Capillary Attraction/Attraction of Cohesion Excerpts

ON THE CONNECTION OF THE PHYSICAL SCIENCES

Pgs. 108-111

BY MARY SOMERVILLE

The oscillations of the atmosphere and the changes in its temperature, are measured by variations in the heights of the barometer and thermometer. But the actual length of the liquid columns depends not only upon the force of gravitation, but upon the cohesive force, or reciprocal attraction between the molecules of the liquid and those of the tube containing it. This peculiar action of the cohesive force is called capillary attraction or capillarity. If a glass tube of extremely fine bore, such as a small thermometer tube, be plunged into a cup of water or spirit of wine, the liquid will immediately rise in the tube above the level of that in the cup; and the surface of the little column thus suspended will be a hollow hemisphere, whose diameter is the interior diameter of the tube. If the same tube be plunged into a cupful of mercury the liquid will also rise in the tube, but it will never attain the level of that in the cup, and its surface will be a hemisphere whose diameter is also the diameter of the tube (N. 168). The elevation or depression of the same liquid in different tubes of the same matter, is in the inverse ratio of their internal diameters (N. 169), and altogether independent of their thickness; whence it follows that the molecular action is insensible at sensible distances, and that it is only the thinnest possible film of the interior surface of the tubes that exerts a sensible action on the liquid. So much indeed is this the case, that when tubes of the same bore are completely wetted with water throughout their whole extent, mercury will rise to the same height in all of them, whatever be their thickness or density, because the minute coating of moisture is sufficient to remove the internal column of mercury beyond the sphere of attraction of the tube, and to supply the place of a tube by its own capillary attraction. The forces which produce the capillary phenomena are the reciprocal attraction of the tube and the liquid, and of the liquid particles on one another; and in order that the capillary column maybe in equilibrio, the weight of that part of it which rises above or sinks below the level of the liquid in the cup must balance these forces.

The estimation of the action of the liquid is a difficult part of this problem. La Place, Dr. Young, and other mathematicians, have considered the liquid within the tube to be of uniform density; but M. Poisson, in one of those masterly productions in which he elucidates the most abstruse subjects, has proved that the phenomena of capillary attraction depend upon a rapid decrease in the density of the liquid column throughout an extremely small space at its surface. Every indefinitely thin layer of a liquid is compressed by the liquid above it, and supported by that below. Its degree of condensation depends upon the magnitude of the compression force; and as this force decreases rapidly toward the surface where it vanishes, the density of the liquid decreases also. M. Poisson has shown that when this force is omitted, the capillary surface becomes plane, and that the liquid in the tube will neither rise above nor sink

below the level of that in the cup. In estimating the forces, it is also necessary to include the variation in the density of the capillary surface round the edges from the attraction of the tube. The direction of the resulting force determines the curvature of the surface of the capillary column. In order that a liquid may be in equilibrio, the force resulting from all the forces acting upon it must be perpendicular to the surface. Now it appears that as glass is more dense than water or alcohol, the resulting force will be inclined toward the interior side of the tube; therefore the surface of the liquid must be more elevated at the sides of the tube than in the center in order to be perpendicular to it, so that it will be concave as in the thermometer. But, as glass is less dense than mercury, the resulting force will be inclined from the interior side of the tube (N. 170), so that the surface of the capillary column must be more depressed at the sides of the tube than in the center, in order to be perpendicular to the resulting force, and is consequently convex, as maybe perceived in the mercury of the barometer when rising. The absorption of moisture by sponges, sugar, salt, &c., are familiar examples of capillary attraction. Indeed the pores of sugar are so minute, that there seems to be no limit to the ascent of the liquid. Wine is drawn up in a curve on the interior surface of a glass; tea rises above its level on the side of a cup; but if the glass or cup be too full, the edges attract the liquid downward, and give it a rounded form. A column of liquid will rise above or sink below its level between two plane parallel surfaces when near to one another, according to the relative densities of the plates and the liquid (N. 171); and the phenomena will be exactly the same as in a cylindrical tube whose diameter is double the distance of the plates from each other. If the two surfaces be very near to one another, and touch each other at one of their upright edges, the liquid will rise highest at the edges that are in contact, and will gradually diminish in height as the surfaces become more separated. The whole outline of the liquid column will have the form of a hyperbola. Indeed so universal is the action of capillarity, that solids and liquids cannot touch one another without producing a change in the form of the surface of the liquid.

