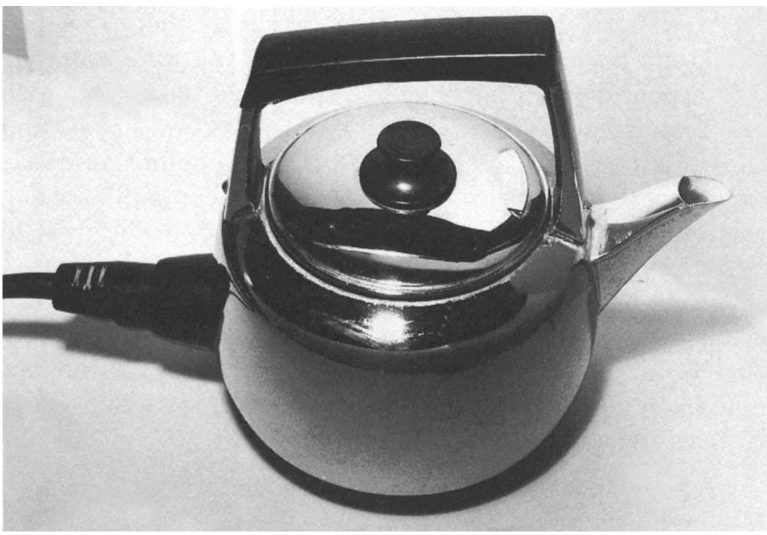

Fig. 1.5. A modern kettle.

Let us continue the experiment by observing now that perhaps the design *did* incorporate a device to be used in the eventuality of the pourer finding the force of gravity surprisingly large. The tip of the spout is curved downwards so as to present a hook-shaped profile below, into which the forefinger of the free hand can be placed to balance the weight. However such an eventuality is *bound* to result in a scalded forefinger. Perhaps it is not so. Perhaps the obviously elegant shape of the entire spout has been designed to produce a beautifully smooth stream of tea, 'laminar flow' as the engineer calls it. We pour. It is a near disaster. The tea splatters out in several directions, some goes in the cup, some in the saucer, a little on the tablecloth and who knows, with some luck, a little on the person for whom the cup was intended. 'Ah', they say, 'it always pours badly when it is nearly full'. Generally it also pours badly when it is nearly empty. You decide that as soon as shops re-open tomorrow morning you will go and buy an attachment for that spout that acts like a nozzle on a water tap.

You reflect on why the designer did not incorporate the properties of the attachment into the spout design, and come to the conclusion that it might have looked ugly; the attachment *certainly* looks ugly. That does not seem to matter; at least let us say that you did not contemplate the possibility that you were acquiring a 'rogue pourer' when you bought it. (But when you finally smash the old brown pot you will go and buy another just like it. And you will not ask for a pouring demonstration before purchase. Such things are simply 'not done'.) Could it be that the teapot designer deliberately built in a 'turbulator' (my own word) to ensure a steady sale for the attachment – perish the thought!

We have now reached the stage where we have poured several cups and the quality of the pouring has undoubtedly improved. What *was* the basic cause of the turbulence? Across the entrance to the spout there is a baffle or filter in the form of a wall containing holes. What is *that* particular feature for?

> As everyone knows, it is to stop tea leaves from coming out with the tea.
>
> Have you seen the size of the holes?
>
> The modern tea leaves could emerge broadside on, twenty abreast!
>
> But of course, most tea addicts of today don't use raw tea leaves; they use teabags.
>
> It'll stop teabags.
>
> The only trouble is that as soon as it has arrested the first teabag, it stops the tea as well!

Why does the modern 'Old Brown' teapot still retain this strange feature? The answer is fairly obvious if you look inside the pot. Imagine yourself as the potter with his lump of clay. He is going to make the body of the pot first and stick the spout and handle on later. To make a hole the size of the base of the spout and later to join it with a spout leaving a smooth finish when you can only get at the outside in the process is difficult. What is far easier is to poke a few holes in a cluster, smooth off the surface and simply stick the spout in place – simple economics.

Back to our tea pourer. When the pot is nearly empty the lid falls off, breaking the cup, and flooding the table with tea. As a piece of scientific equipment the Old Brown is a disaster.

Has nobody ever done better? Well, yes. In 1972 Rosenthal of Germany produced what was perhaps the first teapot ever to be designed scientifically (Fig. 1.6). See at once how elegant it is, constituting a superb example of the philosophy that things that *look* good, *are* good (about which, more later). Without handling it you can see that the centre of mass of pot and tea will lie directly under the first finger at all times, no matter what the pouring angle nor how full it is. It was *designed* to be like that. No spout entrance baffle to act as turbulator, it pours with laminar flow whether you allow a mere trickle of the beloved liquid, or whether you heave it straight over at 90°. It is an interesting experiment to fill this pot with water, give it to someone who has

