Chapter 18

On the compression and spring force of bodies.

133. There can be two types of pores or cavities in a body, according to whether or not they are freely connected to external space. In the second case the subtle matter they contain is locked in so that it can not mix with the external subtle matter, and the latter also finds no passage to enter.

All bodies in the world are composed of coarse and subtle matter, of which the former is called the proper matter, because the other, in view of its practically infinitely low density, contributes nothing to their mass. Since this mixing of the two types of matter extends to the smallest particles, the particles of space in which there is no coarse matter are called the pores of the body, and of these there are several kinds, depending on their size, because even the smallest particles are still filled with pores. The larger of these pores are however not only filled by subtle matter, but also contain air, and therefore also a little of the coarse matter, however it is customary not to count this to the proper matter, and in the present context it is irrelevant whether there is only subtle matter or also air. However the salient difference that must be considered amongst the pores of any body is that some have an open passage to the external aether, whilst others are surrounded by coarse matter to such an extent that the subtle matter can nowhere escape. To make this distinction, we want to call the former *open pores,* and the latter *closed pores*. The former one can regard as open passages that traverse the body in multi-curved paths, such that the external subtle matter can penetrate them feely and flow through. In contrast to this the subtle matter in the closed pores is in no communication with the external, so that when it is compressed to a larger or smaller extent, equilibrium with the external can not be established. We see here at least the possibility of such closed pores, although it has not yet been proved that such pores really exist in bodies.

134. When a body is either compressed into a smaller space or expanded into a larger one, or if otherwise its shape is altered, then there must of necessity occur a change in its pores, some being expanded, but others being compressed.

When the shape of a body is altered, the particles of which the body consists must assume a different position and arrangement; and since the coarse particles, because of their strength, are not able to undergo this change, the change must occur in the pores. To explain this more clearly, let us assume in the first place that a body is compressed into a smaller space. Since coarse matter itself is incompressible, this can not happen other than by making the pores smaller. In that case the apparent density of the body must increase, because the whole matter of which the body consists, or at least the coarse matter, since the subtle matter can be neglected here, must have been brought into a smaller space. Let a^3 be that part of the body that is filled with coarse matter, and e^3 the remaining part that only contains subtle matter, the sum of all pores taken together, then a^3+e^3 is the size of the body, a^3 is its mass and $a^3/(a^3+e^3)$ is its density. But a^3 can not be changed, therefore when the body is brought into a smaller space only e^3 is diminished or the sum of all pores becomes smaller. But when the body is expanded into a larger space, then only the value of e^3 must become larger, in which case the density of the body must decrease. But a change in the body can also take place without e^3 becoming greater or smaller, by some pores being expanded, but others being contracted by just as much, so that the whole sum remains constant. In such a change the body as a whole maintains the same density, because $a^3/(a^3+e^3)$ remains constant, but those parts where the pores were expanded become less dense, but where the pores were contracted, more dense. This difference can sometimes become noticeable; but when the coarse particles and the pores are so intimately mixed that even in the smallest parts the expansion and contraction of the pores are the same, then no difference can be noticed in the density of the parts, although the shape has been altered.

135. If after the change in shape of a body the closed pores are neither larger nor smaller, then the body retains this changed shape. But if the closed pores become wider or narrower, then a force will develop in the body tending to restore the previous shape.

Here we find the cause for the difference between elastic and inelastic bodies. It stems from the closed pores, and depends on whether, after the change of shape, these have been expanded or contracted, or have had their size remain unaltered. For if the pores become narrower, then the subtle matter they contain becomes more compressed and develops a greater force to expand. Since prior to this change this force was in equilibrium with the spring force of the external aether, this equilibrium is now disturbed and a force develops within the body to restore the equilibrium; this occurs when the body resumes its prior shape. The pores can also be enlarged again if the body assumes a shape different from the first, however since it does not remain in this altered shape, but tries to assume another, it acquires also in this case an elastic force. For as whenever a body manifests a force tending to change its present shape, this force is called a spring force, which has its origin in the subtle matter contained in the closed pores having a greater or smaller spring force than the external. From this follows that a body must also manifest a spring force when after a change in shape it closed pores are expanded. But when these pores always maintain their size, and the subtle matter contained in them suffers no change in its spring force, then the body can not develop a force to assume a different shape, whatever alteration of its shape may occur, and such bodies are called inelastic. To this kind belong in particular those that contain no closed pores at all. For since the subtle matter in the open pores is in free communication with the external, the equilibrium is never disturbed, however great a change in shape might have taken place. Here we must mention without doubt soft wax, glue and perhaps also lead, since these materials retain all possible shapes into which they are pressed.

136. A small change that occurs in the closed pores can be sufficient to produce a large spring force in the body. Also the number, size and shape of the closed pores can contribute much to the augmentation of the elastic force.

It is shown in the theory of equilibrium how a small force can be in equilibrium with a large one, and therefore one can understand how it is possible that a small change in the closed pores can produce a large elastic force. But we have also shown that the open aether is strongly compressed, having a spring force at least one hundred times larger than the spring force of air, which is equivalent to a water height of 32 feet. If we now assume that the spring force of the aether rises in proportion to its density, then the spring force of subtle matter, compressed into a space twice smaller, would have to be twice as big. But we have reason to believe that in that case the spring force would have to be even far stronger , or that it would already become twice as big if the closed pores were to be compressed less than to half the space they normally occupy. But since the excess of the spring force of the subtle matter within the closed pores can easily become more than 100 times greater than the spring force of air, through which such large effects can be produced, it is easy to see that even the largest spring force that can be found in any body is readily explained in this way, and that one need not assert a substantial change in the closed pores. Consequently the pores can also be very small and the force be replaced by their quantity, seeing that it is extremely likely that the closed pores must be unbelievably small. Lastly their shape can contribute significantly to an increase in the elastic force, since the latter depends on the area over which the subtle matter acts on the coarse matter. The more the shape of the pores deviates from the spherical, the more must the spring force be increased, since then at constant size the circumference becomes much larger.

