Émilie Du Châtelet, *Foundations of Physics*, 1740.
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Footnotes are ours except where otherwise indicated.
Du Châtelet's marginal notes are placed in **{bold}** in the closest appropriate place in the text. Please see the French original for the position of each note in the margin alongside the paragraph.

Chapter 10. Of the Shape and Porosity of Bodies

186. {All finite extension has a shape.} Shape is a necessary attribute of Body; for one understands by Body extension that has some boundaries: now all limited extension necessarily has a Shape.

187. {We do not know the form of the indivisible parts of matter.} We saw in the preceding Chapter that all Bodies that we see are probably composed by the union and the mixture of the primary parts of Matter, that is to say, the parts that nature does not resolve further into others, and that are indivisible in the order of things that exist; now the primary parts of Matter necessarily have a Shape, but we do not have the organs to distinguish them; we know only that their forms are diverse since the principle of sufficient reason does not allow similar Matter in the universe.

188. {Plate 3. Figs. 11, 12 and 13.} To have an idea of the means by which the different Bodies that fall under our senses can result from the assembly of indivisible parts of Matter, let us suppose, for example, that 3, 4, or any number whatever of these solid parts were united together, and that they composed one such mass; the particles thus composed can be called *first order particles* [ital. in French]: when several masses of this first order unite together, they will compose several large particles which can be called *those of the second order*. These particles of the second order in uniting together will further compose a species of particles larger than those of the two preceding orders, and will be *particles of the third order*. One feels that we can extend almost to infinity this progression of particles different from one another, and that the particles of a single order are themselves susceptible of an innumerable quantity of combinations, according to the way in which they are arranged.

189. {Observations that lead to admitting different orders of particles in the Universe.} The Bodies that are composed of the particles of only one order are more homogeneous than the others, and we see easily that those that are composed of the first order particles are the most

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homogeneous of all.

The Bodies composed of the particles of several orders are heterogeneous, and are all the more so as they are composed of a greater number of particles, and as the orders of these particles differ more from one another.

190. Diverse observations lead us to admit the different orders of particles, and to conclude that their combinations form the different bodies.

1. Tempered steel, although harder, is more brittle than untempered steel; and this is because its grains are larger, as the microscope discloses: now, the larger the spherical particles, the less they are coherent.

2. When we look at blood cells with a microscope, we see that when they are dissolved, each red blood cell is composed of six small serous yellowish globules, and that each of these serous globules is composed of six other lymphatic globules; and we do not yet know just how far this progression of little globules is continued in our blood. **{Fig. 14. Singular observations on our blood.}**

3. One sometimes distinguishes by eye the largest particles composing Bodies; the microscope discloses them in every way. One notices, with the help of this instrument, infinite varieties among the particles that compose Bodies; and the differences are sometimes so remarkable, that we recognize the particles of the same order when we find them in different composites.

191. As all these particles, of whatever order they may be, are composed of indivisible parts of the first Body of matter, the parts that compose them can be separated one from another. Thus, the largest particles can be resolved into smaller ones, and those then into still smaller ones, until we have arrived at the indivisible parts of matter. We see easily by this how the hardest Body can be reduced into very fine powder by attrition, fire, putrefaction, or through the action of some menstruum.[2] These particles thus decomposed can then rejoin together, either when they experience the same combinations, or when they undergo others. From there, once the parts of an animal or of a plant are different, they can enter into the composition of some plant or of some animal different from the first.

192. We see in what happens to Water, which is one of the most simple Bodies that we know, how much the composites formed by the same particles can differ sensibly one from one another; for when the parts of water are brought together in a glass, they compose a rather heavy liquid mass; risen as vapor, they separate from one another and escape our senses; then they reappear in the form of clouds, then they fall again in dew, snow, ice, etc., and being melted, they become once again this heavy liquid mass that was in the vase. We see easily that these variations are only different combinations of the solid parts from which Water is formed, and that it is very

[2] Term used in alchemy to mean a fluid that has the power to dissolve and to coagulate.

likely that the generation, growth and corruption of sensible Bodies depends on the divisions and the assemblies of the irresoluble parts of matter, which remain inalterable in all of these variations, and by their stability, conserve the species of things.

193. The different orders of particles of which I here suppose Bodies are composed, are again, in truth, only in the order of things that some experiences render likely, and for which we must seek confirmation in other experiences. But in whatever way the innumerable number of combinations necessary for producing the diversity that reigns in nature is made, we cannot admire too much the artifice by which so many and such diverse things result from the assembly of the first Bodies.

194. {Of the porosity of Bodies. Fig. 15.} One cannot better represent the way in which Bodies in general are composed, than by imagining several screens placed one on another, and from which will result masses pierced from all sides; and it is thus that all Bodies appear under a microscope. These new eyes that human industry has been able to obtain, has made us see that the parts of Bodies that we believed were the most solid, are more or less arranged as in Figure 15, and when viewed under a microscope, there is no Body that does not appear to contain infinitely more pores than proper matter[3].