The attractions and repulsions arising from capillarity present many curious phenomena. If two plates of glass or metal, both of which are either dry or wet, be partly immersed in a liquid parallel to one another, the liquid will be raised or depressed close to their surfaces, but will maintain its level through the rest of the space that separates them. At such a distance they neither attract nor repel one another; but the instant they are brought so near as to make the level part of the liquid disappear, and the two curved parts of it meet, the two plates will rush toward each other and remain pressed together (N. 172). If one of the surfaces be wet and the other dry, they will repel one another when so near as to have a curved surface of liquid between them; but if forced to approach a little nearer the repulsion will be overcome, and they will attract each other as if they were both wet or both dry. Two balls of pith or wood floating in water, or two balls of tin floating in mercury, attract one another as soon as they are so near that the surface of the liquid is curved between them. Two ships in the ocean may be brought into collision by this principle. But two balls, one of which is wet and the other dry, repel one another as soon as the liquid which separates them is curved at its surface. A bit of tea leaf is attracted by the edge of the cup if wet and repelled when dry, provided it be not too far from the edge and the cup moderately full; if too full, the contrary takes place. It is probable that the rise of the sap in vegetables is in some degree owing to capillarity.

NOTE 168, p. 109.—The surface of a column of water, or spirit of wine, in a capillary tube, is hollow; and that of a column of quicksilver is convex, or rounded, as in fig 41.

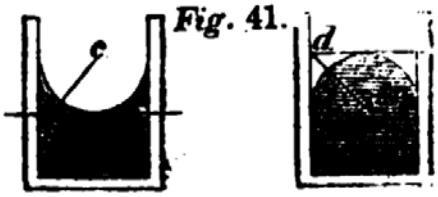


Fig. 41.

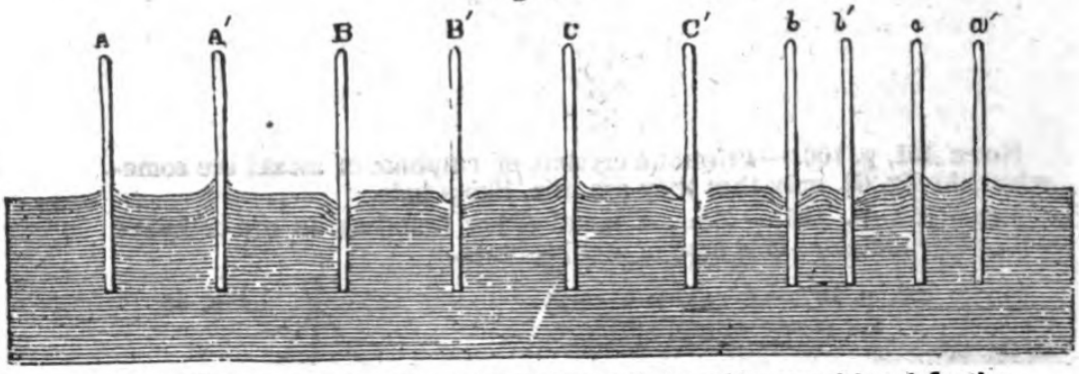
NOTE 169, p. 109.—*Inverse ratio, &c.* The elevation of the liquid is greater in proportion as the internal diameter of the tube is less.

NOTE 170, p. 110.—In fig. 41, the line *c d* shows the direction of the resulting force in the two cases.

NOTE 171, p. 110.—When two plates of glass are brought near to one another in water, the liquid rises between them; and if the plates touch each other at one of their upright edges, the outline of the water will become a hyperbola.

NOTE 172, p. 111.—Let A A′, fig. 42, be two plates, both of which are wet, and B B′, two that are dry. When partly immersed in a liquid, its

Fig. 42.



surface will be curved close to them, but will be of its usual level for the rest of the distance. At such a distance, they will neither attract nor repel one another. But as soon as they are brought near enough to have the whole of the liquid surface between them curved, as in *a a′*, *b b′*, they will rush together. If one be wet and another dry, as C C′, they will repel one another at a certain distance; but as soon as they are brought very near, they will rush together, as in the former cases.

Capillary Attraction/Attraction of Cohesion Excerpts

CONVERSATIONS ON NATURAL PHILOSOPHY

Pgs. 16-17, 19-21

BY JANE MARCET

Mrs. B. Inert matter is as incapable of stopping of itself, as it is of putting itself in motion: when the ball ceases to move, therefore, it must be stopped by some other cause or power; but as it is one with which you are yet unacquainted, we cannot at present investigate its effects.

The last property which appears to be common to all bodies is attraction. All bodies consist of infinitely small particles of matter, each of which possesses the power of attracting or drawing towards it, and uniting with any other particle sufficiently near to be within the influence of its attraction; but in minute particles this power extends to so very small a distance around them that its effect is not sensible, unless they are (or at least appear to be) in contact; it then makes them stick or adhere together, and is hence called the attraction of cohesion. Without this power, solid bodies would fall in pieces, or rather crumble to atoms.