137. This explanation of the elastic force through the subtle matter contained in the closed pores is in complete agreement with the nature of elastic bodies, and is confirmed even more by the way in which different kinds of body acquire an elastic force.

Most elastic bodies lose their elastic force through heat. The subtle matter contained in the pores is set by heat into motion, through which also the smallest particles of bodies are separated from each other, opening up access to previously closed pores. Therefore if prior to heating there were many closed pores in a body, causing its elastic force, then this force must vanish again through heating. But if a heated body such as steel, iron or glass, is suddenly cooled, causing the coarse particles to make contact, then the subtle matter between them can easily be trapped between them such that all access to it is closed off, and in consequence an elastic force must develop. However if the heated body is only cooled gradually, then through its motion the subtle matter can maintain communication much more easily and can largely prevent the development of closed pores. If we furthermore take into consideration that most metals obtain an elastic force through hammering, then we obtain an even stronger confirmation of our explanation. For since through hammering the coarse particles of the metal are driven closer together, there is little doubt that through this many pores that previously were open, are closed, and communication both between themselves and with the external aether is eliminated. Through hammering, previously open pores are closed, and in this way the body must obtain its elastic force. But if the hammering is continued for too long, the particles can not give way any further, leading, as experience shows, to complete separation or fracture. This can be prevented if one repeatedly heats the metal, thus re-opening the closed pores through the movement thus created of the subtle matter.

138. The elastic force of air, that we derive from experiments, is only the excess of its true elastic force over the elastic force of the aether. And therefore we obtain the complete elastic force of air, if to that indicated by experiment, we add the elastic force of the open aether.

Let us imagine a mass of air that is surrounded by aether; this will be pressed from all directions by the elastic force of the aether, and if the air did not have a greater force to expand, it would either remain in its state, or even be pressed into a smaller space. Since air enters a vacuum with great force, but the vacuum is filled with aether, the elastic force of air must be greater than that of the aether, and the force with which air enters the vacuum is only due to the excess. The experiments therefore only show us how much stronger the elastic force of air is than that of the aether; we must thus distinguish the true or entire elastic force of air from the apparent one that experiments indicate. Since the elastic force of liquid matter is determined from the pressure, and since the pressure is best expressed in terms of a height, let us express the elastic force of the aether by the height h, and the apparent elastic force of air by the height q; then the true and total elastic force of air is expressed by the height $h + q$; such a force the air would exert against an entirely empty space, which also contains no aether. But here it must be remarked that the height h must be very much greater than the height q, since to achieve the hardness of bodies a far greater force is required than the apparent elastic force of ordinary air, and it is probable that h is at least 100 times greater than q. Consequently the true elastic force of air is only a very little greater than the elastic force of the aether.

139. The air contains only very little coarse matter and also very few closed pores, through the compression of which the elastic force of air is augmented. Most of the subtle matter of which, apart from coarse matter, air consists, is in open pores and is therefore not compressed with the air.

The air has only got weight due to its content of coarse matter; but since it is 20000 times lighter than gold, but gold contains many pores, it is clear that the coarse matter contained in the air occupies less than the 20000th part of the space, from which follows that the pores which are enclosed between the coarse particles must occupy a very small part of the space. This is understandable regarding the ordinary air that surrounds us. Since the latter can expand so very much before losing all apparent elastic force or get into equilibrium with the aether, we want to consider a cubic foot of such air, the elastic force of which equals that of the aether, and this space will be filled almost entirely with subtle matter. If all subtle matter were in closed pores and were equally compressed together with the air, then the elastic force of ordinary air, which is at least 100 times denser than the natural (sic.) , would also have to be at least 100 times greater than that of the aether, since the latter exceeds it only by a very small amount. There must therefore be very little subtle matter in closed pores and as the air becomes denser it must not be strongly compressed. Let us assume that in the above mentioned cubic foot a proportion $1/n$ is in closed pores, which, when the ordinary air is compressed into an m times smaller space, are compressed only into an i times smaller space. Since the elastic force of the aether is given by the height h, then the elastic force of the air that is compressed into an m times smaller space will be given by the height $h + m(i-1)h/in$, where it must be remembered that i is many times smaller than m, for according to some experiments we might well have that $i = (m)^{\frac{1}{3}}$. If we assume that ordinary air is 125 times denser than natural (sic.), i.e. m=125, then i=5 and its total elastic force is $h + 100h/n$, which must be equal to $h + q$. But we have stated that q is several hundred times smaller than h, so that n would have to be at least 20000. If we had put m = 1000, i = 10 and $q = h/1000$, which perhaps comes nearer to the truth, then $1/1000 = 900/n$ and n = 900000. From which follows that in air the closed pores contribute an almost unimaginably small part to the total expansion, and during compression of the air they suffer only moderate compression. This would even be much less, if the elastic force of the aether increased more rapidly than the density