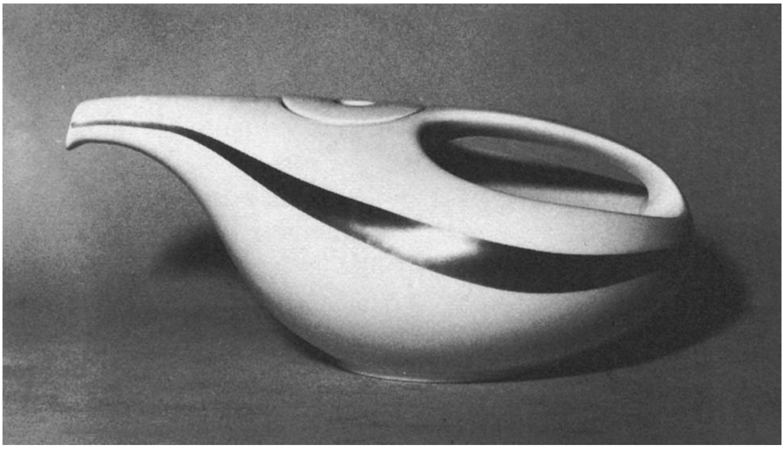

Fig. 1.6. A teapot designed by an engineer.

never handled it and ask them to test its pouring qualities by suddenly rotating it through 90° over a sink or bucket. Nineteen people out of 20 will immediately put their thumb on the lid. It is *tradition* to do so. It has even become, for most of us, instinctive. But the lid does not fall off until you have rotated the pot from its normal position through 135°, which is a silly way to pour tea! It was *designed* to eliminate lid fall.

I have heard it criticised 'because you can't clean the inside'. I am certain that if the restless human mind can devise such a beautiful and functional implement, it can devise a brush to clean it. (Connoisseurs of tea-making tell me you never clean the insides of pots anyway.)

Now, the scientific pot was expensive (£13.95 in 1972). Since when has price had anything to do with popularity? People have birthdays and anniversaries and then there is Christmas. There was a steady trade in Mah Jong sets made from fine split cane and ivory (before ivory was rightly frowned upon), an even bigger trade in expensive chess sets. How much more readily should an article whose use always brings pleasure in a creature-comfort sort of way, three or four times a day, be snapped up? The proof of the pudding was in the eating, of course. How many of these teapots have you seen in the last 5 or 6 years? They hardly sold at all! The design was discontinued at an early date.

I discovered that it had been designed by an Italian engineer who was better known for his design of racing cars. He was a fluid flow specialist. The problem of pouring liquid at 1 mile per hour is similar to that of forcing an object through a gas (air) at 200 mph. Now, why was it not popular? Figure 1.6 shows you its best profile. Seen in plan it is at once obvious that its shape is equally functional. Apart from the spout, it is circular. A circle has maximum area for a given perimeter. It is an 'economic' shape. But it looks like a bed-pan!

The Old Brown teapot is, if only subconsciously, one of your earliest memories, perhaps of visiting Auntie or Granny on Sundays, when you were 5. It was always a happy time and there was always an Old Brown at tea-time.

So, what have we learned from our study of teapots? Undoubtedly something about tradition. Now, in many facets of engineering manufacture, 'tradition' is an excuse for leaving things as they are – for laziness, if you like. No, it is more than that. The first rule of production engineering which reflects right back into articles on the shop counter is that the more you make and sell, the cheaper the price per article. The reason is fairly obvious. No new tools are needed after the first one comes off the production line. The more you make, the better the shop floor operations become. There are fewer rejects, the speed of manufacture increases. Less concentration is required by the operatives; they get production bonuses. They are happier people. It all makes good sense to the economist.

But tradition can be the death of mighty industries. Of this there is no more dramatic example than that of the Lancashire cotton industry. The Lancashire loom was, in the 1930s, along with the umbrella, the best bargain in engineering that could be bought. (Even in the inflated 1960s, an automatically opening umbrella cost only £1.) For £400 you could buy a loom that would weave cloth 54 inches wide, putting in weft threads at more than one a second. The Lancashire loom was an example of an invention 50 years ahead of its time that continued in use until it was 50 years *behind* its time. The philosophy 'What was good enough for my father is good enough for me' was rife in Lancashire in the 1930s where the self-taught directors of industry *boasted* of 'not having been to a university'. Argue with them, as I did, about the possibilities of incorporating linear electric motors for shuttle propulsion and you were told 'It can't go much faster safely', 'Noise doesn't matter' and similar false beliefs. No-one seemed to notice that the Swiss were making looms *without* shuttles, that ran as smoothly as Swiss watches, nor that the textile industry was swinging over from weaving to knitting as the result of tremendous advances in automatic knitting machines. There were a few prophets, one or two of whom I was privileged to know, but no-one wanted to hear them. The Lancashire 'tackler' (who used to take the place of the Irishman as the butt of all the wit of comedians in the UK), whose job was simply to keep looms running, was a skilful man and his principal tools were a spokeshave and a torn up cigarette packet (used frequently as spacing washer or whatever). But his days were numbered, and he never knew until it was too late. Tradition, pure tradition, engulfed him and his fellow operatives. He died like a dinosaur.

So we must arrive at the conclusion that the process of design is, at best, a combination of both our conscious and our unconscious mind, which, having undoubtedly created new designs in our time, demands that everything in nature was similarly designed with purpose aforethought – and it need not be so.