Emily. I am so much accustomed to see bodies firm and solid, that it never occurred to me that any power was requisite to unite the particles of which they are composed. But the attraction of cohesion does not, I suppose, exist in liquids; for the particles of liquids do not remain together so as to form a body, unless confined in a vessel!

Mrs. B. I beg your pardon; it is the attraction of cohesion which holds this drop of water suspended at the end of my finger, and keeps the minute watery particles of which it is composed united. But as this power is stronger in proportion as the particles of bodies are more closely united, the cohesive attraction of solid bodies is much greater than that of fluids. The thinner and lighter a fluid is, the less is the cohesive attraction of. its particles, because they are further apart; and in elastic fluids, such as air, there is no cohesive attraction among the particles.

Emily. That is very fortunate; for it would be impossible to breathe the air in a solid mass; or even in a liquid state. But is the air a body of the same nature as other bodies?

Mrs. B. Undoubtedly, in all essential properties.

Emily. Yet you say that it does not possess one of the general properties of bodies—cohesive attraction?

Mrs. B. The particles of air are not destitute of the power of attraction, but they are too far distant from each other to be influenced by it; and the utmost efforts of human art have proved

ineffectual in the attempt to compress them, so as to bring them within the sphere of each other's attraction, and make them cohere.

Emily. If so, how is it possible to prove that they are endowed with this power?

Mrs. B. The air is formed of particles precisely of the same nature as those which enter into the composition of liquid and solid bodies, in which state we have a proof of their attraction.

25. What would be the consequence, if a body were put in motion and no resistance should be offered? 26. What is the property common to all bodies? 27. Of what do all bodies consist? 28. What is the power called which binds these small particles together? 29. What would be the consequence if the power of cohesive attraction were destroyed? 30. Does the power of cohesion exist also in liquids? 31. How would you prove that it exists in liquids? 32. Why are some bodies hard and others soft? 33. Does the attraction of cohesion exist in the air? 34. But are the particles of the air actually under the influence of this attraction? 35. Why are they not, if attraction belong to them? 36. How do we know that attraction does belong to the air if no influence is exerted upon it?

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Mrs. B. … To return to its antagonist, the attraction of cohesion; it is this power which restores to vapour its liquid form, which unites it into drops when it falls to the earth in a shower of rain, which gathers the dew. into brilliant gems on the blades of grass.

Emily. And I have often observed that after a shower, the water collects into large drops on the leaves of plants; but I cannot say that I perfectly understand how the attraction of cohesion produces this effect.

Mrs. B. Rain does not fall from the clouds in the form of drops, but in that of mist or vapour, which is composed of very small watery particles; these in their descent, mutually attract each other, and those that are sufficiently near in consequence unite and form a drop, and thus the mist is transformed into a shower. The dew also was originally in a state of vapour, but is, by the mutual attraction of the particles, formed into small globules on the blades of grass: in a similar manner the rain upon the leaf collects into large drops, which, when they become too heavy for the leaf to support, fall to the ground.

Emily. All this is wonderfully curious! I am almost bewildered with surprise and admiration at the number of new ideas I have already acquired.

Mrs. B. ... There is another curious effect of the attraction of cohesion which I must point out to you. It enables liquids to rise above their level in capillary tubes; these are tubes, the bores of which are so extremely small that liquids ascend within them, from the cohesive attraction between the particles of the liquid and the interiour surface of the tube. Do you perceive the water rising above its level in this small glass tube, which I have immersed in a goblet full of water?

Emily. Oh yes; I see it slowly creeping up the tube, but now it is stationary; will it rise no higher?

Mrs. B. No; because the cohesive attraction between the water and the internal surface of the tube is now balanced by the weight of the water within it: if the bore of the tube were narrower, the water would rise higher; and if you immerse several tubes of bores of different sizes, you will see it rise to different heights in each of them. In making this experiment, you should colour the water with a little red wine, in order to render the effect more obvious.
All porous substances, such as sponge, bread, linen, &c. may be considered as collections of capillary tubes: if you dip one end of a lump of sugar into water, the water will rise in it; and wet it considerably above the surface of that into which you dip it.

Emily. In making tea I have often observed that effect without being able to account for it.

51. What collects this mist or vapour into drops? 52. What causes the dew on leaves and blades of grass to collect into drops? 53. Why will liquids rise above their level in capillary tubes? 54. On what principle do sponge, and other porous substances absorb liquids?