195. {Experiments that prove it.} A thousand examples agree with those from the microscope to demonstrate to us this extreme porosity of Bodies.

1. Mercury penetrates gold, copper, silver, in fact all metals, as easily as Water penetrates a sponge.
2. Water penetrates the membranes of animals and plants, to which it brings nutritional parts.
3. Gold itself gives passage[4] through its substance to water, which is only around nineteen times less solid.
4. Fluids penetrate one another; thus, if you pour a certain quantity of water on oil of vitriol, the mixture begins by rising, but once the effervescence has stopped and the mixture is at rest, the liquor descends; and this is because water has entered into the pores of the oil.
5. The most dense Bodies become transparent when they are very thin. Thus, a sheet of gold seems transparent under the microscope or through a hole of a camera obscura. Now, this transparency of opaque Bodies, when they are reduced to very thin strips, comes in part from the pores that separate their proper matter.
6. The Phenomena of electricity, magnetism, and light prove yet more invincibly this

[3] See the previous chapter for her discussion of what she means by "proper matter".
[4] Du Chatelet: A hollow gold globe, filled with water and hermetically sealed, having been placed under a press, the water that was enclosed therein comes out through the pores of the gold, like very fine rain: Mr. Newton reports this experiment in his Treatise on Opticks.

extreme porosity of Bodies.

7. The fumes that are emitted by sulfur will penetrate cloth and fabric to blacken the silver or gold that we have wrapped inside, and there are a thousand examples in Chemistry of this penetration of spirits and of odors through the pores of Bodies.

196. {In which sense we can say that a body is more or less solid than another.} We saw above that we must distinguish in Bodies their proper matter that moves and acts with them, from the matter that passes through their pores, which participates neither in their actions nor in their passions. Thus, as there is no void in Nature, all Bodies of equal volume contain the same amount of absolute matter; but nevertheless, two Bodies with equal volume and moved at the same speed do not make the same effect if they do not have the same specific gravity, that is to say, if they do not equally contain proper matter. For the matter that passes through the pores of Bodies does not contribute to their weight and does not participate either in their movement or in their action.

197. Solidity is this resistance that all Bodies make us feel when we want to compress them.

{We have the idea of solidity only from touch.} Touch is the only sense that gives us the idea of solidity; this sense is spread throughout our whole Body, and the other senses are themselves nothing other than diversified touch, the shaking of the nerves, however imperceptible for us, being the source of all of our sensations.

It seems peculiar that, even though all our senses are only modifications of touch, the idea of solidity (which is its proper object) comes to us through one sense only, and that neither our eyes nor our ears give us this idea.

It is very likely that the Creator, who wanted our eyes to judge colors and shapes, and to serve as our guide, and our ears to judge sounds and serve us in the communication of our thoughts with our fellow-men, hid from us the shaking of the retina and of the eardrum, in order to avoid the confusion that so much different shaking would have put into our sensations.

A Being deprived of any tactile faculty and who would have only the sense of hearing, would in truth experience a type of pain in hearing a noise that was too shrill; but although this pain is caused only by the too strong shaking of the eardrum, it would, however, not give this Being any idea of what caused this shaking; for the feeling of pain does not give us any idea of the cause. Thus, although the source of our sensations is the same in each case, and although our senses seem to be reliable [se tenir], nothing, however, is more distinct than their objects: the hand will never judge sounds, nor the ear colors, and we can apply to them this beautiful Verse of Mr. Pope on the different Beings.

For ever near, and for ever separate,[5]

[5] Quoted in English. Source: Pope, *Essay on Man* Epistle VII (1734):
"Feels at each thread, and lives along the line:
In the nice bee, what sense so subtly true

Always near to one another, and always separated (Fr.)

Bodies are more or less solid, according to whether they contain more or less proper matter within the same volume.

198. When we compare the solidity of one Body to that of another Body, we always suppose that these Bodies are of equal volume, that is to say, that one may be substituted for the other by relation to their extension, regardless of the form of these two Bodies. Thus, Bodies A and B, for example **{Fig. 16 and 17}**, while very different in form, have however the same volume because Body B regains in length that which body A has more of in breadth.

199. Although Bodies are more or less solid, depending on whether they contain more or less proper matter within the same volume, they are all equally resistant.

When we do not yet have very clear [nettes, *not* claires] ideas of things, we could be tempted to believe that fluids are deprived of this attribute of matter by which it resists; but when we want to move through them, they make us feel by the resistance that opposes us, that they also possess this property of matter.

200. {We do not know the real mass of any Body.} If we knew some Body which had nothing but proper matter, we would know how much proper matter and foreign matter Bodies contain in a determinate volume; for if a Body of a cubic inch, for example, contained only proper matter, and it had some given weight, and another Body also the size of a cubic inch had only half the weight of the first, the second Body would contain just as much foreign matter as proper matter.

{Gold is used ordinarily as the comparative measure of the solidity of Bodies.} But as we have no knowledge at all of such a portion of matter, we have chosen gold, which is a very dense Body, and yet very porous, to serve as a common measure, and we have supposed that within any volume , gold would contain as much foreign matter as proper matter; having thus compared the heaviness of other Bodies to that of gold, and making them the same volume, we have determined their specific gravity compared to that of gold. Thus, any volume of water weighing around 19.5 times less than an equal volume of gold, and having as a consequence 19.5

From poisonous herbs extracts the healing dew!
How instinct varies in the grovelling swine,
Compared, half-reasoning elephant, with thine!
'Twixt that and reason, what a nice barrier:
For ever separate, yet for ever near!
Remembrance and reflection how allied;
What thin partitions sense from thought divide:
And middle natures, how they long to join,
Yet never pass th' insuperable line!

times less proper matter than gold, which itself has only half proper matter, we have concluded that the quantity of pores and of foreign matter in water is to its proper matter as about 39 to 1.

Gold is therefore the most dense Body that we know, yet it has pores. Thus, there is no portion of matter that is absolutely dense, and reason is in accord with experience in this; for, if there were some entirely dense mass, it would compose a Body that is entirely hard and without elasticity, regardless of whether or not the Body had parts that nature further resolves into other parts, and there cannot be entirely dense Bodies in nature, as we have seen (§. 15).

201. The Bodies that we believe to be the most dense to the naked eye, and that appear to us to be the most continuous on their surface, appear pierced with an infinity of pores when one looks at them with a Microscope, as does, for example, the bark of a tree.

Thus, there are no dense Bodies except by comparison to more porous Bodies.

202. If the proper matter of a Body undergoes some change, the composite is changed and resolved into its principles. If the changes happen only to the matter that passes through its pores, they are only accidental, and the composite is not destroyed.

203. The particles that compose a Body can be arranged in a way that their surface areas appear to touch immediately at all of their points, or that they touch only at some points. If they touch at all their points, the Body is continuous and its parts are simply possible; and we call this Body, *a dense Body*; in the opposite case, this Body is *a porous Body*.

204. If the proper parts that compose a Body approach one another, in such a way that the pores become smaller, the volume of this Body diminishes, and from being porous becomes dense; this effect is called *condensation*. If on the contrary the interstices or pores become larger, the volume of this Body increases, and from being dense, it becomes porous; and this is called *rarefaction*. **{Causes of rarefaction and of condensation.}** These two effects are caused by the greater or lesser quantity of matter that passes through the pores of these Bodies; when this matter is there in greater abundance, the Body is rarefied, when the quantity diminishes, the Body is condensed.

205. {Definition of hardness, and of softness.} If the parts of a Body yield with difficulty, in such a way that one feels the resistance that they make when we want to separate them, we call this Body *a hard Body*. But if its parts yield easily, and make very little resistance when we want to separate them, we call this body *a soft Body*. And when this resistance is still less, the Body becomes fluid.

206. The cohesion of Bodies comes from the conspiring motions[6] of their parts (§. 173). They

[6] This phrase, "conspiring motions", is also found in Musschenbroek 1744, an English translation

are more or less hard, depending on whether the surfaces of their parts are more or less exactly applied one on the other, and on whether their motions conspire more or less; from which arise the different cohesions that make certain Bodies divisible [secables], others friable, others brittle, etc.

207. If in the surface of a Body there are prominences or bumps that project above the other parts, this Body is rough; but the surface is polished or smooth when none of its parts is above the rest.

208. {How a Body becomes fluid.} If the particles of constant matter that compose a Body come to be separated from one another by a fluid that moves very rapidly through them, and if there is no longer any contact between these parts, this Body becomes fluid. And when these parts begin to draw closer together, in such a way that their immediate contact recommences, the Body becomes a solid Body. Lead undergoes these two states successively when exposed to fire and then allowed to cool again.

Although the corpuscles that compose fluid Bodies are really separate, nevertheless they seem continuous to the eye, because of their extreme subtlety, and that of the matter that moves between them. Thus, it is not surprising that fluids yield easily to solids, which split them by separating their parts.

209. Bodies become soft before becoming fluid, because the contact of their parts diminishes little by little, before ceasing entirely, and from there arises successively softness and fluidity.

This separation of parts that compose Bodies is made by the variable matter that fills their pores, by which new paths are opened in the Bodies, and thus breaks the contact of their parts.

210. When only a certain quantity of this matter can be inserted between these parts, Bodies remain soft, and do not become fluid; but these Bodies become hard again if this matter leaves from between their parts, whether by the action of fire, by evaporation of this matter, or by compression of the Body by which we force it to come out.

I will tell you in Chapter 16 how the Newtonians explain by attraction these same Phenomena of cohesion, hardness, softness, and fluidity; for according to some among them, it is in these details that the necessity of admitting attraction is most manifest. Their Observations assuredly merit that we study them, and that we strive to find a mechanical reason for the Phenomena that they have observed.

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of Musschenbroek 1736.